Appendix G Water Quality Technical Appendix

This appendix documents the water quality technical analysis to support the impact analysis in the environmental impact statement (EIS).

G.1 Background Information

This section describes surface water quality that could be potentially affected by implementing the alternatives considered in this EIS. Changes in water quality due to changes in the Central Valley Project (CVP) and State Water Project (SWP) operation may occur in the Trinity River, Sacramento River, Clear Creek, Feather River, American River, Stanislaus River, San Joaquin River, Bay-Delta, and the CVP/SWP service area (south to Diamond Valley). Given the limited changes in outflow to the Pacific Ocean, water quality in the nearshore Pacific Ocean is unlikely to be affected by this project's implementation, and therefore, this technical appendix will not analyze the nearshore Pacific Ocean. Appendix H, *Water Supply Technical Appendix* describes changes to surface water bodies and water supplies.

This appendix focuses on constituents of concern that could be affected by changes in CVP/SWP water operation. The *Final California 2014-2016 Integrated Report* (Section 303(d) List/305(b) Report) identifies constituents of concern as well as other water quality reports. This section describes constituents' sources, water quality effects, objectives, and guidelines, and plans to improve water quality.

G.1.1 Beneficial Uses of Surface Waters in the Study Area

The Regional Water Quality Control Board (RWQCB) *Basin Plans and Integrated Reports* assessed and described water quality conditions throughout the study area. Each region has specific beneficial uses, as summarized in Table G.1-1, Designated Beneficial Uses within Project Study Area, and water quality constituents of concern. However, several pollutants are prevalent throughout the study area. The pollutants' origins and prevalence are discussed below.

Table G.1-1. Designated Beneficial Uses within Project Study Area

Surface Water Body	Municipal and Domestic Supply (MUN)	Agricultural Supply (AGR)	Industrial Service Supply (IND)	Industrial Process Supply (PRO)	Groundwater Recharge (GWR)	Fresh Water Replenishment (FRSH)	Navigation (NAV)	Hydropower Generation (POW)	Water Contact Recreation (REC-1)	Non-Contact Water Recreation (REC-2)	Commercial and Sport Fishing (COMM)	Warm Fresh Water Habitat (WARM)	Cold Fresh Water Habitat (COLD)	Wildlife Habitat (WILD)	Rare, Threatened, or Endangered Species (RARE)	Marine Habitat (MAR)	Migration of Aquatic Organisms (MIGR)	Spawning, Reproduction, and/or Early Development (SPWN)	Shellfish Harvesting (SHELL)	Estuarine Habitat (EST)	Aquaculture (AQUA)	Native American Culture (CUL)	Flood Peak Attenuation/ Flood Water Storage (FLD)	Wetland Habitat (WET)	Water Quality Enhancement (WQE)
Trinity and Lower Klamath Rivers																									
Lower Klamath River and Klamath Glen Hydrologic Subarea	E	E	P	P	E	E	E	P	E	E	E	E	E	E	E	E	E	E	E	E	P	E	–	–	–
Trinity Lake	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	–	P	E	–	–	P	–	–	–	–
Lewiston Reservoir	E	E	P	P	E	E	E	E	E	E	E	P	E	E	E	–	P	E	–	–	E	–	–	–	–
Middle Trinity River and Surrounding Hydrologic Area	E	E	E	P	E	E	E	P	E	E	E	–	E	E	E	–	E	E	–	–	E & P	–	–	–	–
Lower Trinity River and Surrounding Hydrologic Area[1]	E	E	E	P	E	E	E	E & P	E	E	E	–	E	E	E	–	E	E	P	–	E & P	E[2]	–	–	–
Sacramento River Basin																									
Shasta Lake	E	E	–	–	–	–	–	E	E	E	–	E[4]	E[4]	E	–	–	–	E[5,6]	–	–	–	–	–	–	–
Sacramento River: Shasta Dam to Colusa Basin Drain	E	E	E	–	–	–	E	E	E[3]	E	–	E[4]	E[4]	E	–	–	E[5,6]	E[5,6]	–	–	–	–	–	–	–

Surface Water Body	Municipal and Domestic Supply (MUN)	Agricultural Supply (AGR)	Industrial Service Supply (IND)	Industrial Process Supply (PRO)	Groundwater Recharge (GWR)	Fresh Water Replenishment (FRSH)	Navigation (NAV)	Hydropower Generation (POW)	Water Contact Recreation (REC-1)	Non-Contact Water Recreation (REC-2)	Commercial and Sport Fishing (COMM)	Warm Fresh Water Habitat (WARM)	Cold Fresh Water Habitat (COLD)	Wildlife Habitat (WILD)	Rare, Threatened, or Endangered Species (RARE)	Marine Habitat (MAR)	Migration of Aquatic Organisms (MIGR)	Spawning, Reproduction, and/or Early Development (SPWN)	Shellfish Harvesting (SHELL)	Estuarine Habitat (EST)	Aquaculture (AQUA)	Native American Culture (CUL)	Flood Peak Attenuation/ Flood Water Storage (FLD)	Wetland Habitat (WET)	Water Quality Enhancement (WQE)
Colusa Basin Drain	–	E	–	–	–	–	–	–	E[3]	–	–	E[4]	P[4]	E	–	–	E[6]	E[6]	–	–	–	–	–	–	–
Sacramento River: Colusa Basin Drain to Eye ("I") Street Bridge	E	E	–	–	–	–	E	–	E[3]	E	–	E[4]	E[4]	E	–	–	E[5,6]	E[5,6]	–	–	–	–	–	–	–
Whiskeytown Reservoir	E	E	–	–	–	–	–	E	E	E	–	E[4]	E[4]	E	–	–	–	E[6]	–	–	–	–	–	–	–
Clear Creek below Whiskeytown Reservoir	E	E	–	–	–	–	–		E[3]	E	–	E[4]	E[4]	E	–	–	E[5]	E[5,6]	–	–	–	–	–	–	–
Feather River below Lake Oroville (Fish Barrier Dam to Sacramento River)	E	E	–	–	–	–	–	–	E[3]	E	–	E[4]	E[4]	E	–	–	E[5,6]	E[5,6]	–	–	–	–	–	–	–
American River below Lake Natoma (Folsom Dam to Sacramento River)	E	E	E	–	–	–	–	E	E[3]	E	–	E[4]	E[4]	E	–	–	E[5,6]	E[5,6]	–	–	–	–	–	–	–
Yolo Bypass[7]	–	E	–	–	–	–	–	–	E	E	–	E[4]	P[4]	E	–	–	E[5,6]	E[6]	–	–	–	–	–	–	–

Surface Water Body	Municipal and Domestic Supply (MUN)	Agricultural Supply (AGR)	Industrial Service Supply (IND)	Industrial Process Supply (PRO)	Groundwater Recharge (GWR)	Fresh Water Replenishment (FRSH)	Navigation (NAV)	Hydropower Generation (POW)	Water Contact Recreation (REC-1)	Non-Contact Water Recreation (REC-2)	Commercial and Sport Fishing (COMM)	Warm Fresh Water Habitat (WARM)	Cold Fresh Water Habitat (COLD)	Wildlife Habitat (WILD)	Rare, Threatened, or Endangered Species (RARE)	Marine Habitat (MAR)	Migration of Aquatic Organisms (MIGR)	Spawning, Reproduction, and/or Early Development (SPWN)	Shellfish Harvesting (SHELL)	Estuarine Habitat (EST)	Aquaculture (AQUA)	Native American Culture (CUL)	Flood Peak Attenuation/ Flood Water Storage (FLD)	Wetland Habitat (WET)	Water Quality Enhancement (WQE)
Bay-Delta																									
Sacramento-San Joaquin Delta[7,8,9]	E	E	E	E	E	–	E	–	E	E	E	E[4]	E[4]	E	E	–	E[5,6]	E[6]	E	E	–	–	–	–	–
Suisun Bay	–	–	E	E	–	–	E	–	E	E	E	–	–	E	E	–	E	E	–	E	–	–	–	–	–
Carquinez Straight	–	–	E	–	–	–	E	–	E	E	E	–	–	E	E	–	E	E	–	–	E	–	–	–	–
San Pablo Bay	–	–	E	–	–	–	E	–	E	E	E	–	–	–	E	E	–	E	E	E	E	–	–	–	–
San Francisco Bay Central	–	–	E	E	–	–	E	–	E	E	E	–	–	E	E	–	E	E	E	E	–	–	–	–	–
San Francisco Bay Lower	–	–	E	–	–	–	E	–	E	E	E	–	–	E	E	–	E	E	E	E	–	–	–	–	–
San Francisco Bay South	–	–	E	–	–	–	E	–	E	E	E	–	–	E	E	–	E	E	E	E	–	–	–	–	–
San Joaquin River and Tulare Basin																									
San Joaquin River: Friant Dam to Mendota Pool	E	E	–	E	–	–	–	–	E[3]	E	–	E[4]	E[4]	E	–	–	E[5,6]	E[6], P[5]	–	–	–	–	–	–	–
San Joaquin River: Sack Dam to the Mouth of Merced River	P	E	–	E	–	–	–	–	E[3]	E	–	E[4]	–	E	–	–	E[5,6]	E[6], P[5]	–	–	–	–	–	–	–

Surface Water Body	Municipal and Domestic Supply (MUN)	Agricultural Supply (AGR)	Industrial Service Supply (IND)	Industrial Process Supply (PRO)	Groundwater Recharge (GWR)	Fresh Water Replenishment (FRSH)	Navigation (NAV)	Hydropower Generation (POW)	Water Contact Recreation (REC-1)	Non-Contact Water Recreation (REC-2)	Commercial and Sport Fishing (COMM)	Warm Fresh Water Habitat (WARM)	Cold Fresh Water Habitat (COLD)	Wildlife Habitat (WILD)	Rare, Threatened, or Endangered Species (RARE)	Marine Habitat (MAR)	Migration of Aquatic Organisms (MIGR)	Spawning, Reproduction, and/or Early Development (SPWN)	Shellfish Harvesting (SHELL)	Estuarine Habitat (EST)	Aquaculture (AQUA)	Native American Culture (CUL)	Flood Peak Attenuation/ Flood Water Storage (FLD)	Wetland Habitat (WET)	Water Quality Enhancement (WQE)
San Joaquin River: Mouth of Merced River to Vernalis	P	E	–	E	–	–	–	–	E[3]	E	–	E[4]	–	E	–	–	E[5,6]	E[6]	–	–	–	–	–	–	–
New Melones Reservoir	E	E	–	–	–	–	–	E	E	E	–	–	E[4]	E	–	–	–	–	–	–	–	–	–	–	–
Tulloch Reservoir	P	E	–	–	–	–	–	E	E	E	–	E[4]	–	E	–	–	–	–	–	–	–	–	–	–	–
Stanislaus River: Goodwin Dam to San Joaquin River	P	E	E	E	–	–	–	E	E[3]	E	–	E[4]	E[4]	E	–	–	E[5]	E[5,6]	–	–	–	–	–	–	–
San Luis Reservoir	E	E	E	–	–	–	–	E	E	E	–	E[4]	–	E	–	–	–	–	–	–	–	–	–	–	–
O'Neill Reservoir	E	E	–	–	–	–	–	–	E	E	–	E[4]	–	–	–	–	–	–	–	–	–	–	–	–	–
California Aqueduct	E	E	E	E	–	–	–	E	E	E	–	–	–	E	–	–	–	–	–	–	–	–	–	–	–
Delta-Mendota Canal	E	E	–	–	–	–	–	–	E	E	–	E[4]	–	E	–	–	–	–	–	–	–	–	–	–	–

Sources: State Water Resources Control Board (SWRCB) 2006, Hoopa Valley TEPA 2008, Central Valley RWQCB 2018a, North Coast RWQCB 2018; San Francisco Bay RWQCB 2017

Notes:

E: Existing Beneficial Use; P: Potential Beneficial Use

[1] Includes beneficial uses for the Trinity River within the Hoopa Valley Indian Reservation as designated by the Hoopa Valley Indian Reservation Water Quality Control Plan, which, in addition to beneficial uses shown, also designates the Lower Trinity River as a Wild and Scenic waterway, providing for scenic, fisheries, wildlife and recreational purposes.

[2] Not all beneficial uses are present uniformly throughout this water body. They have been summarized to reflect beneficial uses present in multiple segments of the water body.

[3] Canoeing and rafting included in REC-1 designation.
[4] Resident does not include anadromous. Any Segments with both COLD and WARM beneficial use designations will be considered COLD water bodies for the application of water quality objectives.
[5] Cold water protection for salmon and steelhead.
[6] Warm water protection for striped bass (*Morone saxatilis*), sturgeon (*Acipenser*), and shad (*Alosa sapidissima* and *Dorosoma petenense*).
[7] Beneficial uses vary throughout the Delta and will be evaluated on a case-by-case basis. COMM is a designated beneficial use for the Sacramento San Joaquin Delta and Yolo Bypass waterways listed in Appendix 43 of the Basin Plan for the Sacramento River and San Joaquin River Basins and not any tributaries to the listed waterways or portions of the listed waterways outside of the legal Delta boundary unless specifically designated.
[8] Delta beneficial uses are shown as designated by the Water Quality Control Plan for the Sacramento River Basin and the San Joaquin River Basin, and the Water Quality Control Plan for the San Francisco Bay/Sacramento San Joaquin Delta Estuary.
[9] Per State Water Board Resolution No. 90-28, Marsh Creek and Marsh Creek Reservoir in Contra Costa County are assigned the following beneficial uses: REC-1 and REC-2 (potential uses), WARM, WILD and RARE. COMM is a designated beneficial use for Marsh Creek and its tributaries listed in Appendix 43 of the Basin Plan for the Sacramento River and San Joaquin River Basins within the legal Delta boundary.

G.1.1.1 *Salinity*

Salinity, a measure of dissolved salts in water, is a concern in the tidally-influenced Sacramento-San Joaquin Delta (the Delta), as it can affect domestic supply, agriculture, industry, and wildlife (CALFED 2007a). Salinity's impacts on the Delta's domestic supply of water include aesthetic, or cosmetic effects, and increasing the need to reduce salinity for municipal and industrial uses by blending, which can lead to a reduction in the quantity of usable water. Salts in drinking water, such as bromide, can increase harmful byproducts formation. Salinity in the Delta affects agriculture by reducing crop yields and salinity in the soil can cause plant stress. Another salt ion, chloride, in high concentrations in municipal and industrial supply is known to cause corrosion in canned goods because of residual salts in paper boxes or linerboard.

Some fish and wildlife are also affected by salinity concentrations in the Delta because certain levels of salinity are required during different life stages to survive. One measure of salinity in the western Delta is "X2." X2 refers to the horizontal distance from the Golden Gate Bridge up the axis of the Delta estuary to where the tidally averaged near-bottom salinity concentration of 2 parts of salt in 1,000 parts of water occurs. The SWRCB established the X2 standard to improve shallow water estuarine habitat in February through June and relates to the extent of salinity movement into the Delta (California Department of Water Resources [DWR] and Reclamation 2016). The location of X2 is important to both aquatic life and water supply beneficial uses.

The CVP and SWP are operated to achieve salinity objectives in the Delta, as described in detail in Appendix D, *Alternatives Development*.

The California State Water Resources Control Board (SWRCB) Water Right Decision 1641 (D-1641) includes "spring X2" criteria that require CVP/SWP operation to include upstream reservoir releases from February through June to maintain freshwater and estuarine conditions in the western Delta to protect aquatic life. In addition, the 2008 United States Fish and Wildlife Service (USFWS) biological opinion (BO) also includes an additional Delta salinity requirement for September and October in wet and above-normal water years (Fall X2) (USFWS 2008).

G.1.1.2 *Mercury*

Mercury is a constituent of concern throughout California, both as total mercury and as biologically-formed methylmercury, which is more available for food chain exposure and toxicity. Mercury present in the Delta, its tributaries, Suisun Marsh, and San Francisco Bay is derived from current processes as well as a result of historical deposition. Most of the mercury present in these locations is the result of historical mercury ore mining in the Coast Ranges (via Putah and Cache creeks to the Yolo Bypass) and elemental mercury's extensive use in gold extraction processes in the Sierra Nevada (via Sacramento, San Joaquin, Cosumnes, and Mokelumne rivers) (Alpers et al. 2008; Wiener et al. 2003). Elemental mercury from historical gold mining processes appears to be more bioavailable than that from mercury ore tailings because mercury used in gold mining processes was purified before use (Central Valley RWQCB 2010a). Additional mercury sources include atmospheric deposition from local and distant sources, and discharges from wastewater treatment plants (SWRCB 2018a).

Mercury methylation is an important step in the entrance of mercury into food chain (USEPA 2001a; xiv). This transformation can occur in sediment and the water column. Methylmercury is absorbed more quickly by aquatic organisms than inorganic mercury, and it biomagnifies (i.e., the concentration of methylmercury increases in predatory fish as they eat smaller contaminated fish and invertebrates). The pH of water, the length of the aquatic food chain, water temperature, and dissolved organic material and sulfate are all factors that can contribute to methylmercury's bioaccumulation in aquatic organisms. The proportion of an area that is wetlands, the soil type, and erosion can also contribute to the amount of mercury transported from soils to water bodies. These effects can be seen in the variability in bioaccumulated mercury in the Delta.

Contaminated fish consumption is the major pathway for human exposure to methylmercury (USEPA 2001a). Once consumed, methylmercury is almost completely absorbed into the blood and transported to all tissues. It is also transmitted to the fetus through the placenta. Neurotoxicity from methylmercury can result in mental retardation, cerebral palsy, deafness, blindness, and dysarthia in utero, and in sensory and motor impairments in adults. Studies have also reported cardiovascular and immunological effects from low-dose methylmercury exposure.

In an effort to protect aquatic and human health, the U.S. Environmental Protection Agency (USEPA) recommended maximum concentrations "without yielding unacceptable effects" in 2001 for acute exposure, identified as the criteria maximum concentration (CMC), and for chronic exposure, identified as the criterion continuous concentration (CCC) (USEPA 2001a, 2019). In 2000, USEPA established current state-wide water quality criteria for mercury in the California Toxics Rule (CTR) (USEPA 2000). Under these requirements, total recoverable mercury for the protection of human health was set as limits for the consumption of water and organisms, as well as the consumption of organisms only, as summarized in Table G.1-2, Water Quality Criteria for Mercury and Methylmercury (as Total Mercury). Some California RWQCB basin plans also include mercury objectives, as discussed in subsequent sections of this chapter. Where both a CTR criterion and a Basin Plan objective exist, the more stringent value applies (SWRCB 2006).

Table G.1-2. Water Quality Criteria for Mercury and Methylmercury (as Total Mercury)

NRWQC	For the protection of freshwater species		CMC = 1.4 µg/l
			CCC = 0.77 µg/l
	For the protection of saltwater species		CMC = 1.8 µg/l
			CCC = 0.94 µg/l
	For the protection of human health[1]		0.3 mg/kg [2]
CTR	For the protection of human health	Consumption of water + organism	0.050 µg/l
		Consumption of organism only	0.051 µg/l

Source: NRWQC (National Recommended Water Quality Criteria) - USEPA 2019; CTR (California Toxic Rule) - USEPA 2000, USEPA 2001b

Notes:

[1] For the consumption of organisms only and based on a total consumption 0.0175 kg fish and shellfish per day.

[2] Methylmercury in fish tissue (wet weight)

A review of the mercury human health criteria by USEPA in 2001 concluded that a fish tissue (including shellfish) residue water quality criterion for methylmercury is more appropriate than a water-column-based water quality criterion (USEPA 2001a). A fish tissue criterion directly addresses the dominant human exposure route for methylmercury, and thus is more closely tied to the Clean Water Act (CWA), Section 404 goal of protecting public health. USEPA also strongly encourages States and authorized Tribes to develop local or regional water quality criteria if they will be more appropriate for the target population.

SWRCB is considering adopting statewide objectives for methylmercury based on USEPA criteria, which would apply to inland waters, enclosed bays, and estuaries (SWRCB 2006). These objectives would be applicable to waters that are not listed as impaired or that do not require a total maximum daily load (TMDL). Potential elements include a methylmercury fish tissue objective, a total mercury water quality objective, a methylmercury water quality objective, or some combination of these. Implementation procedures related to the National Pollutant Discharge Elimination System (NPDES) permitting process also may be included.

The CTR criterion may be implemented as a fish tissue-based objective (FTO), or it may be converted into an ambient methylmercury water quality objective, the latter reflecting the USEPA's fish consumption rate of 0.0175 kilogram per fish per day (kg/fish/day), or site-specific consumption rates that more accurately reflect local consumption patterns (SWRCB 2006). A USFWS evaluation of the USEPA methylmercury criterion concluded that the FTO of 0.3 milligram (mg) methylmercury/kg fish would be insufficient to protect three species that may occur in the study area: the California least tern (*Sterna antillarum browni*), California clapper rail (*Rallus obsoletus*), and bald eagle (*Haliaeetus leucocephalus*) evaluated in the study.

G.1.1.3 *Selenium*

Selenium is a constituent of concern in the study area because of its potential effects on water quality and aquatic and terrestrial resources, primarily in the San Joaquin Valley and the San Francisco Bay, as well as some locations in Southern California (SWRCB 2011). Elevated selenium concentrations in soil and waterways within the San Joaquin Valley, and to some extent in the San Francisco Bay, are primarily from the erosion of uplifted selenium-enriched Cretaceous and Tertiary marine sedimentary rock located at the base of the east-facing side of the Coastal Range (Presser and Piper 1998; Presser 1994). Natural processes transport the selenium-enriched soil derived from the eroded rock to the western San Joaquin Valley; irrigation processes mobilize selenium from the soil and transported to waterways receiving agricultural drainage (Presser and Ohlendorf 1987). Other sources of selenium to the western Delta and San Francisco Bay include several oil refineries located near Carquinez Strait and San Pablo Bay (Presser and Luoma 2013; SWRCB 2011). The specific water bodies within these areas that may be affected by the project and are impaired by selenium, as specified on the California Section 303(d) list, include the Panoche Creek (from Silver Creek to Belmont Avenue), Mendota Pool, Grasslands Marshes, San Joaquin River (from Mud Slough to Merced River), San Francisco Bay, Sacramento-San Joaquin Delta, and Suisun Bay (SWRCB 2017a).

Adverse effects of selenium may occur from either a selenium deficiency or excess in the diet (ATSDR 2003; Ohlendorf 2003); the latter is the primary concern in the case of the impaired water bodies on the Section 303(d) list. Due to the known effects of selenium bioaccumulation from water to aquatic organisms and higher trophic levels in the food chain, the fresh water, estuarine and wildlife habitat; spawning, reproduction, and early development; and rare, threatened, or endangered species beneficial uses of the water bodies are the most sensitive receptors to selenium exposure. Thus, excessive exposure can lead to selenium toxicity or selenosis and result in death or deformities of fish embryos, fry, or larvae (Ohlendorf 2003; Chapman et al. 2009). Consequently, regulatory agencies established exposure criteria to protect the beneficial uses of the water bodies.

The Agency for Toxic Substances and Disease Registry (ATSDR), California Office of Environmental Health Hazard Assessment (OEHHA), USEPA, SWRCB, and RWQCB determined acceptable selenium exposure levels for humans and water bodies in California. The ATSDR stated the minimum risk levels (MRLs) for selenium to be ingested over a one-year period is 0.005 milligrams per kilogram per day (mg/kg/day), with an uncertainty factor of three (ATSDR 2018). The 0.005 mg/kg/day value is also used by OEHHA to develop guidelines for consuming fish (OEHHA 2008). USEPA set 50 micrograms per liter (µg/l) as the maximum MCL for selenium in drinking water and OEHHA set a more stringent draft public health goal (PHG) of 30 µg/l for selenium in drinking water (USEPA 2009; OEHHA 2010). USEPA also specified through the CTR that the water quality criteria for aquatic life in all of California's fresh water bodies, except for the San Joaquin River from Merced River to Vernalis, are 20 µg/l for short-term (1-hour average) and 5 µg/l for long-term (4-day average) exposure (USEPA 2000). For the San

Joaquin River from Merced River to Vernalis, the short-term exposure is 12 µg/l and long-term limit is 5 µg/l, as stated in the Sacramento-San Joaquin River Basin Plan (Central Valley RWQCB 2011). The water quality criteria for aquatic life in all of California's water bodies is 5 µg/l (4-day average exposure) and 20 µg/l (1-hour exposure) (USEPA 2019).

USEPA, United States Department of the Interior, Bureau of Reclamation (Reclamation), SWRCB, and RWQCB created plans to reduce the toxic levels of selenium in California's impaired water bodies. USEPA's Action Plan consists of recommendations to restore water quality and to protect aquatic species in the San Francisco Bay/Sacramento–San Joaquin Delta (Bay-Delta), which include strengthening selenium water quality criteria to reduce the long-term exposure of sensitive aquatic and terrestrial species to selenium (USEPA 2012). Grasslands Marshes, located in the San Joaquin Valley, include an area contaminated with selenium from agricultural irrigation and drainage practices when the marshes were irrigated with a blend of subsurface agricultural drainage water and higher-quality water. Reclamation's Grasslands Bypass Project reroutes the discharge of selenium-laden subsurface agriculture water from upstream agricultural dischargers that formerly passed through the Grassland Water District and nearby wildlife refuges and wetlands to Mud Slough by conveying it through a portion of the San Luis Drain. The project began in 1996 and has since reduced the selenium load discharged from the Grassland Drainage Area from 9,600 pounds (lbs) to 2,200 lbs in 2011 (GBPOC 2013). Both the USEPA Action Plan and the Grasslands Bypass Project reduce selenium levels in waterways to meet the water quality objective targeted for December 2019. The Central Valley RWQCB released a draft waste discharge requirement in May 2014 that suggests a performance goal of 15 µg/l (monthly mean) and water quality objective of 5 µg/l (4-day average) for Mud Slough (north) and the San Joaquin River (Central Valley RWQCB 2015). This water quality objective for a 4-day average selenium concentration is consistent with the TMDL for the lower San Joaquin River (Central Valley RWQCB 2001). The USEPA also released the final water quality criteria for the protection of freshwater aquatic life from toxic effects of selenium, shown in Table G.1-3, Draft Water Quality Criteria for Selenium (USEPA 2016a).

Table G.1-3. Draft Water Quality Criteria for Selenium

Media Type	Fish Tissue	–	Water Column[3]	–
Criterion Element	Egg/Ovary[1]	Fish Whole-Body or Muscle[2]	Monthly Average Exposure	Intermittent Exposure[4]
Magnitude	15.1 mg/kg	8.5 mg/kg whole body or 11.3 mg/kg muscle (skinless, boneless filet)	1.5 µg/l in lentic aquatic systems 3.1 µg/l in lotic aquatic systems	$WQC_{int} = \dfrac{WQC_{30-day} - C_{bkgrnd}(1 - f_{int})}{f_{int}}$
Duration	Instantaneous measurement[5]	Instantaneous measurement[5]	30 days	Number of days/months with an elevated concentration
Frequency	Not to be exceeded	Not to be exceeded	Not more than once in three years on average	Not more than once in three years on average

Source: USEPA 2016a

[1] Overrides any whole-body, muscle, or water column elements when fish egg/vary concentrations are measured.

[2] Overrides any water column element when both fish tissue and water concentrations are measured.

[3] Water column values are based on dissolved total selenium in water

[4] Where WQC30-day is the water column monthly element, for either a lentic or lotic system, as appropriate. Cbkgrnd is the average background selenium concentration, and fint is the fraction of any 30-day period during which elevated selenium concentrations occur, with fint assigned a value ≥0.033 (corresponding to 1 day).

[5] Instantaneous measurement. Fish tissue data provide point measurements that reflect integrative accumulation of selenium over time and space in the fish at a given site. Selenium concentrations in fish tissue are expected to change only gradually over time in response to environmental fluctuations.

G.1.1.4 *Cadmium, Copper, and Zinc*

Cadmium, copper, and zinc are constituents of concern primarily in the Sacramento River region (SWRCB 2017a). This impairment results largely from discharges of acid mine drainage from inactive mines in the upper Sacramento River watershed, specifically from the Iron Mountain Mines site upstream of Keswick Dam and other mines upstream of Shasta Dam (Central Valley RWQCB 2002a).

Adverse effects of elevated metal concentrations are a concern for water quality and aquatic organisms, resulting in anadromous fish mortality and progressive declines in anadromous fish populations in the Sacramento River (Central Valley RWQCB 2002a). To protect aquatic life, the Central Valley RWQCB developed a TMDL program for dissolved cadmium, cooper, and zinc loading into the upper Sacramento River. Table G.1-4 lists numeric targets for dissolved cadmium, copper, and zinc.

Table G.1-4. Numeric Targets for Dissolved Cadmium, Copper, and Zinc

Metal[1]	Acute Numeric Target (micrograms per liter µg/l])	Chronic Numeric Target (µg/l)
Cadmium	0.22[2]	0.22[2]
Copper	5.6[2]	4.1[3]
Zinc	16[2]	16[2]

Source: Central Valley RWQCB 2002a

[1] The proposed numeric targets are hardness dependent; the numbers in this table are based on a hardness of 40 milligrams per liter as calcium carbonate.

[2] Central Valley Region Water Quality Control Plan trace element water quality objectives (maximum concentrations) for Sacramento River and its tributaries above State Highway 32 Bridge at Hamilton City

[3] California Toxics Rule Criteria for Freshwater Aquatic Life Protection (4-day continuous concentration criteria, not to be exceeded more than once every three year period) for priority toxic pollutants in the State of California for inland surface waters

G.1.1.5 *Nutrients*

Nutrients are a constituent of concern in the lower Klamath River hydrologic area (Klamath Glen HSA) and the Suisun Marsh Wetlands (SWRCB 2017a). Nutrients, such as nitrogen and phosphorus, come from natural sources such as rock and soil weathering, nutrient mixing in ocean water currents, animal manure, atmospheric deposition, and nutrient recycling in sediment (NOAA 2018; USEPA 1998). Anthropogenic sources include fertilizers, detergents, sewage treatment plants, septic systems, combined sewer overflows, and sediment mobilization (USEPA 1998).

Nutrients are essential to maintaining a healthy aquatic ecosystem. However, nitrogen and phosphorus over-enrichment can contribute to a process known as eutrophication, an excessive growth of macrophytes, phytoplankton, and/or potentially toxic algal blooms. Eutrophication may also lead to a decrease of dissolved oxygen, typically at night, when plants stop producing oxygen through photosynthesis but continue to use oxygen. Low dissolved oxygen levels can kill fish, cause an imbalance of prey and predator species, and result in aquatic resources decline (USEPA 1998). Severely low dissolved oxygen conditions are referred to as anoxic and may enhance methylmercury production (San Francisco Bay RWQCB 2012). Over enrichment can also contribute to cloudy or murky water clarity by increasing the amount of materials (e.g., algae) suspended in the water.

Nutrients can also impact ecosystem dynamics in complex ways that extend beyond eutrophication. Changes in the form of available nutrients (chemical state, oxidized versus reduced, organic versus inorganic, dissolved versus particulate) and the proportion of different nutrients produce effects at multiple scales. For example, the balance of nitrogen and phosphorus (N:P) can affect other metabolic aspects of phytoplankton besides growth, including toxin production, cell membrane thickness, and other chemical constituents (Mitra and Flynn 2005; Flynn et al. 1994; Johansson and Granéli 1999a, 1999b; Granéli and Flynn 2006; Oh et al. 2000; Ha et al. 2009; Harris et al. 2016). Further, biomass of certain invasive macrophytes can be affected by the N:P ratio (You et al. 2014 as cited by Dahm et al. 2016).

For decades, researchers have explored the relative use of – or relative preference for – different forms of nitrogen (N) by phytoplankton. Ammonium (NH_4) is generally considered to be the form of nitrogen preferred by phytoplankton because it requires less energy to assimilate than nitrate (NO_3). Research indicates that the form of available nitrogen can affect phytoplankton species composition with some literature suggesting diatoms generally have a preference for NO_3, while dinoflagellates and cyanobacteria generally prefer more chemically reduced forms of nitrogen (NH_4, urea, organic nitrogen) (Berg et al. 2001; Glibert et al. 2004, 2006; Brown 2009). However, more recent research shows certain diatom and chlorophyte species grew significantly faster with NH_4 compared with NO_3 (Berg et al. 2017). This suggests differences in growth rates among species may have a greater role in phytoplankton species composition than variations in N sources (Berg et al. 2017).

At the ecosystem scale, the total load and balance of nutrient elements can have effects that propagate through the food web, with the potential of transforming ecosystems to new stable states (Sterner and Elser 2002; Penuelas et al. 2012). Zooplankton feeding rates and egg production have been linked to variation in nutrient content of their food (Kiorboe 1989). Shifts in zooplankton communities from copepods to cladaceron and calanoid copepods to cyclopoid copepods have followed changes in nitrogen to phosphorous ratios (Glibert et al. 2011; Hessen 1997).

Reinforcing these relationships, several ecosystems elsewhere have seen a resurgence of some native species and a decline of some invasive species, including invasive clams, following reductions in nutrient loads and a restoration of the N:P balance (Ruhl and Rybicki 2010; Greening and Janicki 2006; Rask et al. 1999; Cloern 2001).

G.1.1.6 *Dissolved Oxygen*

Dissolved oxygen is a constituent of concern in the study area primarily in the lower Klamath River, Delta, and Suisun Marsh Wetlands (SWRCB 2017a). Oxygen in water comes primarily from the atmosphere through diffusion at the water surface, as well as from groundwater discharge into streams and when plants undergo photosynthesis, releasing oxygen in exchange for carbon dioxide (USGS 2017; NOAA 2008a). Levels of dissolved oxygen vary with several factors, including season, time of day, water temperature, salinity, and organic matter. The season and time of day dictate photosynthesis processes, which require sunlight. Increases in water temperature and salinity reduce the solubility of oxygen (NOAA 2008b). Fungus and bacteria use oxygen when decomposing organic matter in water bodies. So, the more organic matter present in a water body, the more potential for dissolved oxygen levels to decline.

Adverse effects of low dissolved oxygen are a concern for water quality and aquatic organisms. Low dissolved oxygen impairs growth, immunity, reproduction, and causes asphyxiation and death (North Coast RWQCB 2011).

To protect aquatic life, USEPA established water quality standards for dissolved oxygen (USEPA 1986a). USEPA also established site-specific water quality objectives to protect the beneficial uses of California’s water bodies (Table G.1-1), including warm and cold freshwater habitats in both tidal and non-tidal waters.

Future plans to maintain a healthy level of dissolved oxygen in water bodies are also site-specific, such as plans for the San Joaquin River and the Stockton Deep Water Ship Channel (Central Valley RWQCB 2018a).

G.1.1.7 *Pesticides*

Pesticides are constituents of concern throughout the study area and particularly in the Central Valley. Major pesticides of concern include organophosphate (OP) pesticides, primarily diazinon and chlorpyrifos, and organochlorine (OC) pesticides, mainly Dichloro-Diphenyl-Trichloroethane (DDT) and Group A pesticides. The toxicity and fates of these pesticides are described in the following sections.

G.1.1.7.1 Organophosphate Pesticides

The two most prevalent OP pesticides in the study area are man-made pesticides, diazinon and chlorpyrifos, which were used extensively in agricultural and residential applications. Former and current uses of diazinon and chlorpyrifos resulted in water body contamination throughout the Central Valley, as identified in the Section 303(d) list (SWRCB 2017a). The Central Valley RWQCB also identified hot spots of contamination, particularly in the Delta and urban areas of Stockton and Sacramento (Central Valley RWQCB 2003).

Pesticides are primarily transported into streams and rivers in runoff from agriculture (Central Valley RWQCB 2011), but they also occur or have occurred in urban non-point runoff and stormwater discharges. Treated municipal wastewater can also be a point source. OP pesticides, diazinon and chlorpyrifos, have been banned from non-agricultural uses since December 31, 2004 and December 2001. Reported non-agricultural pesticide use of diazinon and chlorpyrifos declined substantially in some counties between 2000 and 2009 (Central Valley RWQCB 2014). However, the reduction of OP pesticide use resulted in the increasing use of pyrethroids and carbamates as alternative pesticides in urban and agricultural areas.

Diazinon was one of the most common insecticides in the U.S. for household lawn and garden pest control, indoor residential crack and crevice treatments, and pet collars until all residential uses of diazinon were phased out, between 2002 and 2004 (USEPA 2004). Diazinon usage was then prohibited for several agricultural functions in 2007, with only a few remaining agricultural uses permitted, including on some fruit, vegetable, nut and field crops, and as an ear-tag on non-lactating cattle (USEPA 2007). The highest continued use of diazinon is on almonds and stone fruits (USEPA 2004).

G.1.1.7.2 Organochlorine Pesticides

OC pesticides are primarily comprised of DDT and Group A Pesticides (Central Valley RWQCB 2010b). DDT is a persistent chemical that binds tightly to soil and sediment and breaks down slowly in the environment. It degrades to the isomers o,p'- and p,p'- DDT; o,p'- and p,p'-Dicholoro-Diphenyl-Dichloroethylene (DDE) and o,p'- and p,p'- Dichloro-Diphenyl-Dichloroethane (DDD). Group A Pesticides are the total concentration of the OC pesticides: aldrin, dieldrin, endrin, heptachlor, heptachlor epoxide, chlordane (total), hexachlorocyclohexane (total), and include Lindane (gamma-BHC), alpha-BHC, endosulfan (total), and toxaphene. These pesticides have similar chemical properties to DDT and are also persistent in the environment.

The transport of OC pesticides into streams and rivers is primarily from agriculture runoff (Central Valley RWQCB 2011). Other potential point sources of OC pesticides include storm sewer discharges and historic spills. Non-point sources can include areas of previous residential applications, open space and channel erosion, and some background sources through wet and dry atmospheric deposition. Most OC pesticides were previously deposited on terrestrial soils; thus, the erosion and transport of contaminated sediments continue to contribute to detectable levels in stream bed sediment (Central Valley RWQCB 2010b).

Historically, OC pesticides were used as insecticides, fungicides, and antimicrobial chemicals in residential and agricultural pest control (Central Valley RWQCB 2010b). Most were banned in the mid-1970s, and fish tissue concentrations declined rapidly since the ban through the mid-1980s (Greenfield et al., 2004). However, OC pesticides continue to be detected in fish tissue, the water column, and sediment in the Central Valley.

G.1.1.7.3 Pyrethroid Pesticides

Pyrethroids (e.g., bifenthrin, permethrin, cypermethrin) are synthetic insecticides used in agriculture and households. The Surface Water Ambient Monitoring Program (SWAMP) studies indicate that the replacement of organophosphate pesticides by pyrethroids resulted in an increased contribution of pyrethroids to ambient water and sediment toxicity (Anderson et al. 2011). In the water column, toxicity to the water flea *Ceriodaphnia dubia (C. dubia)* is caused by organophosphate and pyrethroid pesticides. Pyrethroids are also the major chemical class of concern in urban stormwater, as indicated by toxicity testing using the amphipod *Hyalella azteca (H. azteca),* which is highly sensitive to pyrethroids (Weston and Lydy 2010). Of the pyrethroid pesticides, bifenthrin is a major concern (Markiewicz et al. 2012).

Fong et al. (2016) suggest that pyrethroid use may have played a role in the Pelagic Organism Decline and urge additional research be conducted. In June 2017, the Central Valley RWQCB adopted the *Amendment to the Basin Plan for the Control of Pyrethroid Pesticide Discharges*, establishing measurable pyrethroid concentration goals and a program of implementation to control pyrethroid pesticides (SWRCB 2017b). On the sediment side, as indicated by *H. azteca*, most of toxicity is attributed to pyrethroids, particularly in urban areas (Markiewicz et al. 2012).

G.1.1.7.4 Other Pesticides

Recent monitoring programs are routinely detecting multiple pesticides in each water sample from the Bay-Delta. Fong et al (2016) report, “For example, 27 pesticides or degradation products were detected in Sacramento River samples, and the average number of pesticides per sample was six. In San Joaquin River samples, 26 pesticides or degradation products were detected, and the average number detected per sample was 9.” The effects of chemical mixtures on aquatic organisms is generally unknown but many chemicals may have additive or synergistic effects. Diuron (3-(3,4-dichlorophenyl)-1,1-dimethylurea, or DCMU) was introduced in 1954 and is currently is one of the most-used herbicides in California (Central Valley RWQCB 2012). Analysts identified non-polar organic compounds, especially herbicides, and the herbicide Diuron as causes of algal toxicity in the Central Valley. It is an herbicide that inhibits photosynthesis and used to control annual broadleaf and grassy weeds. USEPA has not developed a Water Quality Control (WQC) specific to Diuron, but a TMDL in development will include the development of a water quality objective for Diuron in the Central Valley.

G.1.1.8 *Polychlorinated Biphenyls*

Polychlorinated biphenyls (PCBs), a group of synthetic organic chemicals, is a constituent of concern throughout California including the Sacramento River region (Sacramento, Feather, and American rivers), the Delta, Suisun Bay, Carquinez Strait, and San Pablo Bay (SWRCB 2017a). PCBs cause harmful environmental effects and pose a risk to human health (ATSDR 2000).

PCBs are mixtures of a variety of individual chlorinated biphenyl components, known as congeners. In the United States, many of these mixtures were sold under the trade name Aroclor, and manufactured from 1930 to 1977 primarily to be used as coolants and lubricants in transformers, capacitors, and other electrical equipment. Although manufacture was banned in 1979, PCBs continue to cause environmental degradation because they are environmentally persistent, easily redistributed between air, water and soil, and tend to accumulate and biomagnify in the food chain (ATSDR 2000, OEHHA 2008).

The “weathering” of PCBs is a process by which the composition of Aroclor mixtures undergo differential partitioning, degradation, and biotransformation. This results in differential environmental persistence and bioaccumulation of the mixtures, which increase with the degree of chlorination of new mixtures (OEHHA 2008). The PCBs with more chlorine atoms tend to be heavier and remain close to the source of contamination, whereas those with fewer chlorine atoms are easily transported in the atmosphere. Atmospheric deposition is the primary source of PCBs to surface waters, although the redissolution of sediment-bound PCBs also contributes to surface water contamination. PCBs leave the water column through sorption to suspended solids, volatilization from water surfaces, and concentration in plants and animals (ATSDR 2000).

PCBs cannot be distinctly assessed for health effects, as their toxicity is determined by the interactions of individual congeners and the interactions of PCBs with other structurally related chemicals, including those combined with or used in the production of PCBs. However, studies identify several general health effects of PCB exposure. When PCBs are absorbed, they are distributed throughout the body and accumulate in lipid-rich tissues, including the liver, skin tissue, and breast milk. They can also be transferred across the placenta to the fetus. Studies link oral exposure to cancer and adverse neurological, reproductive, and developmental effects. The International Agency for Research on Cancer listed PCBs as probable human carcinogens, and OEHHA administratively listed PCBs on the Proposition 65 list of chemicals known to the State of California to cause cancer (OEHHA 2008).

G.1.2 Trinity and Klamath Rivers

The Trinity River Region includes the area in Trinity County along the Trinity River from Trinity Lake to the confluence with the Klamath River; and in Humboldt and Del Norte counties along the Klamath River from the confluence with the Trinity River to the Pacific Ocean.

This water quality analysis includes Trinity Lake, Lewiston Lake, Trinity River downstream of Lewiston Dam, and the Klamath River from its confluence with the Trinity River to the Pacific Ocean. The analysis does not include Trinity River upstream of Trinity Lake, the South Fork of the Trinity River, or the Klamath River upstream of Trinity River, because these areas are not affected by changes in CVP operation.

Several water quality requirements affect the Klamath River and Trinity River basins. Beneficial uses and water quality objectives provided by the North Coast RWQCB and the Hoopa Valley Tribal Environmental Protection Agency (Hoopa Valley TEPA) are described below, as well as relevant TMDLs. The Yurok Tribe Basin Plan for the Yurok Indian Reservation and the Resighini Rancheria Tribal Water Quality Ordinance also regulate portions of the Trinity and Klamath rivers that flow into and through the reservations; however, because they have not yet been approved by the USEPA, their objectives are not described in detail here. Oregon water quality requirements also affect the water quality of the Klamath River, which originates in Oregon. However, this chapter only discusses the requirements within the Trinity and lower Klamath River Basins.

G.1.2.1 *Beneficial Uses*

Beneficial uses for all water bodies in the study area are determined by the North Coast RWQCB and the Hoopa Valley TEPA (Table G.1-1). In addition to the beneficial uses listed in the Trinity and Klamath River basins, the *Water Quality Control Plan for the North Coast Region* (North Coast Basin Plan) notes that recreational use (i.e., water contact recreation [REC-1] and non-contact water recreation [REC-2]) occurs in all hydrologic units of the Klamath River Basin, with Trinity River being one of the rivers receiving the largest levels of recreational use (North Coast RWQCB 2018). Fish and wildlife reside in virtually all the surface waters within the North Coast Region (North Coast RWQCB 2018). These species include several designated as rare, threatened, and endangered. Trinity Dam also provides the beneficial use of hydroelectric power generation (POW).

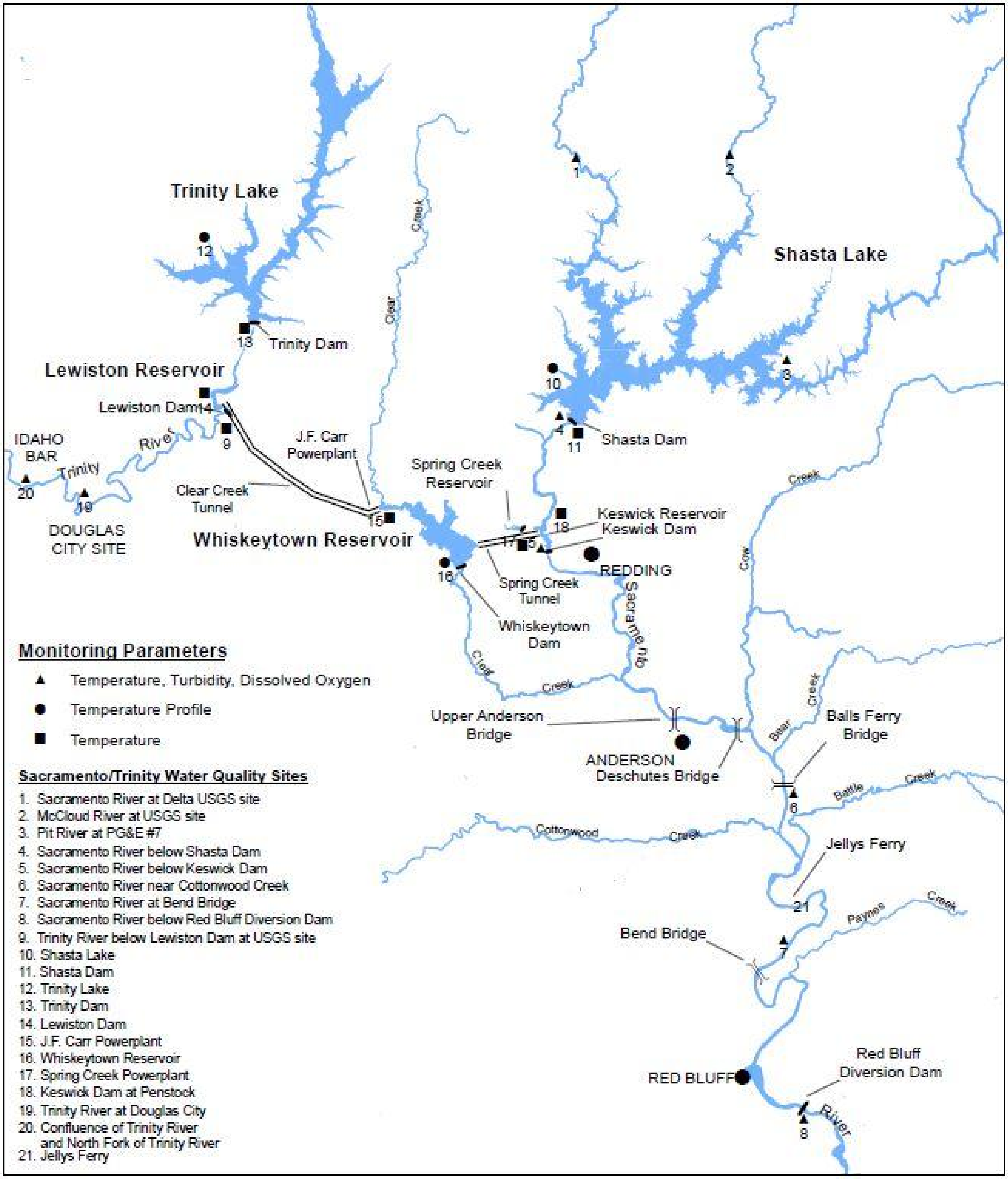
G.1.2.2 *Constituents of Concern*

Under Section 303(d), states, territories, and authorized tribes are required to develop a ranked list of water quality-limited segments of rivers and other water bodies under their jurisdiction. Listed waters do not meet water quality standards even after point sources of pollution have installed the minimum required levels of pollution control technology. The law requires that action plans, or TMDLs, be developed to monitor and improve water quality. TMDL is defined as the sum of the individual waste load allocations from point sources, load allocations from nonpoint sources and background loading, plus an appropriate margin of safety. A TMDL defines the maximum amount of a pollutant that a water body can receive and still meet water quality standards. TMDLs can lead to more stringent National Pollutant Discharge Elimination System permits (CWA section 402). The constituents of concern within the Trinity and Lower Klamath Rivers that are not currently in compliance with existing water quality standards, for which TMDLs are adopted or are in development, are summarized in Table G.1-5, Constituents of Concern per the Section 303(d) list within the Trinity and Lower Klamath Rivers, and discussed below. Figure G.1-1, Water Quality Compliance Stations along Trinity River and Upper Sacramento River presents compliance locations for water quality monitoring along the Trinity River.

Table G.1-5. Constituents of Concern per the Section 303(d) list within the Trinity and Lower Klamath Rivers

Waterbody	Constituent of Concern	TMDL Status[1]
Trinity Lake (was Claire Engle Lake)	Mercury	Expected: 2019
Trinity River HU, Lower Trinity HA; Trinity River HU, Middle HA; Trinity River HU, South Fork HA; Trinity River, Upper HA; Trinity River HU, Upper HA, Trinity River, East Fork	Sedimentation/Siltation, Temperature2, Mercury3	Approved: 2001
Klamath River HU, Lower HA, Klamath Glen HAS	Nutrients, Organic, Enrichment/Low Dissolved Oxygen, Water Temperature	Approved: 2010
	Sedimentation/Siltation	Expected: 2025

Source: SWRCB 2017a
Key:
HU – hydrologic unit
HA – hydrologic area
Notes:
[1] TMDL status is either expected to be completed or approved by USEPA in the year specified
[2] Water temperature is only a constituent of concern for the South Fork Trinity River and a TMDL is expected to be completed in 2019.
[3] Mercury is only a constituent of concern for the East Fork Trinity River in the upper hydrologic area and a TMDL is expected to be completed in 2019.



Source: Reclamation 2015

Figure G.1-1. Water Quality Compliance Stations along Trinity River and Upper Sacramento River

G.1.2.2.1 Mercury

Trinity Lake and the upper hydrologic area of the East Fork Trinity River are two water bodies in the North Coast that are Section 303(d) listed as impaired by mercury (SWRCB 2017a). Mercury in Trinity Lake is attributed to unknown sources (SWRCB 2017c). Substantial mercury contamination is likely due to historical gold and mercury mining activities along the East Fork Trinity River at the inactive Altoona Mercury Mine (May et al. 2004).

The commercial or recreational collection of fish, shellfish, or organisms was deemed impaired since fish tissue exceeded USEPA's recommended fish tissue residue criteria for human health of 0.3 mg of methylmercury (wet weight) per kg of fish tissue (SWRCB 2017c-h). This criterion is based on the consumption-weighted rate of 0.0175 kg of total fish and shellfish per day. In samples from fish in Trinity Lake in September 2001 and 2002, 14 out of 57 fish tissue samples exceeded this fish tissue criterion. White Catfish (*Ameirus catus*), Smallmouth Bass (*Micropterus dolomieu*), and Chinook Salmon (*Oncorhynchus tshawytscha*) composite fish tissue samples exceeded the criterion.

For the protection of marine aquatic life, water quality objectives for mercury were set for discharges within the area specified in the North Coast RWQCB Basin Plan as follows (North Coast RWQCB 2011):

- Six-Month Median: 0.04 µg/l;
- Daily Maximum: 0.16 µg/l;
- Instantaneous Maximum: 0.4 µg/l (conservative estimate for chronic toxicity).

A TMDL is expected to be complete by 2019 to meet the water quality standards in Trinity Lake and the East Fork of Trinity River. The 2011 North Coast RWQCB Basin Plan (North Coast RWQCB 2011) established an approach for calculating effluent limitations.

G.1.2.2.2 Nutrients

The lower Klamath River is on the SWRCB's CWA Section 303(d) list as impaired by nutrients (SWRCB 2017a). Nutrient levels in the Klamath Estuary may cease to be a limiting factor and can promote levels of algal growth that cause a nuisance or adversely affect beneficial uses when excess growth is not consumed by animals or exported by flows (DOI and DFG 2012).

The Klamath River receives the greatest nutrient loading from the Upper Klamath basin, comprising approximately 40% of its total contaminant load (North Coast RWQCB 2010). Tributaries to the Klamath River are the greatest contributors of the remaining nutrient loads, with the Trinity River contributing the most.

The Hoopa Valley TEPA also designates water quality objectives to address contamination by nutrients, presented in Table G.1-6, Specific Use Water Quality Criteria for Waters of the Hoopa Valley Indian Reservation.

Table G.1-6. Specific Use Water Quality Criteria for Waters of the Hoopa Valley Indian Reservation

Contaminant	Trinity River	Klamath River
Maximum Annual Periphyton Biomass	–	150 mg chlorophyll *a*/m^2 of streambed area
pH	MUN-designated waters: 5.0 – 9.0 All other designated uses: 7.0 – 8.5	7.0 – 8.5
Total Nitrogen[1]	–	0.2 mg/l
Total Phosphorus[1]		0.035 mg/l
Microcystis aeruginosa cell density	–	< 5,000 cells/mL for drinking water < 40,000 cells/mL for recreational water
Microcystin toxin concentration		< 1 µg/l total microcystins for drinking water < 8 µg/l total microcystins for recreational water
Total potentially toxigenic blue-green algal species[2]		< 100,000 cells/mL for recreational water
Cyanobacterial scums		There shall be no presence of cyanobacterial scums

Source: Hoopa Valley TEPA 2008

[1] There should be at least two samples per 30-day period. If total nitrogen and total phosphorus standards are not achievable due to natural conditions, then the standards shall instead be the natural conditions for total nitrogen and total phosphorus. Through consultation, the ongoing TMDL process for the Klamath River is expected to further define these natural conditions.

[2] Includes: Anabaena, Microcystis, Planktothrix, Nostoc, Coelsphaerium, Anabaenopsis, Aphanizomenon, Gloeotrichia, and Oscillatoria.

In addition to the water quality criteria established by the Hoopa Valley TEPA (2008), the 2010 *Klamath River TMDLs Addressing Temperature, Dissolved Oxygen, Nutrient, and Microcystin Impairments in California* provides TMDLs for nutrients which address elevated pH levels (DOI and DFG 2012). Nutrient targets include numeric targets for total phosphorus, and total nitrogen (North Coast RWQCB 2010).

The North Coast RWQCB and other affiliated agencies, including SWRCB, USEPA, Reclamation, USFWS, the Oregon Department of Environmental Quality (responsible for implementation of the Klamath TMDLs in Oregon), and other state, federal, and private agencies with operations that affect the Klamath River are implementing the Klamath River nutrient TMDLs (North Coast RWQCB 2010).

G.1.2.2.3 Organic Matter

The lower Klamath River is on the SWRCB's CWA Section 303(d) list as impaired by organic matter (SWRCB 2017a).

The Klamath River has several natural sources of organic matter. The river originates from the Upper Klamath Lake, which is a naturally shallow, eutrophic lake, with high levels of organic matter (algae), including nitrogen fixing blue-green algae (North Coast RWQCB 2010). Other sources of organic matter include runoff from agricultural lands (e.g., irrigation tailwater, storm runoff, subsurface drainage, and animal waste), flow regulations/modification, industrial point sources, and municipal point sources (SWRCB 2011).

The North Coast RWQCB established a TMDL for organic matter and other constituents to protect the beneficial uses of the lower Klamath River, including cold freshwater habitat, in 2010. The TMDL equals 143,019 lbs of Carbonaceous Biochemical Oxygen Demand (CBOD) per day from the Klamath River (North Coast RWQCB 2011). The average organic matter (measured as CBOD) loads from all other Klamath River tributaries are sufficient to meet other related objectives, including dissolved oxygen and biostimulatory substances objectives, in the Klamath River (North Coast RWQCB 2010). The dissolved oxygen objectives are the primary targets associated with organic matter and nutrients. The North Coast RWQCB also established organic matter allocations for the Klamath River below Salmon River, and the major tributaries to the Klamath, including Trinity River.

Implementation actions and other objectives were established to ensure the TMDL is met to protect the beneficial uses of the Klamath River and other water bodies downstream. The North Coast Basin Plan states that a water quality study will be completed to identify actions for monitoring, evaluating, and implementing any necessary actions to address organic matter loading so that the TMDL will be met (North Coast RWQCB 2011).

G.1.2.2.4 Dissolved Oxygen

The lower Klamath River is on the SWRCB's CWA Section 303(d) list as impaired by dissolved oxygen (SWRCB 2017a).

Sources that contribute to low dissolved oxygen include sources of organic enrichment, water temperature, and salinity. Other sources that contribute to low dissolved oxygen are runoff from roads and agriculture that can transport nutrients into water bodies and lower dissolved oxygen through biostimulatory effects (North Coast RWQCB 2010). The over-enrichment and growth of algae and aquatic plants can produce oxygen during the day through photosynthesis, but those same plants can deplete dissolved oxygen at night.

To protect the beneficial uses of the lower Klamath River, including the cold freshwater habitat, water quality objectives were established in the North Coast Basin Plan (2011) and the Hoopa Valley TEPA (2008) for dissolved oxygen in the Klamath River and its major tributary, the Trinity River (Table G.1-7 and Table G.1-8) (North Coast RWQCB 2011). Site Specific Objectives (SSOs) for dissolved oxygen were calculated as part of TMDLs developed by the North Coast RWQCB (2011) and have been incorporated into the North Coast Basin Plan (2011) (Table G.1-9). For those waters without location-specific dissolved oxygen criteria, dissolved oxygen shall not be reduced below minimum levels, shown in Table G.1-10, at any time to protect beneficial uses.

Table G.1-7. Water Quality Objectives for Dissolved Oxygen in Trinity and Lower Klamath

Water body	Dissolved Oxygen (mg/l)	
	Minimum	50% Lower Limit[1]
Trinity Lake and Lewiston Reservoir	7.0	10.0
Lower Trinity River	8.0	10.0
Lower Trinity Area Streams	9.0	10.0
Lower Klamath River Area Streams	8.0	10.0

Source: North Coast RWQCB 2011

[1] 50% lower limit represents the 50 percentile values of the monthly means for a calendar year. 50 percent or more of the monthly means must be greater than or equal to the lower limit.

Table G.1-8. Specific Use Water Quality Criteria for Waters of the Hoopa Valley Indian Reservation

Contaminant	Trinity River	Klamath River
Minimum Water Column Dissolved Oxygen Concentration	11.0 mg/l	SPWN-designated waters[1]: 11.0 mg/l[2] COLD-designated waters: 8.0 mg/l[2]
Minimum Inter-gravel Dissolved Oxygen Concentration	8.0 mg/l	SPWN-designated waters[1]: 8.0 mg/l[2]

Source: Hoopa Valley TEPA 2008

[1] Whenever spawning occurs, has occurred in the past or has potential to occur.

[2] 7-day moving average of the daily minimum DO. If dissolved oxygen standards are not achievable due to natural conditions, the COLD and SPWN standard shall instead be dissolved oxygen concentrations equivalent to 90 percent saturation under natural receiving water temperatures.

Table G.1-9. Site Specific Objectives for Dissolved Oxygen in the Klamath River[1]

Location[2]	Percent Dissolved Oxygen Saturation Based On Natural Receiving Water Temperatures[3]	Time Period
Downstream of Hoopa-California Boundary to Turwar	85	June 1 through August 31
	90	September 1 through May 31
Upper and Middle Estuary	80	August 1 through August 31
	85	September 1 through October 31 and June 1 through July 31
	90	November 1 through May 31
Lower Estuary	For the protection of estuarine habitat (EST), the dissolved oxygen content of the Lower Klamath estuary shall not be depressed to levels adversely affecting beneficial uses as a result of controllable water quality factors.	

Source: North Coast RWQCB 2018

[1] States may establish site specific objectives equal to natural background (USEPA 1986a. Ambient Water Quality Criteria for Dissolved Oxygen, EPA 440/5-86-033; USEPA Memo from Tudor T. Davies, Director of Office of Science and Technology, USEPA Washington, D.C. dated November 5, 1997). For aquatic life uses, where the natural background condition for a specific parameter is documented, by definition that condition is sufficient to support the level of aquatic life expected to occur naturally at the site absent any interference by humans (Davies 1997). These dissolved oxygen objectives are derived from the T1BSR run of the Klamath TMDL model and described in Tetra Tech, December 23, 2009 Modeling Scenarios: Klamath River Model for TMDL Development (Tetra Tech and WR and TMDL Center 2009). They represent natural dissolved oxygen background conditions due only to non-anthropogenic sources and a natural flow regime.

[2] These objectives apply to the maximum extent allowed by law. To the extent that the State lacks jurisdiction, the Site Specific Dissolved Oxygen Objectives for the Mainstem Klamath River are extended as a recommendation to the applicable regulatory authority.

[3] Corresponding dissolved oxygen concentrations are calculated as daily minima, based on site-specific barometric pressure, site-specific salinity, and natural receiving water temperatures as estimated by the T1BSR run of the Klamath TMDL model and described in Tetra Tech, December 23, 2009 (Tetra Tech and WR and TMDL Center 2009). Modeling Scenarios: Klamath River Model for TMDL Development. The estimates of natural receiving water temperatures used in these calculations may be updated as new data or method(s) become available. After opportunity for public comment, any update or improvements to the estimate of natural receiving water temperature must be reviewed and approved by Executive Officer before being used for this purpose.

Table G.1-10. Water Quality Objectives for Dissolved Oxygen for Specified Beneficial Uses

Beneficial Use Designation	Minimum Dissolved Oxygen Limit (mg/l)
WARM, MAR, or SAL	5.0
COLD	6.0
SPWN	7.0
SPWN – during critical spawning and egg incubation periods	9.0
Klamath River Water Column[1] SPWN-designated waters[2]: COLD-designated waters:	 11.0 mg/l[3] 8.0 mg/l[3]
Klamath River Inter Gravel[1] SPWN-designated waters[2]:	8.0 mg/l[3]

Source: North Coast RWQCB 2011
[1] Hoopa Valley TEPA (2008)
[2] Whenever spawning occurs, has occurred in the past or has potential to occur.
[3] 7-day moving average of the daily minimum DO. If dissolved oxygen standards are not achievable due to natural conditions, the COLD and SPWN standard shall instead be dissolved oxygen concentrations equivalent to 90 percent saturation under natural receiving water temperatures.

The 2010 *Klamath River TMDLs Addressing Temperature, Dissolved Oxygen, Nutrient, and Microcystin Impairments in California* provides numerical targets for dissolved oxygen and other constituents (North Coast RWQCB 2010). This TMDL proposed site-specific objectives for dissolved oxygen, which were adopted into the North Coast Basin Plan. The dissolved oxygen objectives are the primary targets associated with nutrient and organic matter, with additional dissolved oxygen-related TMDLs prescribed for total phosphorus, total nitrogen, and organic matter (CBOD) loading. The TMDL also provides numerical targets for benthic algae biomass, suspended algae chlorophyll-a, *microcystis aeruginosa*, and microcystin toxin.

Chapter 7 of the Klamath River TMDLs established plans to monitor dissolved oxygen and other constituents in the Klamath River below Trinity River, near Turwar, and the Klamath River Estuary to further protect the beneficial uses of the Trinity and lower Klamath Rivers (North Coast RWQCB 2010). The TMDL also includes a proposal to revise SSOs for dissolved oxygen in the Klamath River.

G.1.2.2.5 Sedimentation and Siltation

The lower Klamath River and Trinity River are on the SWRCB's CWA Section 303(d) list as impaired by sedimentation and siltation (SWRCB 2017a). The source of sedimentation and siltation in the Trinity and Klamath rivers is not attributed to CVP operation.

Trinity River

Disturbance of sediment and silt is a natural part of stream ecosystems, which can contribute to fluctuating salmonid populations in response to fine sediment embedded in spawning gravels. However, human activities resulted in an increased severity and frequency of habitat disturbance (TRRP and North Coast RWQCB 2009). In the Mainstem Trinity River, sediment loading can be attributed to runoff from areas of active or past mining, timber harvest, and road-related activities. Natural sources, such as landsliding, bank erosion, and soil creep, contribute the greatest sediment loads each year (North Coast RWQCB 2008). Future point sources of sedimentation into the Trinity River Basin, including CalTrans facilities and construction sites larger than five acres, must meet discharge requirements pursuant to California's NPDES general permit for construction site runoff (USEPA 2001c).

The primary adverse impacts of excess sedimentation are those affecting the spawning habitat for anadromous salmonids (TRRP and North Coast RWQCB 2009). The main affected beneficial uses include commercial or sport fishing; cold fresh water habitat; the migration of aquatic organisms; spawning, reproduction, and early development; and rare, threatened, and endangered species. Recreation in the Trinity River Basin, such as boating, fishing, camping, swimming, sightseeing, and hiking, is also potentially affected because sedimentation can affect the water clarity and water quality (USEPA 2001c). The North Coast Basin Plan established water quality objectives for sedimentation and siltation.

The Tribal Environmental Protection Agency (TEPA) withdrew turbidity criteria for all waters within the Hoopa Valley Indian Reservation, as it is still being evaluated. They will be revised for inclusion in the next triennial review (Hoopa Valley TEPA 2018).

In addition to these water quality objectives, the North Coast Basin Plan also prohibits the discharge of soil, silt, bark, sawdust, or other organic and earthen material from any logging, construction, or associated activity into any stream or watercourse in quantities harmful to beneficial uses. It also prohibits the placing or disposal of such materials in locations where they can pass into any stream or watercourse in quantities harmful to beneficial uses (North Coast RWQCB 2011).

The Trinity River TMDL, approved by USEPA in December 2001, addresses sediment loading in the mainstem Trinity River, which exceeds applicable water quality standards (SWRCB 2017c-h, USEPA 2001c). The TMDL determined assimilation capacity for sediment loading and provides the percent reduction of managed sediment discharge required for each subarea. These allocations are adequate to protect aquatic habitat and are expected to be evaluated on a ten-year rolling basis (USEPA 2001c).

Lower Klamath River

The Section 303(d) list also includes the Klamath River downstream of Weitchpec for contamination from sedimentation and siltation, due to exceedances of the sediment water quality criteria, and long-term sedimentation and siltation influxes (SWRCB 2017i).

Major sources of sediment discharge in the lower Klamath River are ongoing logging and runoff from major storm events. According to reports cited by the SWRCB, water quality in runoff from timber harvest in all lower Klamath watersheds exceed cumulative effect thresholds (SWRCB 2017i).

The *Long Range Plan for the Klamath River Basin Fishery Conservation Area Restoration Program* (1986 to 2006) emphasizes sedimentation in the lower Klamath Basin, and notes that the sediment is creating problems with fish passage and stream bed stability (Klamath River Basin Fisheries Task Force 1991). The near extinction of the eulachon indicated problems with sediment supply, size, and bed load movement, and aggradations in salmon spawning reaches are expected to persist for decades (SWRCB 2017i). Increased sediment loads also result from the widening of stream channels, through processes like bank erosion, and, with the related reduction of riparian shade, can contribute to elevated stream temperatures (North Coast RWQCB 2010). The North Coast Basin Plan includes the TMDLs for the region that address sedimentation and siltation (North Coast RWQCB 2011).

G.1.3 Sacramento River

G.1.3.1 *Sacramento River from Shasta Lake to Verona*

Releases from Shasta Lake and diversions from Trinity Lake Water influence water quality in the upper Sacramento River. Annual and seasonal flows in the Sacramento River watershed are highly variable from year to year. These variations in flow are a source of variability in Sacramento drainage water quality.

The water quality constituents currently not in compliance with existing water quality standards, for which TMDLs are adopted or are in development, in this region are: mercury, PCBs, unknown toxicity, and multiple pesticides. Changes to the North Coast Basin Plan addressed chlorpyrifos and diazinon. A TMDL addressed cadmium, copper, and zinc, and temperature is also closely monitored. Figure G.1-2, 303(d) Listed Waterways in the Sacramento River, Feather River, and American River Regions, presents 303(d) listed waterways in the Sacramento River Region.

G.1.3.1.1 Mercury

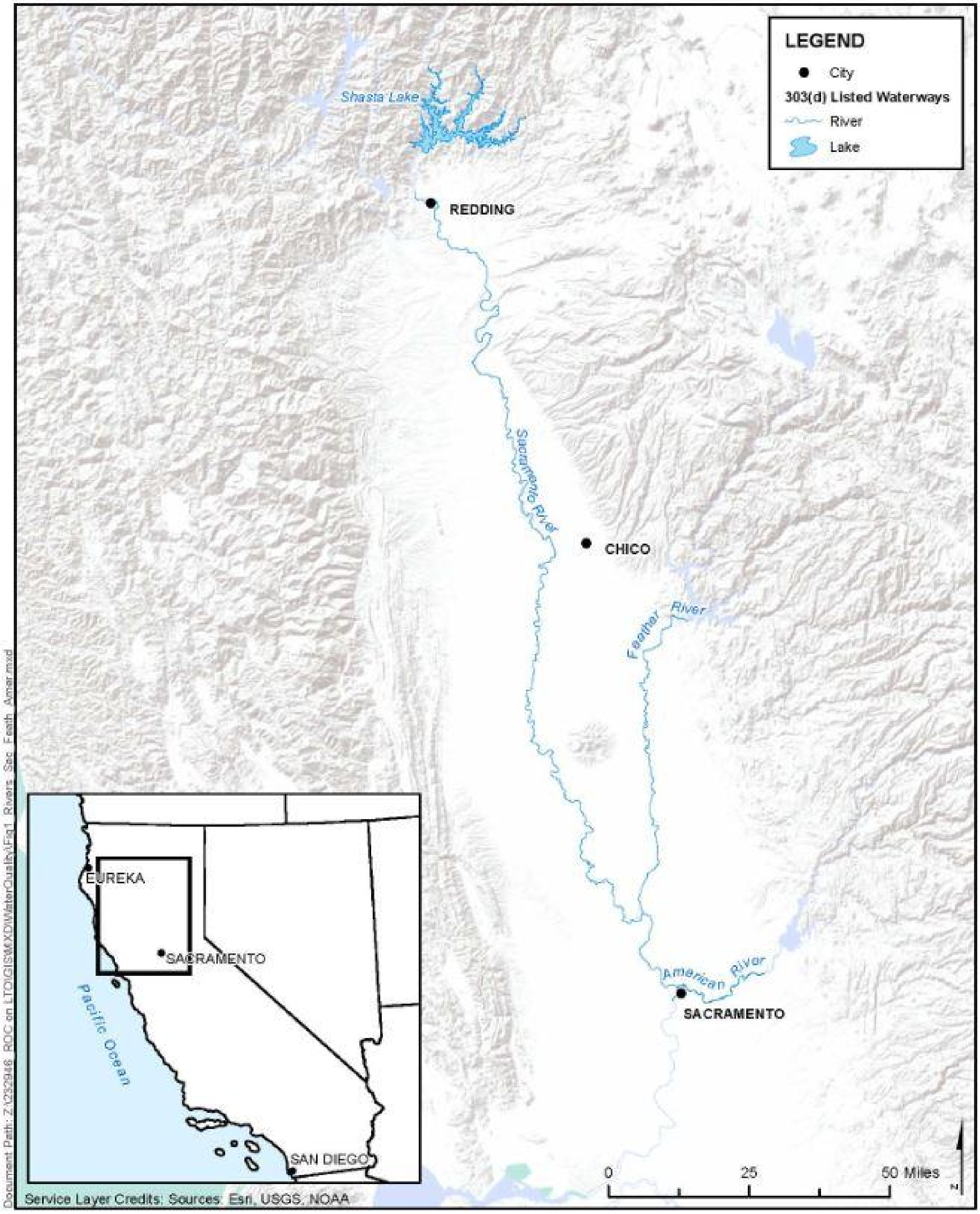
Shasta Lake and the Sacramento River from Cottonwood Creek to Red Bluff are on the Section 303(d) list for mercury contamination (SWRCB 2017a). Mercury is not a constituent of concern for the Sacramento River between Shasta Dam and the Cottonwood Creek. Mercury in the Sacramento River Basin can be attributed to resource extraction (SWRCB 2017j,k).

A 2008 CALFED Bay-Delta Program (CALFED) report titled *Methylmercury Concentrations and Loads in the Central Valley and Freshwater Delta,* tabulates methylmercury concentrations in the Sacramento River from Redding (0.3 nanogram per liter [ng/l]) to Freeport (0.11 ng/l) from 2003 to 2006 (Foe et al. 2008). For the 2016 listing, composite fish tissue samples were collected from Shasta Lake and the Sacramento River from Cottonwood Creek to Knights Landing. The SWRCB deemed the commercial or recreational collection of fish, shellfish, or organisms impaired, since fish tissue exceeded USEPA's recommended Fish Tissue Residue Criteria for human health of 0.3 mg of methylmercury (wet weight) per kg of fish tissue (SWRCB 2017j,k).

USEPA recommended maximum exposure concentrations in an effort to protect the beneficial uses of these water bodies, including the protection of aquatic and human health. In addition, a TMDL is expected to be completed in 2027 to meet the water quality standards in these water bodies (SWRCB 2017f-g).

G.1.3.1.2 Cadmium, Copper, and Zinc

Shasta Lake where West Squaw Creek enters the lake, Spring Creek (from Iron Mountain Mine to Keswick Reservoir), and Keswick Reservoir downstream of Spring Creek are on the Section 303(d) list for impairment by cadmium, copper, and zinc (SWRCB 2017a). The Upper Sacramento River from Keswick Dam to Cottonwood Creek was previously listed on the Section 303(d) list for impairment by cadmium, copper, and zinc, but was delisted after a TMDL completion in 2002 led to the SWRCB determining that the water quality standard was met. Acid mine drainage discharged from inactive mines in the upper Sacramento River watershed, located upstream of Shasta and Keswick dams was the primary cause of the elevated levels (Central Valley RWQCB 2002a). Abatement projects are underway to clean up many inactive mine sites that discharge high concentrations of metals (Central Valley RWQCB 2018a).



Source: SWRCB 2017a

Figure G.1-2. 303(d) Listed Waterways in the Sacramento River, Feather River, and American River Regions

The *2002 Upper Sacramento River TMDL for Cadmium, Copper and Zinc*, and water quality objectives in the North Coast Basin Plan address cadmium, copper, and zinc contamination in the Sacramento River (Central Valley RWQCB 2002a). Although cadmium, copper, and zinc are generally found as mixtures in surface water, the mixtures tend to be antagonistic, less toxic than when found as individual components, and thus the water quality objectives focus on individual parameters. Levels of water hardness affect the toxicity of these metals; increased hardness decreases toxicity. Specific levels of water hardness determine the water quality objectives at certain locations (Central Valley RWQCB 2002a). The TMDL for cadmium, copper, and zinc in Shasta Lake, Spring Creek, and Keswick Reservoir is expected to be completed in 2020 (SWRCB 2017j,l,m).

G.1.3.1.3 Pesticides

The Sacramento River from Red Bluff to Knights Landing is on the Section 303(d) list as impaired by DDT and the Group A pesticide dieldrin. The Sacramento River from Knights Landing to the Delta is on the Section 303(d) list as impaired by chlordane, DDT, and dieldrin (SWRCB 2017a). Chlordane, DDT, and dieldrin are legacy pesticides and were discontinued from the early 1970s to the late 1980s.

Although these pesticides were discontinued in the late 1980s, the narrative water quality objective for toxicity, which applies to single or the interactive effect of multiple pesticides or substances and states that “All waters shall be maintained free of toxic substances in concentrations that produce detrimental physiological responses in human, plant, animal, or aquatic life,” has not been met (Central Valley RWQCB 2018a). Fish concentrations of DDT collected in 2005 exceeded the Total DDT OEHHA screening value of 21 micrograms per kilogram (µg/kg) by up to five times, which was used as a criterion to evaluate the narrative water quality objective by up to five times. Concentrations of dieldrin also exceeded the OEHHA Evaluation Guideline of 0.46 µg/kg (SWRCB 2017n).

To protect the beneficial uses of the Sacramento River and other water bodies downstream, including the impaired commercial or recreational collection of fish, shellfish, or organisms, TMDLs for DDT and dieldrin in the Sacramento River from Red Bluff to Knights Landing are expected to be completed in 2027 (SWRCB 2017n). For the Sacramento River from Knights Landing to the Delta, TMDLs are expected to be completed in 2021 for chlordane, in 2022 for dieldrin, and in 2027 for DDT.

Although the Sacramento River is not on the Section 303(d) list for chlorpyrifos and diazinon contamination, these pesticides are a concern in the Sacramento River for potentially affecting the beneficial uses of Warm and Cold Freshwater Habitat (SWRCB 2017n, Central Valley RWQCB 2007a). Water quality sampling from 1999 to 2006 revealed concentrations of both pesticides at levels of concern in the Sacramento Rivers. In addition to runoff of applied pesticides into irrigation and stormwater runoff into the Sacramento Rivers, atmospheric transport of diazinon from the Central Valley to the Sierra Nevada Mountains has occurred.

G.1.3.1.4 PCBs

The stretch of the Sacramento River from Red Bluff to Knights Landing is on the Section 303(d) list as impaired by PCBs (SWRCB 2017a). According to the Section 303(d) list /305(b) Report Supporting Information, sources of PCBs in Sacramento River are unknown (SWRCB 2017n).

The OEHHA Fish Contaminant Goal (FCG) of total PCBs in fish is 3.6 parts per billion (ppb) (or 3.6 nanograms per gram [ng/g]) (SWRCB 2017n). Fish tissue samples collected in August and October 2005 exhibited exceedances. Six composite samples were analyzed for 48 individual PCB congeners and four Aroclor mixtures, with the four exceedances reported as 102.499 ng/g in Channel Catfish (*Ictalurus* *punctatus*) at Colusa, 9.151 ng/g in Channel Catfish at Grimes, 6.504 ng/g in Sacramento Sucker (*Catostomus occidentalis*) at Colusa, and 5.767 ng/g in Sacramento Sucker at Woodson Bridge.

To protect the beneficial uses of the Sacramento River, including the impaired beneficial use of commercial and sport fishing, a TMDL is expected to be complete in 2027 (SWRCB 2017n).

G.1.3.1.5 Unknown Toxicity

The Sacramento River from Keswick Reservoir to Knights Landing is on the Section 303(d) list as impaired for unknown toxicity (SWRCB 2017a).

Results of survival, growth, and reproductive toxicity tests performed from 1998 to 2007 showed an increase in mortality and a reduction in growth and reproduction in *C. dubia*, the Fathead Minnow (*Pimephales promelas*) and the alga *Pseudokirchneriella subcapitata* (*P. subcapitata*, formerly known as *Selenastrum capricornutum*) (SWRCB 2017k,n-p). Observations violated the narrative toxicity objective found in the *Water Quality Control Plan for the Sacramento River and San Joaquin River Basins* (Sacramento – San Joaquin River Basin Plan), which states that all waters shall be maintained free of toxic substances in concentrations that produce detrimental physiological responses in human, plant, or aquatic life (Central Valley RWQCB 2011). This objective applies regardless of whether the toxicity is caused by a single substance or the interactive effect of multiple substances. Further research is being conducted on the causes of toxicity in the Sacramento River. The TMDL for unknown toxicity in the Upper Sacramento River is expected to be complete in 2019 (SWRCB 2017k,n-p).

A 2012 SWAMP report summarized the occurrences and causes of toxicity in the Central Valley (Markiewicz et al.2012). The SWRCB's SWAMP defines toxicity as a statistically significant adverse impact on standard aquatic test organisms in laboratory exposures. SWAMP testing uses laboratory test organisms as surrogates for aquatic species in the environment to assess the causes of toxicity in California waterways (Anderson et al.2011).

Sediment toxicity was noted to be higher in urban areas including Sacramento, Yuba City, Redding, and Antioch, while sediments from agricultural areas were generally non-toxic (Markiewicz et al.2012). Moderate water toxicity was observed throughout the agricultural and urban-agricultural areas in the upper Sacramento watershed, including in the Colusa Basin, the Sutter Buttes area, and along the eastern valley floor between Chico and Lincoln.

SWAMP studies indicate that replacing organophosphate pesticides by pyrethroids has resulted in an increased contribution of pyrethroids to ambient water and sediment toxicity (Anderson et al. 2011).In sediment, as indicated by H. azteca, the majority of toxicity is attributed to pyrethroids, particularly in urban areas (Markiewicz et al. 2012). Of the pyrethroid pesticides, bifenthrin is a major concern.

G.1.3.2 *Sacramento River from Verona to Freeport*

The water quality of the lower Sacramento River is influenced by the upstream sources discussed above, as well as by inflows from the American River and surrounding urban and agricultural runoff.

G.1.3.2.1 Mercury

The Sacramento River from Knights Landing to the Delta is on the Section 303(d) list for mercury contamination (SWRCB 2017a).

Mercury in this reach of the river is attributed to waterborne inputs from the upper Sacramento, Feather, Yuba, and American rivers (SWRCB 2017p). These major tributaries are also listed as impaired due to mercury. As in the Klamath and Trinity river basins, historical mining has resulted in mercury contamination in the Sacramento River Basin.

Flows from the Yuba River are an important source of mercury loading to the lower Sacramento River. Tailings discharged from gold mines in the Sierra Nevada mountains during the nineteenth century contained substantial amounts of mercury-laden sediment, due to the use of mercury to extract gold. These discharges caused anthropogenic alluvial fans to form at the base of the Sierra Nevada, most notably the Yuba Fan. Singer et al. (2013) predicted that mercury-laden sediment from the original fan deposit will continue to be transported to the Sacramento River for the next 10,000 years.

The Sacramento River is a key source of mercury contamination into the Delta. Over 80% of total mercury flux to the Delta can be attributed to the Sacramento River Basin (Central Valley RWQCB 2010a). The Central Valley RWQCB (2016) compiled data from 2000 to 2003 and reported an average of 0.10 ng/l in the Sacramento River at Freeport. CALFED reported that the Sacramento River at Freeport contributed an average of 0.11 ng/l of methylmercury to the Delta from 2003 to 2006 (Foe et al. 2008).

Water samples were collected from the lower Sacramento River and its tributaries from March 2003 to June 2006 (Foe et al. 2008). Major tributaries to the lower Sacramento River, including the Feather River (0.05 ng/l), American River (0.06 ng/l), Colusa Basin Drain (0.21 ng/l), and Yuba River (0.05 ng/l), contribute to the mean methylmercury concentration of 0.11 ng/l at Freeport in the Sacramento River.

Table G.1-11, Streambed Sediment Concentrations of Mercury in The Sacramento River and Delta Regions presents streambed sediment mercury concentrations from the Sacramento River and Delta regions in 1995, sampled as part of the National Water Quality Assessment (NWQA) Program for the Sacramento River Basin (MacCoy and Domagalski 1999). Limited data for mercury in sediment exist, but the existing data exhibits levels of mercury greatly exceeding the average amount of mercury found on the earth’s surface, 0.05 micrograms per gram (µg/g). The highest streambed sediment concentrations of mercury were measured downstream from the Sierra Nevada and Coast Ranges. Within the Sacramento River, sites downstream of the Feather River had higher concentrations of mercury than sampled locations upstream of the confluence. The Yuba River, Bear River, Sacramento River at Verona, and the Feather River had the highest reported mercury concentrations, which exceeded the threshold effect concentration (0.18 µg/g), but not the probable effect concentration (1.06 µg/g) reported by MacDonald et al. (2000).

Table G.1-11. Streambed Sediment Concentrations of Mercury in The Sacramento River and Delta Regions

Water body/Site	Concentration
Feather River sites	
Feather River	0.21 µg/g
Yuba River	0.37 µg/g
Bear River	0.37 µg/g
Feather & Sacramento Rivers Downstream of the confluence at Verona	0.24 µg/g
Sacramento River sites	
Bend Bridge	0.16 µg/g
Freeport	0.14 µg/g
Cache Creek	0.15 µg/g

Water body/Site	Concentration
Arcade Creek	0.13 µg/g
American River	0.16 µg/g

Source: MacCoy and Domagalski 1999
Reported in bottom material <63 micron fraction dry weight.
* Concentration exceeds the MacDonald et al. (2000) threshold effect concentration (0.18 µg/g dry weight) but not the probable effect concentration (1.06 µg/g dry weight).

The Central Valley RWQCB (2016) made recommendations for the future reduction of mercury contamination in an effort to protect the beneficial uses of the Sacramento River, including the impaired commercial and recreational collection of fish, shellfish, or organisms. The Delta Mercury Control Program (MERP 2012) provides potential load allocations for mercury pertaining to the Sacramento River and the Yolo Bypass, while the Cache Creek Watershed Mercury Program provides load allocations for Cache Creek, Bear Creek, Sulphur Creek, and Harley Gulch.

G.1.3.2.2 Pesticides

The Sacramento River is on the Section 303(d) list as impaired by the pesticides chlordane, DDT, and dieldrin from Knights Landing to the Delta (SWRCB 2017a). The three pesticides listings were based on the evaluation of fish contaminant data from 2005. Chlordane, DDT, and dieldrin are legacy pesticides discontinued in the early 1970s to the late 1980s. However, samples collected in the Sacramento River at the Veterans Bridge in September 2005 revealed elevated pesticide concentrations (SWRCB 2017p).

A composite sample of carp and a composite sample of Channel Catfish had total chlordane concentrations of 6.72 µg/kg and 10.20 µg/kg, both exceeding OEHHAs (2008) FCG of 5.6 µg/kg for total chlordane in fish tissue (SWRCB 2017p).

Composite samples of carp and Channel Catfish contained total DDT concentrations of 59. µg/kg and 109. µg/kg, respectively. These concentrations exceeded the OEHHAs (2008) FCG of 21 µg/kg (SWRCB 2017p).

Composite samples of carp and Channel Catfish contained total dieldrin concentrations of 0.98 µg/kg and 1.49 µg/kg, respectively. These concentrations both exceeded the OEHHAs (2008) FCG of 0.46 µg/kg (SWRCB 2017p).

G.1.3.2.3 PCBs

The Sacramento River from Knights Landing to the Delta is on the Section 303(d) list as impaired by PCBs (SWRCB 2017a).

According to the Section 303(d) List/305(b) Report Supporting Information, sources of PCBs in this reach of the Sacramento River are unknown (SWRCB 2017p).

The Sacramento River from Knights Landing to the Delta was recently listed as contaminated by PCBs. Three of three composite samples analyzed for total PCBs in September 2005 exceeded the OEHHA Fish Contaminant Goal for total PCBs of 3.6 ppb (or 3.6 ng/g), wet weight. The exceeding concentrations were recorded at 53 ng/g in Channel Catfish, 6.0 ng/g in Sacramento sucker, and 26 in carp (SWRCB 2017p).

A TMDL for PCBs in the Sacramento River from Knights Landing to the Delta is expected to be completed in 2021 to protect the beneficial uses of the Sacramento River and downstream waterbodies (SWRCB 2017p).

G.1.3.2.4 Dissolved Oxygen

The Sacramento River is not on the Section 303(d) list for low dissolved oxygen (SWRCB 2017a).

G.1.3.2.5 Salinity, Electrical Conductivity, and Total Dissolved Solids

The Sacramento River is not on the Section 303(d) list as impaired by salinity (SWRCB 2017a).

G.1.3.2.6 Selenium

Water bodies in the Sacramento River Basin are not on the Section 303(d) list as impaired by selenium. Waterborne selenium concentrations in the Sacramento River near Verona are relatively low compared to concentrations in the San Joaquin River Basin. However, the much larger flow that the Sacramento River contributes to the Delta, in comparison to the San Joaquin River's flow, results in a substantial contribution to the mass loading of selenium to the Delta from the Sacramento River (Cutter and Cutter 2004; SWRCB 2008). Loads to the Delta from the Sacramento River were projected to be about half of what the Grasslands basin was projected to contribute to the San Joaquin River, with subsequent loading to the Delta from the San Joaquin River dependent on flow (Presser and Luoma 2006).

Data for selenium in fish from the Sacramento River is limited, but the Central Valley RWQCB sampled Largemouth Bass (*Micropterus salmoides*) in 1999, 2000, 2005, and 2007 from the lower Sacramento River, San Joaquin River, and Delta. The fillet data and whole-body selenium concentrations, estimated using an equation from Saiki et al. (1991), were used to evaluate potential human and wildlife health risks (Foe 2010). Selenium concentrations of the bass from the Sacramento River at Veterans Bridge were well below the draft criteria released in May 2014 (11.8 mg/kg for fillets and 8.1 mg/kg for whole body) (USEPA 2014).

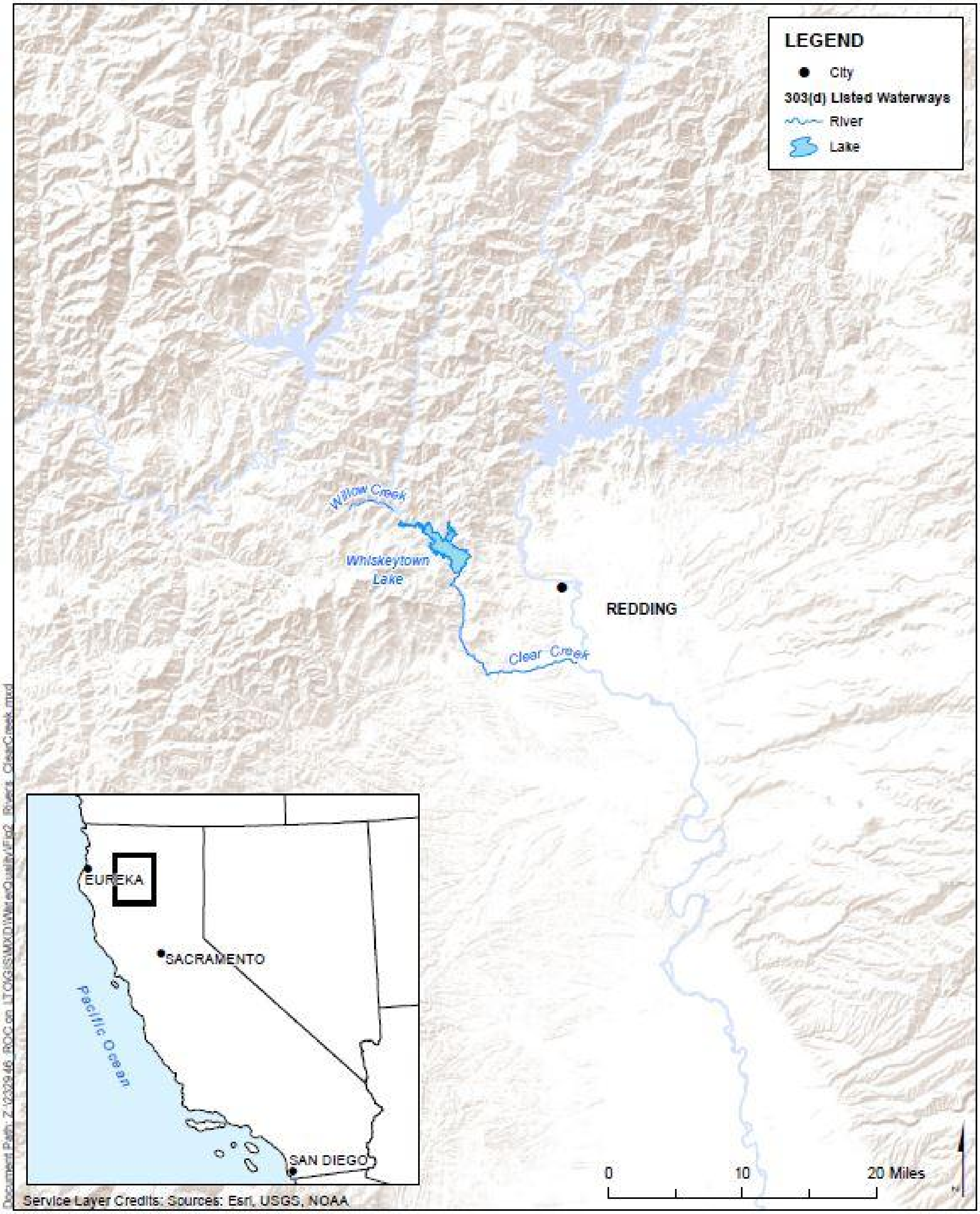
G.1.3.2.7 Unknown Toxicity

The Sacramento River from Knights Landing to the Delta is listed as impaired by toxicity due to the results of survival, growth, and reproductive toxicity tests performed in 2006 and 2007. Observations of increased mortality and reduction in growth and reproduction in *C. dubia* and *P. promelas* compared to laboratory controls violated the narrative toxicity objective of the Sacramento – San Joaquin River Basin Plan. The TMDL for toxicity in this reach of the river is expected to be completed in 2019 (SWRCB 2017p).

G.1.4 Clear Creek

As the main hydrologic barrier between Upper and Lower Clear Creek, Whiskeytown Dam controls the timing and magnitude of flows into Lower Clear Creek. Whiskeytown Reservoir has the potential to affect several supported beneficial uses for cold and warm water, including agricultural water supply, contact and non-contact water recreation, and fish habitat and migration uses.

Willow Creek, a Clear Creek tributary just upstream of Whiskeytown Reservoir, is on the SWRCB's CWA Section 303(d) list as impaired for metals (copper and zinc) (SWRCB 2017a). The contamination comes from an abandoned copper mine operated in the early 1900s, however, monitoring data has not shown a substantial impact on Clear Creek from the metal-contaminated Willow Creek drainage (Sacramento River Watershed Program N.d.). Clear Creek (below Whiskeytown Lake, Shasta County) and Whiskeytown Lake (areas near Oak Bottom, Brandy Creek Campgrounds and Whiskeytown) are not on the Section 303(d) list as impaired by copper or zinc (SWRCB 2017a). Figure G.1-3, 303(d) Listed Waterways in the Clear Creek Region presents 303(d) listed waterways in the Clear Creek region.



Source: SWRCB 2017a

Figure G.1-3. 303(d) Listed Waterways in the Clear Creek Region

G.1.4.1 *Mercury*

Clear Creek (below Whiskeytown Lake, Shasta County) and Whiskeytown Lake (areas near Oak Bottom, Brandy Creek Campgrounds and Whiskeytown) are on the SWRCB's CWA Section 303(d) list as impaired by mercury (SWRCB 2017a). The major source of this contamination is mercury deposits from in the expansive tailings piles of 1800s dredging gold mining operations (Sacramento River Watershed Program N.d.).

In an effort to meet the water quality standards in Clear Creek and Whiskeytown Lake, a TMDL is expected to be complete by 2027 (SWRCB 2017q,r).

G.1.5 Feather River

Water quality constituents of concern in the Lower Feather River have the potential to affect several supported beneficial uses for cold and warm water, including municipal and agricultural water supply, contact and non-contact water recreation, and fish habitat and migration uses. The Section 303(d) listed contaminants in this reach of the Feather River are water temperature (discussed in Appendix O, *Aquatic Resources Technical Appendix*), mercury, pesticides, PCBs, and others. Figure G.1-2, presented above, displays 303(d) listed waterways in the Feather River region.

G.1.5.1 *Mercury*

The Lower Feather River is on SWRCB's CWA Section 303(d) list as impaired by mercury (SWRCB 2017a). The listing was made before the 2006 Integrated Report; thus, evidence of water quality exceedance is not readily available. The Feather River does have relatively large mercury loadings and high mercury concentrations in suspended sediment, contributing to mercury loading to the Delta. The Feather River transports much of the mercury to the Sacramento River that was released in the Sierra Nevada Mountains during gold mining operations (Central Valley RWQCB 2010a).

Federal Energy Regulatory Commission (FERC) relicensing studies indicate that mercury consistently exceeds USEPA guidelines in most fish species and locations, and that biomagnification appears to cause elevated mercury levels in fish (FERC 2007). Lake Oroville has the beneficial effect of capturing contaminated sediments, preventing their further transport downstream.

In the Delta Estuary TMDL for methylmercury, the Central Valley RWQCB (2010a) recommends that the Feather River be targeted for mercury reduction during initial efforts, focusing on the watersheds that export the largest volumes of highly mercury-contaminated sediment to the Delta.

G.1.5.2 *Pesticides*

The Feather River below Lake Oroville is listed as contaminated for chlorpyrifos. Samples collected during storm events at the Feather River near Nicolaus in 2004 exceeded the California DFG Hazard Assessment Criteria of 25 ng/l over a one-hour average. The TMDL for chlorpyrifos in the Feather River is expected to be completed in 2019 (SWRCB 2017s).

Group A Pesticides were also detected in exceedance of water quality criteria (SWRCB 2017s). NPDES permit program data collected between 2000 and 2009 for organochlorine pesticide contamination in the Feather River did not indicate exceedances of CTR criteria, but did show detections in all samples in the water column. Channel Catfish tissue samples from the Feather River at Highway 99 between 1978 and 2008 exhibited high concentrations of DDT and dieldrin. Supplemental documents for a Sacramento – San Joaquin River Basin Plan amendment to address organochlorine pesticides in Central Valley water bodies presented this water quality and fish tissue data. The amendment is currently in development and will include organochlorine pesticides in the Feather River (Central Valley RWQCB 2010c).

G.1.5.3 *PCBs*

The Lower Feather River is on the SWRCB's CWA Section 303(d) list as impaired by PCBs (SWRCB 2017a).

According to the Section 303(d) List/305(b) Report) Supporting Information, sources of PCBs in the Feather River are unknown (SWRCB 2017s). However, the Draft Environmental Impact Report for Oroville Facilities FERC relicensing notes that PCBs have been detected in all fish and crayfish species from all sampled water bodies (FERC 2007). DWR detected Aroclors in at least some fish in all water bodies, as well as in crayfish in the Feather River downstream from the State Route 70 bridge (DWR 2008). Two events in the 1980s resulted in PCB contamination in the Feather River watershed: oil containing PCBs was applied to a dirt road and entered the Ponderosa Reservoir in surface runoff, and PCB-contaminated soil and water at Belden Forebay due to a landslide, which damaged powerhouses. Some remediation was performed in response to these events.

The Feather River evaluation used the same narrative water quality objective and evaluation criteria of 3.6 ng/g as the guidance to place the Sacramento River on the Section 303(d) list. Composite samples of Largemouth Bass and crayfish collected in 2002 and 2003 showed high exceedances of the FCG. Upstream of the Thermalito Afterbay Outlet, a composite sample of Largemouth Bass had a concentration of 15.6 ng/g total PCBs, wet weight. Downstream of the outlet, the concentration of total PCBs in two composite samples of Largemouth Bass were 11.2 and 15.0 ng/g. Downstream of the Highway 70 Bridge, the concentration of total PCBs in a composite sample of crayfish was 56 ng/g (SWRCB 2017s).

An additional study performed in 2003 and 2004 also revealed high exceedances of the OEHHA FCG for PCBs. Concentrations of total PCBs in composite samples of hardhead (*Mylopharodon conocephalus*) and pikeminnow (*Ptychocheilus grandis*) were 26 ng/g and 31 ng/g wet weight. All samples were analyzed for 48 individual PCB congeners and two Aroclor mixtures (SWRCB 2017s).

A TMDL for PCBs in the Lower Feather River is expected to be completed in 2021 to protect the beneficial uses of the Feather River and other water bodies downstream (SWRCB 2017s).

G.1.5.4 *Other Constituents of Concern*

The Lower Feather River is listed as impaired by unknown toxicity due to exceedances of the toxicity criteria outlined by the Central Valley RWQCB (SWRCB 2017s, Central Valley RWQCB 2018a). Water samples were tested with *C. dubia, P. promelas*, and *P. subcapitata* for survival, growth and reproductive toxicity between 1998 and 2007. Of 212 samples tested with *C. dubia* for survival and reproductive toxicity, 85 exceeded the narrative toxicity objective. Of 34 samples tested with *P. promelas* for survival and growth toxicity, seven exceeded the objective. Of 23 samples tested with *P. subcapitata*, none exceeded the objective. Samples taken from the Feather River at Nicolaus, the Thermalito Diversion Pool, downstream from the Feather River Hatchery, upstream and downstream from the Thermalito Afterbay Outlet, downstream from the Sewage Commission Oroville Region (SCOR) Outlet, and downstream from the FERC Project 2100 project boundary were in violation of the toxicity objective.

G.1.6 American River

The lower American River flows for 23 miles from Nimbus Dam to its confluence with the Sacramento River. Water quality in this reach of the river is influenced by releases from upstream reservoirs, including Lake Natoma and Folsom Lake. The runoff that flows into Folsom Reservoir and Lake Natoma, upstream of the lower American River, is generally high quality (Wallace, Roberts, and Todd et al. 2003). Water quality parameters measured in Folsom Reservoir, upstream of the lower American River, include pH, turbidity, dissolved oxygen (DO), total organic carbon (TOC), nutrients (nitrogen and phosphorus), electrical conductivity, total dissolved solids (TDS), and fecal coliform. Figure G.1-2, presented above, displays 303(d) listed waterways in the American River region.

G.1.6.1 *Mercury*

The American River from Nimbus Dam to the confluence with the Sacramento River is on SWRCB's CWA Section 303(d) list as contaminated by mercury, due to exceedances of OEHHA's guidance tissue levels for mercury (SWRCB 2017t). The major source is mercury from historical mining activities that is slowly distributed downstream.

The American River contributes mercury to the Sacramento River, and thus the Delta, due to its relatively large mercury loadings and high mercury concentrations in suspended sediment (Central Valley RWQCB 2010a). Like the Feather River, the lower American River is recommended for initial mercury reduction efforts as part of the Sacramento – San Joaquin Delta Estuary TMDL for Methylmercury. In addition to load allocations recommended as part of the Delta TMDL for methylmercury, mercury contamination in the American River and its reservoirs will be addressed as part of the statewide water quality control program for mercury (SWRCB 2018a).

G.1.6.2 *PCBs*

The lower American River is on the SWRCB's CWA Section 303(d) list as impaired by PCBs (SWRCB 2017a).

Composite samples of White Catfish and Sacramento Sucker collected in the American River at Discovery Park were analyzed for 48 individual PCB congeners and three Aroclor mixtures (SWRCB 2017t). The total PCBs recorded in the White Catfish and Sacramento Sucker were 3.934 ng/g and 44.094 ng/g. An additional Sacramento Sucker composite sample collected at Nimbus Dam did not exceed the OEHHA goal.

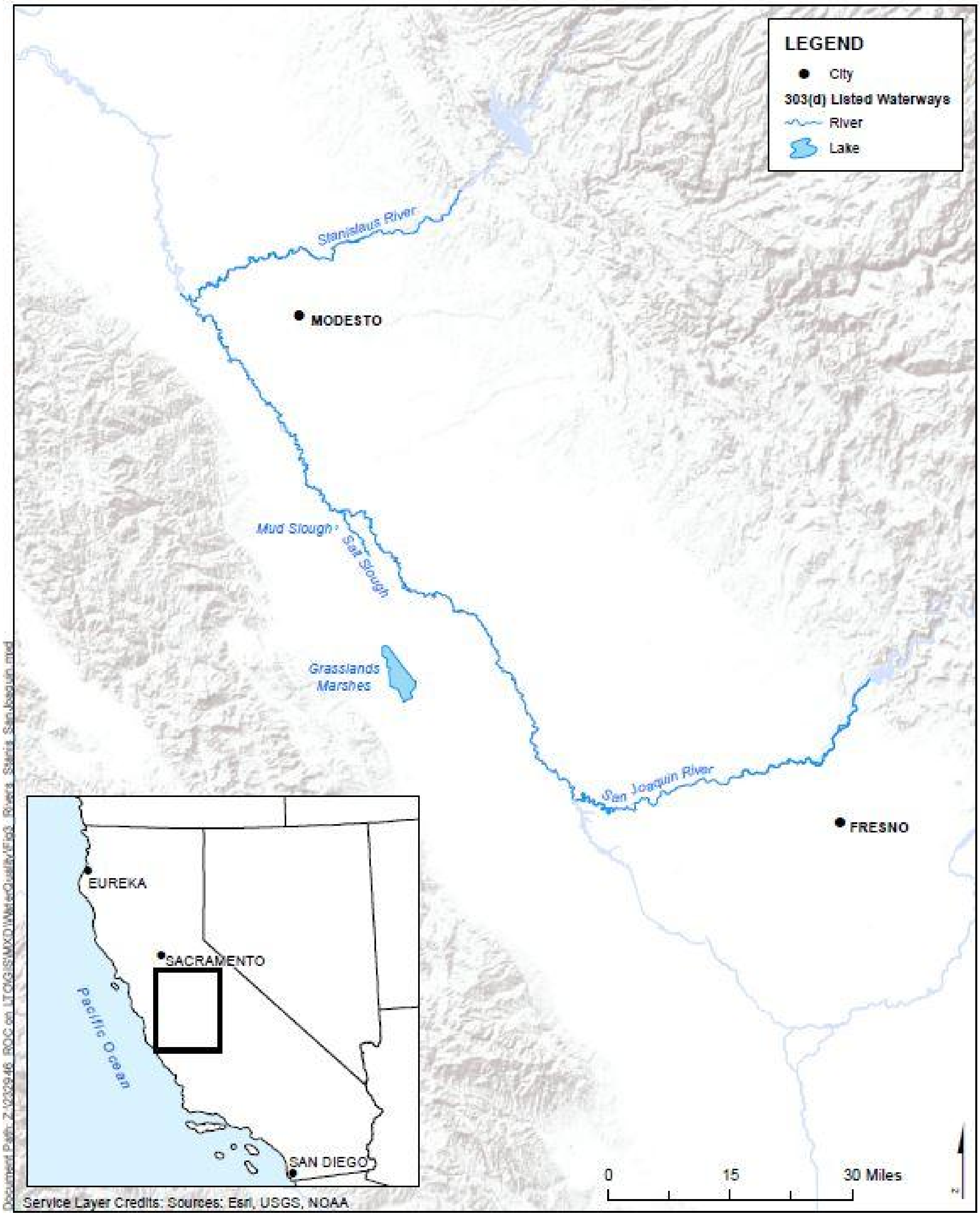
A TMDL for PCBs in the lower American River is expected to be completed in 2021 to protect the beneficial uses of the American River and other water bodies downstream (SWRCB 2017t).

G.1.6.3 *Unknown Toxicity*

The lower American River is on the SWRCB's CWA Section 303(d) list as impaired by unknown toxicity. Samples collected at Discovery Park indicated toxicity for vertebrates and invertebrates, based on survival, growth, and reproduction toxicity tests with *C. dubia* and *P. promelas*. These tests, conducted between 1998 and 2007, exhibited increases in mortality and reductions in growth and reproduction in the test organisms (SWRCB 2017t). The TMDL is expected to be completed in 2021 (SWRCB 2017t).

G.1.7 Stanislaus River

Figure G.1-4, 303(d) Listed Waterways in the Stanislaus River and San Joaquin River Regions presents 303(d) listed waterways within the Stanislaus River region.



Source: SWRCB 2017a

Figure G.1-4. 303(d) Listed Waterways in the Stanislaus River and San Joaquin River Regions

G.1.7.1 *Mercury*

The Lower Stanislaus River is on the SWRCB's CWA Section 303(d) list as impaired by mercury (SWRCB 2017a). Mercury has impaired the beneficial use of the commercial or recreational collection of fish, shellfish, or organisms (SWRCB 2017u-w). The lower Stanislaus River was evaluated prior to 2006, so the evidence for the list is not readily available. However, the total methylmercury concentration in the Stanislaus River at Caswell State Park from 2003 to 2006 was 0.12 ng/l (Foe et al. 2008). Concentrations of methylmercury in Largemouth Bass, carp, Channel Catfish, and White Catfish tissue samples from the Stanislaus River between 1999 and 2000 exceeded the USEPA methylmercury fish tissue criterion (0.3 mg/kg wet weight) for the protection of human health (Shilling 2003).

To protect the beneficial uses of the water bodies mentioned above, including the commercial and recreational collection of fish, shellfish, or organisms, TMDLs are expected to be completed between 2019 to 2021 to meet the water quality standards in these water bodies (SWRCB 2017u-w).

G.1.7.2 *Pesticides*

The Lower Stanislaus River is on SWRCB's CWA Section 303(d) list as impaired by pesticides (chlorpyrifos, diazinon, Group A Pesticides) (SWRCB 2017a). OP pesticides (e.g., diazinon and chlorpyrifos) and OC pesticides (e.g., Group A Pesticides) are primarily transported to streams and rivers in runoff from agriculture (Central Valley RWQCB 2011). Sources and descriptions of the listed pesticides are discussed further in Section G.1.1.7, Pesticides.

G.1.7.3 *Other Constituents of Concern*

The Lower Stanislaus River is on SWRCB's CWA Section 303(d) list as impaired by unknown toxicity (SWRCB 2017a). The Central Valley RWQCB (2011) Basin Plan established a narrative water quality objective, which addresses *E. coli*, to protect the beneficial uses of Lower Stanislaus River. A TMDL aiming to meet the water quality standards in the lower Stanislaus River is expected to be complete in 2021.

G.1.8 San Joaquin River

Water quality conditions in the San Joaquin River are described for locations that would be influenced by the alternatives, including Stanislaus River near Caswell Park by the confluence with the San Joaquin River, San Joaquin River near Vernalis, and San Joaquin River near Buckley Cove and Stockton.

Water quality concerns in the San Joaquin River near Vernalis are primarily salinity, boron, and selenium, which are influenced by low flows due to upstream diversions, as well as water use and agricultural return flows. Figure G.1-4, presented above, shows the 303(d) listed waterways in the San Joaquin River region.

G.1.8.1 *Selenium*

The San Joaquin River from Mud Slough to Merced River is on the SWRCB's CWA list as impaired by selenium (SWRCB 2017a). Other water bodies that drain to the San Joaquin River upstream of this reach and are listed as impaired by selenium contamination on the Section 303(d) list include Mendota Pool, Panoche Creek from Silver Creek to Belmont Avenue, Agatha Canal, Grasslands Marshes, and Mud Slough (North, downstream of San Luis Drain).

USEPA approved TMDLs for selenium for the San Joaquin River (Mud Slough to Merced River) (in 2002), Grasslands Marshes (in 2000), Agatha Canal (in 2000), and Mud Slough (north, downstream of

San Luis Drain) (in 2002) (SWRCB 2017z-ac). A TMDL is expected to be completed for Panoche Creek in 2019 and another for Mendota Pool in 2021. Table G.1-12, Water Quality Objectives for Selenium in the San Joaquin River Region, mg/l, presents water quality objectives defined in the Basin Plan for the Sacramento River basin and the San Joaquin River basin are shown in (Central Valley RWQCB 2018a).

Table G.1-12. Water Quality Objectives for Selenium in the San Joaquin River Region, mg/l

Objective	Applies to:
0.012 (maximum concentration)	San Joaquin River, mouth of the Merced River to Vernalis
0.005 (4-day average)	–
0.020 (maximum concentration)	Mud Slough (north), and the San Joaquin River from Sack Dam to the mouth of Merced River
0.005 (4-day average)	–
0.020 (maximum concentration)	Salt Slough and constructed and re-constructed water supply channels in the Grassland watershed*
0.002 (monthly mean)	–

Source: Central Valley RWQCB 2018a
*Applies to channels identified in Appendix 40 of the Central Valley RWQCB (2018) Basin Plan

The drainage area for the Grasslands Bypass Project is a major but decreasing source of selenium to the San Joaquin River. Selenium from subsurface agricultural drainage waters originating in the drainage area was historically transported through the Grassland Marshes via tributaries such as Mud Slough and Salt Slough (Central Valley RWQCB 2001). Efforts to decrease the selenium loading to the San Joaquin River include the Grassland Bypass Project, discussed in more detail below, which has decreased selenium loading by an average of 55% from the Grasslands Drainage Area in comparison to pre-Grassland Bypass Project conditions (1986-1996 to 1997-2011) (GBPOC 2013). In the San Joaquin River below the Merced River, selenium concentrations decreased from an average of 4.1 µg/l during pre-project conditions (1986 to 1996) to 2 µg/l (1997 to 2011). The continued operation of the Grassland Bypass Project is expected to achieve the Central Valley RWQCB Basin Plan objectives for the San Joaquin Valley (Reclamation & SLDMWA 2009).

The Central Valley RWQCB sampled Largemouth Bass from the San Joaquin River, lower Sacramento River, and Delta during 1999, 2000, 2005, and 2007 (Foe 2010). The samples were analyzed as fillets to evaluate potential human health risks, and whole-body selenium concentrations were estimated using an equation from Saiki et al. (1991) to evaluate risks to wildlife. The data do not exceed the May 2014 USEPA draft water quality criteria.

The 2014 Central Valley RWQCB draft discharge requirements aim to meet the water quality objective for the San Joaquin River. In 2010, the Central Valley RWQCB and SWRCB approved amendments (Resolution 2010-0046) to the Sacramento – San Joaquin River Basin Plan to address selenium control in the San Joaquin River basin as related to the Grassland Bypass Project, described below (Central Valley RWQCB 2010d, SWRCB 2010).

Other relevant requirements/actions to meet the water quality objectives for the San Joaquin River, in addition to the Central Valley RWQCB draft waste discharge requirements (2010d) include the following:

- The Basin Plan amendments (Central Valley RWQCB 2010d, SWRCB 2010) modify the compliance time schedule for discharges regulated under waste discharge requirements to meet the selenium objective or comply with a prohibition of discharge of agricultural subsurface drainage to Mud Slough (north), a tributary to the San Joaquin River, in Merced County. For Mud

Slough (north) and the San Joaquin River from the Mud Slough confluence to the mouth of the Merced River:

- The interim performance goal is 15 µg/l (monthly mean) by December 31, 2015.
- The water quality objective to be achieved by December 31, 2019, is 5 µg/l (4-day average).

An extensive water quality and biological monitoring program was implemented in conjunction with the Grassland Bypass Project, and reports are issued periodically through the San Francisco Estuary Institute (e.g., SFEI 2011).

G.1.8.2 *Electrical Conductivity and Salinity*

Grasslands Marshes, North Mud Slough (downstream of San Luis Drain), and Salt Slough (upstream from confluence with the San Joaquin River) are Central Valley water bodies placed on the Section 303(d) list approved by USEPA in 2010 as impaired by electrical conductivity (SWRCB 2011), and continue to be Section 303(d) listed in the most recent, 2016 update (SWRCB 2017a). Salinity, which is linked to electrical conductivity, is a major concern for water quality in the San Joaquin Valley (Central Valley RWQCB 2011). The RWQCB has adopted a TMDL for the San Joaquin River upstream of Vernalis for salt and boron.

Elevated electrical conductivity in the Grasslands Marshes, North Mud Slough (downstream of San Luis Dam), Salt Slough (upstream from confluence with the San Joaquin River), and San Joaquin River (Bear Creek to Vernalis) can be attributed to agriculture (SWRCB 2017x-aa,ac-af). Likewise, high salinity in the San Joaquin River near Vernalis is linked to the discharge of water from agricultural practices (CALFED 2007a). Saline water from agricultural return flow is added to the southern Delta by the San Joaquin River, where a portion is pumped by the export pumps back to the farms that eventually drain back to the river, exacerbating the problem of salinity control and salt buildup in the San Joaquin Valley.

The SWRCB (2006) Basin Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary established water quality objectives to protect the beneficial uses of these water bodies, including agricultural supply, and municipal and domestic supply. It focuses particularly on the San Joaquin River from Bear Creek to Mud Slough (Table G.1-13, SWRCB Water quality objectives for electrical conductivity in the San Joaquin River [Airport Way Bridge, Vernalis]).

Table G.1-13. SWRCB Water quality objectives for electrical conductivity in the San Joaquin River (Airport Way Bridge, Vernalis)

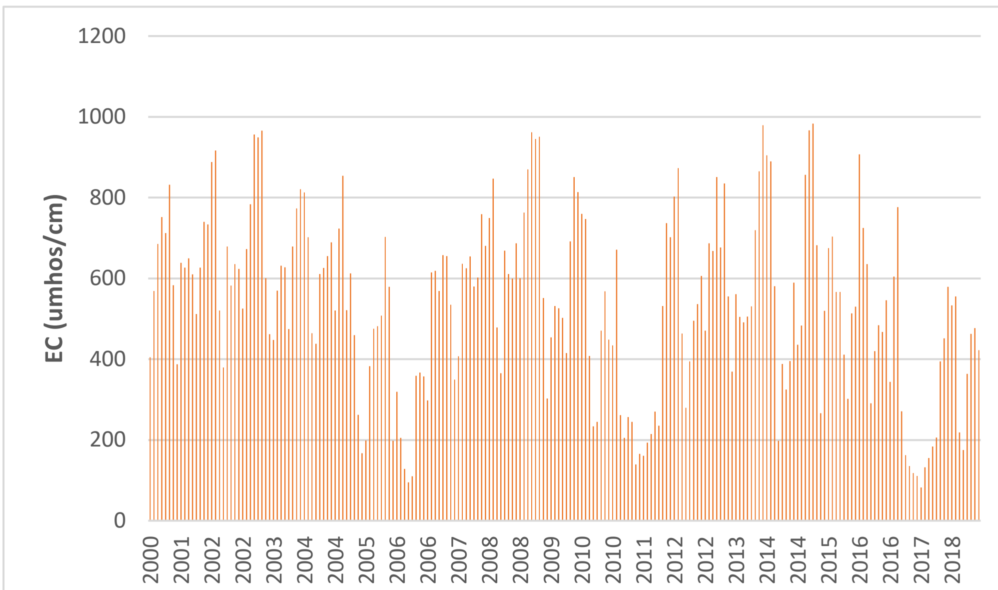
Time Period	Water Quality Objective[1]
April 1 to August 31	0.7 mmhos (700 µS/cm)
September 1 to March 31	1.0 mmhos (1000 µS/cm)

Source: SWRCB 2006
[1] Maximum 30-day running average of mean daily

Several samples from the San Joaquin River (Bear Creek to Vernalis) between October 1995 and February 2007 exceeded the SWRCB Basin Plan's water quality objective for electrical conductivity in the San Joaquin River (SWRCB 2017x-aa, ac-af).Samples were collected from the San Joaquin River at Lander Avenue, Fremont Ford, Patterson Fishing Access, Hills Ferry Bridge, and Crows Landing. Guidelines for evaluating the Grasslands Marshes, North Mud Slough, and Salt Slough are not available because the listing was made prior to 2006.

Figure G.1-5, Monthly Average Specific Conductance in San Joaquin River at Vernalis shows salinity in the lower San Joaquin River as observed at Vernalis. The record of monthly average electrical conductivity (EC) readings for recent years for the San Joaquin River at Vernalis is shown on often exceeds the water quality objective for individual records during summer months. The highest salt concentrations emanate from Mud and Salt sloughs, while less saline water provides dilution from the Merced River (CALFED 2007a). There is a marked increase in salinity during dry months and dry years at Vernalis, ranging from midwinter lows near 100 micromhos per centimeter (µmhos/cm) up to summer high values near 1000 µmhos/cm.

A TMDL is expected to be completed in 2019, except for the San Joaquin River from Tuolumne to Stanislaus River, which is expected to be completed in 2021 (SWRCB 2017x-aa, ac-af). The Central Valley RWQCB implemented the comprehensive salt management program, known as CV-SALTS (Central Valley Salinity Alternatives for Long Term Sustainability), to develop salt control strategies for the San Joaquin and the entire Central Valley watershed (Central Valley RWQCB 2010e, 2011). The San Joaquin River Water Quality Improvement Program (SJRIP) is designed to address issues of chronically saline water, reuse, treatment options, and the development of salt-tolerant crops for this area of the valley, as part of the Grasslands Bypass Project.



Source: DWR 2019a

Figure G.1-5. Monthly Average Specific Conductance in the San Joaquin River at Vernalis

G.1.8.3 *Mercury*

Mercury is a constituent of concern for the San Joaquin River from Bear Creek to Mud Slough (SWRCB 2017a). The San Joaquin River from Friant Dam to Bear Creek was not included on the Section 303(d) list for mercury contamination.

Mercury in this reach of the San Joaquin River can be attributed to resource extraction. Historically, there were gold mining operations along the major tributaries of the San Joaquin River, including the Merced River, Tuolumne River, Stanislaus River, and Cosumnes River in the San Joaquin River basin (Central Valley RWQCB 2010a).

Mercury and enhanced mercury methylation can affect the beneficial uses of the San Joaquin River and receiving waters downstream. At the Delta boundary in Vernalis, the waterborne methylmercury concentration in the San Joaquin River from 2003 to 2006 ranged from 0.10-0.75 ng/l with an average of 0.19 ng/l (Foe et al. 2008). The average fish tissue mercury concentration in Largemouth Bass from Vernalis in 2000 was 0.68 mg/kg (wet weight) (Central Valley RWQCB 2010a). This fish tissue concentration exceeds the USEPA wet weight methylmercury fish tissue criterion (0.3 mg/kg) for the protection of human health.

To further protect the health of humans and wildlife, the Delta TMDL specified narrative and more-stringent numeric water quality objectives for the most bioavailable and toxic form of methylmercury (Central Valley RWQCB 2011). The Delta TMDL (Central Valley RWQCB 2010a), which is applicable to the Delta, Yolo Bypass, and their waterways, includes the reach of the San Joaquin River from Bear Creek to Mud Slough.

G.1.8.4 *Pesticides*

The San Joaquin River (all segments from Mendota Pool to Vernalis), North Mud Slough (downstream of San Luis Drain), and Salt Slough (upstream from confluence with the San Joaquin River) are on the SWRCB's CWA Section 303(d) list as impaired by pesticides (SWRCB 2017a). North Mud Slough is listed as impaired by pesticides. Salt Slough is listed as impaired by chlorpyrifos and prometryn. The San Joaquin River is listed as impaired by OP pesticides (chlorpyrifos and diazinon), OC pesticides (DDT, DDE, Group A Pesticides, including toxaphene), alpha.-BHC, and diuron. Impairment listings vary between reaches of the San Joaquin River. Several other small tributaries to the San Joaquin River from the west are also on the Section 303(d) as impaired by pesticides (i.e., Mud Slough North [upstream and downstream of San Luis drain]).

Pesticides in North Mud Slough, Salt Slough, and the San Joaquin River are from agriculture runoff, with the exception of the alpha-BHC in the San Joaquin River (from Merced to Tuolumne) and toxaphene in the San Joaquin River (from Stanislaus to the Vernalis), whose sources are unknown (SWRCB 2017x-z,ac-ag).

G.1.8.5 *Boron*

The lower San Joaquin River upstream of Vernalis is listed as impaired due to elevated concentrations of boron (Central Valley RWQCB 2002b, 2007c). An Amendment to the Sacramento – San Joaquin River Basin Plan for the control of salt and boron discharges into the lower San Joaquin River (resolution R5-2004-0108) (Central Valley RWQCB 2007b) describes a pending TMDL and establishes Waste Load Allocations to meet boron water quality objectives near Vernalis (at the Airport Way Bridge).

Mean salinity in the lower San Joaquin River at Vernalis has doubled since the 1940s, and boron and other trace elements also increased to concentrations that exceed the water quality criteria of 750 µg/l. These criteria were established to protect sensitive crops under long-term irrigation (USEPA 1986b). Water quality improves in the San Joaquin River downstream of confluences with the Merced, Tuolumne, and Stanislaus rivers.

Most of the boron load to the Delta comes from the lower San Joaquin River's surface and subsurface agricultural discharges (Central Valley RWQCB 2007b) on soils overlying old marine deposits, and from groundwater (Hoffman 2010, CALFED 2000). Major boron contributions come from Salt and Mud sloughs to the lower river (Central Valley RWQCB 2002b). Point sources contribute a minimal salt and boron load to the San Joaquin River (Central Valley RWQCB 2007b).

Boron concentrations in surface water from two surface water sources in the lower San Joaquin River are variable and range from 100 to over 1000 µg/l (Hoffman 2010). Effluent from subsurface drains in the

New Jerusalem Drainage District were reported up to 4200 µg/l (Hoffman 2010). These concentrations at times exceed the water quality criteria and thresholds for sensitive crops (i.e., bean tolerance threshold is 750 to 1000 µg/l).

In 2018, the Central Valley RWQCB approved amendments to the Sacramento – San Joaquin River Basin Plan to incorporate a Central Valley-wide Salt and Nitrate Control Program (Central Valley RWQCB 2018b).

G.1.8.6 *Arsenic*

The San Joaquin River from Bear Creek to Mud Slough is on the SWRCB's CWA Section 303(d) list as impaired by arsenic (SWRCB 2017a). Arsenic can cause adverse dermal, cardiovascular, respiratory, gastrointestinal, and neurological effects, as well as cancer (ATSDR 2007a). A TMDL addressing impairment due to arsenic is expected to be complete in 2021 to protect the beneficial uses of this reach of the San Joaquin River, including the municipal and domestic supply (SWRCB 2017ah).

G.1.8.7 *Bacteria*

The San Joaquin River (Mud Slough to Merced River) and Salt Slough (upstream from confluence with the San Joaquin River) is on the SWRCB's CWA Section 303(d) list as impaired by indicator bacteria (SWRCB 2017a).

G.1.8.8 *Invasive Species*

The San Joaquin River (Friant Dam to Mendota Pool) is on the SWRCB's CWA Section 303(d) list as impaired by invasive species (SWRCB 2017a).

A TMDL for invasive species is expected to be completed in 2019. It will aim to meet the narrative water quality objective in the San Joaquin River (Friant Dam to Mendota Pool).

G.1.9 Bay-Delta

The "Bay-Delta" region includes the legal Delta, Suisun Bay and Marsh, and San Francisco Bay.

G.1.9.1 *Overview*

Primary factors affecting water quality in the Delta, Suisun Bay, and Suisun Marsh include patterns of land use in the upstream watersheds; inter-annual hydrologic variations; operations of the SWP, CVP, and flow control gates within the Delta and Marsh; and activities and sources of pollutants within and upstream of these water bodies. Point and nonpoint pollutant sources include drainage from inactive and abandoned mines and related debris/sediment from headwaters, industrial and municipal wastewater treatment plant discharges, agricultural return flows, urban storm water runoff, atmospheric deposition, recreational uses, and metabolic waste from wildlife and livestock. Natural erosion, in-stream sediments, and atmospheric deposition also affect water quality. The magnitude of each source's effect correlates with the relative contribution from each source at a given location and can differ by constituent or with hydrologic and climatic conditions during different times of year, and from year-to-year.

The San Francisco Bay water quality is similarly affected by upstream land uses; hydrologic variations; pollutant source input from municipal wastewater discharges, agricultural return flows, urban runoff, and mining activities; and recreational uses (Cohen 2000). The northern and central portions of San Francisco Bay are strongly influenced by freshwater Delta inputs, whereas the southern portion of the Bay is often dominated by ocean water and is generally isolated from the northern portion (Cohen 2000). Thus, this water quality effects discussion will focus on the northern and central portions of the Bay.

G.1.9.2 *Beneficial Uses*

The Delta, Suisun Bay and Marsh, and San Francisco Bay provide water for many beneficial uses, as shown in Table G.1-1. The *Water Quality Control Plan for the San Francisco Bay/Sacramento–San Joaquin Delta Estuary* (Bay-Delta WQCP; SWRCB 2006) designates beneficial uses of the Delta. The *Central Valley Regional Water Quality Control Board Water Quality Control Plan* (Central Valley RWQCP; Central Valley RWQCB 2018a) also designates beneficial uses of the Delta within its jurisdiction, which includes the western, northwestern, southern, central, and eastern portions. Additionally, the *San Francisco Bay Regional Water Quality Control Board Water Quality Control Plan* (San Francisco Bay RWQCP; San Francisco Bay RWQCB 2017) designates beneficial uses for the western portion of the Delta within its jurisdiction, and for Suisun Bay, Suisun Marsh, and San Francisco Bay.

G.1.9.3 *Constituents of Concern*

The Section 303(d) list for California identifies the Delta waterways, Suisun Bay, Suisun Marsh, and San Francisco Bay as impaired for many constituents as shown in Table G.1-14, Clean Water Act Section 303(d) Listed Pollutants and Sources in the Delta, Suisun Bay, and Suisun Marsh, and Table G.1-15, Clean Water Act Section 303(d) Listed Pollutants and Sources in the Delta and San Francisco Bay.

The Delta, Suisun Bay, and San Francisco Bay are listed as impaired by invasive species on the SWRCB's Section 303(d) list because they have invasive species, with specific sources to these water bodies unknown (SWRCB 2017a). Changes in water quality can make conditions more favorable for invasive species (e.g., aquatic vegetation and benthic macroinvertebrates), and invasive species can affect water quality conditions (e.g., turbidity, organic enrichment). However, invasive species are biological parameters and not water quality parameters; thus, invasive species within the Delta, Suisun Bay, and San Francisco Bay are not addressed further within this technical appendix.

The entire Delta is also listed on the SWRCB's Section 303(d) list as impaired by unknown toxicity. Aquatic toxicity refers to the mortality of aquatic organisms or sublethal effects (e.g., reduced growth or reproduction) and can be caused by any number of individual constituents of concern, or through additive or synergistic effects attributable to the presence of multiple toxicants. Within the Delta, toxicity is known to occur, but the constituent(s) causing toxicity is unknown (SWRCB 2017a). Thus, unknown toxicity within the Delta is not addressed further within this technical appendix.

The central and lower portions of San Francisco Bay are included on the SWRCB's Section 303(d) list of impaired water bodies due to trash. The presence of trash is associated with humans discarding unwanted items on land or in surface waters, not CVP/SWP operations. Thus, trash within San Francisco Bay is not addressed further within this technical appendix.

Additional constituents of concern for the Delta include bromide, organic carbon, and nutrients. Bromide is a salinity-related parameter of concern in the Delta because it reacts with ozone, and other municipal water treatment plant disinfectants. These reactions forms bromate, bromoform, and other brominated trihalomethane compounds, as well as haloacetic acids, which are regulated disinfection byproducts in drinking water. Organic carbon is also of concern in the Delta because of the potential for disinfection byproducts to form in treated drinking water supplies. The Delta was not included on the SWRCB's Section 303(d) list approved as impaired by nutrients, however, nutrients are of interest in the Delta (e.g., Central Valley RWQCB 2010f) and are the focus of ongoing research.

Table G.1-14. Clean Water Act Section 303(d) Listed Pollutants and Sources in the Delta, Suisun Bay, and Suisun Marsh

Pollutant/ Stressor	Listed Source	Delta Region								Specific Delta Waterways																		Suisun	
		Central	Eastern	Export Area	Northern	Northwestern	Southern	Stockton DWSC	Western	Lower Calaveras River	Bear Creek	Lower Cosumnes River	Duck slough	Five Mile Slough	French Camp Slough	Kellogg Creek	Marsh Creek	Middle River	Lower Mokelumne River	Mormon Slough	Mosher Slough	Old River	Pixley Slough	Sand Creek	Smith Canal	Tom Paine Slough	Walker Slough	Suisun Bay	Suisun Marsh
Arsenic	Source unknown								X																				
Chlordane	Source unknown				X				X																			X	
Chloride	Source unknown																									X			X
Chlorpyrifos	Source unknown, agriculture, urban runoff/ storm sewers	X	X	X	X	X	X	X	X	X			X	X	X				X	X	X	X	X	X					
Copper	Source unknown										X								X										
DDE/DDT	Source unknown	X	X	X	X	X	X	X	X															X				X	
Diazinon	Source unknown, agriculture, urban runoff/storm sewers	X	X	X	X	X	X	X	X	X	X			X	X						X		X	X					
Dieldrin	Source unknown				X				X															X				X	
Dioxin	Source unknown							X																				X	
Disulfoton	Source unknown																						X	X					
Electrical conductivity / salinity	Source unknown			X		X	X		X							X						X		X		X			X
Furan compounds	Source unknown							X																				X	
Group A pesticides [a]	Source unknown	X	X	X	X	X	X	X	X																				
Organophosphorus Pesticides	Source unknown																								X				
Indicator bacteria	Source unknown, urban runoff/storm sewers									X	X	X		X	X	X	X			X	X		X	X	X		X		

Pollutant/ Stressor	**Listed Source**	**Delta Region**								**Specific Delta Waterways**																		**Suisun**	
		Central	**Eastern**	**Export Area**	**Northern**	**Northwestern**	**Southern**	**Stockton DWSC**	**Western**	**Lower Calaveras River**	**Bear Creek**	**Lower Cosumnes River**	**Duck slough**	**Five Mile Slough**	**French Camp Slough**	**Kellogg Creek**	**Marsh Creek**	**Middle River**	**Lower Mokelumne River**	**Mormon Slough**	**Mosher Slough**	**Old River**	**Pixley Slough**	**Sand Creek**	**Smith Canal**	**Tom Paine Slough**	**Walker Slough**	**Suisun Bay**	**Suisun Marsh**
Invasive species	Source unknown	X	X	X	X	X	X	X	X																			X	
Mercury	Resource extraction, industrial-domestic wastewater, atmospheric deposition, nonpoint source	X	X	X	X	X	X	X	X	X							X		X		X							X	X
Nutrients	Source unknown																												X
Organic enrichment/ low dissolved oxygen	Municipal point sources, urban runoff/storm sewers, hydromodification, source unknown							X		X	X			X	X	X		X	X	X	X	X	X		X	X			X
PAHs	Source unknown								X																				
PCBs	Source unknown				X			X	X																			X	
Temperature	Source unknown							X																					
TDS	Source unknown																					X							X
Toxicity [b]	Source unknown	X	X	X	X	X	X	X	X						X	X	X		X	X			X	X					
Selenium	Source unknown																											X	
Zinc	Source unknown																		X										

Source: SWRCB 2017a.

Notes:

DDT = dichlorodiphenyltrichloroethane, PCB = polychlorinated biphenyls, EC = electrical conductivity, DO = dissolved oxygen, TDS = total dissolved solids.

[a] Group A pesticides include aldrin, dieldrin, chlordane, endrin, heptachlor, heptachlor epoxide, benzene hexachloride (BHC; including lindane), endosulfan, and toxaphene.

[b] Toxicity is known to occur, but the constituent(s) causing toxicity is unknown.

Table G.1-15. Clean Water Act Section 303(d) Listed Pollutants and Sources in the Delta and San Francisco Bay

Pollutant/ Stressor	Listed Source	San Francisco Bay					
		Delta	Carquinez Straight	San Pablo Bay	Central	Lower	South
Arsenic	Source unknown						
Chlordane	Source unknown	x	x	x	x	x	x
Chloride	Source unknown						
Chlorpyrifos	Source unknown, agriculture, urban runoff/ storm sewers						
Copper	Source unknown						
DDT	Source unknown	x	x	x	x	x	x
Diazinon	Source unknown, agriculture, urban runoff/storm sewers						
Dieldrin	Source unknown	x	x	x	x	x	x
Dioxin	Source unknown	x	x	x	x	x	x
Disulfoton	Source unknown						
Electrical conductivity / salinity	Source unknown						
Furan compounds	Source unknown	x	x	x	x	x	x
Group A pesticides [a]	Source unknown						
Organophosphorus Pesticides	Source unknown						
Indicator bacteria	Source unknown, urban runoff/storm sewers						
Invasive species	Source unknown	x	x	x	x	x	x
Mercury	Resource extraction, industrial-domestic wastewater, atmospheric deposition, nonpoint source	x	x	x	x	x	x
Nutrients	Source unknown						
Organic enrichment/ low dissolved oxygen	Municipal point sources, urban runoff/storm sewers, hydromodification, source unknown						
PAHs	Source unknown						
PCBs	Source unknown	x	x	x	x	x	x
Temperature	Source unknown						
TDS	Source unknown						
Toxicity [b]	Source unknown						
Trash	Source unknown				x	x	
Selenium	Source unknown	x	x	x	x		x
Zinc	Source unknown						

Source: SWRCB 2017a

G.1.9.4 *Salinity*

G.1.9.4.1 Delta, Suisun Bay, and Suisun Marsh

Salinity in the Delta channels can vary depending on several factors, including surface water hydrology and inflow quality, water project operations, and hydrodynamics. Hydrology and upstream water project operations influence Delta inflows, which in turn influence the balance with the highly saline seawater intrusion. Delta salinity conditions are affected by upstream source water quality that flows into the Delta, as well as in-Delta sources such as agricultural returns, natural leaching, and municipal and industrial discharges. Operation of various Delta gates and barriers, pumping rates of various diversions, and the volume of open water bodies are other key factors influencing Delta hydrodynamics and salinity.

Salinity in Suisun Bay is primarily affected by Delta outflow to the bay and tidal inflows from San Francisco Bay. Salinity within Suisun Marsh is similarly affected by inflows from the Delta, as affected by water project operations, Suisun Bay inflows, and the use of the Suisun Marsh Salinity Control Gates, which are located on Montezuma Slough near Collinsville. The Salinity Control Gates are operated periodically from September to May to meet the Bay-Delta WQCP objectives and D-1641 requirements. The Salinity Control Gate operations restrict the inflow of high-salinity flood-tide water from Grizzly Bay into the marsh, but allow freshwater ebb-tide flow from the mouth of the Delta to pass through. The gate operation lowers salinity in Suisun Marsh channels and results in a net movement of water from east to west. When the Delta outflow is low to moderate and the gates are not operating, net movement of water is from west to east, resulting in higher-salinity water in Montezuma Slough.

The Bay-Delta WQCP (SWRCB 2006) includes numeric salinity-related objectives for the Delta and Suisun Marsh. It includes chloride objectives to protect municipal and industrial water supply beneficial uses. It also includes Electrical Conductivity (EC) objectives for multiple western, interior, and south Delta compliance locations to protect agricultural supply beneficial uses. The Bay-Delta WQCP specifies salinity objectives for fish and wildlife protection: EC objectives for the Delta and Suisun Marsh, a narrative salinity objective for brackish tidal marshes of Suisun Bay, and the X2 standard that regulates the location and number of days of allowable encroachment into the west Delta of salinity exceeding 2 parts per thousand isohaline (2.64 millisiemens per centimeter) (SWRCB 2006). In general, the chloride and EC objectives vary depending on the month and water-year type. Compliance with salinity objectives is largely dependent on Delta inflows and outflows. The CVP and SWP are operated to achieve Delta salinity objectives.

Waterways within the Delta and Suisun Marsh have been identified as impaired due to elevated salinity and are included on the SWRCB's Section 303(d) list (SWRCB 2017a). The Delta waterways listed as impaired due to elevated EC include southern, western, and northwestern portions, the export area, the Stockton Deep Water Ship Channel, Old River, and Tom Paine Slough. Tom Paine Slough is also listed as impaired for chloride. Suisun Marsh is listed as impaired due to elevated chloride, EC, and total dissolved solids (TDS).

The SWRCB is in the process of updating flow and water quality objectives in the Bay-Delta WQCP. The SWRCB adopted the Lower San Joaquin River and Southern Delta portion of the Bay-Delta WQCP update in December 2018. Updates for the Sacramento River and its tributaries, including Delta eastside streams (Calaveras, Cosumnes, and Mokelumne rivers) are in development (SWRCB 2018b).

In addition to EC and chloride, the salinity-related constituent bromide is of concern in Delta waters, even though the Delta is not listed as impaired by bromide. The complex interplay between hydrology, water project operations, bromide sources, and hydrodynamics results in bromide's presence in Delta waters. The primary source of bromide in the Delta is seawater intrusion. Bromide concentrations also are generally higher in the lower San Joaquin River and Delta island agricultural drainage because of irrigation practices and evaporative concentration that occurs in water diverted from the Delta for irrigated agriculture. Recirculation, or the process of agricultural drainage entering the San Joaquin River and its subsequent and repetitive diversion for agricultural practices, also contributes to elevated bromide concentrations in the San Joaquin River.

There are no federally-promulgated or state adopted water quality objectives for bromide in surface waters. In 1998, a panel of three water quality and treatment experts, engaged by the California Urban Water Agencies, developed potential drinking water treatment regulatory scenarios and defined appropriate associated treatment process criteria (California Urban Water Agencies 1998). They estimated the Delta source water quality required to achieve compliance under the anticipated regulatory scenarios. Two regulatory scenarios were identified: (1) a near-term scenario consisting of then, and still current, treatment rules governing pathogen inactivation and disinfection; and (2) a long-term scenario that included more stringent versions of the rules. For the near-term, current regulatory scenario, total organic carbon from 4 to 7 mg/l and bromide from 100 to 300 µg/l was determined as acceptable levels that provided users adequate flexibility in their choice of treatment method (CALFED 2007b).The long-term scenario was based on the current drinking water thresholds of 80 µg/l total trihalomethanes, 60 µg/l haloacetic acids, and 10 µg/l bromate (as running annual averages) being cut in half, as well as an additional 1 to 2-log inactivation of *Giardia* and 1-log inactivation of *Cryptosporidium* being imposed by future rule-making. The panel recommended source water bromide levels of 50 µg/l, which would give users adequate flexibility in treatment method while still complying with the scenario's defined reduced disinfection byproduct levels. The more stringent scenario for disinfection byproduct regulations and pathogen inactivation requirements has not been adopted by State or federal regulatory agencies.

G.1.9.4.2 San Francisco Bay

Cohen (2000) characterizes the salinity of the San Francisco Bay estuary into three broad regions, when considering the bay's biota. The first zone is the Delta as the freshwater region. The second zone is the lower salinity region, which consists of Suisun Bay and extends sometimes into Carquinez Strait and San Pablo Bay, as well as areas along other freshwater inflows, such as the Napa River and Petaluma River on San Pablo Bay, and sloughs and creeks entering the southern portion of the bay. The third zone, the higher salinity region, is the main portions of the South, Central, and San Pablo bays. The freshwater inflows from the Delta flows into the bay near the water surface and gradually mixes in due to its lower density as compared to sea water (Cohen 2000). The Delta inflows also create horizontal salinity gradients, with lower salinity water near the Delta and higher salinity water near the mouth of the bay (Cohen 2000).

The twice daily tidal cycle results in substantial water movement in and out of San Francisco Bay. With each tidal cycle, an average of 1,300,000 acre-feet of seawater moves into and out of San Francisco Bay (Cohen 2000). By comparison, daily freshwater inflow averages about 50,000 acre-feet (Cohen 2000), which is about 4% of the inflow volume of seawater.

The San Francisco Bay RWQCP water quality objective for salinity requires that controllable water quality factors shall not increase the total dissolved solids or salinity of waters of the state in a way that would negatively affect beneficial uses, particularly fish migration and estuarine habitat (San Francisco Bay RWQCB 2017).

G.1.9.5 *Mercury*

G.1.9.5.1 Delta

Legacy mining in the headwaters of the Sacramento River watershed is the primary source of mercury contamination in the Delta and Suisun Bay. Over 80% of the total mercury flux to the Delta can be attributed to the Sacramento River and Yolo Bypass (Central Valley RWQCB 2010g). The Sacramento River is the primary tributary source of mercury to the Delta in dry years and the proportion of mercury loading from the Yolo Bypass increases in wet years to the extent that it is comparable to that of the Sacramento River. Cache Creek is also a major source of mercury to the Yolo Bypass where high mercury concentrations are transported in suspended sediment. Therefore, a priority for mercury reduction management strategies is controlling mercury inputs from tributary sources.

Sediment in Cache Creek that is not captured by the Cache Creek Settling Basin is transported into the Yolo Bypass (approximately half of the sediment transported by Cache Creek). Outflow from the settling basin (and possibly in other tributaries to the Yolo Bypass) exceeds the CTR mercury criterion of 0.050 μg/l for drinking water; thus, when flows from Cache Creek dominate Yolo Bypass, the bypass also likely exceeds the CTR criterion (Central Valley RWQCB 2010g). Compounding the issue of mercury contamination in the Yolo Bypass, a U.S. Geological Survey (USGS) study noted that the bypass has conditions conducive to the production of methylmercury, including stagnant waters and marshes with an abundance of sulfate and organic carbon (USGS 2002). Mine remediation, erosion control in mercury-enriched areas, and removing floodplain sediments containing mercury will reduce mercury loads in Cache Creek (Central Valley RWQCB 2010g). Regularly excavating the sediment accumulating in the Cache Creek Settling Basin will also reduce mercury entering the Delta.

It has been estimated that the flux of methylmercury from Delta sediments contributes over 30% of the waterborne methylmercury load in the Delta (Central Valley RWQCB 2010g). Therefore, the spatial variability of mercury and methylmercury in sediments is an important characteristic of the Delta's current condition for mercury exposure and could be important for determining future mercury risk. The National Water Quality Assessment Program for the Sacramento River basin sampled streambed sediment mercury concentrations from the Delta in 1995 (MacCoy and Domagalski 1999: 13). Sediment mercury concentrations of 0.14 μg/g (dry weight basis in the <63 micron fraction) at Freeport and 0.15 μg/g in Cache Creek were less than the threshold effect concentration (0.18 μg/g) and probable effect concentration (1.06 μg/g) reported by MacDonald et al. (2000: 23–24). These reported mercury concentrations in sediment greatly exceeded the average amount of background mercury found on the earth's surface, which is about 0.05 μg/g.

The Central Valley RWQCB initiated the Delta Regional Monitoring Program (Delta RMP) to establish a coordination system among the many agencies and groups that monitor water quality, flows, and ecological conditions in the Delta. The Delta RMP ensures that all data are synthesized and assessed on a regular basis, with the primary goal of tracking and documenting beneficial use protection and restoration efforts' effectiveness through the comprehensive monitoring of contaminants and contaminant effects in the Delta. The Delta RMP began a methylmercury monitoring program in 2016 to establish baseline concentrations and support long-term trend monitoring as a critical performance measure for mercury control programs. Field workers collected Largemouth Bass and Spotted Bass (*Micropterus punctulatus*) from August and September 2016 at six locations distributed across the Delta that coincide with the TMDL subareas (Davis et al. 2018: 4). Total mercury in fish tissues (length-normalized to 350 millimeters [mm]) ranged from 0.15 mg/kg wet weight at Little Potato Slough to 0.61 mg/kg wet weight at the Sacramento River at Freeport. Methylmercury concentrations in unfiltered water ranged from 0.021 to 0.22 ng/l among four monitoring events from August 2016 to April 2017. Concentrations of total mercury in unfiltered water ranged from 0.91 to 13 ng/l.

USEPA approved the Sacramento-San Joaquin Delta Estuary TMDL for methylmercury (Delta Methylmercury TMDL) (Central Valley RWQCB 2010g) in 2011 to protect human health, wildlife, and aquatic life. The TMDL establishes methylmercury fish tissue objectives and waste load allocations for agricultural drainage, tributary inputs, and point and non-point source dischargers in the Delta (including Yolo Bypass). The methylmercury objective requires fish tissue concentrations to not exceed 0.08 and 0.24 mg/kg, wet weight, in muscle tissue of trophic level three and four fish, respectively (150–500 mm total length). Further, the average methylmercury concentrations shall not exceed 0.03 mg methylmercury/kg, wet weight, in whole fish less than 50 mm in length.

In conjunction with the mercury and methylmercury load reduction goals of the Delta Methylmercury TMDL, the Central Valley RWQCB developed a Delta Mercury Exposure Reduction Program (Delta MERP; Sacramento-San Joaquin Delta Conservancy 2019) as a multiple stakeholder effort to promote a better understanding of mercury bioaccumulation in Delta fish and support approaches for reducing human exposure to mercury from fish caught in the Delta.

The Central Valley RWQCB is also developing a state-wide mercury control program for reservoirs and a Central Valley mercury control program for rivers (Central Valley RWQCB 2017a).

G.1.9.5.2 San Francisco Bay, Suisun Bay and Suisun Marsh

Delta inputs primarily drive mercury concentrations in northern San Francisco Bay, Suisun Bay, and Suisun Marsh. Methylmercury concentrations in surface waters and sediment are highest in the South Bay because of conditions favoring methylation and historical mercury inputs from the New Almaden Mine. These sources led to higher average total mercury concentrations in striped bass (*Morone saxatilis*) tissues (0.44 mg/kg wet weight) from the San Francisco Bay than any other estuary in the United States (Davis et al. 2014). The San Francisco Bay Regional Monitoring Program (Bay RMP) conducts fish tissue sampling and analysis in the San Francisco Bay every three years to monitor tissue mercury concentrations in fish tissues. Concentrations in several sport fish did not decline from 1994 to 2009 and tissue samples from most species exceeded 0.2 mg/kg wet weight total mercury in fish from San Pablo Bay, Central Bay, and South Bay (Davis et al. 2012). Sampling from shorelines throughout the Bay area in 2008 to 2010 found average total mercury tissue concentrations of Mississippi Silverside (*Menidia beryllina*) exceeded 0.2 mg/kg wet weight in the South Bay and ranged from <0.06 to 0.197 mg/kg wet weight in all areas of the Bay (Greenfield et al. 2013).

The San Francisco Bay Mercury TMDL includes Suisun Bay and describes numeric targets for mercury in fish tissue (San Francisco Bay RWQCB 2006). The San Francisco Bay Mercury TMDL added Suisun Marsh more recently (San Francisco Bay RWQCB 2018); the Suisun Marsh TMDL is pending USEPA approval.

G.1.9.6 *Selenium*

G.1.9.6.1 Delta, Suisun Bay, and Suisun Marsh

Inputs from the Sacramento and San Joaquin rivers drive selenium concentrations in the Delta. Concentrations are higher in the San Joaquin River; however, greater flows in the Sacramento River result in a substantial contribution to the mass loading of selenium to the Delta (Cutter and Cutter 2004; Tetra Tech, Inc. 2008). Presser and Luoma (2006) project that loads to the Delta from the Sacramento River are about half of the Grasslands basin’s projected contribution to the San Joaquin River, with subsequent loading to the Delta from the San Joaquin River dependent on flow (Presser and Luoma 2006).

Implementation of the Grassland Bypass Project in 1996 led to a 60% decrease in selenium loads to the Delta from the San Joaquin River at Vernalis from the Grassland Drainage Area in comparison to pre-project conditions (Tetra Tech, Inc. 2008).

Suisun Bay is on the SWRCB's CWA Section 303(d) list as impaired due to elevated concentrations of selenium. However, the list does not identify Suisun Marsh as an impaired water body for selenium contamination. The Suisun Bay selenium impairment is attributed to discharge from natural sources, industrial point sources such as oil refineries, and the presence of exotic species, which increase selenium bioaccumulation into the food web (SWRCB 2017a). *Corbula* (*Potamocorbula*) *amurensis*, a species of clam and an important food source for sturgeon and certain ducks, bioaccumulates selenium at a high rate (Stewart et al. 2004 as cited by Beckon and Maurer 2008). The exotic species was first discovered in Suisun Bay in 1986 and was common by 1990 in estuarine waters from San Pablo Bay to Suisun Bay (Cohen 2011).

USEPA developed national recommended chronic aquatic life criteria for selenium, promulgated criteria specific to the San Francisco Bay, Suisun Bay, and Delta, and recently proposed separate selenium criteria for California and the Bay-Delta. In 1992, USEPA promulgated water quality criteria for selenium applicable to San Francisco Bay, Suisun Bay, and the Delta, expressed as a total recoverable water column concentration (58 Fed. Reg. 103 (December 22, 1992)). In 2016, USEPA published the current national recommended chronic aquatic life criterion for selenium, which consists of fish tissue and water column concentration thresholds (USEPA 2016a). USEPA also proposed aquatic life and aquatic-dependent wildlife criteria in 2016 specifically for the Bay-Delta (USEPA 2016b). The proposed Bay-Delta criteria include the same whole body and muscle criteria for fish as USEPA's national recommended criterion, but has lower criteria for water column concentrations to account for greater bioaccumulation of selenium in the tissues of organisms residing in Delta waters. Unlike the national criterion, the proposed Bay-Delta criteria do not include a tissue-based criterion for fish eggs/ovaries, but do include a tissue-based criterion for clams. In 2018, USEPA proposed selenium criteria for California that consist of the 2016 national recommended criterion with a bird tissue criterion added, and a performance-based approach to translate the tissue criterion elements into protective water column elements on a site-specific basis instead of specific water column criterion elements. The proposed USEPA (2019) criteria for California would not apply to surface waters where site-specific selenium criteria have been adopted or in waters with selenium criteria promulgated in the National Toxics Rule (e.g., the lower San Joaquin River, Grasslands watershed, San Francisco Bay, Suisun Bay, and the Delta).

G.1.9.6.2 San Francisco Bay

The entire San Francisco Bay is on the SWRCB's CWA Section 303(d) list as impaired by selenium. Surface water exports from the Delta, local tributaries, and atmospheric deposition are the primary selenium sources to the northern portion of the bay (San Francisco Bay RWQCB 2015). To protect the most susceptible fish, White Sturgeon (*Acipenser transmontanus*), from selenium toxicity, a selenium TMDL was adopted in 2016 for the North San Francisco Bay, defined to include a portion of the Delta (i.e., Delta segment), Suisun Bay, Carquinez Strait, San Pablo Bay, and the Central Bay (SWRCB 2016a). The TMDL included numeric targets for selenium in fish tissue (8.0 µg/g dry weight in whole body; 11.3 µg/g dry weight in muscle) and the water column (0.5 µg/l dissolved total selenium) (San Francisco Bay RWQCB 2015). Selenium concentrations in White Sturgeon muscle collected from the North Bay from 2015 to 2017 averaged 11.8 µg/g dry weight in 2015, 10.6 µg/g dry weight in 2016, and 7.3 µg/g dry weight in 2017 (Sun et al. 2019). When considered with water-year type, data suggests that selenium concentrations in sturgeon tissues were driven more by hydrology than water column concentrations (Sun et al. 2019).

Existing selenium concentrations in the water column are below the TMDL target of 0.5 µg/l and have been declining since the late 1990s. Therefore, the TMDL does not require load reductions below current levels and the implementation plan's main goal is to prevent increases of selenium concentrations in North Bay waters and attain safe levels of selenium in fish, specifically benthic feeders (e.g., Sacramento Splittail [*Pogonichthys macrolepidotus*] and sturgeon). The TMDL includes a load allocation for the Central Valley watershed (4070 kg/year) and requires monitoring to identify any need for adaptive implementation (San Francisco Bay RWQCB 2015).

The TMDL does not include the South Bay because it is affected by local and watershed sources not associated with the Delta or refineries, while the primary selenium loading to the North Bay and the Suisun Bay area is from the Delta and oil refineries in the vicinity of Carquinez Strait (Lucas and Stewart 2007; Stewart et al. 2013).

G.1.9.7 *Trace Metals*

Trace metals impairments within the assessment area include arsenic in the western Delta, copper in Bear Creek and the lower Mokelumne River, and zinc in the lower Mokelumne River (SWRCB 2017a).

Arsenic is a tasteless and odorless semi-metal element highly toxic to humans. Long-term, chronic exposure to arsenic has adverse dermal, cardiovascular, respiratory, gastrointestinal, and neurological effects, and has been linked to cancer of the bladder, lungs, skin, kidneys, nasal passages, liver, and prostate (ATSDR 2007b). Short-term exposure to high doses of arsenic can cause acute symptoms such as skin damage, circulatory system dysfunction, stomach pain, nausea and vomiting, diarrhea, numbness in hands and feet, partial paralysis, and blindness. The Section 303(d) impairment listing is based on elevated arsenic concentrations in *Corbicula* tissue samples collected from 1993–2008 in Bear Creek. A TMDL to protect the beneficial uses due to arsenic impairment is expected to be completed in 2027 (SWRCB 2017a).

Copper occurs in organic and inorganic forms. Organic copper is an essential micronutrient for animals, while exposure to high concentrations of inorganic copper can be toxic (ATSDR 2004). In humans, short-term exposure to copper can cause nausea and vomiting; long-term exposure can cause liver or kidney damage (ATSDR 2004). Copper levels in Bay-Delta waters are not sufficiently high to result in health effects to humans, but copper is of concern because low (i.e., at the parts per billion) levels can be toxic to aquatic life, depending on other ambient water quality conditions (e.g., hardness, organic carbon levels). The Section 303(d) listing for copper for the lower Mokelumne River was based on decisions made prior to 2006 and no additional data was considered for the current listing. In Bear Creek, 4 of 19 surface water samples collected in 2000–2002 exceeded the CTR criteria for copper for the protection of aquatic life (SWRCB 2017a). TMDLs to address these water quality impairments are expected to be complete by 2020 for the lower Mokelumne River and 2021 for Bear Creek (SWRCB 2017a).

Zinc is an essential micronutrient for plants and animals, but at elevated concentrations in surface water interferes with the metabolism of calcium and iron (ATSDR 2005). This can lead to osteomalacia (softening of the bone) from deficiency in minerals including calcium and phosphorous. Zinc can also damage fish gills and lead to hypoxia from reduced oxygen exchange. The lower Mokelumne River Section 303(d) listing was based on decisions made prior to 2006 and no additional data was considered, although, zinc concentrations measured in 2002 did not exceed the CTR criteria (SWRCB 2017). A TMDL addressing zinc impairments in the lower Mokelumne River is expected to be complete by 2027 (SWRCB 2017).

G.1.9.8 *Nutrients*

Nutrients such as nitrogen and phosphorus originate from natural sources and anthropogenic sources, including point and non-point source discharges. Although nutrients are necessary for a healthy ecosystem, the over-enrichment of nitrogen and phosphorus can lead to eutrophication, increased production of blue green algae, more invasive aquatic macrophytes, and nutrient-related problems in drinking water systems.

G.1.9.8.1 Delta, Suisun Bay, and Suisun Marsh

A decline in pelagic fish species in the Delta, known as the pelagic organism decline (POD), including the endangered Delta Smelt (*Hypomesus transpacificus*), may be related to bottom-up effects from nutrients among other drivers (Baxter et. al. 2008; Sommer et al. 2007). Nutrients are also affected by flow and other factors (e.g., temperature, turbidity, and invasive species) that are potentially associated with the POD.

Unlike most water bodies where nutrients cause too much primary production, the problem affecting beneficial uses in parts of the Delta is too little primary production to support fish populations (Hammock et al. 2019 and references within). Despite decades of monitoring and intensive research efforts, the cause for low productivity remains unclear (Hammock et al. 2019). Several hypotheses to explain the low productivity have been proposed. Jassby recognizes light as the limiting factor preventing high primary production within the Delta, rather than nutrients (Jassby et al. 2002, Jassby 2008). Dugdale et al. (2007) and Parker (2012) offer another hypothesis, that ammonium (a dominant form of nitrogen in the Delta and Suisun Bay) inhibits the uptake of nitrate, which is more conducive to beneficial algae blooms. Glibert et al. (2011) suggest that the current form and ratio of nutrients (i.e., elevated nitrogen, resulting in a high nitrogen to phosphorus ratio) in the Delta may give preferential advantage to smaller celled and less nutritious primary producers. Alternatively, other factors contributing to little primary production may be caused by invasive clams introduced in the mid-1980s that consume algae, reducing food availability for zooplankton and fish (Lucas and Thompson 2012; Kimmerer et al. 1994) or reduced phosphorus that becomes a limiting factor for primary production (Van Nieuwenhuyse 2007). Grazing by invasive clams (i.e., *Potamocurbula ameurensis*) is the most widely accepted hypothesis for why productivity remains low (Hammock et al. 2019 and references within).

More classical signs of eutrophication are often found in the central and southern Delta near Stockton where nutrient enrichment feeds algal blooms that can cause areas of oxygen depletion. High nutrient concentrations, warm temperatures, and low flow are conditions shown to be conducive to toxic blue-green algae growth (i.e., cyanobacteria) with Microcystis blooms becoming more prevalent in the central and southern Delta (Lehman et al. 2008). Recent studies have shown that many of these Microcystis blooms are fueled by ammonium, not nitrate (Lehman et al. 2015, 2017).

Municipal discharges into the Delta and its source waters contribute nutrients. The Sacramento Regional Wastewater Treatment Plant is the largest point source of ammonium in the Delta, contributing 90% of the ammonium in the Sacramento River from 1986 to 2005 (Jassby 2008). The ammonium is transformed to nitrate as it is transported through the Delta (Kraus et al. 2017). Future nitrogen inputs to the Delta from treated wastewater will be reduced by 2021 because the Sacramento Regional Wastewater Treatment Plant is implementing nitrification and denitrification tertiary treatment to comply with NPDES permit requirements. The Stockton Regional Wastewater Control Facility, which discharges to the San Joaquin River, was another source of nitrogen loading. Stockton implemented nitrification in 2007 to reduce ammonium discharged in their treated effluent and is required to reduce nitrate discharges by 2024 to comply with NPDES permit requirements.

Another source of nutrients to the Delta is agricultural return flows. The Central Valley RWQCB Irrigated Lands Regulatory Program aims to prevent agricultural runoff containing nutrients from impairing surface waters. Growers are required to implement management practices to protect surface water, especially in areas where monitoring has identified problems associated with irrigated agriculture. Growers must conduct farm evaluations to determine the effectiveness of farm practices in protecting water quality.

Nutrients and their effects on Delta water quality are a focus of the Delta RMP, as part of its mission is to understand regional water quality conditions and trends, and to inform regulatory and management decisions. The program supports efforts by the USGS to monitor and synthesize existing data to understand how nitrogen and phosphorus from fertilizers and in runoff may be affecting Delta waterways. High frequency nutrient monitoring data (about every 15 minutes) is collected in the Delta to examine the relationships between nutrient concentrations, nutrient cycling, and aquatic habitat conditions (Downing et al. 2017). High frequency data collection by the USGS began in 2013 and 11 stations operated throughout the Delta by 2016, measuring temperature, pH, specific conductance, turbidity, dissolved oxygen, nitrate, chlorophyll-a, phycocyanin, and dissolved organic matter concentrations (Downing et al. 2017). The spatial and temporal trends in nutrient concentrations and nutrient-related parameters are reasonably well understood (Jabusch, Trowbridge, Wong, and Heburger 2018). The data indicates increasing trends for chlorophyll-a at the Sacramento and San Joaquin River confluence, Suisun Bay, and Franks Tract. Efforts are ongoing to understand the sources, sinks, and nutrient transformation behind these trends (Novick et al. 2015).

Suisun Marsh is currently listed as impaired due to nutrients (SWRCB 2017a). Specific sources of nutrients to Suisun Marsh include agricultural, urban, and livestock grazing drainage through tributaries, the Delta, nutrient exchange with Suisun Bay, atmospheric deposition, and discharge from the treated sewage (Tetra Tech, Inc. and Wetlands and Water Resources 2013). Concentrations of total ammonia from 2000–2011 in Boynton, Peytonia, Sheldrake, and Chadbourne Sloughs (0–0.4 mg/l), as well as in Suisun Slough (0–0.3mg/l), exceeded the water quality objective (Tetra Tech, Inc. and Wetlands and Water Resources 2013). Elevated concentrations of chlorophyll-a, in comparison to concentrations at reference sites at Mallard, suggest possible impairments by nutrients. Research suggests other possible narrative nutrient criteria impairments caused by excess algal growth in wetlands, elevated organic carbon, and trends in dissolved oxygen and mercury methylation.

Central Valley RWQCB, California EPA, and stakeholders developed a *Delta Nutrient Research Plan* (Central Valley RWQCB 2018c) to determine if numeric water quality objectives for nutrients are needed to address nutrient-associated water quality concerns in the Delta. The nutrient-associated water quality concerns include harmful algal blooms and associated toxins and nuisance compounds, excess aquatic plant growth, the low abundance of phytoplankton species that support the food web, and low dissolved oxygen in some waterways. The *Delta Nutrient Research Plan* reports that scientific data gaps currently limit the ability to develop nutrient benchmarks, goals, triggers, targets, and water quality objectives. The plan presents a framework and prioritized actions to gather the information necessary to develop protective thresholds and identify management options to reduce nutrient-associated adverse effects.

G.1.9.8.2 San Francisco Bay

The San Francisco Bay is recognized as a nutrient-enriched estuary. However, dissolved oxygen concentrations are much higher and phytoplankton biomass is much lower than what would be expected in an estuary with such nutrient enrichment (Cloern 1996). The Bay has some of the lowest primary production rates of an estuarine coastal ecosystem in the world (Cloern et al. 2014 as cited by Fichot et al. 2015). A growing body of recent evidence suggests that the Bay's characteristic nutrient enrichment resilience is weakening (SFEI 2016). In response to concerns over nutrient enrichment and low phytoplankton growth, the San Francisco Bay RWQCB worked collaboratively with stakeholders to develop the *San Francisco Bay Nutrient Management Strategy* with goals to manage nutrient loads and maintain beneficial uses within the Bay (SFEI 2016).

Large nutrient loads entering the San Pablo Bay from Suisun Bay, which includes Delta outflows, are the dominant source of nutrients to the San Pablo Bay throughout much of the year (Novick and Senn 2014). Therefore, nutrient loads to and transformations within the Delta, combined with Delta outflow, affect nutrient concentrations entering San Pablo Bay. The dissolved inorganic nitrogen and dissolved inorganic phosphorus loads from Suisun Bay dominate nutrient inputs throughout much of the year and are drivers of nutrient-dependent processes (e.g., algae growth).

The influence of Delta-derived freshwater flows is muted in the South Bay and Lower South Bay by oceanic flows in and out of the Golden Gate (Senn and Novick 2013). The dominant source of dissolved inorganic nitrogen and dissolved inorganic phosphorus year-round in the lower South Bay, South Bay, and Central Bay is discharge from municipal wastewater treatment plants (Novick and Senn 2014).

G.1.9.9 *Organic Enrichment and Dissolved Oxygen*

G.1.9.9.1 Delta, Suisun Bay, and Suisun Marsh

Localized incidents of organic enrichment and depressed dissolved oxygen concentrations occur in the eastern, southern, and western Delta, and in Suisun Marsh. Several Delta waterways in the eastern and southern Delta, and Suisun Marsh are included on the SWRCB's Section 303(d) list of impaired water bodies due to organic enrichment and low dissolved oxygen (Table G.1-14, Clean Water Act Section 303(d) Listed Pollutants and Sources in the Delta, Suisun Bay, and Suisun Marsh; Table G.1-15, Clean Water Act Section 303(d) Listed Pollutants and Sources in the Delta and San Francisco Bay).

Notable low dissolved oxygen concentrations occur in the Delta in the Stockton Deep Water Ship Channel, most often during the months of June through October, although low dissolved oxygen conditions have also occurred in the winter months (Central Valley RWQCB 2005; Schmieder et al. 2008). Historical low dissolved oxygen concentrations are attributed to a combination of low flow and high nutrient loads (USEPA 2015). Dissolved oxygen concentrations increased since the Stockton Deep Water Ship Channel TMDL's adoption in 2007. The duration and magnitude with which dissolved oxygen levels are lower than water quality objectives are smaller than before adoption (USEPA 2015). Low (e.g., 3 mg/l) dissolved oxygen concentrations of a short duration are considered not harmful to aquatic life (USEPA 2015). The Port of Stockton operates two aeration facilities located within the Deep Water Ship Channel to improve dissolved oxygen concentrations. The Port operates the aerators whenever dissolved oxygen concentrations drop below 5.2 mg/l. However, from August to November, that threshold is raised to 6.2 mg/l to benefit the endangered winter-run Chinook Salmon that immigrate through on their way to upstream spawning habitat (Port of Stockton 2019).

Notable low dissolved oxygen conditions also occur in the Suisun Marsh sloughs, and are attributed to aquatic plant material and detritus decomposition. Operations and discharges from managed wetlands within the Marsh show a strong effect on dissolved oxygen within the Marsh sloughs (San Francisco Bay RWQCB 2018). The San Francisco Bay RWQCB adopted a TMDL to address low dissolved oxygen in the Marsh (San Francisco Bay RWQCB 2018), which has been approved by the SWRCB and California Office of Administrative Law and is pending approval by USEPA. The TMDL aims to address low dissolved oxygen/organic enrichment (and mercury problems) and evaluate the degree to which nutrients may contribute to dissolved oxygen deficit. The implementation plan is projected to attain the water quality standard within twenty years.

The Bay-Delta WQCP and Central Valley RWQCP contain numeric dissolved oxygen objectives applicable to the Delta, and the San Francisco Bay RWQCP contains numeric objectives applicable to

Suisun Bay and Marsh. The Bay-Delta WQCP dissolved oxygen objective is 6 mg/l for the protection of fish and wildlife beneficial uses and applies to the San Joaquin River between Turner Cut and Stockton (SWRCB 2006). The Central Valley RWQCP dissolved oxygen objectives apply to all Delta waters except for those bodies of water constructed for special purposes and from which fish have been excluded or where the fishery is not important as a beneficial use (Central Valley RWQCB 2018a). The objectives are: 7.0 mg/l in the Sacramento River (below the I Street Bridge) and in all Delta waters west of the Antioch Bridge; 6.0 mg/l in the San Joaquin River (between Turner Cut and Stockton, 1 September through 30 November); and 5.0 mg/l in all other Delta waters except for those bodies of water constructed for special purposes, and from which fish have been excluded, or where the fishery is not important as a beneficial use.

G.1.9.9.2 San Francisco Bay

San Francisco Bay is not listed as impaired due to organic enrichment or dissolved oxygen. As noted above in Section F.1.9.8.2, dissolved oxygen concentrations are much higher and phytoplankton biomass is much lower than what would be expected in an estuary with such nutrient enrichment (Novick and Senn 2014).

Minimum dissolved oxygen objectives are described in the San Francisco Bay RWQCP. The objective is 5 mg/l in tidal waters downstream of Carquinez Bridge. In non-tidal waters upstream of the Carquinez Bridge, the minimum objectives are 7.0 mg/l in cold water habitat and 5 mg/l in warm water habitat.

G.1.9.10 *Pathogens and Indicator Bacteria*

The term *pathogens* refers to viruses, bacteria, and protozoa that pose human health risks. Pathogens of concern include bacteria, such as *Escherichia coli* and *Campylobacter*; viruses, such as hepatitis and rotavirus; and protozoans, such as *Giardia* and *Cryptosporidium*. Most data that exists regarding pathogens are for coliform bacteria, which are indicators of potential fecal contamination by humans or other warm-blooded animals, because of their relative abundance and ease of measuring in water samples.

G.1.9.10.1 Delta, Suisun Bay, and Suisun Marsh

The *Conceptual Model for Pathogens and Pathogen Indicators in the Central Valley and Sacramento-San Joaquin Delta* (Pathogens Conceptual Model; Tetra Tech, Inc. 2007) characterizes relative pathogen contributions to the Delta from the Sacramento and San Joaquin rivers and various pathogen sources, including wastewater discharges and urban runoff. The Pathogens Conceptual Model determined that coliform indicators vary by orders of magnitudes over small distances and short time-scales. Pathogens concentrations appear to be more closely related to what happens in the proximity of a sampling station, rather than what happens in the larger watershed where substantial travel time and concomitant pathogen die-off can occur. Of the known sources of coliform, total coliform concentrations for wastewater treatment plant effluents were fairly low, whereas the highest total coliform concentrations in water were observed near samples influenced by urban areas. In the San Joaquin River valley, the model observed comparably high concentrations of *E. coli* for waters affected by urban environments and intensive agriculture in the San Joaquin Valley. Fecal indicator data showed minimal relationships with flow rates, although the model observed most of the high concentrations during the wet months of the years, possibly indicating the contribution of stormwater runoff. The model observed the highest total coliform and *E. coli* concentrations in the discharge from the Natomas East Main Drainage Canal and several stations near sloughs, indicating the relative influence of urban and wildlife pathogen sources on receiving water concentrations.

The Central Valley RWQCP (Central Valley RWQCB 2018a) specifies numerical water quality objectives for fecal coliform bacteria to protect water contact recreation. The Central Valley RWQCP also includes a narrative water quality objective for *Cryptosporidium* and *Giardia* that states: "Waters shall not contain *Cryptosporidium* and *Giardia* in concentrations that adversely affect the public water system component of the MUN beneficial use." The objective applies to the Delta and tributaries below the first major dams and allows utilities to request assistance from the state to conduct source evaluations and implement potential control actions if the drinking water utility monitoring at intakes indicates increased risks to treatment from these pathogens. The San Francisco Bay RWQCP (San Francisco Bay RWQCB 2017) specifies numerical water quality objectives for bacteria applicable to Suisun Bay and Marsh for the protection of water contact and non-contact water recreation, and shellfish harvesting.

Areas of the Delta are on the SWRCB Section 303(d) list of impaired water bodies due to elevated indicator bacteria (SWRCB 2017a). A TMDL is developed for six of the urban waterways listed in the Stockton area: Lower Calaveras River, Five Mile Slough, Mormon Slough, Mosher Slough, Smith Canal, and Walker Slough. The other listed water bodies include the Stockton Deep Water Ship Channel and French Camp Slough, which are also located in the Stockton area. Suisun Marsh and Suisun Bay are not on the SWRCB Section 303(d) list as impaired due to elevated indicator bacteria.

G.1.9.10.2 San Francisco Bay

Section 303(d) does not list San Francisco Bay surface waters as impaired due to pathogens or indicator bacteria. However, six beaches located on San Francisco Bay are listed as impaired due to fecal indicator bacteria. A San Francisco Bay Beaches Bacteria TMDL (San Francisco Bay RWQCB 2016) addresses the impairment to protect human health.

G.1.9.11 *Legacy Contaminants*

G.1.9.11.1 Dioxins and Furans

Dioxins and dioxin-like compounds are chemical compounds with similar chemical structures and biotic effects. There are several hundred of these compounds, which can be grouped into three families: chlorinated dibenzo-p-dioxins, chlorinated dibenzofurans, and certain PCBs. PCBs are addressed separately below.

Chlorinated dibenzo-p-dioxins and chlorinated dibenzofurans are created unintentionally, usually through combustion processes. Forest fires and volcanoes can contribute these compounds to the atmosphere, as well as certain human activities (e.g., incineration of municipal solid waste, metal smelting, coal fired power plants, wood burning, and chlorine bleaching of wood pulp).

Dioxin and furan compounds are extremely persistent, and once released into the environment can cycle through various phases including water, sediment, soil, air, and biota. Dioxin and furan compounds bioaccumulate in the tissues of exposed organisms because of their stability, affinity for accumulation in the fats of animals, and slow biodegradation rates. Dioxin and furan compounds can affect beneficial uses including municipal and domestic (drinking water) supply, commercial and sport fishing, the preservation of rare and endangered species, shellfish harvesting, and warm fresh water, cold fresh water, estuarine, and wildlife habitat.

The Stockton Deep Water Ship Channel is on the SWRCB's Section 303(d) list as impaired due to dioxin and furan compounds. The listing is associated with localized high dioxin and furan concentrations in sediment traced to a wood preserving facility, McCormick and Baxter Creosoting Company, immediately south of Mormon Slough (Hayward et al. 1996). The facility is now a Superfund site and has undergone substantial cleanup efforts. The surface water-sediment remedy (sand cap) and soil remedy (soil excavation, consolidation and capping) are implemented and considered protective of human health and the environment (USACE 2018).

Section 303(d) listed the entire San Francisco Bay for dioxin and furan compounds in 1999, due to a OEHHA fish consumption advisory issued in San Francisco Bay. The Delta was later added to the SWRCB's Section 303(d) list for dioxin and furan compounds because of the migration of striped bass and sturgeon from the Bay into the Delta. Stormwater runoff is approximately 80% of the dioxins and furans load in the Bay (USEPA 2017). Atmospheric deposition is believed to be the primary source because of roughly equivalent concentrations in stormwater runoff around the Bay. Direct atmospheric deposition onto the Bay accounts for approximately 18% of the Bay's dioxins and furans load. The remaining 2% of the load is from wastewater treatment plants and refineries (USEPA 2017).

G.1.9.11.2 Polychlorinated Biphenyls (PCBs)

PCB manufacturing in the United States was discontinued in 1979. Today, PCBs can enter the environment from a variety of sources, including leaking pre-1979 electrical transformers still in use, atmospheric deposition over connected watersheds, and industrial and municipal wastewater discharges. PCBs are extremely stable, and once released to the environment, can cycle through various phases including water, sediment, soil, air, and biota.

Section G.1.1.8 provides additional background information regarding sources of PCBs in the environment, and associated human health and environmental concerns.

The northern and western Delta, Stockton Deep Water Ship Channel, Suisun Bay, and all segments of San Francisco Bay are listed as impaired due to PCBs, with the source of the impairment unknown (SWRCB 2017a). Although research has not quantified sources of PCB loading to the Delta, suspension and transport of contaminated sediments is likely a dominant process. Leatherbarrow et al. (2005) found that PCB concentrations at Mallard Island fluctuated with tide, with highest PCB concentrations associated with flood tide (i.e., Bay water inflow to the Delta). This observation is consistent with their hypothesis that legacy contaminants resuspended from Bay sediments and transported into the west Delta on a flood tide contain higher concentrations of PCBs than riverine suspended sediment being transported from the Delta into the Bay. Furthermore, the mixture of PCBs in riverine suspended sediment is indicative of recent atmospherically-deposited PCBs rather than the resuspension of PCBs deposited in the Delta decades earlier.

The narrative water quality objective, which states that controllable water quality factors shall not cause a detrimental increase in toxic substances found in bottom sediments or aquatic life, and the numeric water quality objective of 0.00017 µg/L total PCBs in surface water, are exceeded. There are also elevated concentrations in sport-fish. The San Francisco Bay RWQCB (2017) describes an action plan and TMDL approved by USEPA in 2010 for PCBs, including dioxin-like congeners, in the Delta, Suisun Bay, Carquinez Strait, San Pablo Bay, Richardson Bay, and the Central and Lower San Francisco Bay. The TMDL includes a numeric target of 10 µg/kg wet weight in fish tissues to protect human health and aquatic life. Clean-up investigations are ongoing at sources of contamination to the Delta from the legacy contaminants. The implementation plan describes reductions in PCB sources (i.e., storm water runoff and PCB contaminated sites within the Bay), actions to reduce risks to people consuming fish from the Bay, and monitoring PCB concentrations in fish tissues, surface water, and sediments. Actions to reduce PCB concentrations in San Francisco Bay will include dredging and material disposal outside of the Bay, natural attenuation, and outflow through the Golden Gate.

A TMDL for the Stockton Deep Water Ship Channel is expected in 2019.

G.1.9.11.3 Polyaromatic Hydrocarbons (PAHs)

Polycyclic aromatic hydrocarbons (PAHs) have limited industrial utility and largely enter the environment by natural means, such as from volcanoes and forest fires, or incidental means related to human activities, such as burning wood, fossil fuel burning, and trash. Particles contaminated with PAHs can eventually settle to the ground throughout a watershed and ultimately enter waterways through stormwater runoff. Hundreds of PAH compounds exist; naphthalene and benzo(a)pyrene are among the common compounds.

PAHs can potentially affect beneficial uses including municipal and domestic drinking water supply, commercial and sport fishing, preserving rare and endangered species, shellfish harvesting, and warm fresh water, cold fresh water, estuarine, and wildlife habitat.

The western Delta is on the Section 303(d) list as impaired due to PAHs (SWRCB 2017a). The specific sources of the Delta impairment are unknown (SWRCB 2017a), however, sources of PAHs to San Francisco Bay provide insight into possible sources to the Delta. A major source of PAHs to San Francisco Bay water and sediments is petroleum combustion, while minor amounts of PAHs are derived from biomass (wood and grasses) and coal combustion, and from uncombusted petroleum (Oros et al. 2007). Storm water runoff is the primary contributor of PAHs to the Bay, followed by tributary inflow, wastewater treatment plant effluent, atmospheric deposition, and dredged material disposal (Oros et al. 2007).

G.1.9.12 *Pesticides*

G.1.9.12.1 Delta, Suisun Bay, and Suisun Marsh

The entire Delta region is on SWRCB's CWA Section 303(d) list as impaired by Group A pesticides, DDE/DDT, chlorpyrifos, and diazinon (SWRCB 2017a). Smith Canal within the Delta is impaired by organophosphorus pesticides. Pixie Slough and Sand Creek are impaired by disulfoton (SWRCB 2017a). The north Delta, and the west Delta are impaired by chlordane and dieldrin, while Sand Creek is listed for dieldrin. Pesticide impairments in Suisun Bay include dieldrin and DDT, while Suisun Marsh is impaired by chlordane (SWRCB 2017a). The Central Valley RWQCP includes a diazinon and chlorpyrifos TMDL for the Delta (Central Valley RWQCB 2018a).

Current use pesticide data collected under the Delta RMP reflects pesticide conditions in Delta surface waters. The Delta RMP monitored 154 current use pesticides and toxicity monthly from July 2015–June 2016 at five major inputs to the Delta: the San Joaquin River at Vernalis, the San Joaquin River at Buckley Cove, the Sacramento River at Hood, Mokelumne River at New Hope Road, and Ulatis Creek at Browns Road (De Parsia et al. 2018; Jabusch et al. 2018). All of the water samples detected pesticides, with mixtures ranging from 2 to 25 pesticides. A total of 52 pesticide compounds were detected: 19 fungicides, 17 herbicides, 9 insecticides, 6 breakdown products, and 1 synergist. The most frequently detected pesticide compounds were the herbicides hexazinone (95% of samples) and diuron (73% of samples) and the fungicides boscalid (93% of samples) and azoxystrobin (75% of samples).

The Central Valley RWQCB Irrigated Lands Regulatory Program aims to prevent agricultural runoff containing pesticides from impairing surface waters. Growers are required to implement management practices to protect surface water. Growers must conduct farm evaluations to determine the effectiveness of farm practices in protecting water quality.

G.1.9.12.2 San Francisco Bay

Section 303(d) listed San Francisco Bay (Central, Lower, and South) and the Delta segment as impaired by the legacy pesticides chlordane, DDT, and dieldrin in 1988. The bioaccumulation DDT and dieldrin in fish led to the listings. The 303(d) impairment list added the organophosphate pesticide diazinon after repeated episodic observations of toxicity in Bay waters following runoff events (SFEI 2007). Historical pesticide sources include domestic and commercial uses, and a former DDT and dieldrin manufacture and distribution site adjacent to the Lauritzen Channel, within the Richmond Inner Harbor, where stockpiles led to contamination of Bay sediments (Swartz et al. 1994). The United Heckathorn Superfund Site in Richmond's sediment was remediated in 1990 and the attenuation of these legacy pesticides in sediment and aquatic organism tissues throughout the Bay are currently monitored.

The San Francisco Bay RWQCB (2005) adopted a TMDL for diazinon and pesticide-related toxicity in urban creeks to address beneficial use impairments in all San Francisco Bay Region urban creeks and to reduce pesticide concentrations in the Bay where these urban creeks discharge. Proposed targets are expressed in terms of toxic units and diazinon concentrations.

G.1.9.13 *Organic Carbon*

In an aquatic system, organic carbon encompasses a broad range of compounds that fundamentally contain carbon in their structure. Organic carbon may be contributed to the aquatic environment by degraded plant and animal materials, and from anthropogenic sources such as domestic wastewater, urban runoff, and agricultural discharge. Organic carbon is a critical part of the food web and sustains aquatic life in the Delta, Suisun Bay, and San Francisco Bay. However, the presence of organic carbon in Delta waters also is of concern because it is a precursor contributing to disinfection byproduct formation at the drinking water treatment plants that divert water from the Delta.

Sources of organic carbon in the Delta include peat soils, upland, agricultural and urban runoff, wetlands, algae production, and municipal wastewater discharges. Organic carbon is present in all the streams and rivers flowing into the Delta, and the upstream sources supply most of the organic carbon load to the Delta. Between 50 and 90% of the dissolved organic carbon load entering the Delta arrives from river flows (CALFED 2008). Major in-Delta sources include wetlands (5–30%), algae (approximately 5%), and peat islands (40%) (CALFED 2008). The upstream and internal loads, and their related sources, vary by season (CALFED 2008). Approximately 5 to 50% is lost due to internal recycling (CALFED 2008).

Delta inflows are a primary source of organic carbon, followed by in-Delta sources. Across seasons, the San Joaquin River and Sacramento River inflow concentrations to the Delta exhibit contrasting relationship. The highest concentrations in the Sacramento River occur in the wet months, whereas in the highest concentrations in the San Joaquin River occur in the dry months (Tetra Tech, Inc. 2006). The higher dry month San Joaquin River concentrations are attributed to the contribution of agricultural drainage to total flows in the San Joaquin River during the dry season (Tetra Tech, Inc. 2006).

Monthly average total organic carbon concentrations in the Sacramento River at Hood/Greene's Landing range from 2 to 3 mg/l. San Joaquin River monthly average total organic carbon concentrations range from 3 to 4 mg/l at Vernalis (Tetra Tech, Inc. 2006). Most organic carbon in the Delta is in the dissolved form, which is generally less bioavailable to the base of the food web compared with particulate organic carbon (POC) or organic carbon derived from primary production (Tetra Tech, Inc. 2006). Conversely, dissolved organic carbon has the greatest potential to form disinfectant byproducts (e.g., THMs) in reactions with chlorine as part of wastewater and drinking water treatment.

The Delta is an important source of organic carbon to Suisun Bay and the northern portion of San Francisco Bay. Jassby et al. (1993) found that, in 1980, 83% of the dissolved organic carbon load in Suisun Bay and 62% of the dissolved organic carbon load in the northern portion of San Francisco Bay was from Delta inflow. Within Suisun Marsh, managed wetlands are the largest direct source of organic carbon to the sloughs. The watersheds surrounding Suisun Marsh also contribute a substantial portion of the organic carbon load via stormwater, followed by tidal marshes and treated wastewater effluent from the Fairfield Suisun Sewer District's wastewater treatment facility (San Francisco Bay RWQCB 2018).

Organic carbon flows from the Delta into the San Francisco Bay estuary where it supports microbial production at the base of the food web (CALFED 2008). There are no federal or state numeric surface water quality objectives for organic carbon. There is a state narrative water quality objective, federal drinking water treatment requirements related to total organic carbon levels, and a CALFED goal. The Central Valley RWQCP (Central Valley RWQCB 2018a) contains a narrative water quality objective that waters shall not contain chemical constituents, including organic carbon, in concentrations that adversely affect beneficial uses. Under USEPA's Disinfectants and Disinfection Byproducts Rule (63 FR 69390), municipal drinking water treatment facilities are required to remove specific percentages of total organic carbon in source waters through enhanced treatment methods, unless the drinking water treatment system can meet alternative criteria. USEPA's action thresholds begin at 2 to 4 mg/l and, depending on source water alkalinity, may require a drinking water utility to employ treatment to achieve as much as a 35% reduction in total organic carbon. Where source water total organic carbon is between 4 and 8 mg/l, a 45% reduction in total organic carbon may be required.

The CALFED Bay-Delta Program (2000) established a goal to achieve 3 mg/l as a long-term average for total organic carbon at Delta drinking water intakes. The goal is based on a study prepared by California Urban Water Agencies recommending Delta source water quality targets sufficient to achieving disinfection byproduct criteria in treated drinking water and sufficient to allow continued flexibility in treatment technology. Specifically, the CALFED Drinking Water Program goal aims to achieve either: average concentrations at Clifton Court Forebay and other southern and central Delta drinking water intakes of 3.0 mg/l total organic carbon along with 50 µg/l bromide, or an equivalent level of public health protection using a cost-effective combination of alternative source waters, source control, and treatment technologies (CALFED 2000). In establishing its goal, CALFED assumed more stringent disinfection byproduct criteria for treated drinking water than are currently in place. California Urban Water Agencies (1998) have concluded that source water with total organic carbon between 4 and 7 mg/l is sufficient to meet currently established drinking water criteria for disinfection byproducts, depending on the amount of *Giardia* inactivation required.

Monthly median concentrations of total organic carbon in the San Joaquin River at Vernalis are 3 to 5 mg/l, and 90th percentile concentrations are 7 mg/l or less, except in September and October, when 90th percentile concentrations are 10 mg/l (Tetra Tech, Inc. 2006). In the Sacramento River at Hood/Greene's Landing, monthly median concentrations range between 1 and 3 mg/l, and monthly average concentrations range from 2 to 3 mg/l, and 90th percentile concentrations are 4 mg/l or less (Tetra Tech, Inc. 2006).

G.1.10 CVP and SWP Service Areas (south to Diamond Valley)

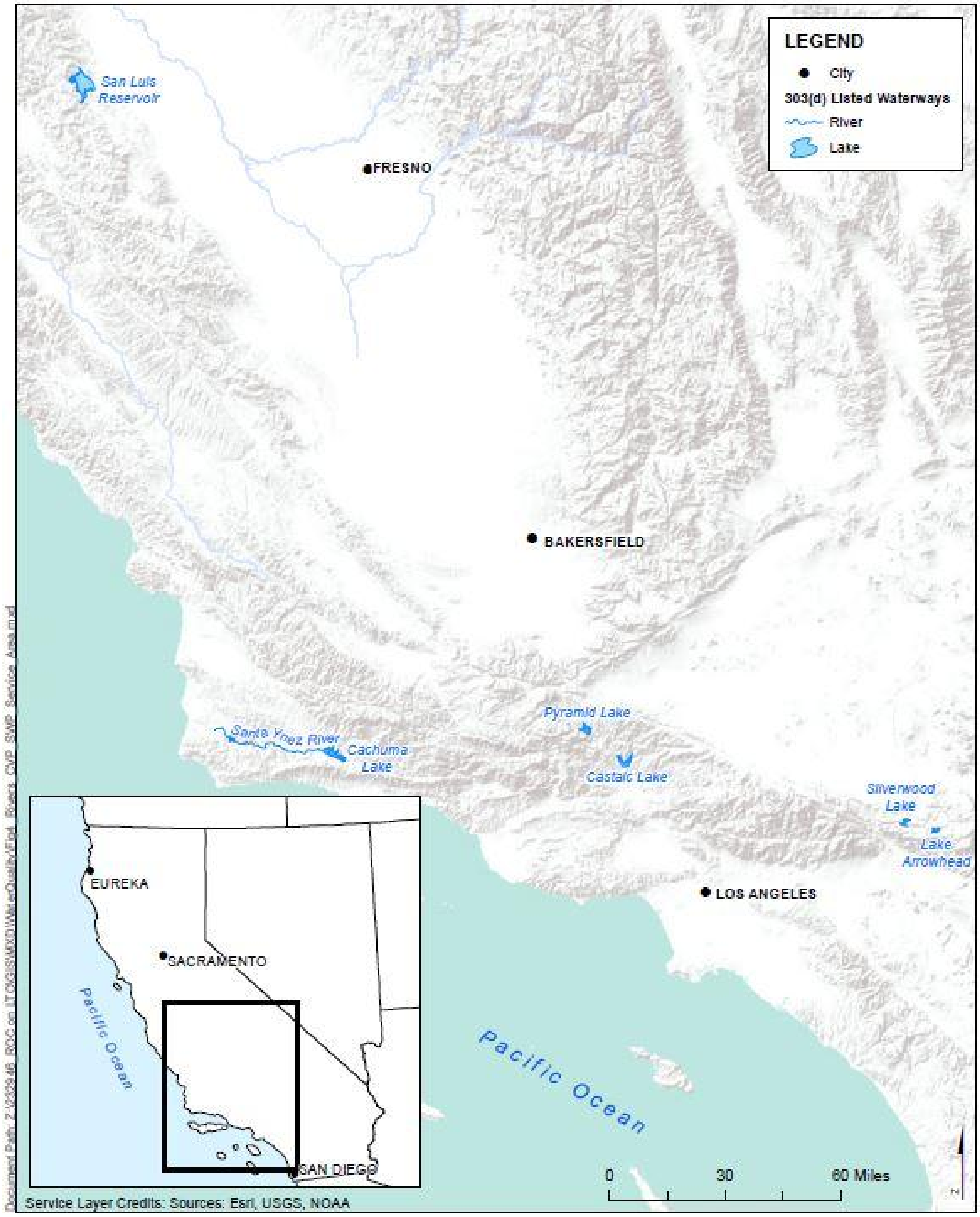
Figure G.1-6, 303(d) Listed Waterways in the CVP and SWP Service Areas presents 303(d) listed waterways in the CVP and SWP service areas.

G.1.10.1 *San Luis Reservoir*

San Luis Reservoir is an off-stream storage facility located along the California Aqueduct downstream of Jones and Banks Pumping Plant and could be potentially affected by CVP/SWP project implementation.

G.1.10.1.1 Mercury

San Luis Reservoir is on the SWRCB's CWA Section 303(d) list as impaired by mercury (SWRCB 2017a). Mercury in San Luis Reservoir is from an unknown source (SWRCB 2017ai).



Source: SWRCB 2017a

Figure G.1-6. 303(d) Listed Waterways in the CVP and SWP Service Areas

Mercury and enhanced mercury methylation can affect the beneficial uses of San Luis Reservoir. In 2009, fish tissue analysis collected at four location from San Luis Reservoir, showed an average mercury concentration in Largemouth Bass ranging from 0.51 ppm to 0.62 ppm and 0.19 ppm to 0.35 ppm in Common Carp (*Cyprinus carpio*) (SWAMP 2009). A total of 33 out of 47 samples exceeded the OHHEA fish tissue screening value for human health (SWRCB 2017ai).

TMDLs are expected to be completed by 2027 to meet the water quality standards in San Luis Reservoir to protect the beneficial uses of San Luis Reservoir, including the commercial and recreational collection of fish, shellfish, or other organisms of beneficial use (SWRCB 2017ai).

G.1.10.1.2 Pesticides

San Luis Reservoir is on the Section 303(d) list as impaired by pesticides (Total DDT and chlordane) (SWRCB 2017a). Orangochlorine pesticides (e.g., DDT and chlordane) are primarily transported to streams and rivers in runoff from agriculture (Central Valley RWQCB 2011). Sources and descriptions of the listed pesticides are discussed further in Section G.1.1.7.

G.1.10.1.3 PCBs

San Luis Reservoir is on SWRCB's CWA Section 303(d) list as impaired by PCBs (SWRCB 2017a), based on composite samples of Common Carp collected from the San Luis Reservoir for PCB congeners and Aroclor mixtures (SWRCB 2017ai). The total PCBs recorded ranged from 42 ppb to 133 ppb (SWAMP 2009).

A TMDL for PCBs in the lower American River is expected to be completed in 2027 to protect the beneficial uses of San Luis Reservoir (SWRCB 2017ai).

G.1.10.2 *Cachuma Lake*

Reclamation in Santa Barbara County owns and operates the Cachuma Lake facility. Mercury is a constituent of concern for Cachuma Lake. The Santa Ynez River flows through Cachuma Lake. The Santa Ynez River (above Lake Cachuma) is on SWRCB's CWA Section 303(d) list as impaired by temperature and toxicity (SWRCB 2017a). TMDLs for temperature and toxicity are expected to be completed in 2023 (SWRCB 2017aj). The Santa Ynez River (Cachuma Lake to below city of Lompoc) is on the SWRCB's CWA Section 303(d) list as impaired by sedimentation/siltation, temperature, sodium, TDS, and toxicity (SWRCB 2017a). TMDLs for sediment/siltation, sodium, and TDS are expected to be complete in 2027 (SWRCB 2017ak).

G.1.10.2.1 Mercury

Cachuma Lake is on SWRCB's CWA Section 303(d) list as impaired by mercury (SWRCB 2017a) from an unknown source (SWRCB 2017al).

Mercury and enhanced mercury methylation can affect the beneficial uses of Cachuma Reservoir. In 2009, all five tissue samples from fish collected at one Cachuma Lake location exceeded the criterion for Mercury (SWRCB 2017al).

SWRCB set TMDLs in 2018 to protect the beneficial uses of Cachuma Lake, including the commercial and recreational collection of fish, shellfish, or organisms' beneficial use (SWRCB 2017al). As of February 2019, USEPA has not approved TMDLs for Cachuma Lake (DWR 2019b).

G.1.10.3 *Quail Lake*

Section 303(d) does not list Quail Lake, a SWP facility in Los Angeles County as impaired for any constituents of concern (SWRCB 2017a).

G.1.10.4 *Pyramid Lake*

Pyramid Lake is a SWP facility located in Los Angeles County, upstream of Castaic Lake on the West branch of the California Aqueduct.

G.1.10.4.1 Mercury

Section 303(d) does not list Pyramid Lake as impaired by mercury (SWRCB 2017a).

Mercury and enhanced mercury methylation can affect the beneficial uses of Pyramid Lake. In 2009, analysts generated 24 sample composites of Largemouth Bass and Brown Bullhead (*Ameiurus nebulosus*) from two locations on Pyramid Lake (SWAMP 2009). A total of 14 out of 24 samples exceeded the OHHEA fish tissue screening value for human health (SWRCB 2017am).

To protect the commercial and recreational collection of fish, shellfish, or organisms beneficial use of Pyramid Lake, TMDLs are set for completion by 2021 (SWRCB 2017am).

G.1.10.4.2 Pesticides

Pyramid Lake is on SWRCB’s CWA Section 303(d) list as impaired by chlordane, DDT and the Group A pesticide dieldrin (SWRCB 2017a). Three of four fish samples (two Brown Bullhead and one Largemouth Bass) collected in 2009 at Pyramid Lake exceeded the Total DDT OEHHA screening value of 21 µg/kg (SWRCB 2017am).

To protect the beneficial uses of the Pyramid Lake, TMDLs for chlordane, DDT, and dieldrin are expected to be completed in 2027 (SWRCB 2017am).

G.1.10.4.3 PCBs

Pyramid Lake is on SWRCB’s CWA Section 303(d) list as impaired by PCBs (SWRCB 2017a). In 2009, composite samples of Largemouth Bass and Brown Bullhead from Pyramid Lake at two locations and analyzed them for PCBs concentrations (SWRCB 2017am). The average PCB concentrations at Pyramid Lake were among the highest in the state, with 238 ppb in Brown Bullhead. Pyramid Lake was one of two lakes in the state exceeding the 120 ppb no consumption advisory tissue levels (SWAMP 2008).

A TMDL for PCBs in Pyramid Lake is expected to be completed in 2027 to protect beneficial uses (SWRCB 2017am).

G.1.10.5 *Castaic Lake*

Castaic Lake is a SWP facility located in Los Angeles County at the terminal end of the West Branch of the California Aqueduct.

G.1.10.5.1 Mercury

Castaic Lake is on SWRCB’s CWA Section 303(d) list as impaired by mercury (SWRCB 2017a). TMDLs are set for completion by 2027 (SWRCB 2017an).

Twenty-four sample composites were collected from two locations at Castaic Lake generated from Largemouth Bass (22) and Common Carp (2). Eight samples exceeded the 0.3 mg/kg OEHHEA fish tissue screening value for human health (SWAMP 2009).

G.1.10.5.2 PCBs

Castaic Lake is on SWRCB's CWA Section 303(d) list as impaired by PCBs (SWRCB 2017a). To protect the commercial and recreational collection of fish, shellfish, or organisms beneficial use of Castaic Lake, TMDLs are set for completion by 2027 (SWRCB 2017an).

G.1.10.6 *Silverwood Lake*

Silverwood Lake is a SWP facility located in San Bernardino County along the East Branch of the California Aqueduct.

G.1.10.6.1 Mercury

Silverwood Lake is on the SWRCB's CWA Section 303(d) list as impaired by mercury (SWRCB 2017a). All fifteen samples collected from Silverwood Lake in 2009 exceeded criterion for Mercury (SWRCB 2017ao). To protect the commercial and recreational collection of fish, shellfish, or organisms beneficial use of Silverwood Lake, TMDLs are set for completion by 2025 (SWRCB 2017ao).

G.1.10.6.2 PCBs

Silverwood Lake is on the SWRCB's CWA Section 303(d) list as impaired by PCBs (SWRCB 2017a). In 2009, composite samples of Largemouth Bass were collected in Silverwood Lake and analyzed for PCBs concentrations (SWRCB 2017ao). Average PCB concentrations at Silverwood Lake were among the highest in the state, with 93 ppb in largemouth bass (SWAMP 2008).

A TMDL for PCBs in Pyramid Lake is expected to be completed in 2025 to protect beneficial uses (SWRCB 2017ao).

G.1.10.7 *Crafton Hills Reservoir*

Section 303(d) does not list Crafton Hills Reservoir, a SWP facility located in the City of Yucaipa within San Bernardino County, as impaired for any constituents of concern (SWRCB 2017a).

G.1.10.8 *Lake Perris*

Section 303(d) does not list Lake Perris, a SWP facility located in Riverside County, as impaired for any constituents of concern (SWRCB 2017a).

G.1.10.9 *Diamond Valley Lake*

Section 303(d) does not list Diamond Valley Lake, an offstream storage facility located in Riverside County, as impaired for any constituents of concern (SWRCB 2017a).

G.1.10.10 *Lake Piru*

Section 303(d) does not list Lake Piru, an offstream storage facility located in Riverside County, as impaired for any constituents of concern (SWRCB 2017a).

G.1.10.11 *Lake Arrowhead*

G.1.10.11.1 Mercury

Lake Arrowhead is on the SWRCB's CWA Section 303(d) list as impaired by mercury (SWRCB 2017a). In 2009, 12 out of 15 Largemouth Bass sample composites from Lake Arrowhead exceeded the OHHEA fish tissue screening value for human health (SWAMP 2009, SWRCB 2017ap).

To protect the commercial and recreational collection of fish, shellfish, or organisms beneficial use of Lake Arrowhead, TMDLs are set for completion by 2025 (SWRCB 2017ap).

G.2 Evaluation of Alternatives

This section describes the technical background for the evaluation of environmental consequences associated with the CVP/SWP Alternatives and the No Action Alternative.

G.2.1 Methods and Tools

The impact analysis considers changes in surface water quality conditions related to changes in CVP/SWP operation under the alternatives as compared to the No Action Alternative due to changes in river flows and surface water deliveries. For all regions except the Bay-Delta, the analysis used changes in flow to investigate potential water quality impacts. Section G.2.1.2, *Bay-Delta Region Specific Methods*, provides a detailed description of the methods used for the Bay-Delta region.

If the Summer-Fall Delta Smelt Habitat action includes operations of the SMSCG or a Fall X2 action, the water requirements in the summer and fall could be greater than shown for Alternative 1. Alternative 1 indicates some water quality benefits when flows increase, as described below in more detail. In years with the summer or fall actions, the water quality benefits would be less than indicated in the Alternative 1 modeling.

G.2.1.1 *Changes in Flow*

Changes in CVP/SWP operation will change the flow in rivers within the study area. Flow is used as a surrogate for water quality in this analysis. Flow reductions in rivers could result in increased concentrations of constituents of concern because there would be less water in the waterway to dilute runoff containing those constituents. Constituents of concern are present in study area waterways due to a number of sources, including urban and agricultural runoff along with legacy drainage from areas that historically had supported mining activities. If the constituent source is downstream from a reservoir, reductions in flow could result in increased constituent of concern concentrations due to reductions in dilution. If the constituent source is located upstream of a reservoir, an increase or decrease in flow due to changes in CVP/SWP operation would not reduce concentrations of constituents of concern.

The surface water quality analysis was conducted using the CalSim II model, as described in Appendix F, *Model Documentation*. The analysis simulated the operational assumptions of each alternative described in Chapter 3, *Description of Alternatives*.

The modeling did not include certain actions, including the Shasta Dam Raise and water transfers. For the full list of actions not included in the CalSim II modeling, see Appendix F.

G.2.1.2 *Bay-Delta Region Specific Methods*

Section G.1.9, above, identifies numerous constituents or constituent categories present in the Delta, Suisun Bay, Suisun Marsh, or San Francisco Bay at levels that currently impair the water bodies' beneficial uses. Constituents of concern include: salinity-related constituents (i.e. EC, chloride, and TDS), temperature, mercury, selenium, trace metals, dissolved oxygen, pathogens, legacy contaminants (e.g., dioxin and furan compounds, PCBs, and PAHs), and pesticides. Thus, the project alternative evaluation of the Delta, Suisun Bay, Suisun Marsh, and San Francisco Bay water quality addresses effects on these constituents and constituent categories. The analysis addresses temperature within the context of the project alternatives' effects on dissolved oxygen.

In addition to addressing constituents currently known to impair beneficial uses, other constituents of concern for the Bay-Delta also were evaluated. Organic carbon is of concern because of the drinking water supply drawn from the Delta, and organic carbon's effect on food webs in the Delta, Suisun Bay, and San Francisco Bay. Bromide in Delta waters could also impact drinking water supplies. Nutrients levels in the Delta could potentially induce biostimulation, which can affect drinking water supplies and aquatic life. Nutrient levels are of concern in Suisun Bay, Suisun Marsh, and San Francisco Bay due to potential food web effects.

The following sections describe the approach to evaluating the project alternatives' project- and programmatic-level components' effects on water quality in the Delta, Suisun Bay and Marsh, and San Francisco Bay for constituents of concern.

The project-level evaluation of the project alternatives' effects on surface water quality in the Delta, Suisun Bay, and Suisun Marsh consisted of quantitative and qualitative analyses. Evaluations of the salinity-related parameters EC and chloride were conducted in a quantitative manner, utilizing modeling output from DSM2-QUAL. The mercury and selenium evaluations also utilized the DSM2-QUAL modeling output, coupled with bioaccumulation models. Evaluations of the effects of project alternatives on the other constituents of concern was conducted in a qualitative manner, considering the sources, of the constituents of concern and how the alternatives could affect the relative concentrations in Delta inflows and within the Bay-Delta.

The evaluation of each alternative's effect on surface water quality in San Francisco Bay used qualitative analyses and considered qualitative and quantitative analyses for the Delta and Suisun Bay, and Delta outflows as modeled by CalSim II (presented in Appendix F, Attachment 3-2, *Flow Results (CalSim II)*).

The following sections provide additional detail about the evaluation methods for the EC, chloride, bromide, mercury, and selenium evaluations.

G.2.1.2.1 EC, Chloride, and Bromide

The EC evaluation used monthly average EC output from DSM2-QUAL, which was modeled EC in the Delta for water years 1922 through 2003. The analysis summarized percent exceedances of monthly average EC for the 82-year simulation period in tables and plotted by month in exceedance plot format for the following locations:

- Sacramento River downstream of Steamboat Slough.
- Cache Slough at Ryer Island.
- Sacramento River downstream of Georgiana Slough.
- Sacramento River at Emmaton.

- Sacramento River at Rio Vista.
- San Joaquin River at Vernalis.
- San Joaquin River at Jersey Point.
- Old River at Rock Slough.
- Old River at Highway 4.
- Victoria Canal.
- San Joaquin River at Antioch.
- San Joaquin River at Mallard Slough.
- Sacramento River at Collinsville.
- Chipps Island North Channel.
- Chipps Island South Channel.
- Sacramento River at Port Chicago.
- Banks Pumping Plant.
- Jones Pumping Plant.

Appendix F, Attachment 3-6, *Salinity Modeling Results (DSM2)* presents the EC modeling results.

The discussion of EC levels under the project alternatives, as compared to the No Action Alternative, focuses on six assessment locations: the Sacramento River at Emmaton, San Joaquin River at Vernalis, San Joaquin River at Jersey Point, Sacramento River at Collinsville, Banks Pumping Plant, and Jones Pumping Plant. The Sacramento River at Emmaton, San Joaquin River at Vernalis and Jersey Point, and Banks and Jones pumping plants are Bay-Delta WQCP compliance locations for agricultural beneficial uses (SWRCB 2006). The San Joaquin River at Jersey Point and Sacramento River at Collinsville (located at the eastern edge of Suisun Marsh) are Bay-Delta WQCP compliance locations for fish and wildlife beneficial use protection (SWRCB 2006).

The analysis generated monthly average chloride concentrations, using monthly EC output from DSM2, for the following assessment locations, which are Bay-Delta WQCP compliance locations for municipal and industrial beneficial uses protection (SWRCB 2006):

- Contra Costa Pumping Plant #1.
- San Joaquin River at Antioch.
- Banks Pumping Plant.
- Jones Pumping Plant.
- Barker Slough at NBA Intake.

The analysis calculated chloride from the EC output using the two equations below:

$$Cl = (0.15 * EC - 12) \; and \; Cl = (0.285 * EC - 50) \begin{pmatrix} 0.15 * EC - 12 \\ 0.285 * EC - 50 \end{pmatrix}$$

In the equation above, Cl is the chloride concentration in mg/l, and EC is in µmhos/cm. The above equation is based on historical data for Mallard Island, Jersey Island, and Old River at Rock Slough (Contra Costa Water District 1997). Two regression equations are used to calculate chloride concentrations based on whether the location is riverine or seawater dominant. To be conservative, this assessment used the maximum chloride concentration calculated using the above two equations. The chloride modeling results are presented in Appendix F, *Salinity Modeling Results (DSM2)*.

The analysis compared each action alternative's modeled monthly average EC and chloride to the No Action Alternative in the summary tables and probability exceedance plots provided in Appendix F, *Salinity Modeling Results (DSM2)*. The analysis evaluated probability exceedance plots to determine how often the specified EC and chloride levels would be exceeded for the alternative as compared to what would occur for the No Action Alternative at the assessment locations. It compared modeled monthly average EC and chloride levels for each action alternative to those for the No Action Alternative at various Delta locations for the entire period of record modeled, and by water year type.

The qualitative bromide assessment is based on changes in EC and considered historical bromide concentrations in the Delta.

G.2.1.2.2 Methylmercury

The mercury assessment focuses on fish tissue concentrations of methylmercury, to be consistent with the Sacramento-San Joaquin Delta Estuary TMDL for methylmercury, which established waste load allocations and fish tissue objectives expressed as methylmercury. The assessment of the alternatives' effect on Delta methylmercury is based on modeled concentrations at specific Delta locations, as determined from DSM2 output. The analysis used the QUAL module of DSM2 to simulate source water fingerprinting, which identifies the relative contributions of water sources to the volume at the specified Delta location. The analysis input modeled methylmercury concentrations for the entire 82-year modeled period of water years 1922 through 2003 and the consecutive five-year drought period of water years 1987 through 1991 into the Central Valley RWQCB TMDL model for the Delta to develop an estimate of fish tissue concentrations. Appendix G, Attachment 1, *Methylmercury Model Documentation* describes the methods for developing the modeled water and fish tissue concentrations in more detail.

The analysis evaluated project alternatives' effects on fish tissue methylmercury concentrations by comparing exceedances of the fish tissue water quality objective for methylmercury trophic level 4 fish of 0.24 mg/kg. The analysis determined exceedances of the fish tissue water quality objective by evaluating exceedance quotients (EQs), which are ratios of the modeled fish tissue concentration divided by the water quality objective of 0.24 mg/kg. Values over 1.0 indicate modeled tissue concentrations exceed the water quality objective. The analysis compared EQs for the project alternatives to the EQs for the No Action Alternative at various Delta locations to determine if the project alternatives would increase the potential for mercury bioaccumulation in fish within the Delta.

In 2017, the SWRCB approved *Part 2 of the Water Quality Control Plan for Inland Surface Waters, Enclosed Bays, and Estuaries of California—Tribal and Subsistence Fishing Beneficial Uses and Mercury Provisions*, which established mercury limits to protect the beneficial uses associated with the consumption of fish by both people and wildlife. However, the mercury water quality objectives do not supersede the Central Valley RWQCB's site-specific numeric mercury water quality objectives established for the Delta (SWRCB 2017aq). Thus, the SWRCB water quality objectives were not applied in the methylmercury assessment.

For alternatives that include changes in the extent of tidal habitat, the assessment qualitatively addresses the potential to enhance mercury bioavailability and risk at a programmatic level.

G.2.1.2.3 Selenium

The selenium assessment evaluates changes to selenium concentrations in tissues that affect the health of fish, as well as wildlife and humans consuming fish in the Delta, using a suite of modeling tools. The analysis used the DSM2 QUAL module to simulate source water finger printing to quantify the relative contributions of water sources to the volume at specified Delta locations. The source water fingerprinting values (expressed as a % of each Delta source water) multiplied by source water concentrations determined annual average selenium concentrations in the Delta water column at specified locations. The analysis input modeled selenium concentrations for the entire 82-year modeled period of water years 1922 through 2003 and the consecutive five-year drought period of water years 1987 through 1991 into the bioaccumulation models to estimate bioaccumulation in bird eggs and fish fillets, and to model selenium bioaccumulation in Sturgeon (*Acipenseridea*) living in the western Delta. Appendix G, Attachment 2, *Selenium Model Documentation* describes the methods for modeling water column concentrations and bioaccumulation are described in more detail.

The analysis evaluated the alternatives' effects on selenium bioaccumulation in biota by comparing exceedances of bird egg and fish tissue benchmarks. As described above for methylmercury, the analysis characterized exceedances of bird egg and fish tissue benchmarks using EQs. Values over 1.0 indicate modeled bird egg and fish tissue concentrations exceed the applicable toxicity benchmarks. The project alternatives' EQs compared to the EQs for the No Action Alternative, at various Delta locations, determined if the project alternatives would increase the potential for selenium bioaccumulation in bird eggs and fish within the Delta.

For alternatives that include changes in the extent of tidal habitat, the evaluation qualitatively addresses the potential to enhance selenium bioavailability and risk at a programmatic level.

G.2.1.3 *Programmatic-Level Assessment*

The qualitative water quality assessment of the alternatives' programmatic-level components considered the specific actions to be implemented by the programmatic component. It also considered if that action or component could contribute additional sources of water quality constituents of concern, or otherwise alter water quality. The analysis qualitatively addressed the water quality effects of programmatic components construction also, considering the anticipated construction activities that may be required and the materials that may be involved, as well as measures that would require implementation prior to initiating construction activities.

G.2.2 No Action Alternative

Potential changes in water quality

The No Action Alternative would generate no changes in CVP or SWP system operations, and as a result there would be no change in the limits on water supply deliveries currently in place. Given the lack of changes under the No Action Alternative to CVP and SWP operations there would also be no change to the water quality conditions. This includes water quality conditions within the study area that affect beneficial uses.

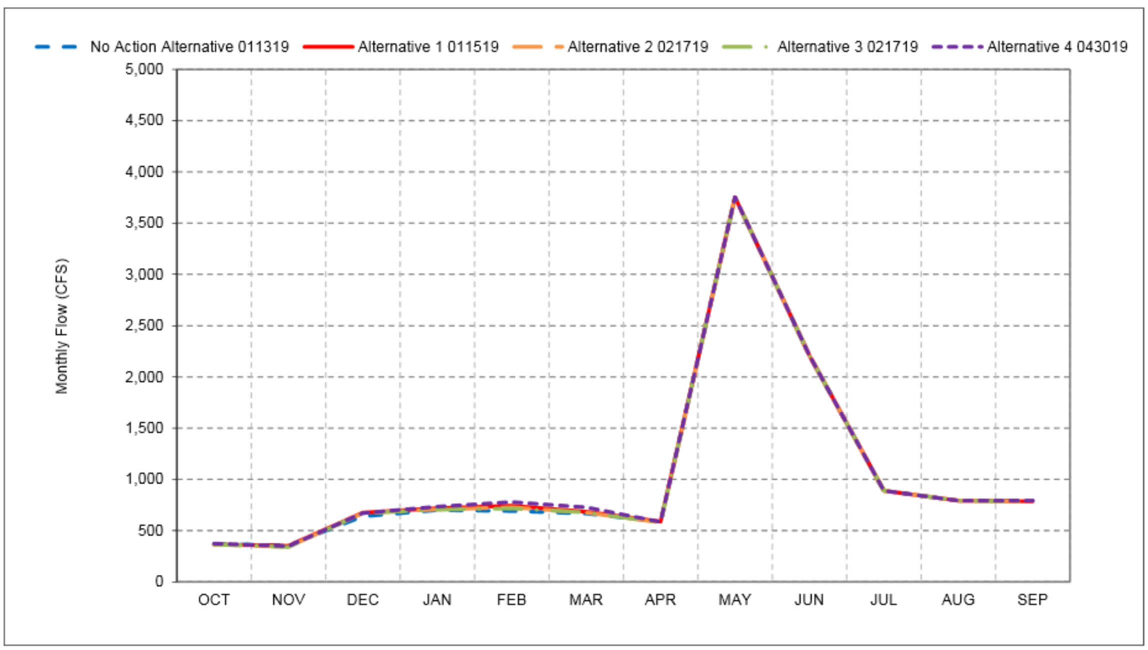
G.2.3 Alternative 1

G.2.3.1 *Project-Level Effects*

Potential changes in water quality

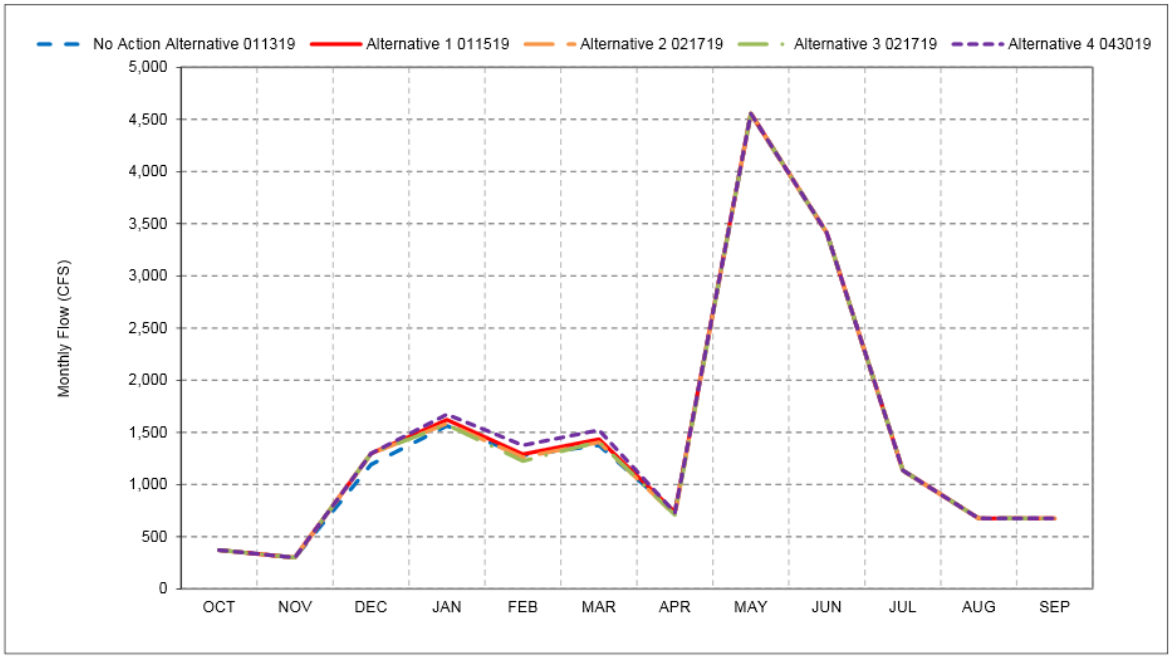
G.2.3.1.1 Trinity River

Operations in the Trinity River would remain similar to those under the No Action Alternative. The Trinity River Restoration Program Record of Decision controls Trinity River operations, and Reclamation would continue to release flows into the Trinity River as they do under the No Action Alternative. Figure G.2-1 through Figure G.2-6, illustrate flow changes for all water year types. Figure G.2-1, Trinity River Flow below Lewiston Dam, Long-Term Average Flow demonstrates that changes in long-term average flows under Alternative 1 are not expected to change by more than 8% compared to the No Action Alternative. Figure G.2-3, Trinity River Flow below Lewiston, Above Normal Year Average Flow, shows the largest change in flow is shown in where flows under Alternative 1 are expected to increase in February of above normal water years by approximately 58% compared to the No Action Alternative. Increasing and decreasing fluctuations in flow under Alternative 1 are expected to a lesser extent in other year types. Because Alternative 1 would have limited changes in flows on the Trinity River, changes in flows would have limited potential to affect water quality. Increases in flow would be considered beneficial based on the improvement of water quality through dilution of constituents of concern. The evaluation does not expect decreases in flow to be a large enough magnitude to affect water quality.



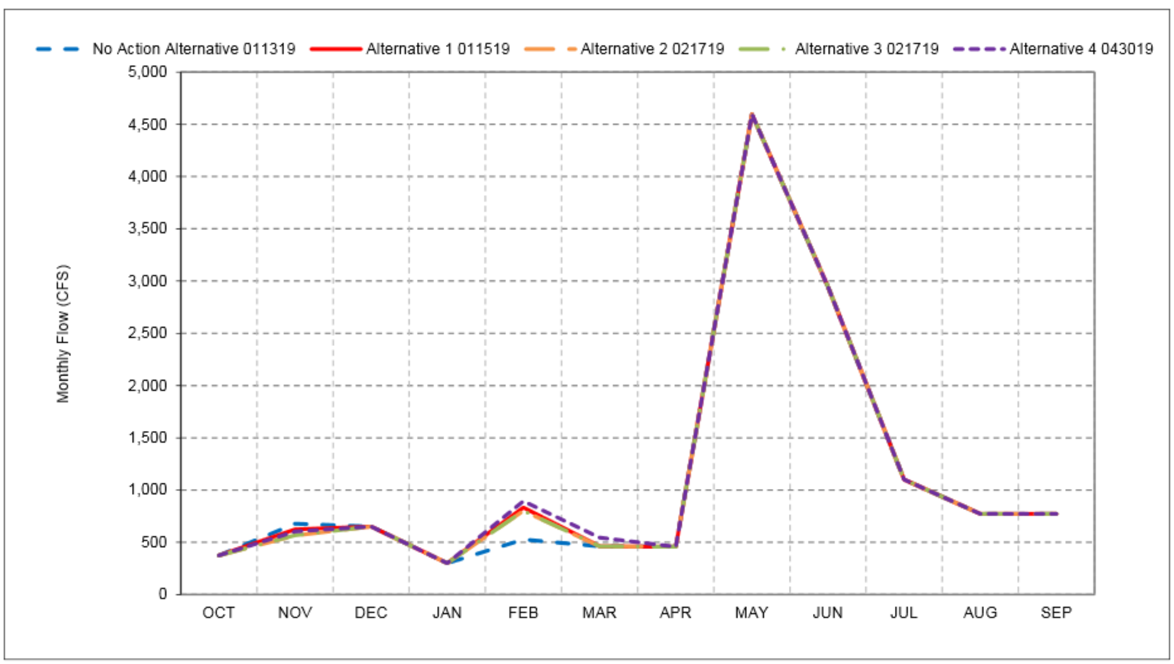
*As defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999).
*These results are displayed with calendar year - year type sorting.
*All scenarios are simulated at ELT (Early Long-Term) Q5 with 2025 climate change and 15 cm sea level rise.
*These are draft results meant for qualitative analysis and are subject to revision.

Figure G.2-1. Trinity River Flow below Lewiston, Long-Term Average Flow



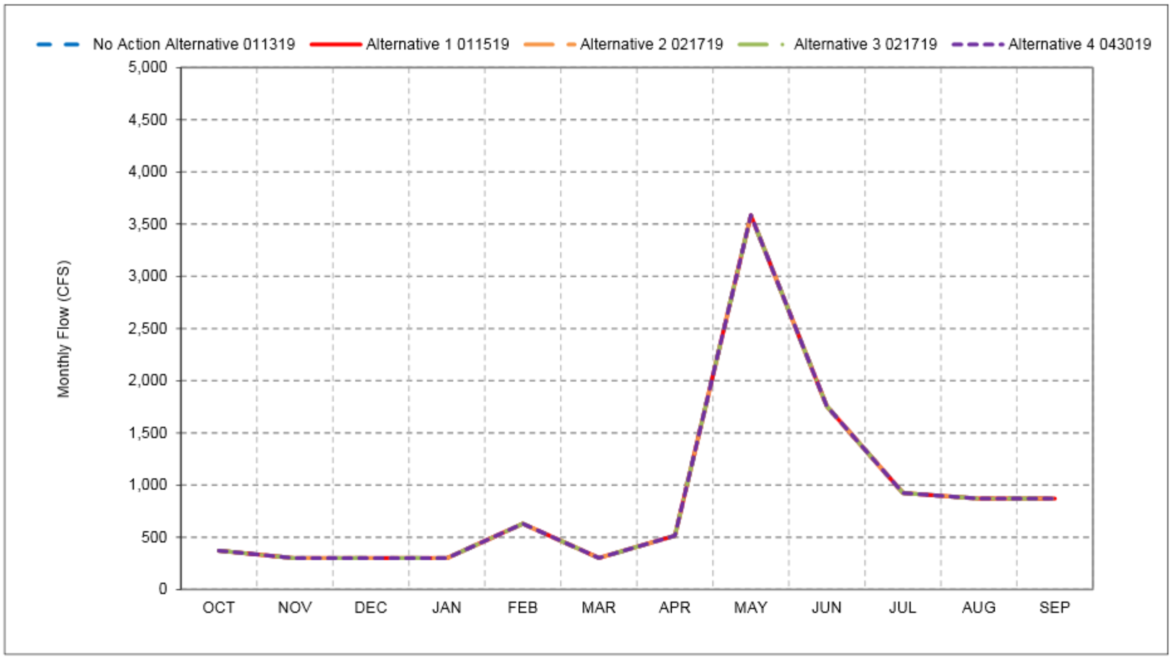
*As defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999).
*These results are displayed with calendar year - year type sorting.
*All scenarios are simulated at ELT (Early Long-Term) Q5 with 2025 climate change and 15 cm sea level rise.
*These are draft results meant for qualitative analysis and are subject to revision.

Figure G.2-2. Trinity River Flow below Lewiston, Wet Year Average Flow



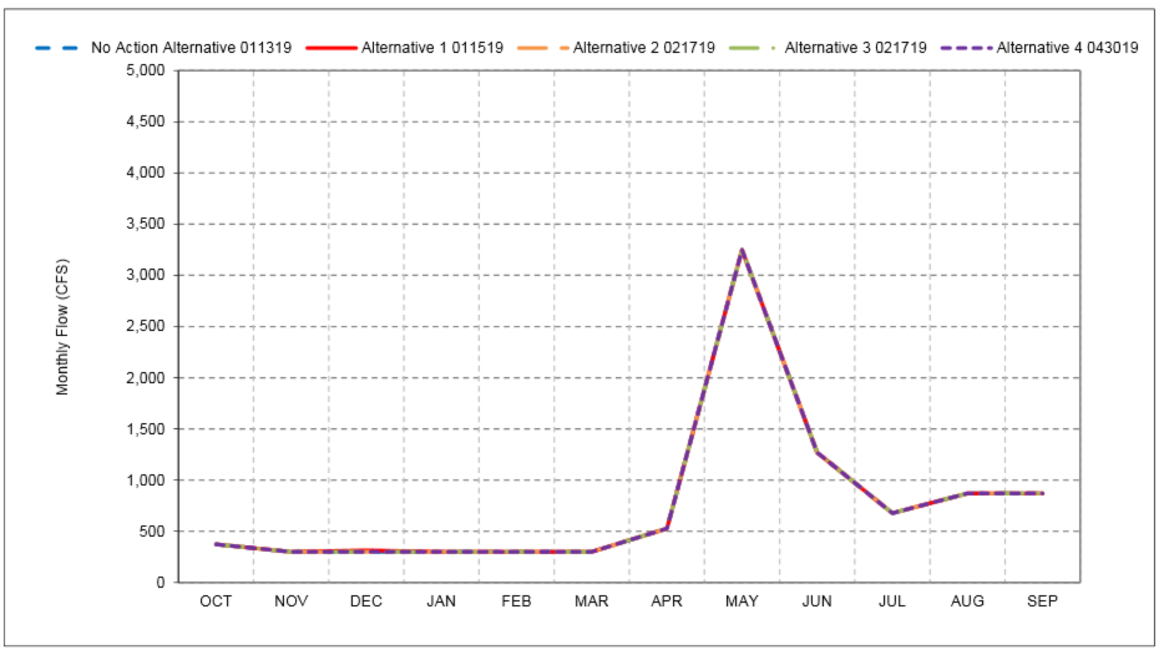
*As defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999).
*These results are displayed with calendar year - year type sorting.
*All scenarios are simulated at ELT (Early Long-Term) Q5 with 2025 climate change and 15 cm sea level rise.
*These are draft results meant for qualitative analysis and are subject to revision.

Figure G.2-3. Trinity River Flow below Lewiston, Above Normal Year Average Flow



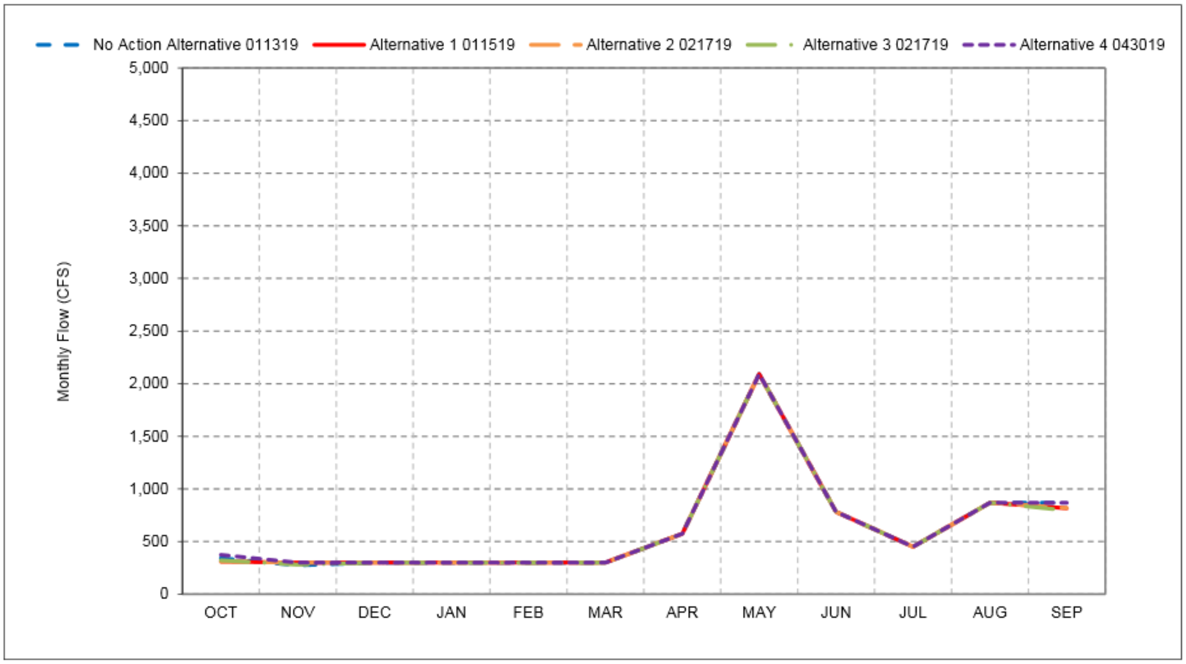
*As defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999).
*These results are displayed with calendar year - year type sorting.
*All scenarios are simulated at ELT (Early Long-Term) Q5 with 2025 climate change and 15 cm sea level rise.
*These are draft results meant for qualitative analysis and are subject to revision.

Figure G.2-4. Trinity River Flow below Lewiston, Below Normal Year Average Flow



*As defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999).
*These results are displayed with calendar year - year type sorting.
*All scenarios are simulated at ELT (Early Long-Term) Q5 with 2025 climate change and 15 cm sea level rise.
*These are draft results meant for qualitative analysis and are subject to revision.

Figure G.2-5. Trinity River Flow below Lewiston, Dry Year Average Flow

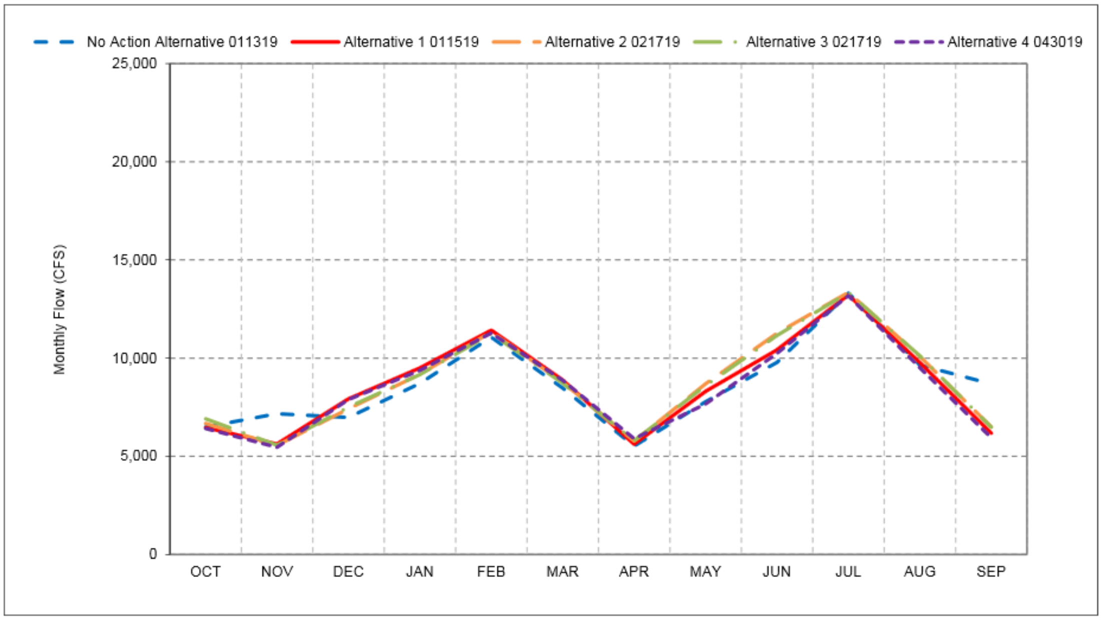


*As defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999).
*These results are displayed with calendar year - year type sorting.
*All scenarios are simulated at ELT (Early Long-Term) Q5 with 2025 climate change and 15 cm sea level rise.
*These are draft results meant for qualitative analysis and are subject to revision.

Figure G.2-6. Trinity River Flow below Lewiston, Critical Year Average Flow

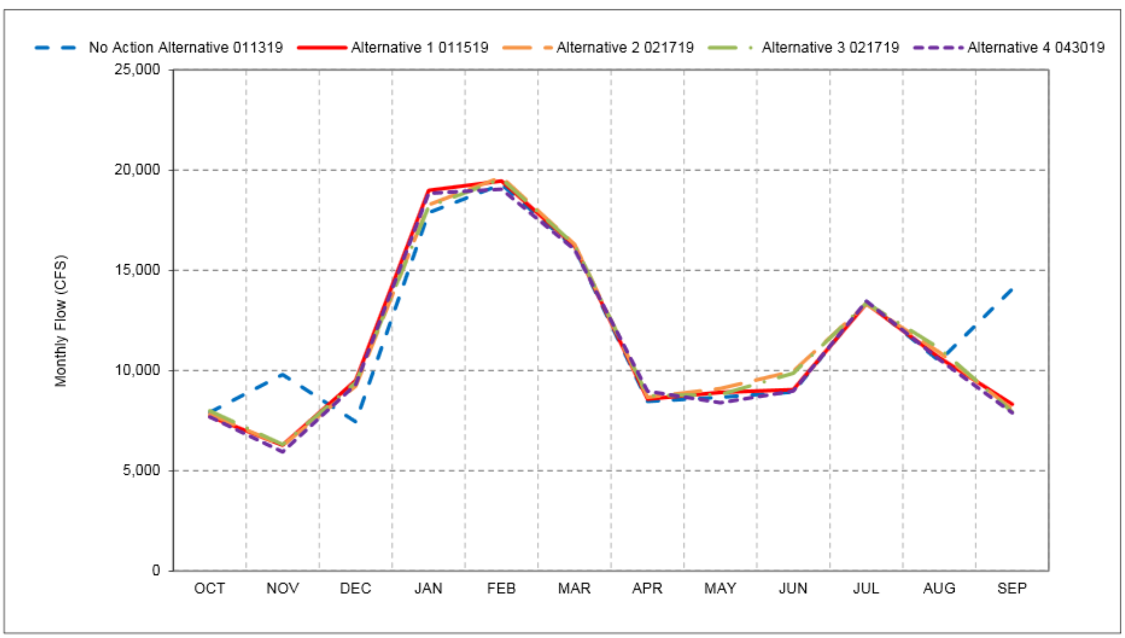
G.2.3.1.2 Sacramento River

Alternative 1 would cause flow changes in the Sacramento River from changes in spring pulse flows, cold water pool management, change in Delta fall requirements, and fall and winter refill. Flow changes could affect water quality in the Sacramento River because flows released from Keswick can dilute concentrations of constituents of concern that enter the river as it flows south. Figures G.2-7 through G.2-12 illustrate changes in flow on the Sacramento River downstream of Keswick Reservoir for different year types. Under Alternative 1, long-term average flow changes are not expected to deviate substantially from the No Action Alternative (see Figure G.2-7, Sacramento River Flow downstream of Keswick Reservoir, Long-Term Average Flow). The largest changes in flow under Alternative 1 are expected during the fall months of Wet and Above Normal Year Types (see Figures G.2-8 and G.2-9). The changes in flow come from changes to fall X2 requirements for Delta Smelt compared to the No Action Alternative. Under Alternative 1, reservoir releases would occur at different times, generally resulting in flow decreases during the fall and flow increases during winter and early spring, to regulate temperature management objectives and spring pulse flows. Substantial decreases in flow are expected only in wet and above normal water year types, in which case a decrease in flow is not expected to affect water quality due to higher base flows. Trends are similar for other sampling locations along the Sacramento River and can be viewed in Appendix F. While Alternative 1 would create flow changes, including decreases of up to 49%, in the Sacramento River, the flow changes would occur during wet and above normal water years when base flow is adequate and decreases in flow are not expected to cause violations of water quality standards. Overall, water quality would not be substantively affected by changes in flow under Alternative 1 and increased frequency of exceedances of water quality thresholds are not expected.



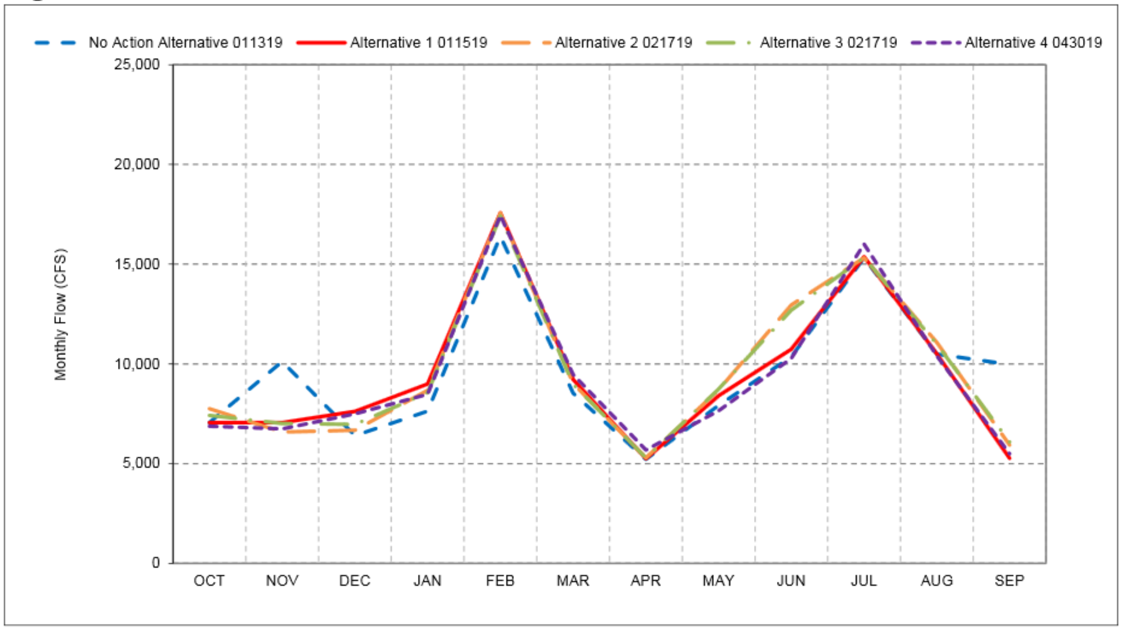
*As defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999).
*These results are displayed with calendar year - year type sorting.
*All scenarios are simulated at ELT (Early Long-Term) Q5 with 2025 climate change and 15 cm sea level rise.
*These are draft results meant for qualitative analysis and are subject to revision.

Figure G.2-7. Sacramento River Flow downstream of Keswick Reservoir, Long-Term Average Flow



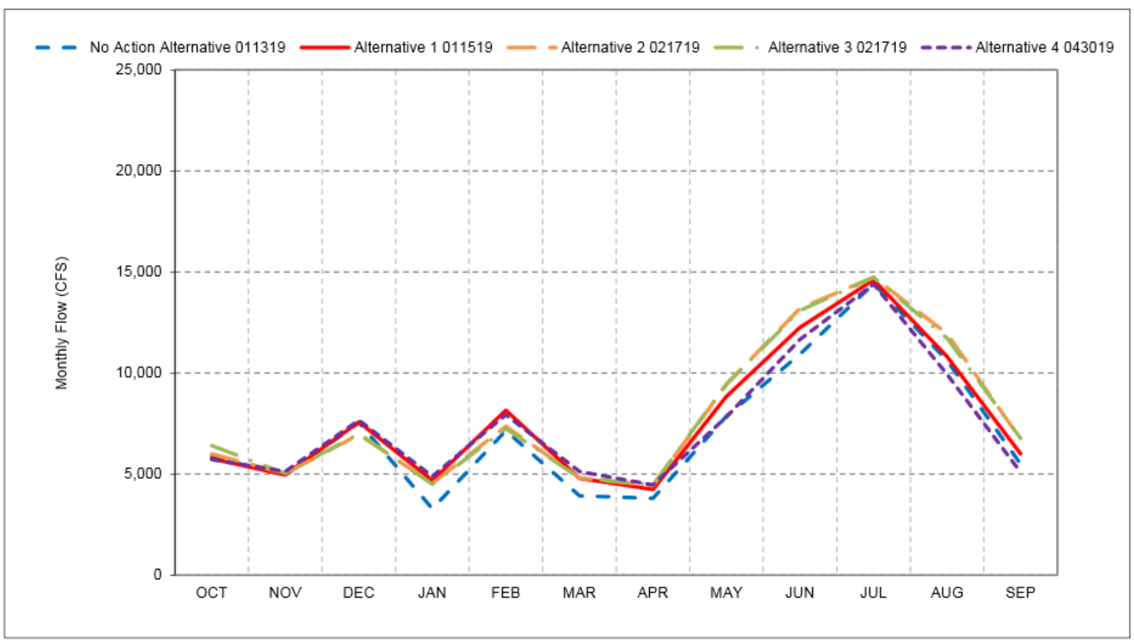
*As defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999).
*These results are displayed with calendar year - year type sorting.
*All scenarios are simulated at ELT (Early Long-Term) Q5 with 2025 climate change and 15 cm sea level rise.
*These are draft results meant for qualitative analysis and are subject to revision.

Figure G.2-8. Sacramento River Flow downstream of Keswick Reservoir, Wet Year Average Flow



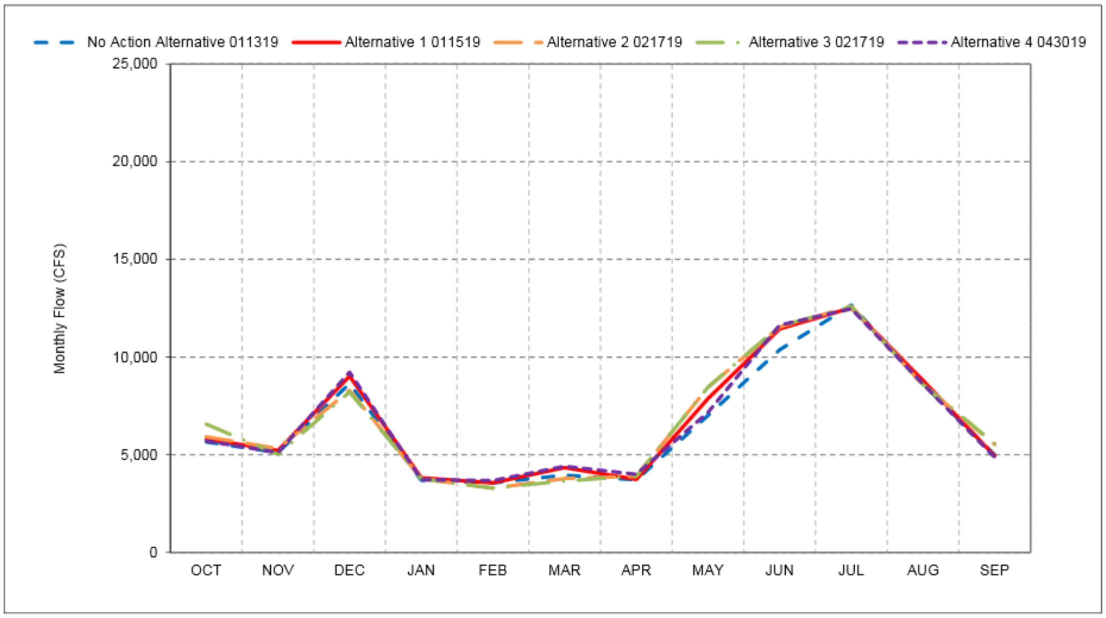
*As defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999).
*These results are displayed with calendar year - year type sorting.
*All scenarios are simulated at ELT (Early Long-Term) Q5 with 2025 climate change and 15 cm sea level rise.
*These are draft results meant for qualitative analysis and are subject to revision.

Figure G.2-9. Sacramento River Flow downstream of Keswick Reservoir, Above Normal Year Average Flow



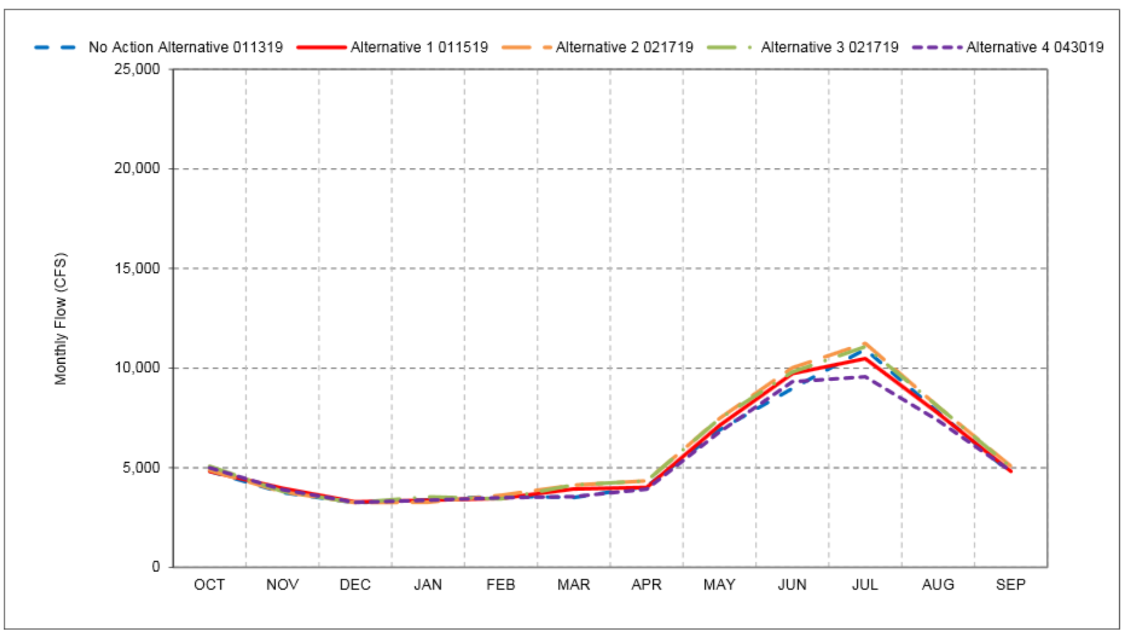
*As defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999).
*These results are displayed with calendar year - year type sorting.
*All scenarios are simulated at ELT (Early Long-Term) Q5 with 2025 climate change and 15 cm sea level rise.
*These are draft results meant for qualitative analysis and are subject to revision.

Figure G.2-10. Sacramento River Flow downstream of Keswick Reservoir, Below Normal Year Average Flow



*As defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999).
*These results are displayed with calendar year - year type sorting.
*All scenarios are simulated at ELT (Early Long-Term) Q5 with 2025 climate change and 15 cm sea level rise.
*These are draft results meant for qualitative analysis and are subject to revision.

Figure G.2-11. Sacramento River Flow downstream of Keswick Reservoir, Dry Year Average Flow



*As defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999).
*These results are displayed with calendar year - year type sorting.
*All scenarios are simulated at ELT (Early Long-Term) Q5 with 2025 climate change and 15 cm sea level rise.
*These are draft results meant for qualitative analysis and are subject to revision.

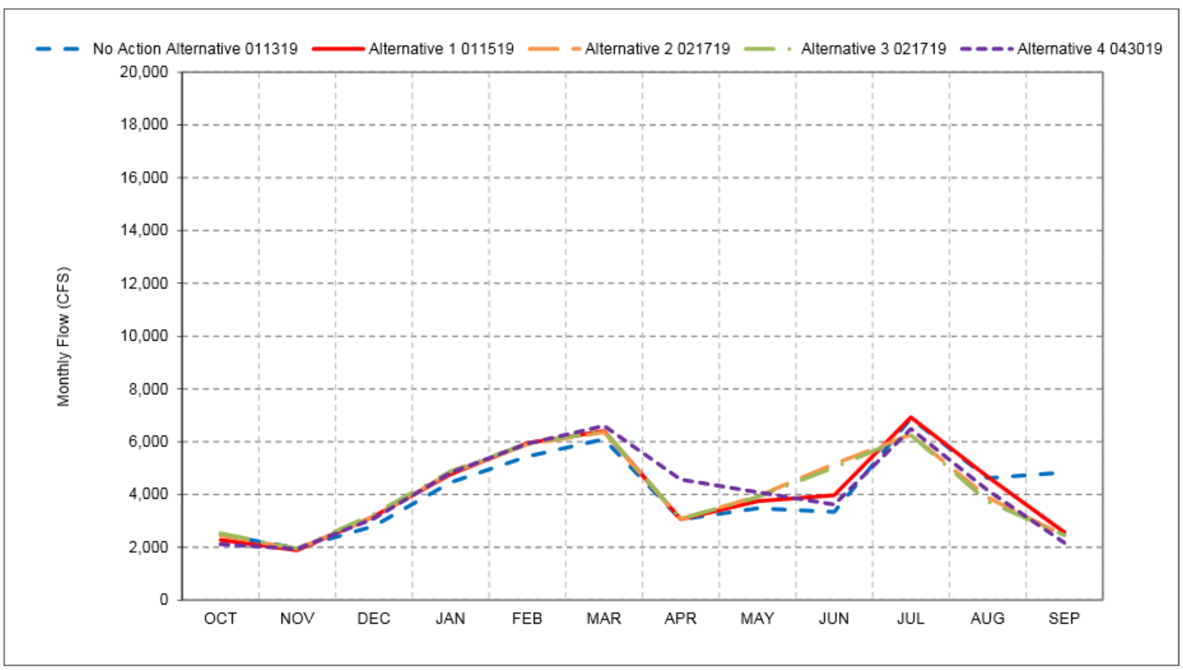
Figure G.2-12. Sacramento River Flow downstream of Keswick Reservoir, Critical Year Average Flow

G.2.3.1.3 Clear Creek

Flows in Clear Creek under Alternative 1 would increase compared to the No Action Alternative. The analysis considers flow increases beneficial to water quality by making more water available for dilution of constituents of concern (i.e., mercury), therefore no changes to existing water quality would occur.

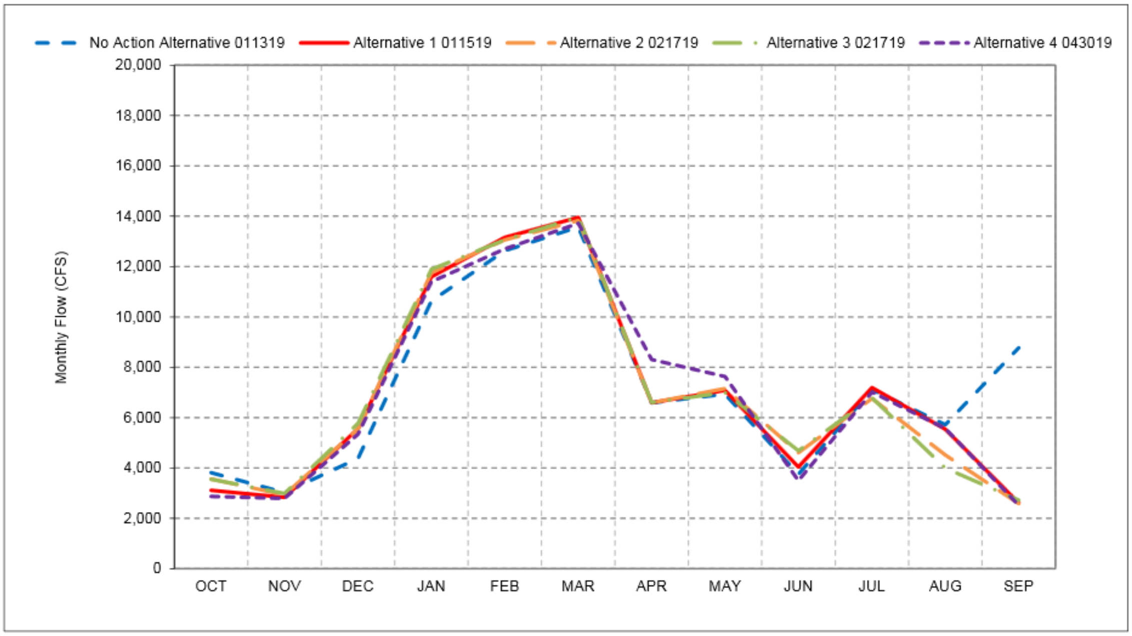
G.2.3.1.4 Feather River

The analysis modeled flows at two locations on the Feather River: the Sacramento River Confluence and downstream of Thermalito Afterbay. The Oroville complex operations are according to the FERC license under both the No Action Alternative and Alternative 1, but reservoir release changes somewhat because of changing Delta requirements. The largest flow decrease would be in September of wet water years and the largest flow increase would be in February of below normal water years for both locations. The flow decreases are generally in the fall of wet and above normal water years; similar to the Sacramento River, this change is caused by the change in fall X2 requirements in the Delta. The flow change moves reservoir releases to other periods. Figures G.2-13 through G.2-18 illustrate flow changes. Flow changes at the Sacramento River Confluence follow similar patterns, but have a smaller magnitude to those at Thermalito Afterbay. Similar to the Sacramento River, decreases in flow are expected only during wet and above normal water year types, when base flows are adequate to minimize impacts to water quality. Flow increases are expected in all water year types compared to the No Action Alternative, especially during Spring and Summer, which could improve water quality based on the dilution of constituents of concern. The evaluation does not expect overall changes in flow under Alternative 1 to cause water quality standard violations or to affect water quality along the Feather River.



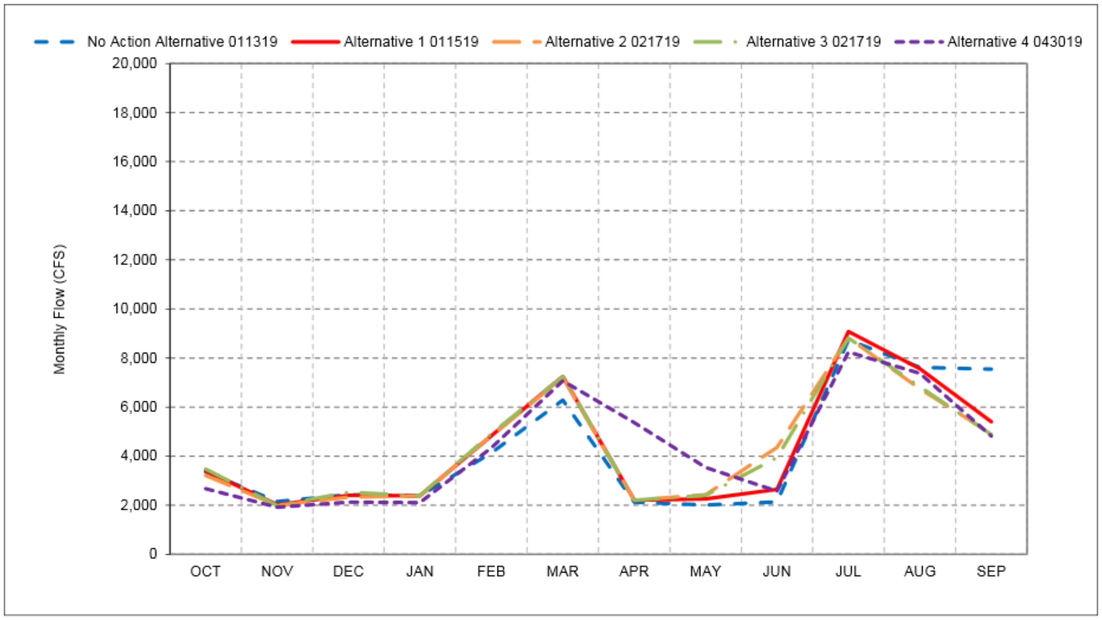
*As defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999).
*These results are displayed with calendar year - year type sorting.
*All scenarios are simulated at ELT (Early Long-Term) Q5 with 2025 climate change and 15 cm sea level rise.
*These are draft results meant for qualitative analysis and are subject to revision.

Figure G.2-13. Feather River Flow downstream of Thermalito, Long-Term Average Flow



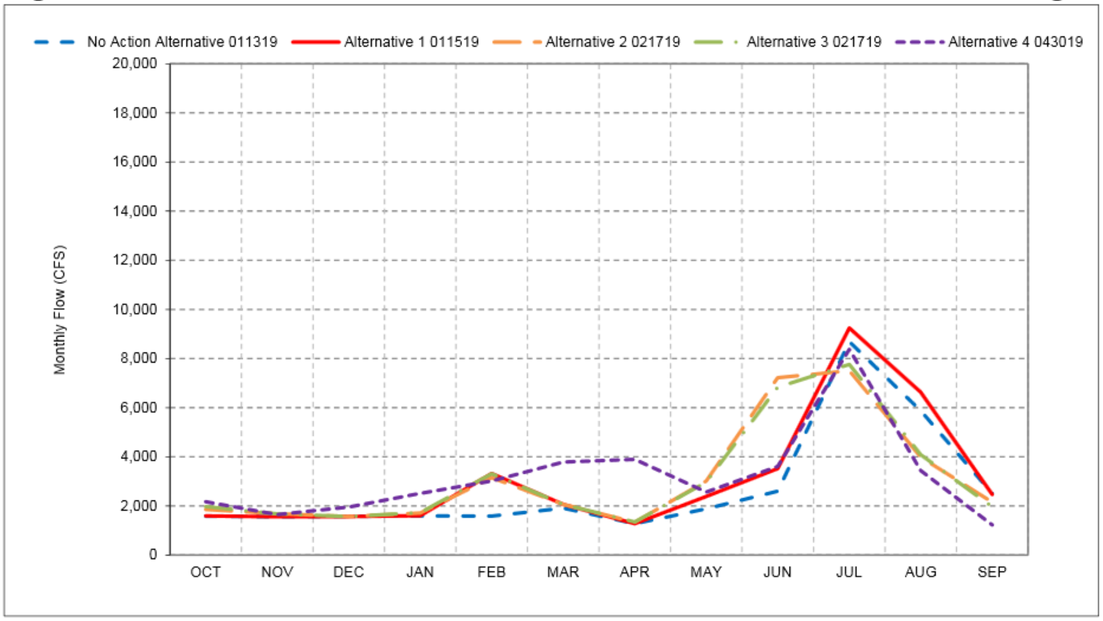
*As defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999).
*These results are displayed with calendar year - year type sorting.
*All scenarios are simulated at ELT (Early Long-Term) Q5 with 2025 climate change and 15 cm sea level rise.
*These are draft results meant for qualitative analysis and are subject to revision.

Figure G.2-14. Feather River Flow downstream of Thermalito, Wet Year Average Flow



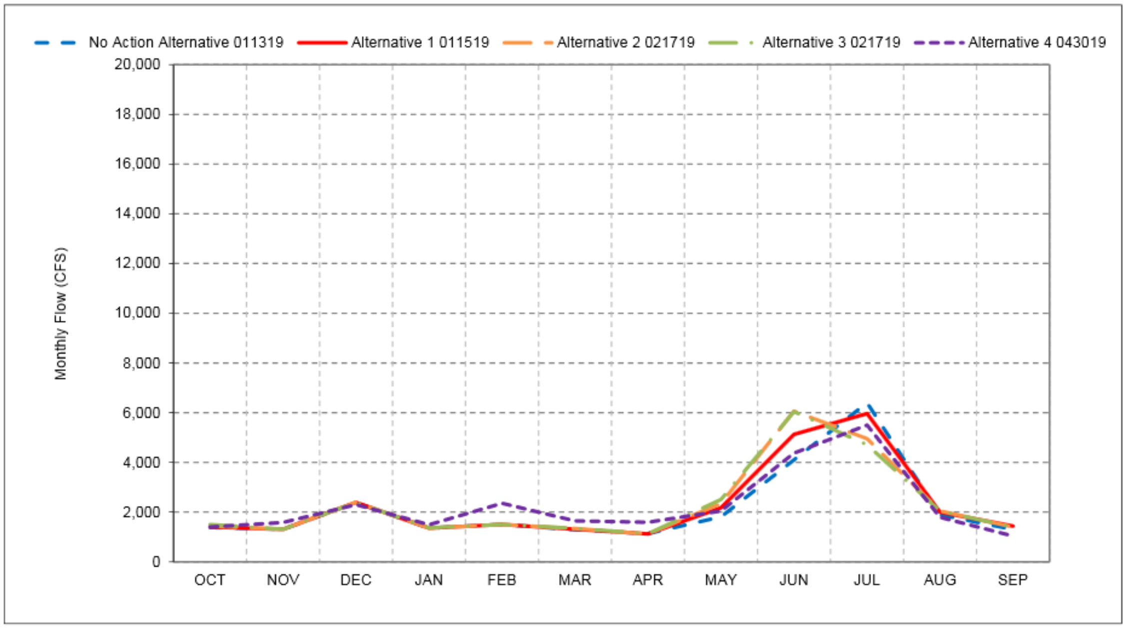
*As defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999).
*These results are displayed with calendar year - year type sorting.
*All scenarios are simulated at ELT (Early Long-Term) Q5 with 2025 climate change and 15 cm sea level rise.
*These are draft results meant for qualitative analysis and are subject to revision.

Figure G.2-15. Feather River Flow downstream of Thermalito, Above Normal Year Average Flow



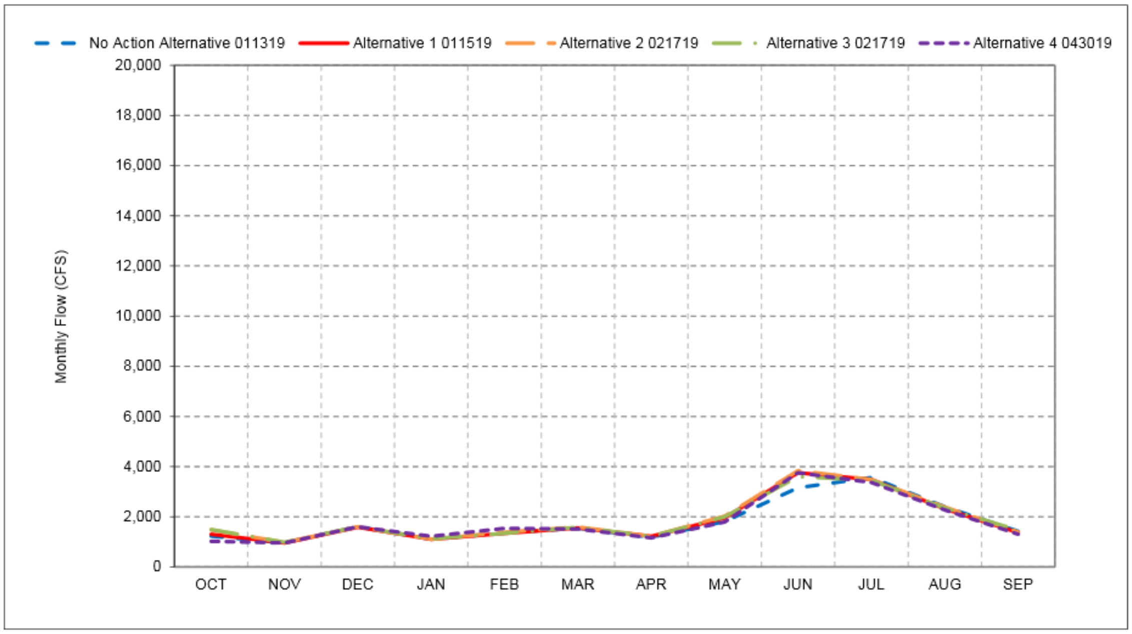
*As defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999).
*These results are displayed with calendar year - year type sorting.
*All scenarios are simulated at ELT (Early Long-Term) Q5 with 2025 climate change and 15 cm sea level rise.
*These are draft results meant for qualitative analysis and are subject to revision.

Figure G.2-16. Feather River Flow downstream of Thermalito, Below Normal Year Average Flow



*As defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999).
*These results are displayed with calendar year - year type sorting.
*All scenarios are simulated at ELT (Early Long-Term) Q5 with 2025 climate change and 15 cm sea level rise.
*These are draft results meant for qualitative analysis and are subject to revision.

Figure G.2-17. Feather River Flow downstream of Thermalito, Dry Year Average Flow

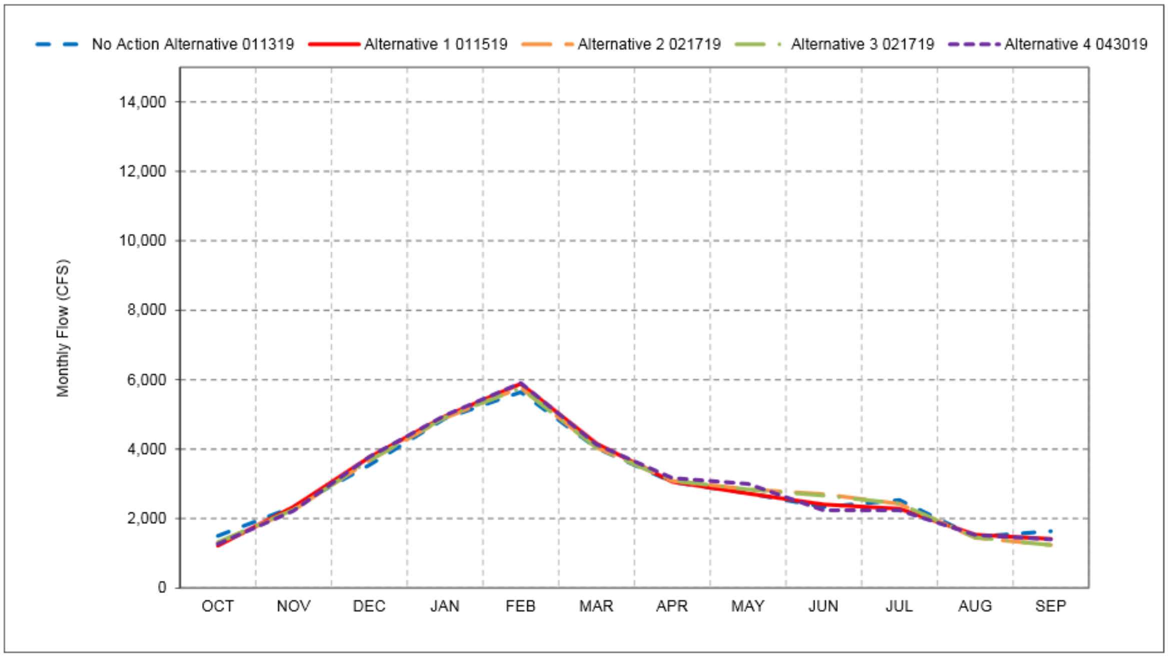


*As defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999).
*These results are displayed with calendar year - year type sorting.
*All scenarios are simulated at ELT (Early Long-Term) Q5 with 2025 climate change and 15 cm sea level rise.
*These are draft results meant for qualitative analysis and are subject to revision.

Figure G.2-18. Feather River Flow downstream of Thermalito, Critical Year Average Flow

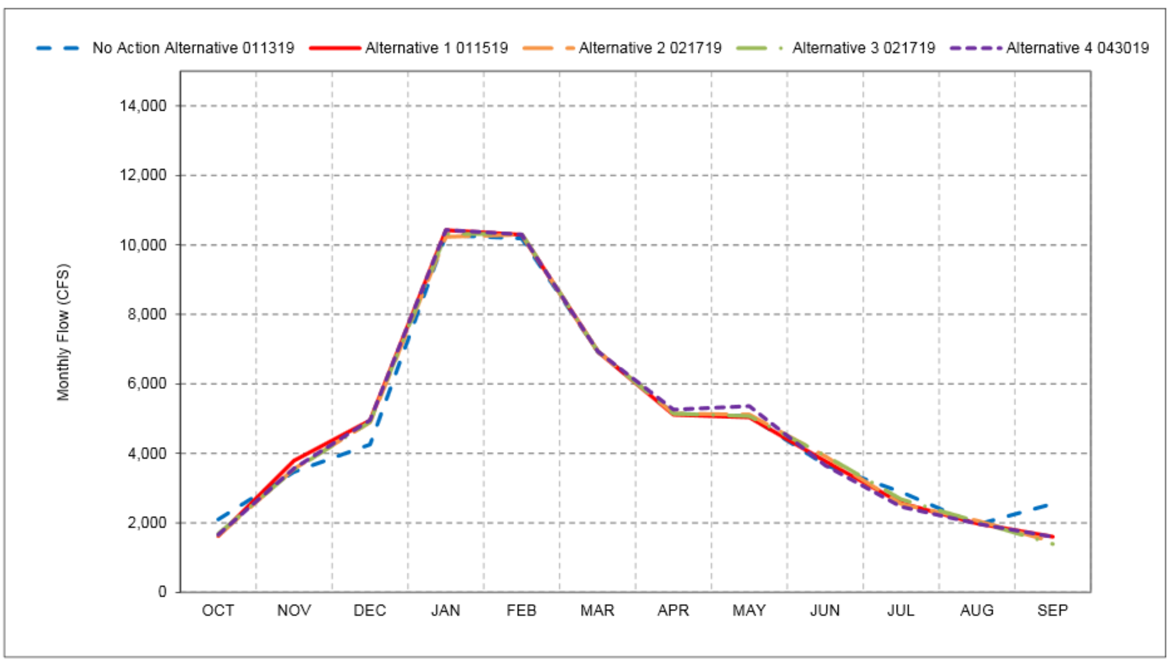
G.2.3.1.5 American River

The analysis modeled flows at two locations on the American River: H Street and below Nimbus Dam. Flows under Alternative 1 would be different from those under the No Action Alternative because Alternative 1 incorporates the 2017 Modified Flow Management Standard and would contribute to meeting different fisheries requirements in the Delta. Based on modeling, the maximum average increase in flows on the American River at H Street would be during February of critical water years, when flows are expected to increase by 46%. The maximum average decrease in flows would be during September of wet water years, when flows are expected to decrease by 37%. Figures G.2-19 through G.2-24 illustrate flow changes on the American River at H Street. Changes in flow below Nimbus Dam follow a similar trend but are generally smaller. While the evaluation considers a decrease in flows harmful to water quality due to the reduction of dilution of constituents of concern, changes in flows are small enough and at times of year that they would not be expected to result in adverse effects to water quality in the American River.



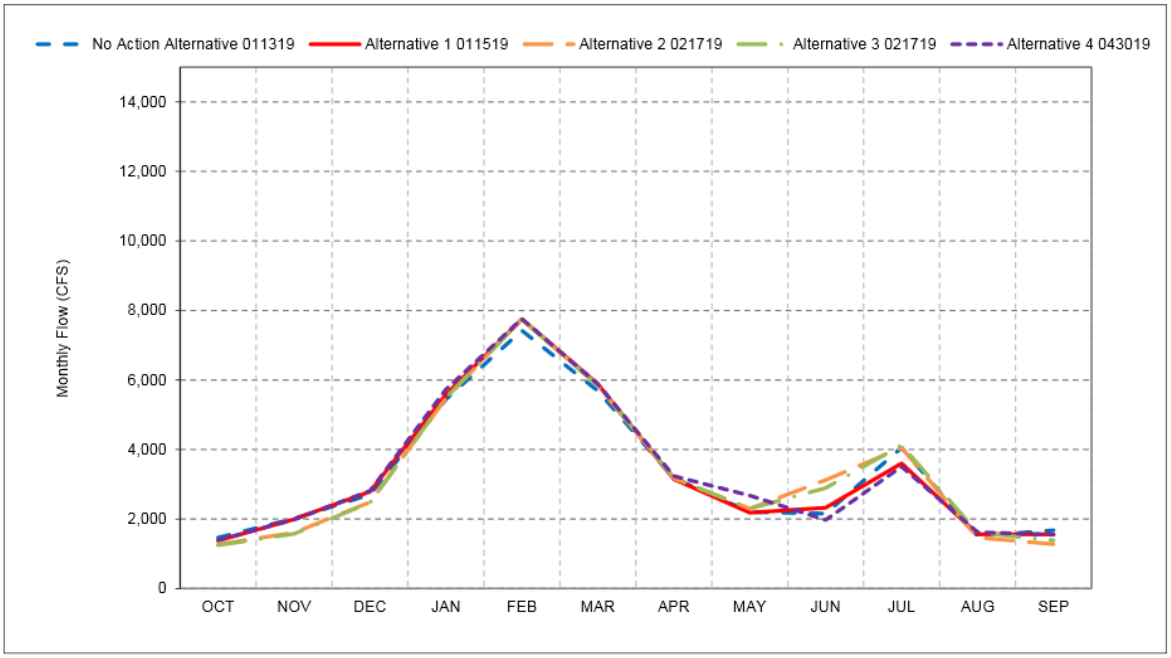
*As defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999).
*These results are displayed with calendar year - year type sorting.
*All scenarios are simulated at ELT (Early Long-Term) Q5 with 2025 climate change and 15 cm sea level rise.
*These are draft results meant for qualitative analysis and are subject to revision.

Figure G.2-19. American River at H Street, Long-Term Average Flow



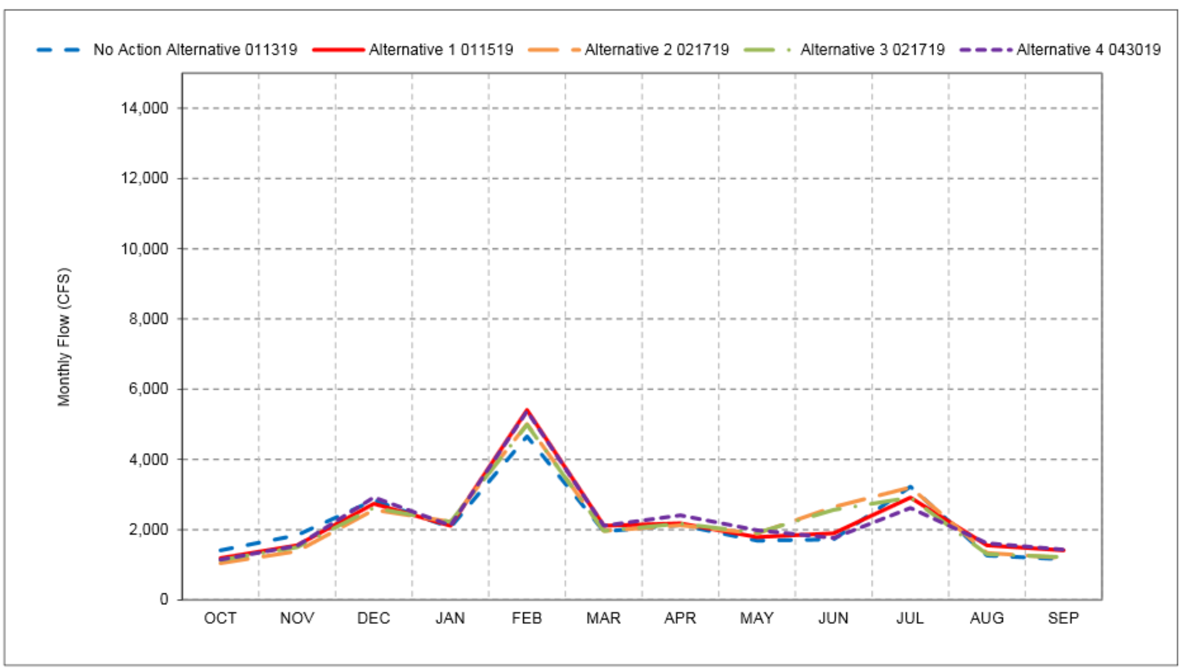
*As defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999).
*These results are displayed with calendar year - year type sorting.
*All scenarios are simulated at ELT (Early Long-Term) Q5 with 2025 climate change and 15 cm sea level rise.
*These are draft results meant for qualitative analysis and are subject to revision.

Figure G.2-20. American River at H Street, Wet Year Average Flow



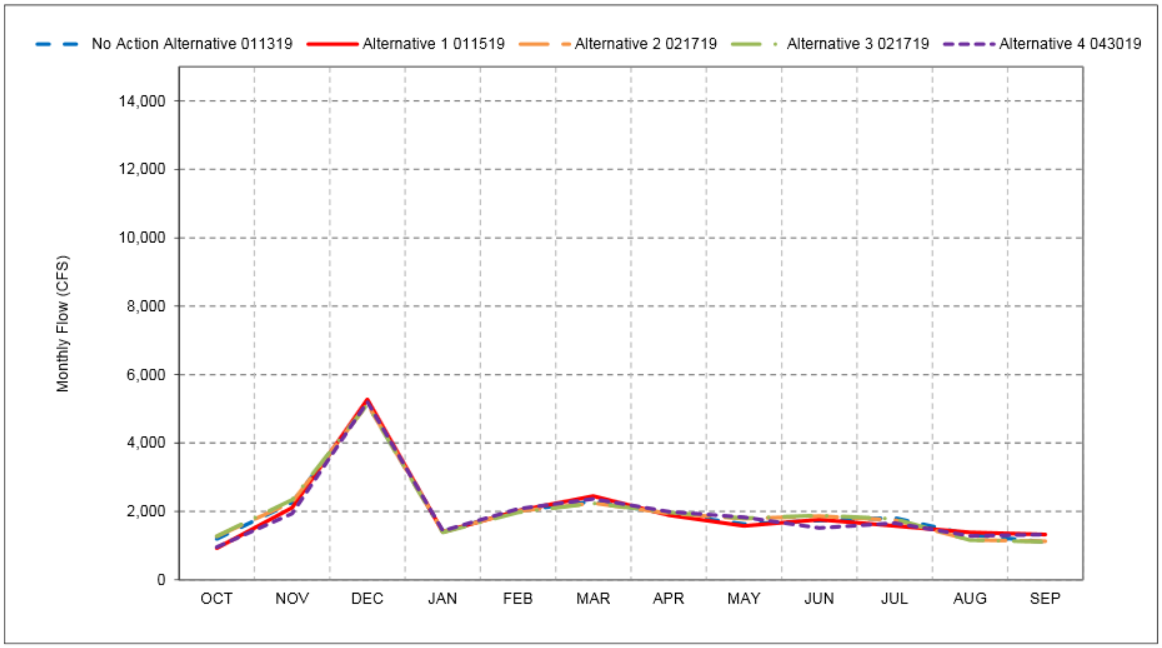
*As defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999).
*These results are displayed with calendar year - year type sorting.
*All scenarios are simulated at ELT (Early Long-Term) Q5 with 2025 climate change and 15 cm sea level rise.
*These are draft results meant for qualitative analysis and are subject to revision.

Figure G.2-21. American River at H Street, Above Normal Year Average Flow



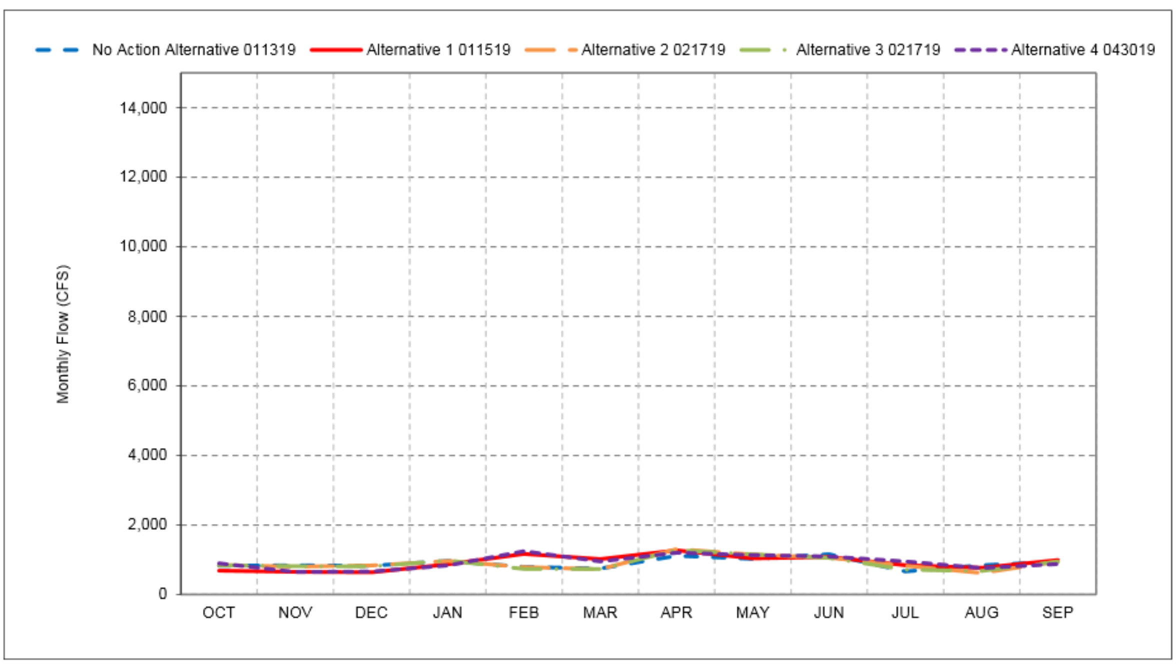
*As defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999).
*These results are displayed with calendar year - year type sorting.
*All scenarios are simulated at ELT (Early Long-Term) Q5 with 2025 climate change and 15 cm sea level rise.
*These are draft results meant for qualitative analysis and are subject to revision.

Figure G.2-22. American River at H Street, Below Normal Year Average Flow



*As defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999).
*These results are displayed with calendar year - year type sorting.
*All scenarios are simulated at ELT (Early Long-Term) Q5 with 2025 climate change and 15 cm sea level rise.
*These are draft results meant for qualitative analysis and are subject to revision.

Figure G.2-23. American River at H Street, Dry Year Average Flow

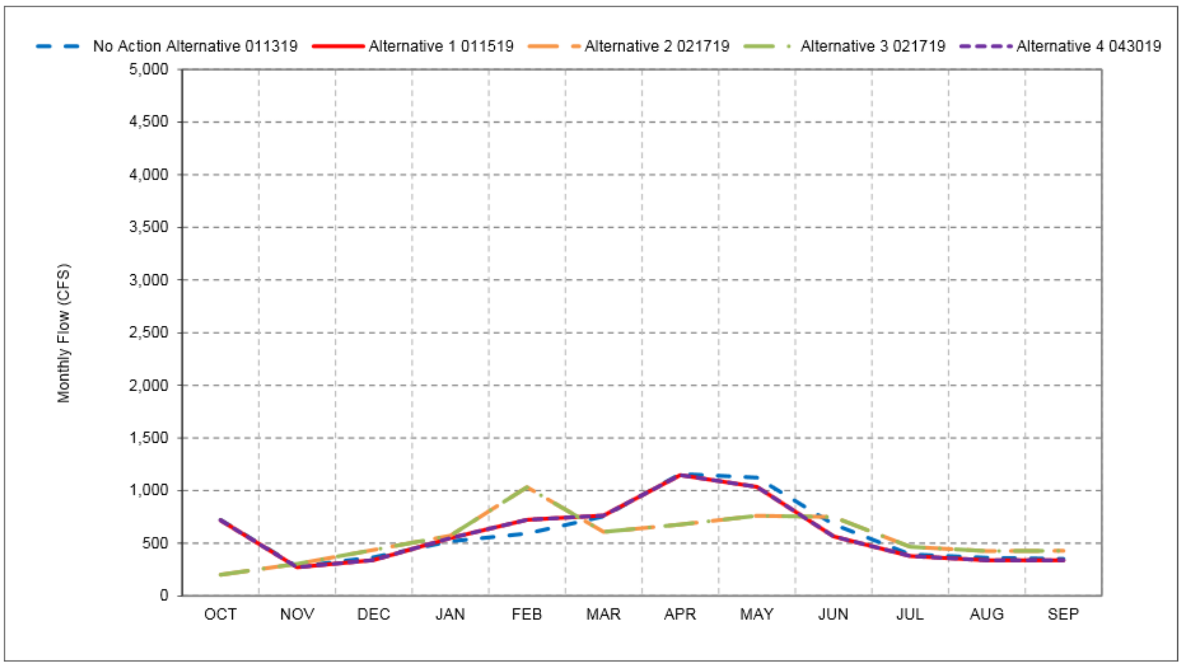


*As defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999).
*These results are displayed with calendar year - year type sorting.
*All scenarios are simulated at ELT (Early Long-Term) Q5 with 2025 climate change and 15 cm sea level rise.
*These are draft results meant for qualitative analysis and are subject to revision.

Figure G.2-24. American River at H Street, Critical Year Average Flow

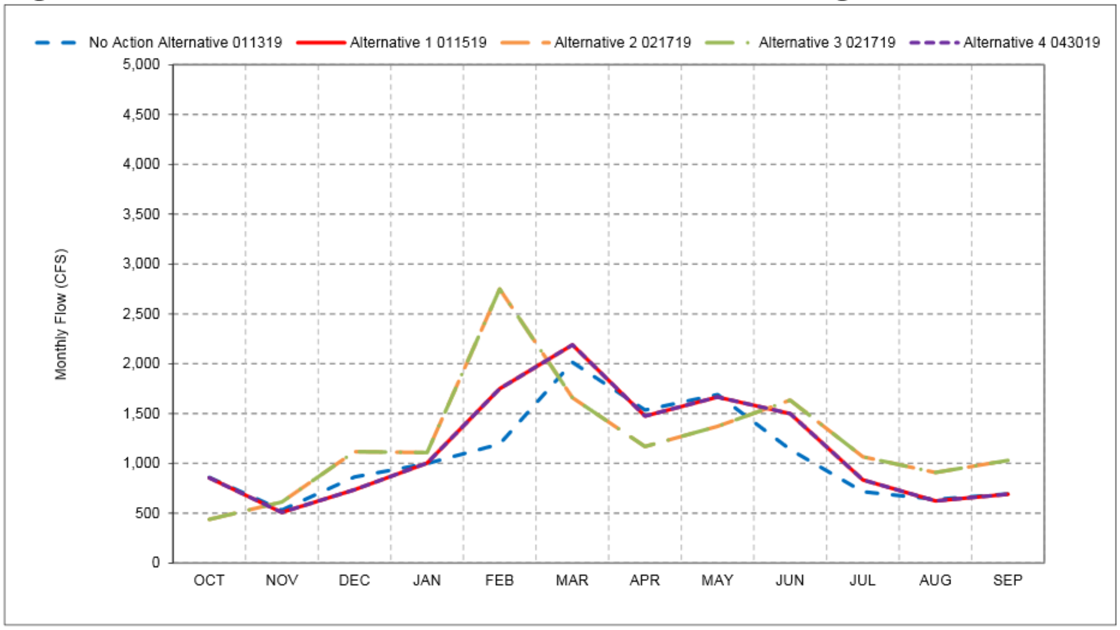
G.2.3.1.6 Stanislaus River

The analysis modeled flows at two locations on the Stanislaus River: at the mouth and below Goodwin Dam. Flow changes would be identical for both locations on the Stanislaus River. Alternative 1 would change flows on the Stanislaus River because it incorporates the Stepped Release Plan for New Melones Reservoir, which aims to create a release plan that is better able to meet the multiple reservoir purposes. The largest flow decrease would be in June of above normal water years and the largest flow increase would be in February of wet water years under Alternative 1. Stanislaus River flows below Goodwin Dam are expected to have a maximum increase of approximately 94% in January of below normal water years, and a maximum decrease by approximately 62% in June of above normal water years. Figures G.2-25 through G.2-30 show changes in flow below Goodwin Dam. While the evaluation considers a decrease in flows as harmful to water quality because it reduces dilution of constituents of concern, changes in flows are small enough and at times of year that they would not be expected to result in increased frequency of exceedances of water quality thresholds in Stanislaus River.



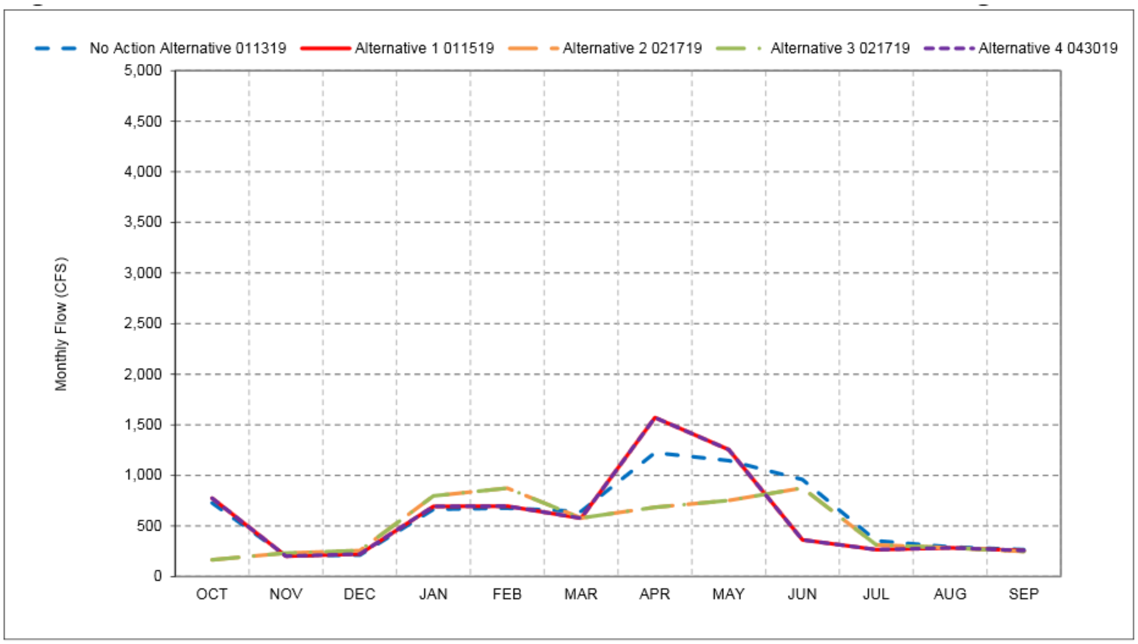
*As defined by the San Joaquin Valley 60-20-20 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999).
*These results are displayed with calendar year - year type sorting.
*All scenarios are simulated at ELT (Early Long-Term) Q5 with 2025 climate change and 15 cm sea level rise.
*These are draft results meant for qualitative analysis and are subject to revision.
*New Melones forecasts are used as the basis of water operations.

Figure G.2-25. Stanislaus River Flow below Goodwin, Long-Term Average Flow



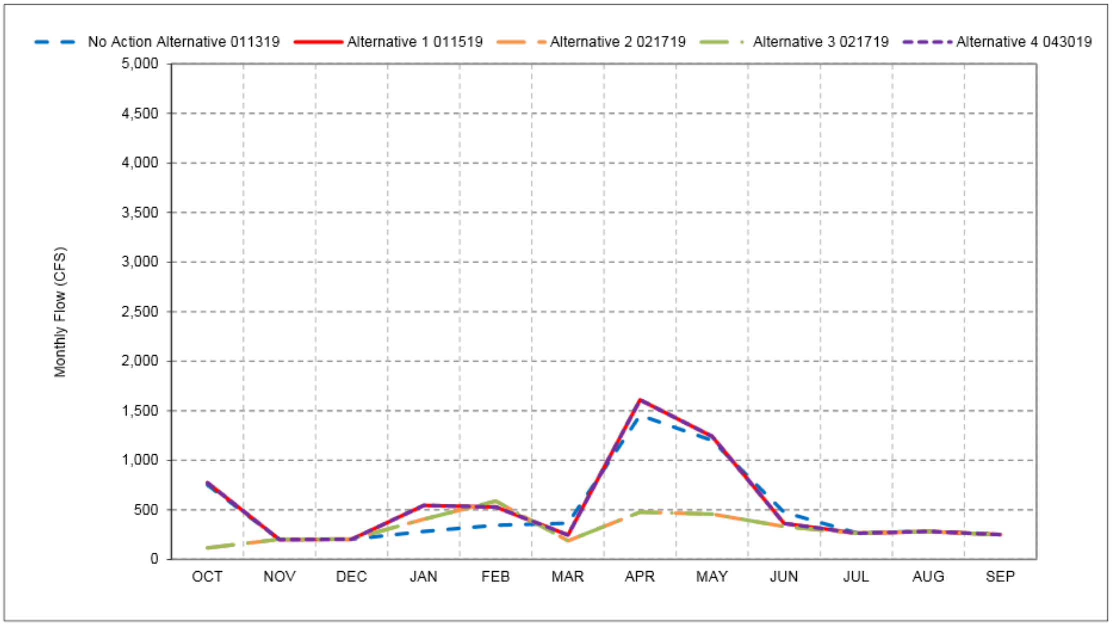
*As defined by the San Joaquin Valley 60-20-20 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999).
*These results are displayed with calendar year - year type sorting.
*All scenarios are simulated at ELT (Early Long-Term) Q5 with 2025 climate change and 15 cm sea level rise.
*These are draft results meant for qualitative analysis and are subject to revision.
*New Melones forecasts are used as the basis of water operations.

Figure G.2-26. Stanislaus River Flow below Goodwin, Wet Year Average Flow



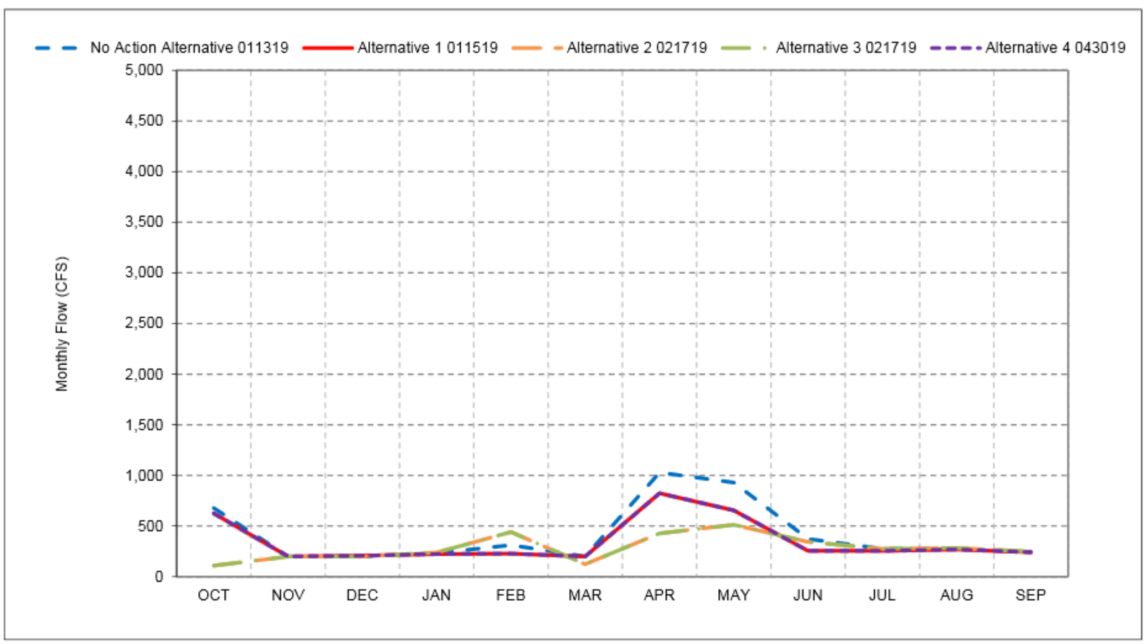
*As defined by the San Joaquin Valley 60-20-20 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999).
*These results are displayed with calendar year - year type sorting.
*All scenarios are simulated at ELT (Early Long-Term) Q5 with 2025 climate change and 15 cm sea level rise.
*These are draft results meant for qualitative analysis and are subject to revision.
*New Melones forecasts are used as the basis of water operations.

Figure G.2-27. Stanislaus River Flow below Goodwin, Above Normal Year Average Flow



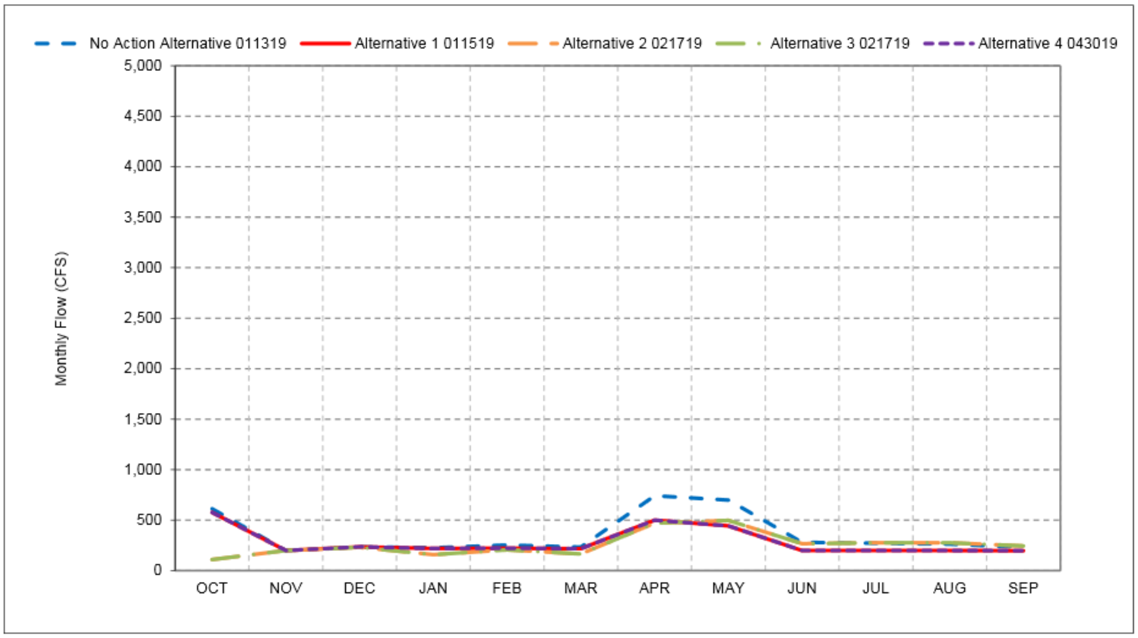
*As defined by the San Joaquin Valley 60-20-20 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999).
*These results are displayed with calendar year - year type sorting.
*All scenarios are simulated at ELT (Early Long-Term) Q5 with 2025 climate change and 15 cm sea level rise.
*These are draft results meant for qualitative analysis and are subject to revision.
*New Melones forecasts are used as the basis of water operations.

Figure G.2-28. Stanislaus River Flow below Goodwin, Below Normal Year Average Flow



*As defined by the San Joaquin Valley 60-20-20 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999).
*These results are displayed with calendar year - year type sorting.
*All scenarios are simulated at ELT (Early Long-Term) Q5 with 2025 climate change and 15 cm sea level rise.
*These are draft results meant for qualitative analysis and are subject to revision.
*New Melones forecasts are used as the basis of water operations.

Figure G.2-29. Stanislaus River Flow below Goodwin, Dry Year Average Flow

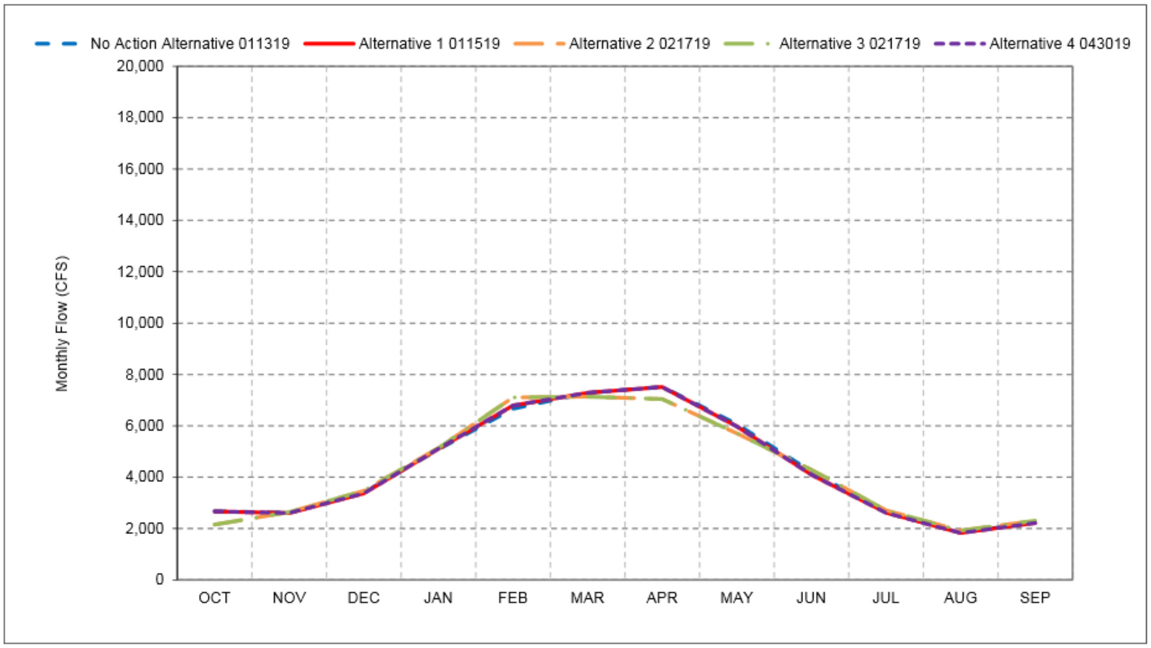


*As defined by the San Joaquin Valley 60-20-20 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999).
*These results are displayed with calendar year - year type sorting.
*All scenarios are simulated at ELT (Early Long-Term) Q5 with 2025 climate change and 15 cm sea level rise.
*These are draft results meant for qualitative analysis and are subject to revision.
*New Melones forecasts are used as the basis of water operations.

Figure G.2-30. Stanislaus River Flow below Goodwin, Critical Year Average Flow

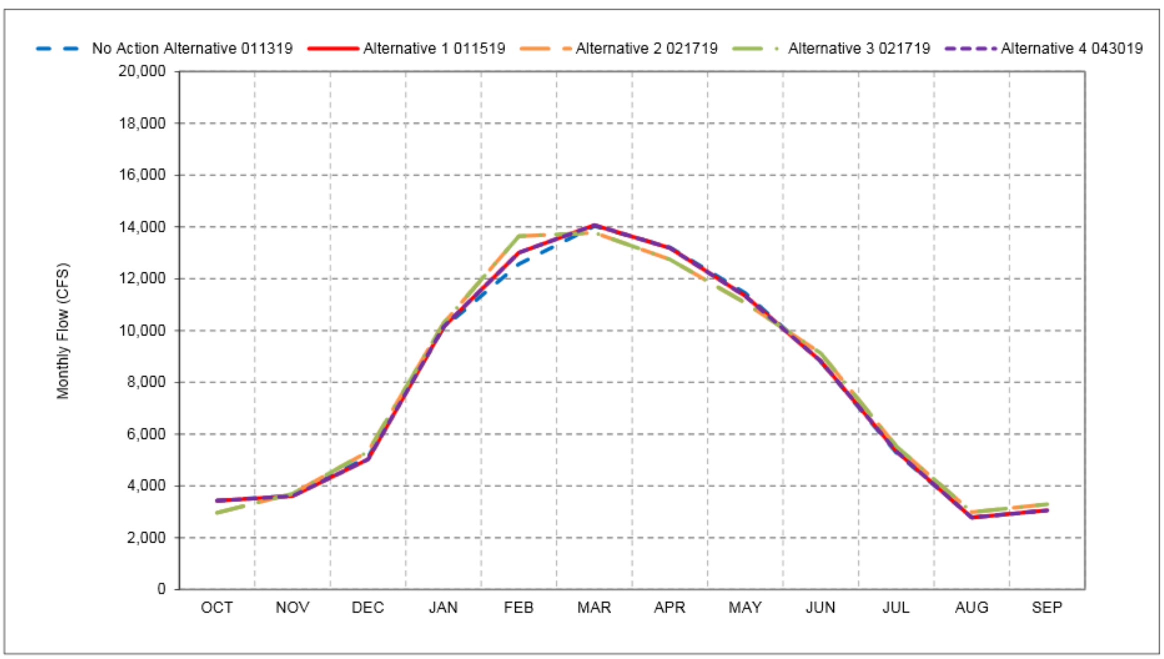
G.2.3.1.7 San Joaquin River

Flows in the San Joaquin River under Alternative 1 would remain similar to those under the No Action Alternative. The analysis modeled flows at four locations on the San Joaquin River: at Gravelly Ford, below the confluence with the Merced River, below Sack Dam, and at Vernalis. There would be no flow change at Gravelly Ford under Alternative 1 as compared to the No Action Alternative. Flow change below the confluence with the Merced River and below Sack Dam would be less than 1%. At Vernalis, Alternative 1 would result in a small decrease in flows for all water year types during October and spring months of March, April, and May. Figures G.2-31 through G.2-36 illustrate flow changes at Vernalis. The minimal change in flow under Alternative 1 would not likely result in increased frequency of exceedances of water quality thresholds in the San Joaquin River.



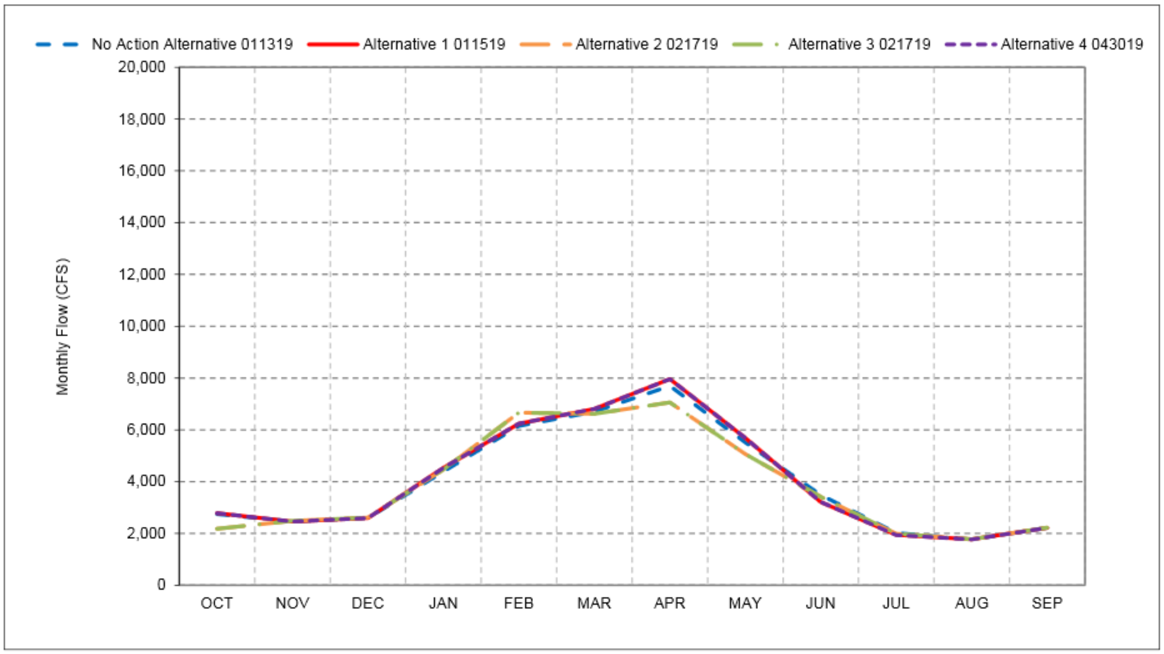
*As defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999).
*These results are displayed with calendar year - year type sorting.
*All scenarios are simulated at ELT (Early Long-Term) Q5 with 2025 climate change and 15 cm sea level rise.
*These are draft results meant for qualitative analysis and are subject to revision.

Figure G.2-31. San Joaquin River at Vernalis, Long-Term Average Flow



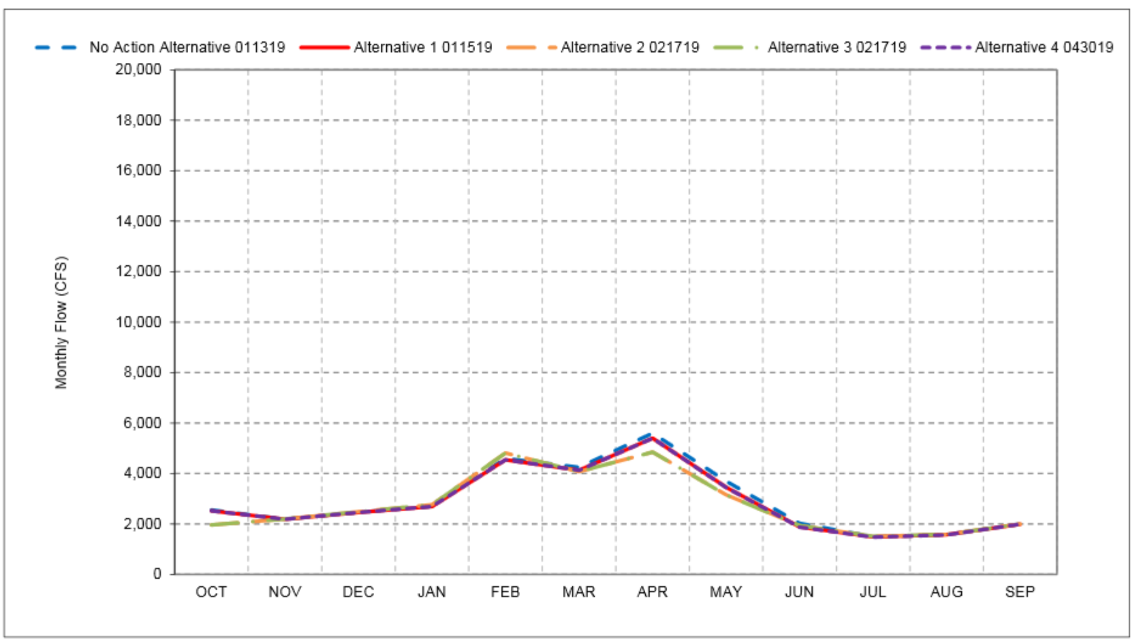
*As defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999).
*These results are displayed with calendar year - year type sorting.
*All scenarios are simulated at ELT (Early Long-Term) Q5 with 2025 climate change and 15 cm sea level rise.
*These are draft results meant for qualitative analysis and are subject to revision.

Figure G.2-32. San Joaquin River at Vernalis, Wet Year Average Flow



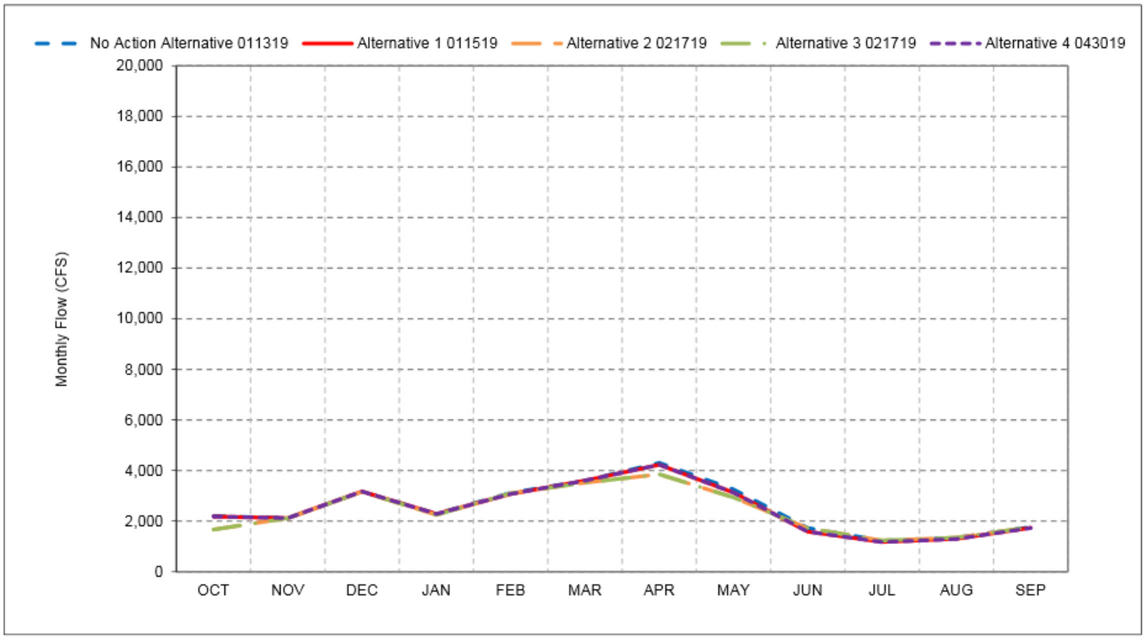
*As defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999).
*These results are displayed with calendar year - year type sorting.
*All scenarios are simulated at ELT (Early Long-Term) Q5 with 2025 climate change and 15 cm sea level rise.
*These are draft results meant for qualitative analysis and are subject to revision.

Figure G.2-33. San Joaquin River at Vernalis, Above Normal Year Average Flow



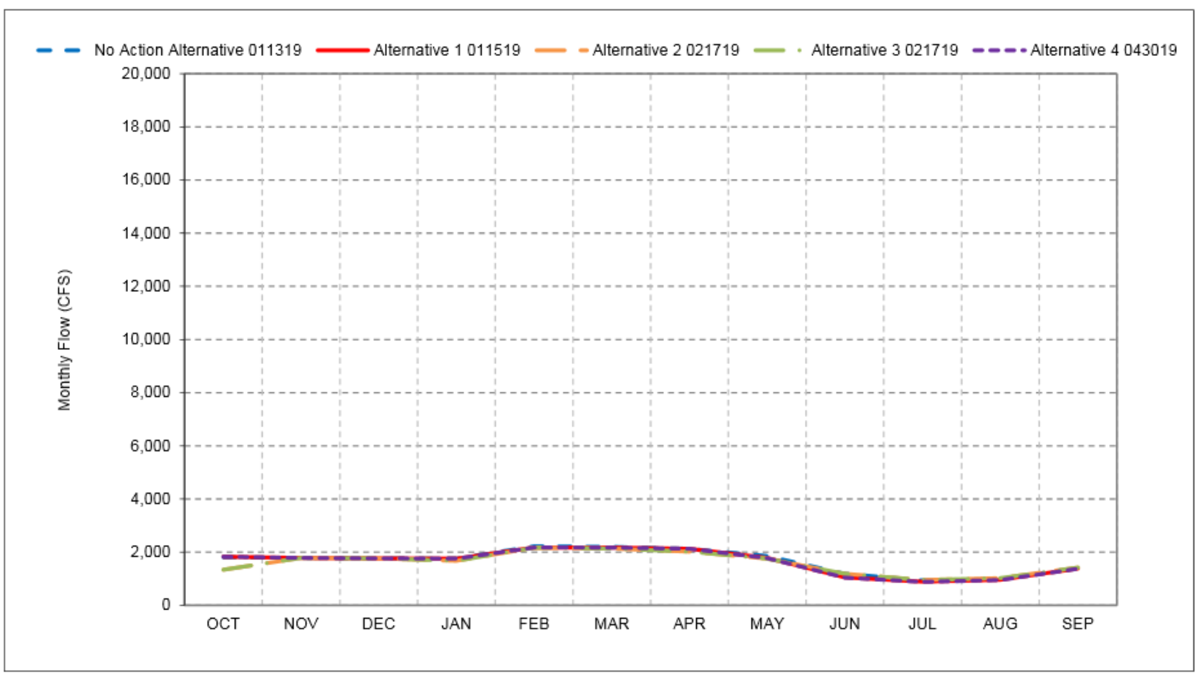
*As defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999).
*These results are displayed with calendar year - year type sorting.
*All scenarios are simulated at ELT (Early Long-Term) Q5 with 2025 climate change and 15 cm sea level rise.
*These are draft results meant for qualitative analysis and are subject to revision.

Figure G.2-34. San Joaquin River at Vernalis, Below Normal Year Average Flow



*As defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999).
*These results are displayed with calendar year - year type sorting.
*All scenarios are simulated at ELT (Early Long-Term) Q5 with 2025 climate change and 15 cm sea level rise.
*These are draft results meant for qualitative analysis and are subject to revision.

Figure G.2-35. San Joaquin River at Vernalis, Dry Year Average Flow



*As defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999).
*These results are displayed with calendar year - year type sorting.
*All scenarios are simulated at ELT (Early Long-Term) Q5 with 2025 climate change and 15 cm sea level rise.
*These are draft results meant for qualitative analysis and are subject to revision.

Figure G.2-36. San Joaquin River at Vernalis, Critical Year Average Flow

G.2.3.1.8 CVP and SWP Service Area (south to Diamond Valley)

Alternative 1 would generally result in higher monthly average chloride concentrations in the months of September through January, particularly in wet and above normal water year types, and similar or lower concentrations in the remaining months, as compared to the No Action Alternative. Since this water is delivered to reservoirs for storage in the CVP/SWP reservoirs, reservoir chloride concentrations may increase. While there would be higher chloride concentrations under Alternative 1, relative to the No Action Alternative, in some months, the CVP/SWP would continue to be operated, in real-time, to meet the Bay-Delta WQCP objectives for chloride, which aim to protect municipal and industrial beneficial uses. In the months of September through January, when chloride would be higher compared to the No Action Alternative, the maximum mean daily chloride objectives of 250 mg/l would continue to apply at Contra Costa Pumping Plant #1, Banks and Jones pumping plants, and Barker Slough at North Bay Aqueduct (SWRCB 2006). Also, the maximum mean daily chloride objective of 150 mg/l would continue to apply at Contra Costa Pumping Plant #1 or San Joaquin River at Antioch for a certain number of days per year, depending on water year type (SWRCB 2006). Thus, Alternative 1 would not contribute to the impairment of municipal and industrial beneficial uses of the CVP/SWP service area.

G.2.3.1.9 Bay-Delta

Potential Changes in EC

Delta

Monthly average EC levels in the Sacramento River at Emmaton would often be substantially higher in September through December of wet and above normal water year types under Alternative 1, relative to the No Action Alternative (Appendix F, Attachment 3-6, *Salinity Results (DSM2)*, Table 4-1, Sacramento River at Emmaton Salinity, Figures 4-1 through 4-6, and 4-15 through 4-18). Monthly average EC levels in January through August under Alternative 1 would be similar to No Action Alternative EC levels (Appendix F, Attachment 3-6, Table 4-1, Figures 4-7 through 4-14).

Monthly average EC levels in the San Joaquin River at Vernalis under Alternative 1 would, overall, be similar to levels occurring under the No Action Alternative (Appendix F, Attachment 3-6, Table 6-1, Figures 6-1 through 6-18). Somewhat higher monthly EC levels would occur in the months of April and May under Alternative 1, relative to the No Action Alternative (Appendix F, Attachment 3-6, Figures 6-10 and 6-11).

Monthly average EC levels in the San Joaquin River at Jersey Point, like the Sacramento River at Emmaton, would often be substantially higher in September through December of wet and above normal water year types under Alternative 1, relative to the No Action Alternative (Appendix F, Attachment 3-6, Table 7-1, Figures 7-2, 7-3, 7-15 through 7-18). Other months would also see somewhat higher EC levels under Alternative 1, relative to the No Action Alternative (Appendix F, Attachment 3-6, Table 7-1, Figures 7-7 through 7-14).

Monthly average EC levels at the Banks and Jones pumping plants under Alternative 1, relative to the No Action Alternative, would be higher in September through January, most notably in wet and above normal water year types (Appendix F, Attachment 3-6, Tables 15-1 and 16-1, Figures 15-1 through 15-6 and 16-1 through 16-6). In February through August, monthly average EC levels under Alternative 1 would be similar to or lower than No Action Alternative EC levels (Appendix F, Attachment 3-6, Tables 15-1 and 16-1, Figures 15-8 through 15-14 and 16-8 through 16-14).

If the Summer-Fall Delta Smelt Habitat action under Alternative 1 includes a Fall X2 action, EC levels under Alternative 1 could be different than discussed above. The Fall X2 action could result in EC levels being lower than modeled, particularly in the western Delta, resulting in less of a difference between Alternative 1 and the No Action Alternative in the fall.

While there would be higher monthly average EC levels under Alternative 1 relative to the No Action Alternative, in some months, the CVP and SWP would continue to be operated, in real-time, to meet the Bay-Delta WQCP objectives for EC. The objectives are for protecting agricultural, and fish and wildlife beneficial uses. The western Delta EC objectives for the Sacramento River at Emmaton and San Joaquin River at Jersey Point for agricultural beneficial use protection apply from April through June, July, or August, depending on water year type (SWRCB 2006). The San Joaquin River at Jersey Point objective for fish and wildlife protection also applies during April and May (SWRCB 2006). During these months, the monthly average EC levels under Alternative 1 would be similar to the No Action Alternative (Appendix F, Attachment 3-6, Tables 4-1 and 7-1). The southern Delta EC objectives for the protection of agricultural uses for the San Joaquin River at Vernalis and the export area for Banks and Jones pumping plant apply year-round. Banks and Jones pumping plants would have higher EC levels in the fall, but lower monthly average EC in spring and summer, relative to the No Action Alternative (Appendix F, Attachment 3-6, Tables 15-1 and 16-1). Monthly average EC levels at Vernalis under Alternative 1 would be overall similar to the No Action Alternative (Appendix F, Attachment 3-6, Table 6-1). Thus, the differences in EC in the Delta under Alternative 1, relative to the No Action Alternative, would not contribute to agricultural or fish and wildlife beneficial use impairments in the Delta.

Suisun Marsh

In the Sacramento River at Collinsville, which is a Bay-Delta WQCP compliance location for the eastern portion of Suisun Marsh, monthly average EC levels would be substantially higher under Alternative 1, relative to the No Action Alternative, in September through December of wet and above normal water year types (Appendix F, Attachment 3-6, Table 11-1, Figures 11-2 and 11-3). The EC differences would occur primarily at the low end of the modeled EC range; there is little difference between the upper monthly average EC levels at Collinsville under Alternative 1, relative to the No Action Alternative (Appendix F, Attachment 3-6, Figures 11-15 through 11-18). Higher monthly average EC levels would also occur in December through May of all water year types under Alternative 1, relative to the No Action Alternative (Appendix F, Attachment 3-6, Table 11-1, Figures 11-1, 11-7 through 11-11, and 11-18).

One Alternative 1 component is to operate the Suisun Marsh Salinity Control Gates, in coordination with the Roaring River Distribution System west-side drain, during September and October following above normal and wet water years to achieve a target low salinity zone areal extent for the benefit of Delta Smelt. Another Alternative 1 component is increased Suisun Marsh Salinity Control Gates operation to direct more fresh water into Suisun Marsh. The component involves closing the gates on flood tides and opening the gates on ebb tides to reduce salinity within the marsh, potentially in late spring/summer of drier water years, depending on salinity conditions. Reclamation and DWR would coordinate monitoring the process to ensure that water operations are undertaken as necessary to minimize the potential for unintended salinity changes in the Suisun Bay and the Sacramento-San Joaquin River confluence area. Thus, the proposed operation of the SMSCG would not contribute to adverse effects to salinity parameters, such as the EC.

Suisun Bay and San Francisco Bay

Based on the modeling results discussed above, the EC of Delta outflow under Alternative 1 may be different than that which would occur under the No Action Alternative in certain months of certain water year types. Alternative 1 would result in lower Delta outflow rates, relative to the No Action Alternative, notably in the months of September, October, November, April, and May (Appendix F, Modeling, Attachment 3-2, *Flow Results* [CalSim II], Table 41-1). The differences in Delta EC and outflow could cause the freshwater-seawater salinity gradient within Suisun Bay and the northern portion of San Francisco Bay to be different between Alternative 1 and the No Action Alternative. The evaluation does not expect the differences to result in substantial changes in overall salinity conditions within Suisun Bay and San Francisco Bay, because seawater is the predominant source of salinity in the bays.

Potential Changes in Chloride

The discussion below provides an assessment of differences between chloride at the five assessment locations – Contra Costa Pumping Plant #1, San Joaquin River at Antioch, Banks and Jones pumping plants, and North Bay Aqueduct – under Alternative 1 as compared to the No Action Alternative. The assessment is based on modeling results presented in Appendix F, Attachment 3-10, *Salinity Results (DSM2)*.

Monthly average chloride concentrations at Contra Costa Pumping Plant #1 would often be substantially higher in October through December of wet and above normal water year types, and somewhat higher in September and January of all water year types under Alternative 1, relative to the No Action Alternative (Appendix F, Attachment 3-10, Table 19-1, Figures 19-1 through 19-18). In April and May of all water year types, chloride concentrations would be somewhat lower than would occur under the No Action Alternative (Appendix F, Attachment 3-10, Table 19-1, Figures 19-10 and 19-11). Monthly average chloride concentrations in the months of February, March, and June through August would be similar to concentrations under the No Action Alternative (Appendix F, Attachment 3-10, Table 19-1, Figures 19-8, 19-9, and 19-12 through 19-14).

Monthly average chloride concentrations in the San Joaquin River at Antioch would often be substantially higher in September through December of wet and above normal water year types, and somewhat higher in these months in dry and critical water year types under Alternative 1, relative to the No Action Alternative (Appendix F, Attachment 3-10, Table 20-1, Figures 20-1 through 20-6). In the months of January through August, monthly average chloride concentrations would also be somewhat higher in all water year types (Appendix F, Attachment 3-10, Table 20-1, Figures 20-7 through 20-14).

Monthly average chloride concentrations at Banks and Jones pumping plants would be somewhat higher in the months of September through January of all water year types under Alternative 1, relative to the No Action Alternative (Appendix F, Attachment 3-10, Table 21-1 and Table 22-1, Figures 21-1 through 21-6 and 22-1 through 22-6). In the months of February through August, monthly average chloride concentrations under Alternative 1 would be similar to or lower than those that would occur under the No Action Alternative (Appendix F, Attachment 3-10, Table 21-1 and Table 22-1, Figures 21-8 through 21-14, and 22-8 through 22-14).

Monthly average chloride concentrations in Barker Slough at the North Bay Aqueduct under Alternative 1 would be the same as concentrations that would occur under the No Action Alternative (Appendix F, Attachment 3-10, Table 23-1, Figures 23-1 through 23-18).

If the Summer-Fall Delta Smelt Habitat action under Alternative 1 includes a Fall X2 action, chloride concentrations under Alternative 1 could be different than discussed above. The Fall X2 action could result in chloride concentrations being lower than modeled, particularly in the western Delta, resulting in less of a difference between Alternative 1 and the No Action Alternative in the fall.

In summary, Alternative 1 would generally result in higher monthly average chloride concentrations in the months of September through January, particularly in wet and above normal water year types, and similar or lower concentrations in the remaining months, as compared to the No Action Alternative. While there would be higher chloride concentrations under Alternative 1, relative to the No Action Alternative, in some months, the CVP and SWP would continue operate, in real-time, to meet the Bay-Delta WQCP objectives for chloride, which are for protection of municipal and industrial beneficial uses. In the months of September through January, when chloride would be higher compared to the No Action Alternative, the maximum mean daily chloride objectives of 250 mg/L would continue to apply at Contra Costa Pumping Plant #1, Banks and Jones pumping plants, and Barker Slough at North Bay Aqueduct (SWRCB 2006). Maximum mean daily chloride objective of 150 mg/l would continue to apply at Contra Costa Pumping Plant #1 or San Joaquin River at Antioch for a certain number of days per year, depending on water year type (SWRCB 2006). Thus, Alternative 1 would not contribute to the impairment of municipal and industrial beneficial uses of Delta waters.

Suisun Bay, Suisun Marsh, and San Francisco Bay waters are not designated for municipal and domestic supply uses, and other salinity-related effects in these waters are addressed above in the EC discussion.

Potential Changes in Bromide

Data correlates Delta bromide concentrations with Delta EC levels and chloride concentrations (DWR 2012, Denton 2015). The relationships between bromide and EC, and bromide and chloride vary by Delta location, season, hydrology, and Delta barrier operations (Denton 2015). During periods of low Delta outflow, such as the summer and fall, seawater can dominate at certain locations, making seawater the primary source of bromide to the Delta (Denton 2015). During periods of high outflow, agricultural return flow can be the primary source of bromide at certain locations (Denton 2015). A relationship developed by DWR (2012) for export locations in the Delta with less than 40% seawater expresses the concentration of bromide as a function of EC as follows:

$$CBr- = 0.0004EC - 0.0364$$

where EC is the monthly average electrical conductivity (µmhos/cm) level and CBr- is the monthly average bromide concentration (mg/l)

The EC modeling results show that EC, on average, would be higher at some Delta locations in some months under Alternative 1, relative to the No Action Alternative (Appendix F, Attachment 3-6). For example, in Old River at Rock Slough, long-term monthly average EC under Alternative 1 would be 93 to 264 µmhos/cm higher than under the No Action Alternative in September through December (Appendix F, Attachment 3-6, Table 8-1 and Figures 8-1 through 8-18). Based on the above equation, this corresponds to long-term monthly average bromide concentrations being between 37 and 105 µg/L higher than under the No Action Alternative. At the Banks and Jones pumping plants, the long-term monthly average EC would be 44 to 193 µmhos/cm higher than under the No Action Alternative in the months of September through December (Appendix F, Attachment 3-6, Tables 15-1 and 16-1, Figures 15-1 through 15-18, and Figures 16-1 through 16-18). This corresponds to long-term monthly average bromide concentrations being between 18 and 77 µg/L higher than under the No Action Alternative at the pumping plants. The months of September through December are generally when EC would be highest at these locations compared to other times of the year (Appendix F, Attachment 3-6, Tables 8-1, 15-1, and 16-1); thus, bromide concentrations would also expect to be highest in these months compared to other times of the year.

As described in Section G.1.9, there are not federal or state adopted water quality criteria for bromide applicable to the Delta. Bromide is a constituent of concern for drinking water treatment due to bromide being a precursor to the formation of bromate, bromoform, trihalomethanes, and other brominated disinfection byproducts when water containing bromide is treated for municipal drinking water supplies.

To meet current drinking water regulations for disinfection byproducts, CALFED (2007a) determined that bromide from 100 to 300 µg/l (and total organic carbon from 4 to 7 mg/l) is acceptable to provide users adequate flexibility in their choice of treatment method.

Historical monitoring data compiled for the CALFED *Water Quality Program Stage 1 Final Assessment* (CALFED 2007b) shows that bromide concentrations at drinking water intakes can be highly variable. Bromide concentrations at Banks and Jones pumping plants ranged from less than 50 to over 600 µg/l from 1990 to 2006, and at Old River and Rock Slough concentrations ranged from 50 to over 600 µg/l from 1990 to 2006 (CALFED 2007b). The CALFED Final assessment (2007b) estimated that running annual average concentrations of bromide range from 89 to 424 µg/l at Banks and Jones pumping plants, and 133 to 190 µg/l at Contra Costa Water District intakes on Old River and Rock Slough. Thus, concentrations of bromide at Delta drinking water intake locations are highly variable and have historically fallen outside of the range of 100 to 300 µg/l.

The potentially higher bromide concentrations under Alternative 1, relative to the No Action Alternative, could result in greater potential for disinfection byproduct formation in drinking water supplies that use Delta source waters, but the degree to which this would occur is uncertain. Treatment plants that use the Delta as a source for drinking water already experience highly variable bromide concentrations and, thus, must implement appropriate treatment technologies to ensure compliance with drinking water regulations for disinfection byproducts. Despite the potential for higher bromide concentrations under the Alternative 1, relative to the No Action Alternative, at specific times and locations, it is expected that Alternative 1 would not contribute to drinking water impairments related to bromide, relative to those that would occur under the No Action Alternative.

If the Summer-Fall Delta Smelt Habitat action under Alternative 1 includes a Fall X2 action, bromide concentrations under Alternative 1 could be different than discussed above. The Fall X2 action could result in bromide concentrations being lower, particularly in the western Delta, resulting in less of a difference between Alternative 1 and the No Action Alternative in the fall.

Because Suisun Bay and San Francisco Bay are not designated for municipal and domestic supply use, and seawater is the primary source of bromide in the western Delta, changes in bromide concentrations in the Delta outflow to the bays are not of concern in these water bodies relative to drinking water supplies or other beneficial uses.

Potential Changes in Methylmercury

Long-term average water column concentrations of methylmercury in the Delta under Alternative 1 would be the same as, or slightly (0.01 ng/L) lower than, those that would occur under the No Action Alternative (Appendix G, Attachment 1, Table G1.1-2, Modeled Methylmercury Concentrations in Water). Thus, Alternative 1 would not contribute to higher concentrations of methylmercury in the Delta through changes in source water inflows.

All modeled fish tissue concentrations exceed the water quality objective of 0.24 mg/kg under the No Action Alternative and Alternative 1, as shown by fish tissue concentration results (Appendix G, Attachment 1, Tables G1.5-1, Methylmercury Concentrations in 350 millimeter Largemouth Bass Fillets for the No Action Alternative and G1.5-2, Methylmercury Concentrations in 350 millimeter Largemouth Bass Fillets for Alternative 1, and Comparison to No Action Alternative, and by the EQs plotted and provided in Appendix G, Attachment 1, Figures G1.5-1 and G1.5-2, Level of Concern Exceedance Quotients for Mercury Concentrations in 350 millimeter Largemouth Bass Fillets for All Years); all EQs are greater than 1.0. Under Alternative 1, fish tissue methylmercury concentrations would be from 1 to 4% lower at all modeled locations, except San Joaquin River at Stockton and Barker Slough at North Bay

Aqueduct Intake, where concentrations would be 1% higher, as compared to the No Action Alternative, for the entire period modeled (Appendix G, Attachment 1, Table G1.5-2). For the drought period modeled, fish tissue methylmercury concentrations would be from 1 to 7% lower at all modeled locations, except San Joaquin River at Stockton, where concentrations would be 2% higher, as compared to the No Action Alternative (Appendix G, Attachment 1, Table G1.5-2). Based on the overall lower methylmercury concentrations at almost all modeled Delta locations, water operations under Alternative 1 would not contribute to the additional water quality degradation with respect to methylmercury, or to increased health risks to wildlife or human consuming wildlife, as compared to the No Action Alternative. Thus, the differences in methylmercury in the Delta under Alternative 1, relative to the No Action Alternative, would not contribute to additional beneficial use impairments in the Delta.

Long-term average methylmercury concentrations in the western Delta under Alternative 1 would be similar to those that would occur under the No Action Alternative (Appendix G, Attachment 1, Table G1.5-2). Alternative 1 would result in lower Delta outflow rates, notably in the months of September, October, November, April, and May (Appendix F, Attachment 3-2, *Flow Results* (CalSim II), Table 41-1). Thus, water operations under Alternative 1 would not contribute to the additional water quality degradation with respect to methylmercury or increased bioaccumulation in biota in Suisun Bay and San Francisco Bay, as compared to the No Action Alternative.

Potential Changes in Selenium

Based on modeled Delta water concentrations, presented in Appendix G, Attachment 2, Table G2.2-1, Modeled Period Average Selenium Concentrations in Water for No Action Alternative and Alternatives 1 through 4, selenium concentrations in the Delta under Alternative 1 would be similar or lower than those occurring under the No Action Alternative. Long-term average selenium concentrations in the water column at the three western Delta locations under Alternative 1 would be identical to conditions under the No Action Alternative. Thus, Alternative 1 would not contribute to the additional water quality degradation with respect to selenium, as compared to the No Action Alternative.

Modeled selenium concentrations in biota (whole-body fish, bird eggs [invertebrate diet], bird eggs [fish diet], and fish fillets) at all locations in the Delta under Alternative 1 are similar to those modeled for the No Action Alternative, as shown in Appendix G, Attachment 2, Table G2.3-1, Summary Table for Annual Average Selenium Concentrations in Biota for No Action Alternative and Alternative 1. EQs computed for the applicable toxicity benchmarks show that selenium concentrations in biota under both the No Action Alternative and Alternative 1 would be below the thresholds identified for ecological risk (Appendix G, Attachment 2, Tables G2.3-5, Summary Table for Selenium Concentrations in Biota, and Comparisons for No Action Alternative to Benchmarks, and G2.3-6, Summary Table for Selenium Concentrations in Biota, and Comparisons for Alternative 1 to No Action Alternative and Benchmarks, Figures G2.3-1 through G2.3-4). Thus, Alternative 1 would not result in increased health risks to wildlife or human consuming wildlife associated with whole-body fish, bird eggs (invertebrate diet), bird eggs (fish diet), and fish fillets, as compared to the No Action Alternative.

Modeled selenium concentrations in whole-body Sturgeon (*Acipenseridae*) in the western Delta under Alternative 1 also are similar to or slightly lower than those modeled for the No Action Alternative (Appendix G, Attachment 2, Tables G2.3-10, Summary of Period Average Selenium Concentrations in whole-body Sturgeon, and G2.3-12, Percent Change in Selenium Concentrations in Whole Body Sturgeon Relative to No Action Alternative). Low Toxicity Threshold EQs are less than 1.0 for the entire 82-year period modeled and slightly exceed 1.0 for the drought period modeled (Appendix G, Attachment 2, Table G2.3-11, Comparison of Annual Average Selenium Concentrations in Whole-body Sturgeon to Toxicity Thresholds, and Figure G2.3-5, Low Toxicity Threshold Exceedance Quotients for Selenium Concentrations in Whole-body Sturgeon for Drought Years), and Alternative 1 numbers are similar to the

No Action Alternative. Modeled EQs for the High Toxicity Threshold at all locations are less than 1.0 for the entire period modeled and the drought period modeled, and Alternative 1 numbers are similar to the No Action Alternative. Thus, Alternative 1 would not result in increased health risks to wildlife or human consuming wildlife associated with sturgeon, as compared to the No Action Alternative.

Long-term average water column selenium concentrations in the western Delta under Alternative 1 would be similar to those that would occur under the No Action Alternative (Appendix G, Attachment 2, Table G2.2-1). Alternative 1 would result in lower Delta outflow rates, notably in the months of September, October, November, April, and May (Appendix F, Attachment 3-2, *Flow Results* (CalSim II), Table 41-1). Thus, Alternative 1 would not contribute to additional water quality degradation with respect to selenium or increased bioaccumulation in biota in Suisun Bay and San Francisco Bay, as compared to the No Action Alternative.

Potential Changes in Trace Metals

Trace metals, including aluminum, arsenic, cadmium, chromium, copper, iron, lead, manganese, nickel, silver, and zinc, occur naturally in the river inflows to the Delta. Trace metals concentrations in the Sacramento and San Joaquin rivers, the primary inflows that would be affected by Alternative 1, are below applicable water quality objectives/criteria and this below impairment levels (SWRCB 2017aq). In general, concentrations of trace metals within the Delta are at levels that do not cause beneficial use impairments (SWRCB 2017aq). The trace metals-related impairments in the Delta include arsenic in the western Delta, copper in the portion of Bear Creek in the eastern portion of the Delta, and copper and zinc in the portion of the lower Mokelumne River within the Delta (SWRCB 2017aq; Section G.1.8). The Delta inflows from the Sacramento River and San Joaquin River that would occur under Alternative 1 would not affect these impairments due to trace metals. The Sacramento River and San Joaquin River inflows that would occur under Alternative 1 would not result in additional impairments in the Delta, Suisun Bay and Marsh, or San Francisco Bay, relative to the No Action Alternative, because trace metals conditions within these rivers are applicable water quality objectives and thus below impairment levels.

Potential Changes in Nutrients

The primary nutrients considered in this analysis include ammonium, nitrate, and phosphorus. The two main anthropogenic sources of these nutrients in the Delta are urban point sources (wastewater effluent), and agricultural non-point sources (agricultural runoff and return flows of fertilizers mixed in irrigation water). Nutrient removal projects by two major wastewater treatment plants that discharge into the Sacramento and San Joaquin rivers watersheds and the Delta (i.e., Sacramento Regional Wastewater Treatment Plant and Stockton Regional Wastewater Control Facility) will be complete by 2025. Agricultural non-point source discharges are regulated under the Central Valley RWQCB's *Irrigated Lands Regulatory Program Waste Discharge Requirements*, which mandates nutrient monitoring in the major agricultural reaches, implementing best management practices (BMPs) to reduce nutrient discharges to streams, and controlling fertilizer application and management.

Alternative 1 would result in some differences in Delta inflow rates from the Sacramento River and San Joaquin River, relative to the No Action Alternative. Alternative 1 could create differences in the proportion of Sacramento River and San Joaquin River water at various Delta locations, which may result in differences in nutrient distributions relative to the No Action Alternative at various Delta locations. The analysis anticipates that any difference in nutrient distributions under Alternative 1, relative to the No Action Alternative, would be minimal. Nutrient loadings would be reduced throughout the entire Delta by the regulatory processes described above by 2025. Thus, the evaluation does not expect river inflows under Alternative 1 to contribute to differences in Delta nutrient concentrations or in nutrient distributions that would result in adverse effects to beneficial uses or substantially degrade the water quality, relative to the nutrient conditions that would occur under the No Action Alternative.

Because nutrient concentrations in the Delta under Alternative 1 are not expected to be substantially different from those that would occur under the No Action Alternative, this evaluation does not expect substantial differences in nutrient concentrations in Delta outflow to Suisun Bay and Marsh, and San Francisco Bay. However, there could be some nutrient loading differences from the Delta to Suisun Bay and Marsh, and San Francisco Bay because of Delta outflow differences. Alternative 1 would result in lower Delta outflow rates, relative to the No Action Alternative, notably in the months of September, October, November, April, and May (Appendix F, Attachment 3-2, *Flow Results (CalSim II)*, Table 41-1). Thus, it is possible that nutrient loading to Suisun Marsh, Suisun Bay, and San Francisco Bay may be slightly lower under Alternative 1, relative to the No Action Alternative, in September, October, November, April, and May, when Delta outflow would be lower.

The evaluation does not expect any potential lower nutrient loading from the Delta to Suisun Bay and Marsh, and San Francisco Bay due to different outflow patterns under Alternative 1, relative to the No Action Alternative, to adversely impact primary productivity in these embayments for several reasons. First, there are numerous drivers of primary productivity throughout Suisun Bay and Marsh, and San Francisco Bay. They include high turbidity (light limitation), strong tidal mixing (breaks down stratification and reduces light availability), and abundant grazing (removes phytoplankton from the water column). These factors, not nutrients, currently limit algal production within the embayments (references within SFEI 2016). Thus, any minor change to nutrient loading that may occur under Alternative 1, relative to the No Action Alternative, would not result in lower primary productivity rates in these areas. Second, although Suisun Bay and San Francisco Bay have been nutrient enriched for many years, there is evidence that current nutrient levels are starting to cause adverse effects to the phytoplankton community. Recent observations indicate a shifting phytoplankton community composition away from healthy assemblages towards algal species that form harmful algae blooms (Senn and Novick 2014 and references within). As such, the potential for slightly lower nutrient loadings during certain months of the year due to a change in Delta outflows may be beneficial to Suisun Bay and Marsh, and San Francisco Bay. Finally, the only postulated effect of changes in phosphorus loads to Suisun and San Francisco Bays is related to the influence of nutrient stoichiometry on primary productivity. However, any changes to phosphorus loads under Alternative 1 would be proportional to changes to nitrogen loads, thus the ratios of these two nutrients are expected to change negligibly, if at all. In addition, any effect on phytoplankton community composition would likely be small compared to the effects of grazing from introduced clams and zooplankton in the estuary (Senn and Novick 2014, Kimmerer and Thompson 2014). Therefore, this evaluation does not expect the differences in total nitrogen and phosphorus loading that would occur in Delta outflow to Suisun Bay and Marsh, and San Francisco Bay, relative to the No Action Alternative, to result in water quality degradation with regard to nutrients that would result in adverse effects to beneficial uses or the further impairment of Suisun Bay and Marsh, or San Francisco Bay.

Potential Changes in Dissolved Oxygen

Dissolved oxygen levels in Delta, Suisun Bay and Marsh, and San Francisco Bay waters are primarily affected by water temperature, flow velocities, nutrients (e.g., phosphorus and nitrogen), and the photosynthesis, respiration, and decomposition of aquatic organisms. The sediment oxygen demand of organic material deposited in the low velocity channels also affects dissolved oxygen levels in Delta waters.

The potential for differences in these factors and dissolved oxygen decreases to occur under Alternative 1, relative to the No Action Alternative, are addressed below.

- *Temperature:* Atmospheric exchange processes primarily drive Delta, Suisun Marsh, and Suisun Bay water temperatures on both short and long timescales (Kimmerer 2004; Wagner et al. 2011; Vroom et al. 2017; Enright et al. 2013). Ocean inflow primarily drives Northern San Francisco Bay water temperature (Vroom et al. 2017). Thus, the differences in Delta inflows that would occur under Alternative 1, relative to the No Action Alternative, would not result in water temperature differences what would lead to lower dissolved oxygen levels.
- *Channel Velocities:* The relative degree of tidal exchange, flows, and turbulence that contributes to exposure of Delta, Suisun Bay and Marsh, and San Francisco Bay waters to the atmosphere for reaeration would not be substantially different from the No Action Alternative. The water bodies would continue to experience the daily ebb and flood tides that contribute to water movement within the channels, which contributes to the water column's reaeration.
- *Nutrients:* The primary oxygen-demanding nutrient is ammonium. The major ammonium sources to the Delta are wastewater treatment plant discharges, and treatment plant modifications have been or are being implemented to reduce ammonia discharges (Section G.1.8). Nutrients can also affect dissolved oxygen by promoting aquatic plants biostimulation. However, as described above, the evaluation does not expect Alternative 1 to result in changes in nutrient levels within Delta, Suisun Marsh and Bay, and San Francisco Bay waters, relative to the No Action Alternative, that would encourage additional biostimulation of algae or aquatic plants.
- *Sediment Oxygen Demand:* The differences in Delta inflows that would occur with Alternative 1, relative to the No Action Alternative, would not result in higher concentrations of organic material in the Delta, Suisun Bay and Marsh, and San Francisco Bay sediments that would lead to higher oxygen demand.

Section 303(d) lists some waterways in the eastern, southern, and western Delta as impaired by low oxygen levels (Section G.1.8). A TMDL has been approved for the Stockton Deep Water Ship Channel in the eastern Delta to control the discharge of oxygen-demanding substances, and aerators operated by the Port of Stockton improved dissolved oxygen conditions within the channel. Alternative 1 would not result in changes in Delta inflows, relative to the No Action Alternative, that would make the impairment worse. Alternative 1 would not make the other dissolved oxygen impairments in the Delta worse, relative to the No Action Alternative.

Operations of the managed wetlands and associated discharges cause the current Suisun Marsh dissolved oxygen impairments (Section G.1.8). Therefore, changes in Delta flows into the marsh that could occur under Alternative 1 would not make this impairment worse, relative to the No Action Alternative.

Potential Changes in Pathogens

Delta pathogens levels are more closely related to what happens in the proximity of a particular Delta location than to what happens in the larger watershed where substantial travel time and concomitant pathogen die-off can occur (Section G.1.8). Thus, the differences in Delta inflows under Alternative 1, relative to the No Action Alternative, would not contribute to higher pathogens levels within the Delta.

Potential Changes in Legacy Contaminants

The Delta is on the SWRCB's CWA Section 303(d) list as impaired by dioxin and furan compounds, PCBs, and PAHs (Section G.1.8). It lists Suisun Bay and San Francisco Bay for dioxin and furan compounds, and PCBs. Dioxin and furan compounds, PCBs, and PAHs are identified as “legacy contaminants” because of their persistence in the environment long after use.

River inflows are not the primary sources of dioxin and furan compounds, PCBs, and PAHs in the Delta (Section G.1.9). The Delta’s primary source of dioxin and furan compounds and PAHs in watersheds in atmospheric deposition, which, in turn, enters water bodies via stormwater runoff. The Delta’s primary source of PCBs is the suspension and transport of Bay suspended sediment into the western Delta on flood tides. Dioxin and furan compounds, PCBs, and PAHs deposition and transport would continue to occur independent of CVP/SWP operation. Thus, changes in river inflows to the Delta due to Alternative 1 implementation would not substantially affect concentrations of dioxin and furan compounds, PCBs, and PAHs in the Delta, relative to the No Action Alternative. For these same reasons, Suisun Bay and San Francisco Bay concentrations of dioxin and furan compounds, and PCBs would not be substantially affected by Alternative 1, relative to the No Action Alternative.

Potential Changes in Pesticides

Effects from CVP/SWP Operation

Pesticide concentrations in the Delta, Suisun Bay and Marsh, and San Francisco Bay waters are primarily affected by surface water and stormwater discharges from agricultural and urban land use areas (Central Valley RWQCB 2006, 2014, 2017b). Applications by structural pest control professionals and over-the-counter pesticide use can be among the greatest contributors of pesticides in urban runoff (San Francisco Bay RWQCB 2005). Pyrethroid insecticide use in urban areas is relatively consistent throughout the year, while agricultural pyrethroid use is highest in the winter (Central Valley RWQCB 2017b). Individual pesticide use and the resulting concentrations in receiving waters can vary seasonally, by source, and depend on weather patterns that influence runoff and river flows.

Differences in the Sacramento River and San Joaquin River inflows to the Delta between Alternative 1 and the No Action Alternative could lead to differing pesticide concentrations within Delta waterways, or in the Delta outflow to Suisun Marsh and Bay, and San Francisco Bay. The difference would depend on the relative presence and concentrations of pesticides in the inflows of these rivers, and the relative contributions from other Delta inflows and in-Delta sources.

Several factors affect the presence of pesticides in Delta inflows. Pesticides must be used in a location with hydrologic connectivity to surface water and in amounts that are not easily diluted in the environment. The pesticide must be transportable, which is largely determined by its individual chemical properties, such as water solubility, vaporization, and soil sorption. The pesticide must be sufficiently stable in the environment, so that residues of the applied pesticide or its degradates, which can also adversely affect beneficial uses, are present during runoff events. If transported to surface waters, sufficient amounts of pesticide must be present so that, once diluted by surface water flows, the resulting concentration is a magnitude that can elicit a measurable effect on beneficial uses. Alternatively, pesticides that are transported in the water column can sorb to particles and settle into the sediment, where they can also affect beneficial uses (Central Valley RWQCB 2017b). Factors unrelated to the pesticide are also important, including substrate erosivity, precipitation amount, irrigation and runoff rates, and time elapsed from application to runoff.

Several pesticide control programs and monitoring efforts in the Delta watershed aim to address past pesticide-related impairments and prevent potential future impairments. The Central Valley RWQCB (2005, 2006, 2014) adopted TMDLs for diazinon and chlorpyrifos for several Section 303(d)-listed segments of the Sacramento River, San Joaquin River, and Delta, as well as to address impairments related to these pesticides. Likewise, the Central Valley RWQCB (2017b) adopted a Basin Plan

Amendment for the control of pyrethroids in the entirety of the Sacramento River and San Joaquin River basins. The Central Valley RWQCB's Delta RMP includes a program to describe the status and trends of pesticide concentrations in the Delta, aiming to support future regulatory and management decisions about pesticides control. Monitoring data may indicate the effectiveness of control programs and identify additional pesticides causing toxicity that may need to be the focus of future regulatory actions. The Central Valley RWQCB Irrigated Lands Regulatory Program aims to prevent agricultural runoff containing pesticides from impairing surface waters (Section G.1.8).

Considering the factors described above, Alternative 1 would not result in substantially higher pesticide concentrations in the Delta in a way that would increase the risk of water quality degradation or pesticide-related toxicity to aquatic life, as compared to conditions that would occur under the No Action Alternative. Several primary factors external to CVP/SWP operation affect pesticide presence and concentrations in Delta inflows and throughout the Delta. The Central Valley RWQCB's external regulatory actions to monitor future pesticide presence in the Delta watershed surface waters and adopt TMDLs and water quality objectives, mean that pesticide conditions in the Delta under Alternative 1 and the No Action Alternative would likely be similar. For the same reasons, this evaluation would expect pesticide conditions in Suisun Bay and Marsh, and San Francisco Bay under Alternative 1 to be similar to No Action Alternative conditions.

Effects due to Clifton Court Forebay Weed Removal Program

The Clifton Court Forebay Weed Removal Program would potentially involve using copper-based herbicides and algaecides to control aquatic weeds and algal blooms in the forebay. Herbicides and algaecides application in Clifton Court Forebay would require coverage under the *Statewide General National Pollutant Discharge Elimination System (NPDES) Permit for Residual Aquatic Pesticide Discharges to Waters of the United States from Algae and Aquatic Weed Control Applications (*General Pesticide Permit; NPDES No. CAG990005; Water Quality Order No. 2013-0002-DWQ, as amended by Orders 2014-0078-DWQ and 2015-0029-DWQ) (SWRCB 2016b). The General Permit covers pesticide applications using products containing 2,4-D, acrolein, calcium hypochlorite, copper, diquat, endothall, fluridone, glyphosate, imazamox, imazapyr, penoxsulam, sodium carbonate peroxyhydrate, sodium hypochlorite, and triclopyr-based algaecides and aquatic herbicides, and adjuvants containing ingredients represented by the surrogate nonylphenol (SWRCB 2016b). To obtain General Permit coverage, the applicant must submit an Aquatic Pesticides Application Plan that includes, among other requirements, BMPs for applying herbicides at an appropriate rate, preventing spill, coordinating with water diverters so beneficial water uses are not impacted, and preventing fish kill, and a monitoring program. Considering that BMP implementation would be required for the General Permit, the Clifton Court Forebay Weed Removal Program would not contribute to additional beneficial use impairments in the Delta related to herbicide applications, as compared to the No Action Alternative.

Potential Changes in Organic Carbon

Delta inflows are a notable source of organic carbon to the Delta, followed by in-Delta sources (Section G.1.8). Alternative 1 would result in some changes in Delta inflow rates from the Sacramento River and San Joaquin River, relative to the No Action Alternative, which could result in changes in the proportion of Sacramento River and San Joaquin River water at various Delta locations. The water proportion changes may result in organic carbon concentration differences relative to the No Action Alternative at various Delta locations.

Source water with total organic carbon between 4 and 7 mg/l is believed sufficient to meet currently established drinking water criteria for disinfection byproducts, depending on the amount of Giardia inactivation required (CALFED 2007a). Sacramento River monthly average total organic carbon concentrations tend to be 3 mg/l or less (Tetra Tech, Inc. 2006). San Joaquin River monthly average total organic carbon concentrations are generally 5 mg/l or less, with the exception of September and October, when concentrations are up to 10 mg/l are more likely (Tetra Tech, Inc. 2006). Considering the relative Sacramento River, San Joaquin River, and in-Delta contributions of total organic carbon to the Delta, this evaluation does not expect that higher San Joaquin River flows to the Delta in September and October would result in contributions to total organic carbon concentrations at Delta drinking water intake locations to be above 7 mg/l more frequently under Alternative 1, relative to the No Action Alternative. In other months, higher San Joaquin River inflows, relative to the No Action Alternative, may contribute to an increased frequency of total organic carbon concentrations being above 4 mg/l at Delta drinking water intake locations, but would not contribute an increased frequency above 7 mg/l, because total organic carbon concentrations tend to be 7 mg/l or less in the other months. Thus, while Sacramento River and San Joaquin River inflow rates to the Delta under Alternative 1 would differ from the No Action Alternative, the river inflow difference would not contribute to Delta total organic carbon concentrations that would negatively affect drinking water treatment operations for Delta waters users.

In Suisun Marsh, managed wetlands followed by watershed stormwater contributions are the primary sources of organic carbon (Section G.1.8). Thus, this evaluation would not expect changes in total organic carbon concentrations in the Delta outflow to Suisun Marsh under Alternative 1, relative to the No Action Alternative, to contribute to adverse effects on organic enrichment conditions within the marsh.

Suisun Bay and San Francisco Bay are not designated for municipal and domestic supply use, thus changes in organic carbon concentrations in the Delta outflow to the bays are not of concern in these water bodies relative to drinking water supplies. However, total organic carbon is an important component of the food web in these water bodies; the Delta provides 68% of the total organic carbon to Suisun Bay and the northern portion of San Francisco Bay (Section G.1.8; Jassby et al. 1993). The Delta also provides the majority of dissolved organic carbon to Suisun Bay and the northern portion of San Francisco Bay, but this is generally less bioavailable to the food web base compared with total organic carbon and/or carbon from primary production (Stepanauskas et al. 2005; Tetra Tech 2006).

Alternative 1 would result in lower Delta outflow rates, relative to the No Action Alternative, notably in the months of September, October, November, April, and May (Appendix F, Attachment 3-2, *Flow Results (CalSim II)*, Table 41-1). The lower outflow rates could potentially result in reduced total organic carbon and dissolved organic carbon loads to Suisun Bay and San Francisco Bay during those months. A lower dissolved organic carbon load to Suisun and San Francisco Bay would not be expected to adversely affect food webs because dissolved organic carbon is generally less available to the base of the food web compared with particulate organic carbon or carbon from primary production (Tetra Tech 2006). Thus, lower dissolved organic carbon inputs under Alternative 1, relative to the No Action Alternative, are unlikely to directly affect the food web (Tetra Tech 2006).

Much of the organic carbon transported from the Delta to Suisun Bay and San Francisco Bay is in the form of detritus (Durand 2015). However, total organic carbon contained in freshwater phytoplankton from the Delta represents most of the total organic carbon actually used in the Suisun and northern San Francisco Bay food webs (Kimmerer 2004). Alterations to the Delta's seasonal flow schedule could change how total organic carbon (e.g., phytoplankton) is transported to Suisun Bay and the San Francisco Bay (Kimmerer 2004). This could potentially reduce food availability to consumers in Suisun Bay and the northern portion of the San Francisco Bay during the months flows are lower under Alternative 1, relative to the No Action Alternative (Jassby and Cloern 2000). However, the relationship between flows and total organic carbon inputs may not be linear. For example, phytoplankton in the Delta may bloom primarily when freshwater flow rates are low and residence times are high (references within Kimmerer 2004). As such, it is difficult to ascertain exactly how food webs in Suisun Bay and the northern San Francisco Bay would be affected by the lower Delta outflows and total organic carbon loading under Alternative 1, relative to the No Action Alternative.

G.2.3.2 *Program-Level Effects*

Under Alternative 1, program-level effects would include effects from intake lowering, tidal habitat restoration, increased aquatic weed removal in the Delta, the introduction of dredge material for turbidity, and construction activities associated with facility improvements.

G.2.3.2.1 Tidal Habitat Restoration

The tidal habitat restoration would largely focus on the Delta region. Newly created tidal habitat restoration areas can potentially affect mercury and selenium bioaccumulation, and dissolved organic carbon. The construction of tidal habitat areas and facility improvements are addressed below in Section G.2.3.2.4.

Mercury

Newly created tidal habitat areas have the potential to become new sources of methylmercury to the Delta (Alpers et al. 2008). Methylmercury production is highest in high elevation marshes subjected to wet and dry periods occurring during the highest monthly tidal cycles, as compared to lower elevation marshes not subjected to dry periods (Alpers et al. 2008). Floodplains and seasonally flooded agricultural lands also have relatively high rates of methylmercury production (Alpers et al. 2008). Water and sediment properties determine mercury methylation rates in tidal habitats, including sediment grain size, pH, binding constituent availability (e.g., iron, sulfur, organic matter), and factors influencing the success of the microbes responsible for the methylation process (e.g., nutrients and dissolved oxygen) (Alpers et al. 2008).

DWR is conducting a study of methylmercury import to and export from tidal wetlands in the Delta, Yolo Bypass, and Suisun Marsh (DWR 2015). The study evaluated several hypotheses, including: (1) tidal wetlands are a net source of total methylmercury on an annual basis; (2) tidal wetlands are a net source of total mercury on an annual basis; (3) tidal wetlands have higher total and dissolved methylmercury exports during the warmer, summer months; (4) tidal wetlands are a net source of dissolved mercury and a sink for particulate methylmercury and total mercury on an annual basis; and (5) organic carbon concentrations and methylmercury concentrations are positively correlated. Preliminary results from a tidal wetland in the Yolo Wildlife Area showed the area was a sink for total methylmercury and more often a sink for dissolved methylmercury than a source (DWR 2015). Study of other tidal wetlands is ongoing.

Some habitat restoration activities would likely occur on lands in the Delta formerly used for irrigated agriculture. In-Delta irrigated agriculture can be a substantial source of methylmercury (Central Valley RWQCB 2010a). Thus, the new tidal habitat would not necessarily be a new source of methylmercury to the Delta.

The degree to which new tidal habitat areas may be future sources of methylmercury to the aquatic environment of the Delta is uncertain. The new tidal habitat's specific siting and design would affect the potential for methylmercury generation and transport. However, the amount of tidal habitat restoration area proposed for Alternative 1 is the same as what would occur under the No Action Alternative. Therefore, the new tidal habitat areas would not present additional sources of organic carbon or pose additional risk to fish, wildlife, and humans, relative to the No Action Alternative.

Selenium

Conversion of lands within the Delta to tidal habitat has the potential to result in localized increased water residence times. Water would flow in and out of the restored tidal habitat areas, thus residence times would not increase without bound and water column selenium concentrations would not build up and be recycled in sediments and organisms, as may be the case within a closed system. If increases in fish tissue or bird egg selenium concentrations were to occur, the increases would be of concern primarily where fish tissue or bird egg selenium concentrations are already near or above toxicity benchmarks. Where biota concentrations are currently low and not approaching toxicity benchmarks (which, as discussed in the Project-Levels effect analysis of selenium, is the case throughout the Delta, except for sturgeon in the western Delta), changes in residence time alone would not be expected to cause biota concentrations that approach or exceed toxicity benchmarks. The western Delta and Suisun Bay may have areas where biota tissue concentrations would be high enough that additional bioaccumulation in sturgeon would be a concern.

Several TMDLs were adopted and implemented to address selenium impairments within the Central Valley and San Francisco Bay regions (Section G.1.9). TMDL implementation led to declining selenium contributions to the Delta and within San Francisco Bay, and implementation would continue independent of Alternative 1. Thus, while there is the potential for increased selenium bioaccumulation in biota associated with development of tidal habitat restoration areas, with ongoing implementation of selenium TMDLs, a substantial increase in selenium bioaccumulation in biota would not be expected above that which would occur with the No Action Alternative in a way that would increase risk to fish, wildlife, or humans.

Organic Carbon

Newly-created tidal habitat could potentially lead to new substantial sources of localized total and dissolved organic carbon loading within the Delta. New tidal habitat established in areas presently used for agriculture, which also is a source of total and dissolved organic carbon loading, also could result in a substitution and temporary increase in localized total and dissolved organic carbon loading. Preliminary results from the ongoing DWR study in the Delta found that the tidal habitat in the Yolo Wildlife Area was a sink for both total and dissolved organic carbon (DWR 2015). The degree to which new tidal habitat areas may be future sources of organic carbon to the aquatic environment of the Delta is uncertain. The specific siting and design of the new tidal habitat would likely affect the potential for organic carbon generation and transport. The amount of tidal habitat restoration area proposed for Alternative 1 is the same as what would occur under the No Action Alternative. Therefore, the new tidal habitat areas would not present additional sources of organic carbon to the Delta, Suisun Bay and Marsh, and San Francisco Bay, relative to the No Action Alternative.

G.2.3.2.2 Increased Aquatic Weed Removal

Implementing an aquatic weed removal program that involves herbicides could result in exposing the aquatic system to potentially toxic conditions if not properly managed. Pesticide application would require coverage under the General Pesticide Permit, which would require submittal of an Aquatic Pesticides Application Plan that includes BMPs for applying herbicides at an appropriate rate, preventing spill, coordinating with water diverters so that beneficial uses of water are not impacted, and measures to prevent fish kill (SWRCB 2016b). Considering that implementation of BMPs would be required as part of the General Pesticide Permit requirements, the Increased Aquatic Weed Removal program would not contribute to additional beneficial use impairments related to herbicide applications, as compared to the No Action Alternative.

G.2.3.2.3 Introduce Dredge Material for Turbidity

The program to introduce dredge material to the Delta would be targeted to increase turbidity at specific locations within the Delta for beneficial habitat effects. The sediment augmentation program would be designed for consistency with Central Valley RWQCP objectives for turbidity, i.e., except for periods of storm runoff, turbidity of Delta waters not exceeding 50 Nephelometric Turbidity Units in the Central Delta waters and 150 Nephelometric Turbidity Units in other Delta waters. Thus, the introduction of dredge material to increase turbidity at specific Delta locations is not expected to cause turbidity-related impairments to Delta waters' beneficial uses.

G.2.3.2.4 Construction-Related Activities

Construction activities necessary to implement various facility improvements and tidal habitat restoration areas could result in the direct discharge of contaminants to adjacent Delta waters, due to the work to Delta waterways. Construction activities could include clearing vegetation; grading, excavation and soil placement; and in-channel work, such as dredging. Due to the direct connectivity with Delta channels, these construction activities have the potential to result in direct discharge of eroded soil and construction-related contaminants. The construction activity intensity, along with the fate and transport characteristics of the chemicals used, would largely determine the magnitude, duration, and frequency of construction-related discharges and the resulting concentrations and degradation associated with the specific constituents of concern.

Land surface grading and excavation activities, or the exposure of disturbed sites immediately following construction, but prior to stabilization, could result in rainfall-related soil erosion, runoff, and offsite sedimentation in surface water bodies. Soil erosion and runoff could also result in increased concentrations and loading of organic matter, nutrients (nitrogen and phosphorus), and other contaminants contained in the soil (such as trace metals, pesticides, or animal-related pathogens). Graded and exposed soils also could be compacted by heavy machinery, resulting in reduced infiltration of rainfall and runoff, thus increasing the rate of contaminated runoff to downstream water bodies.

Construction activities would be expected to involve transporting, handling, and using a variety of hazardous substances and non-hazardous materials that may adversely affect water quality if discharged inadvertently to construction sites or directly to water bodies. Typical construction-related contaminants include petroleum products for refueling and machinery maintenance (e.g., fuel, oils, solvents), concrete, paints and other coatings, cleaning agents, debris and trash, and human wastes. Contaminants released or spilled on bare soil also may result in groundwater contamination. Dewatering operations may contain elevated levels of suspended sediment or other constituents that could cause water quality degradation.

The SWRCB's NPDES stormwater program requires permits for discharges from construction activities that disturb one or more acres. SWRCB adopted a general NPDES permit for stormwater discharges associated with construction activity (Construction General Permit) in Order No. 2009-0009-DWQ, which became effective on July 1, 2010 (as amended by revised orders 2010-0014-DWQ and 2012-006-DWQ). The Construction General Permit includes specific requirements based on the site's "risk level." Three different risk levels are dependent on two factors: (1) project sediment runoff risk; and (2) receiving water risk. Obtaining coverage under the Construction General Permit requires filing a Notice of Intent and preparing and implementing a stormwater pollution prevention plan (SWPPP), which specifies BMPs to reduce or eliminate sediment and other pollutants in stormwater as well as non-stormwater discharges. The Construction General Permit requires implementing BMPs that control pollutant discharges using best available technology economically achievable for toxic contaminants, best conventional technology for conventional contaminants, and any other necessary BMPs to meet water quality standards. The Construction General Permit contains technology-based numeric action levels for pH and turbidity, and requires visual monitoring for potential contaminant runoff at all sites, and effluent monitoring at all risk level 2 and 3 sites, with follow-up actions required for exceedances of numeric action levels. Risk level 2 and 3 sites also must prepare and implement Rain Event Action Plans for all storm events forecast to have measurable precipitation. The Construction General Permit specifies runoff reduction requirements for all sites not covered by a municipal NPDES permit, to minimize post-construction stormwater runoff impacts. Implementing the necessary BMPs, as required by the Construction General Permit, would reduce potential adverse discharge effects of constituents of concern.

Facility improvements also may require additional environmental permits, such as CWA Section 401 water quality certifications from the RWQCB, California Department of Fish and Wildlife Streambed Alteration Agreements, and USACE CWA Section 404 dredge and fill permits. These other permit processes may include requirements to implement additional action-specific BMPs to reduce potential adverse discharge effects of constituents of concern associated with construction activities.

While program-level activities could have short-term effects on water quality, implementation of Mitigation Measures WQ-1, WQ-2, WQ-3, and WQ-4, described below in Section G.2.7, would reduce the severity of these effects. Adverse impacts to water quality and violations of water quality standards are not expected as a result of program-level activities.

G.2.4 Alternative 2

G.2.4.1 *Project-Level Effects*

Potential changes in water quality

G.2.4.1.1 Trinity River

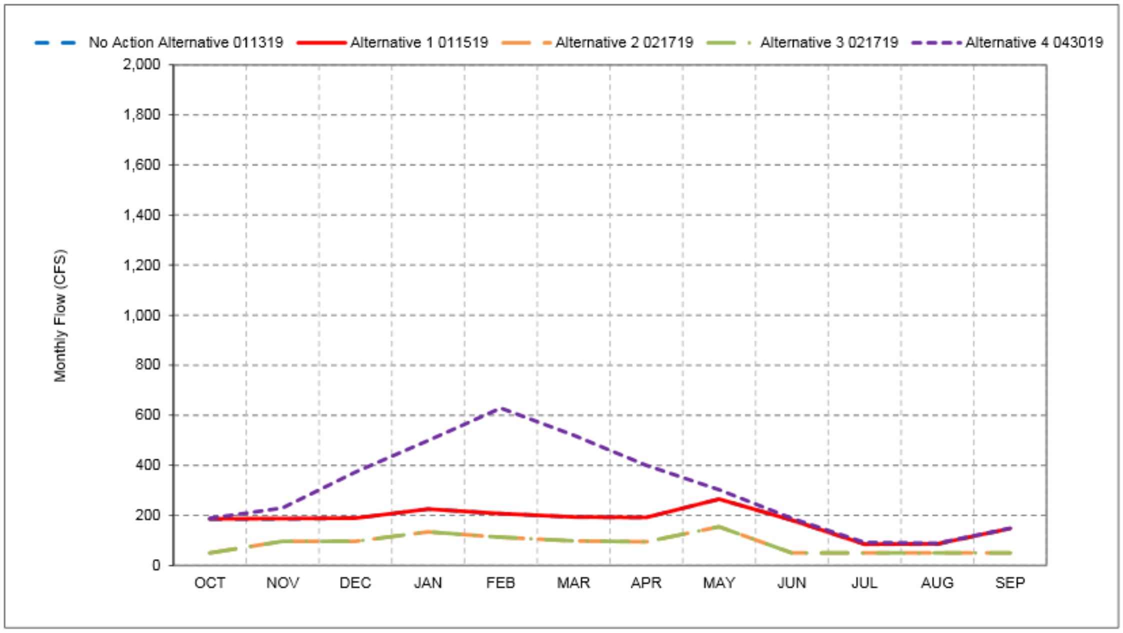
Operations in the Trinity River under Alternative 2 would remain similar to those under the No Action Alternative. The maximum average change in flows is modeled during February of above normal water year types, when flows are expected to increase by approximately 52%. Figures G.2-1 through G.2-6 illustrate flow changes. Increases in flows would be beneficial to water quality; therefore, no violations of existing water quality standards would occur.

G.2.4.1.2 Sacramento River

Changes in flow under Alternative 2 compared to the No Action Alternative in the Sacramento River increase in late winter and early spring and decrease during late fall and early winter. Under Alternative 2, trends in flow would be similar to those shown under Alternative 1, and average flows could decrease a maximum of 44% compared to the No Action Alternative. The decrease in flow would occur at Wilkins Slough during wet water year types. Increases in flow are also expected under Alternative 2 during some months, especially during dry and critical water years, but not to the extent of the decrease in flows. Figures G.2-7 through G.2-12 illustrate flow changes. As flow increases are beneficial to water quality because it dilutes constituents of concern, flow decreases are not expected to be large enough to negatively impact water quality and increase the frequency of exceedances of water quality thresholds in the Sacramento River.

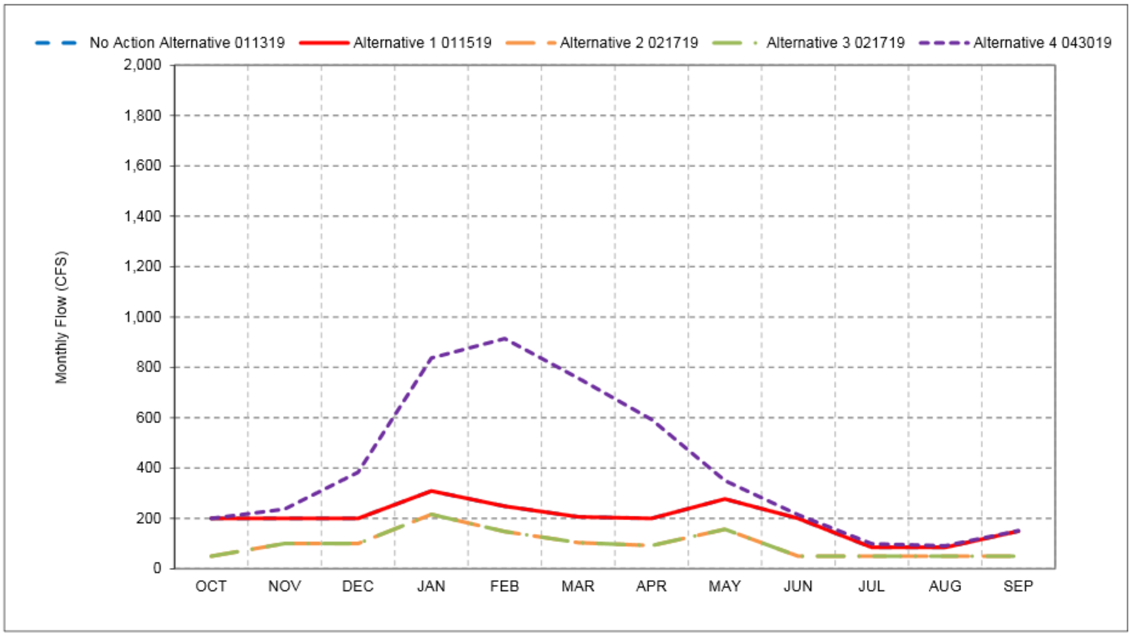
G.2.4.1.3 Clear Creek

Flows in Clear Creek under Alternative 2 would decrease as compared to the No Action Alternative because Alternative 2 does not include flows in Clear Creek from the National Marine Fisheries Service (NMFS) BO Action I.1.1 and CVPIA 3406(b)(2) flows. The maximum average change in flows is modeled during October and June of wet and above normal water years, when flows are expected to decrease by approximately 75%. Figures G.2-37 through G.2-42 illustrate changes in flow under Alternative 2. As mentioned in Section G.1.4.1, gold mining activity occurred within the Clear Creek watershed between Whiskeytown Lake and the confluence with the Sacramento River during the Gold Rush era (USGS 2005), resulting in mercury contamination of Clear Creek and Whiskeytown Lake that currently persist. Reductions in flow due to changes in the operations of CVP/SWP under Alternative 2 could result in less dilution causing increased concentrations of mercury within Clear Creek compared to the No Action Alternative.



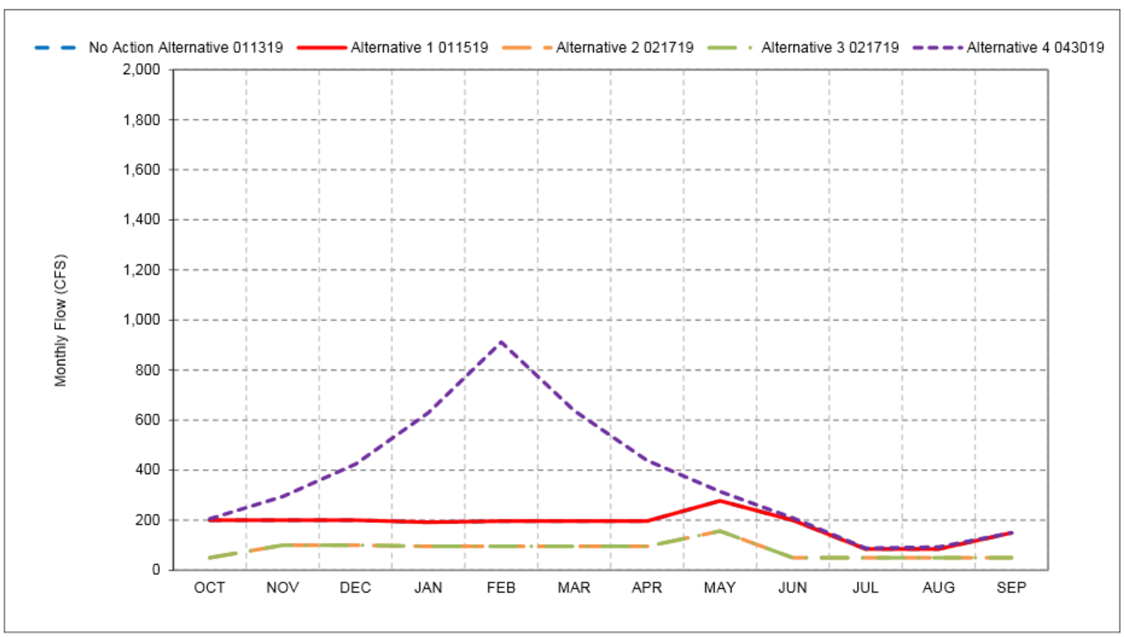
*As defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999).
*These results are displayed with calendar year - year type sorting.
*All scenarios are simulated at ELT (Early Long-Term) Q5 with 2025 climate change and 15 cm sea level rise.
*These are draft results meant for qualitative analysis and are subject to revision.

Figure G.2-37. Clear Creek below Whiskeytown Dam Flow, Long-Term Average Flow



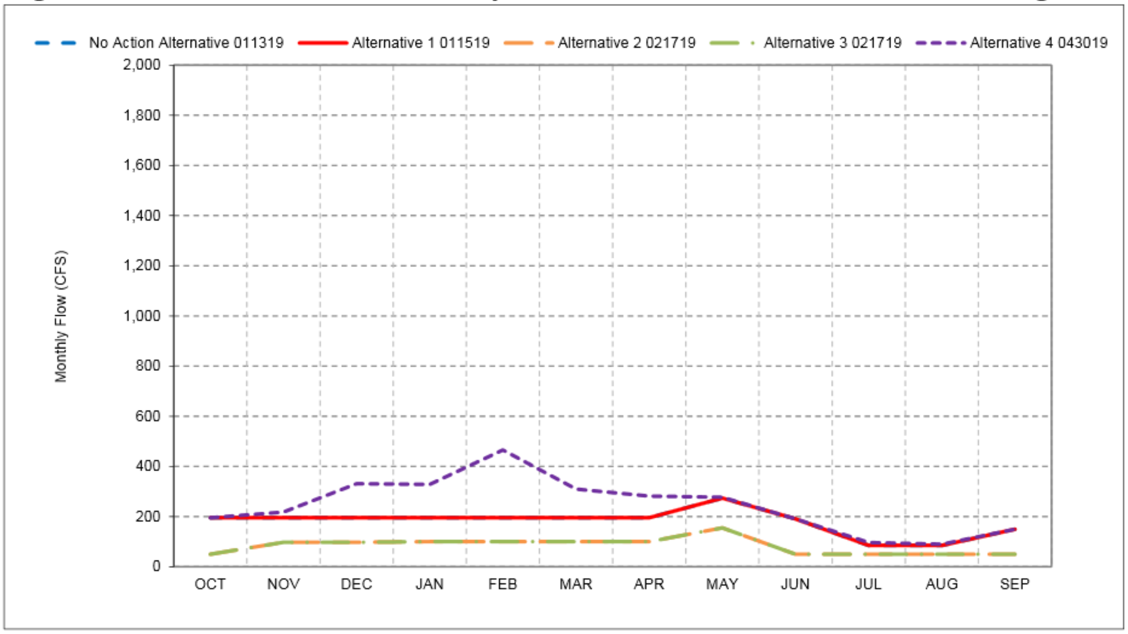
*As defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999).
*These results are displayed with calendar year - year type sorting.
*All scenarios are simulated at ELT (Early Long-Term) Q5 with 2025 climate change and 15 cm sea level rise.
*These are draft results meant for qualitative analysis and are subject to revision.

Figure G.2-38. Clear Creek below Whiskeytown Dam Flow, Wet Year Average Flow



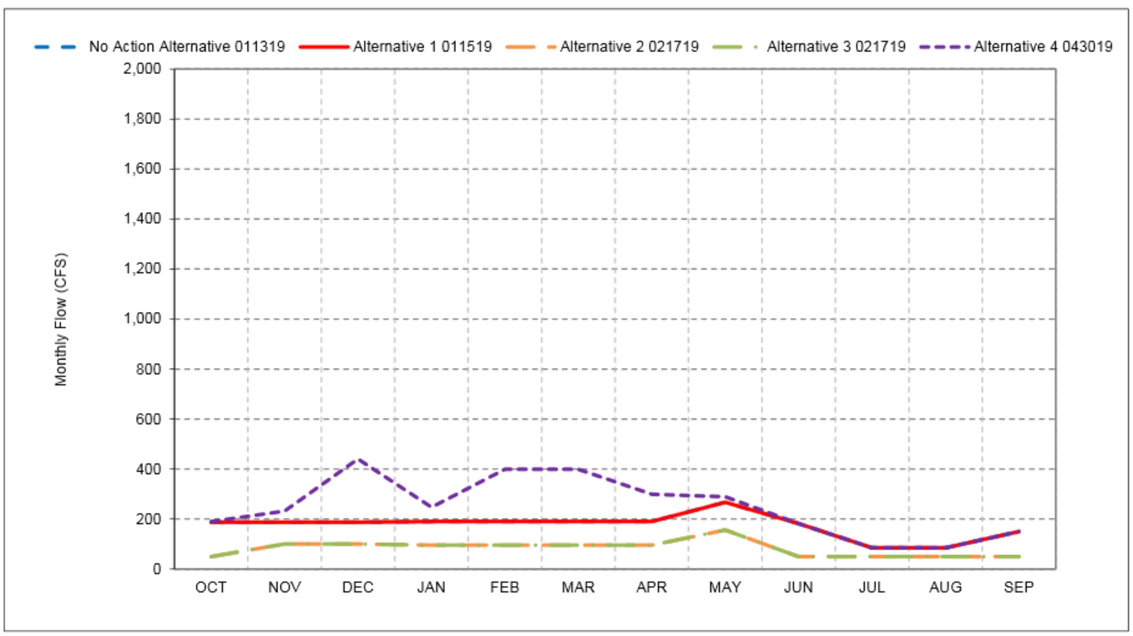
*As defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999).
*These results are displayed with calendar year - year type sorting.
*All scenarios are simulated at ELT (Early Long-Term) Q5 with 2025 climate change and 15 cm sea level rise.
*These are draft results meant for qualitative analysis and are subject to revision.

Figure G.2-39. Clear Creek below Whiskeytown Dam Flow, Above Normal Year Average Flow



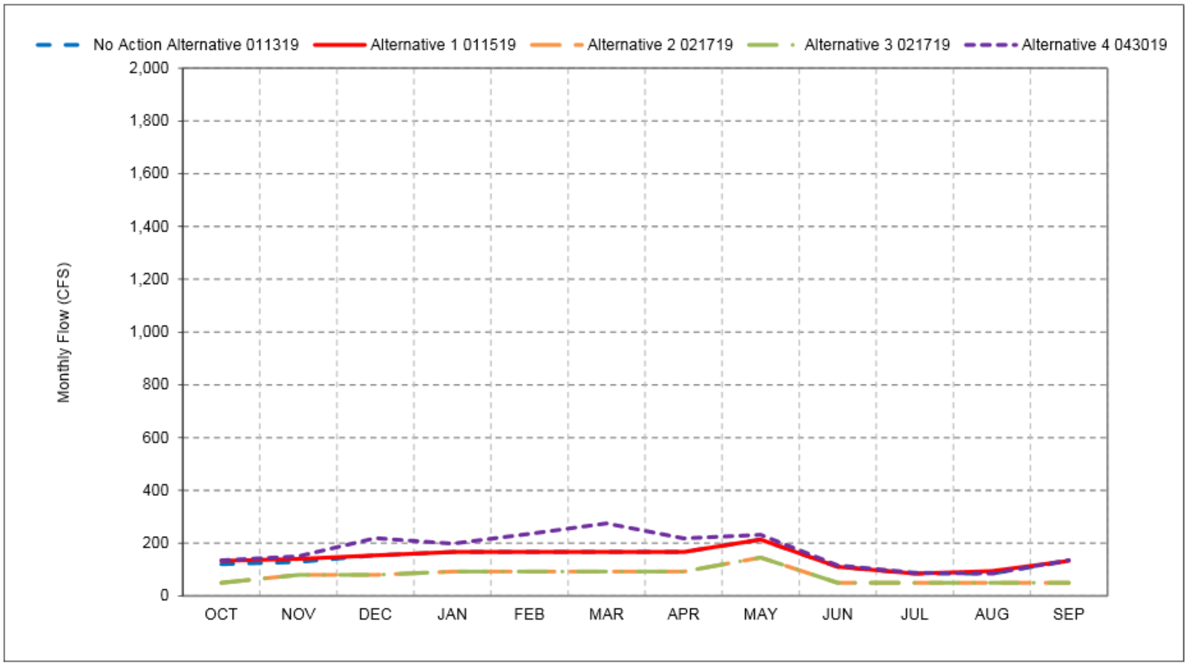
*As defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999).
*These results are displayed with calendar year - year type sorting.
*All scenarios are simulated at ELT (Early Long-Term) Q5 with 2025 climate change and 15 cm sea level rise.
*These are draft results meant for qualitative analysis and are subject to revision.

Figure G.2-40. Clear Creek below Whiskeytown Dam Flow, Below Normal Year Average Flow



*As defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999).
*These results are displayed with calendar year - year type sorting.
*All scenarios are simulated at ELT (Early Long-Term) Q5 with 2025 climate change and 15 cm sea level rise.
*These are draft results meant for qualitative analysis and are subject to revision.

Figure G.2-41. Clear Creek below Whiskeytown Dam Flow, Dry Year Average Flow



*As defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999).
*These results are displayed with calendar year - year type sorting.
*All scenarios are simulated at ELT (Early Long-Term) Q5 with 2025 climate change and 15 cm sea level rise.
*These are draft results meant for qualitative analysis and are subject to revision.

Figure G.2-42. Clear Creek below Whiskeytown Dam Flow, Critical Year Average Flow

G.2.4.1.4 Feather River

Alternative 2 would require fewer releases from Lake Oroville to meet Delta standards, so the flows within the Feather River would shift to different times of year. The largest decrease in flows would be in September of wet water years and the largest increase in flows are expected in June of below normal water years under Alternative 2. Changes in flow would be similar for both locations on the Feather River. Feather River flows at the Sacramento River Confluence would have the largest increase of approximately 130% and largest decrease of approximately 57%. Feather River flows downstream of Thermalito Afterbay would have the largest increase of approximately 177% and largest decrease of approximately 71%. Figures G.2-13 through G.2-18 illustrate monthly changes in Feather River flow for all water year types under Alternative 2 compared to the No Action Alternative. Flow increases are considered beneficial to water quality because they dilute constituents of concern, and flow decreases are expected when water conditions are wet or above normal water years and have less impact on water quality. Frequency increases of exceedances of water quality standards in the Feather River are not expected.

G.2.4.1.5 American River

Under Alternative 2, Reclamation would operate Folsom Reservoir, making releases according to the 2006 American River Flow Management Standard, which is also included in the No Action Alternative. However, Reclamation would not release water to meet NMFS BO Action II.1 and other Delta standards, which would shift the timing of releases from Folsom. The largest flow decreases would be in September of wet water years and the largest flow increases would be in June of above normal water years. Flow changes would be similar for both locations on the American River. American River flows at H Street and below Nimbus Dam would have a maximum increase of approximately 48% and a maximum decrease of approximately 43%. Figures G.2-19 through G.2-24 present monthly changes in American River flow at H Street for all Water Year types under Alternative 2 compared to the No Action Alternative. Flow increases are beneficial to water quality because they dilute constituents of concern, and flow decreases, expected when conditions are wet or above normal, have a minor impact on water quality. Frequency increases of exceedances of water quality standards in the American River are not expected.

G.2.4.1.6 Stanislaus River

Like Alternative 1, changes in flow would be identical for both locations (at Mouth and below Goodwin) on the Stanislaus River. The largest flow decrease would be in April of below normal water years and the largest flow increase would be in February of wet water years under Alternative 2. Stanislaus River flows below Goodwin Dam would have a maximum increase of approximately 130% and a maximum decrease of approximately 85%. Figures G.2-25 through G.2-30 present monthly changes in Stanislaus River flow for all water year types under Alternative 2 compared to the No Action Alternative. As described in Section G.1.7.2, pesticides are a constituent of concern in the Lower Stanislaus River, largely caused by urban and agricultural runoff. At times when flow increases, water quality could improve as more water is available to dilute pesticide runoff in the Stanislaus River. Flow decreases during spring and summer months of all water year types could cause water quality degradation because less water would be available to dilute pesticide concentrations.

G.2.4.1.7 San Joaquin River

The greatest flow change in the San Joaquin River would be at Vernalis, where flows would decrease by a maximum of 26%. Figures G.2-31 through G.2-36 show changes in the San Joaquin River at Vernalis. The small change in flow under Alternative 2 would not likely result in adverse effects on water quality nor an increase in frequency of exceedances of water quality thresholds in the San Joaquin River.

G.2.4.1.8 CVP and SWP Service Area (south to Diamond Valley)

Alternative 2 would generally result in higher monthly average chloride concentrations at Banks and Jones Pumping Plants in the months of September through January, particularly in wet and above normal water year types, and similar or lower concentrations in the remaining months, as compared to the No Action Alternative. Since this water is delivered to reservoirs for storage in CVP/SWP reservoirs, chloride concentrations in these reservoirs may increase. While there would be higher chloride concentrations under Alternative 2, relative to the No Action Alternative, in some months, the CVP/SWP would continue operation, in real-time, to meet the Bay-Delta WQCP objectives for chloride, which aim to protect municipal and industrial beneficial uses. In September through January, when chloride would be higher compared to the No Action Alternative, the maximum mean daily chloride objectives of 250 mg/l would continue to apply at Contra Costa Pumping Plant #1, Banks and Jones pumping plants, and Barker Slough at North Bay Aqueduct (SWRCB 2006). Also, the maximum mean daily chloride objective of 150 mg/l would continue to apply at Contra Costa Pumping Plant #1 or San Joaquin River at Antioch for a certain number of days per year, depending on water year type (SWRCB 2006). Thus, Alternative 2 would not contribute to municipal and industrial beneficial uses CVP/SWP service area impairment.

G.2.4.1.9 Bay-Delta

Potential Changes in EC

Delta

Monthly average EC levels in the Sacramento River at Emmaton would often be substantially higher in September through December of wet and above normal water year types under Alternative 2, relative to the No Action Alternative (Appendix F, Attachment 3-6, Table 4-2, Figures 4-2, 4-3, 4-15 through 4-18). Monthly average EC levels in January of below normal, dry, and critical water year types also would be substantially higher relative to the No Action Alternative (Appendix F, Attachment 3-6, Table 4-2, Figure 4-7). Monthly average EC levels in February through August under Alternative 2 would be similar to or lower than the No Action Alternative EC levels (Appendix F, Attachment 3-6, Table 4-2, Figures 4-8 through 4-14).

Monthly average EC levels in the San Joaquin River at Vernalis under Alternative 2 would, overall, be similar to levels that would occur under the No Action Alternative, except in October, when EC levels would be substantially higher than the No Action Alternative (Appendix F, Attachment 3-6, Table 6-2, Figures 6-1 through 6-18). Somewhat higher monthly EC levels would occur in the months of March through June under Alternative 2, relative to the No Action Alternative (Appendix F, Attachment 3-6, Table 6-2, Figures 6-9 and 6-12).

Monthly average EC levels in the San Joaquin River at Jersey Point, like the Sacramento River at Emmaton, would often be substantially higher in September through December of wet and above normal water year types under Alternative 2, relative to the No Action Alternative (Appendix F, Attachment 3-6, Table 7-2, Figures 7-2, 7-3, 7-15 through 7-18). February, March, April, May, and June would also see somewhat higher EC levels under Alternative 2, relative to the No Action Alternative (Appendix F, Attachment 3-6, Table 7-2, Figures 7-8 through 7-12).

Monthly average EC levels at the Banks and Jones pumping plants under Alternative 2, relative to the No Action Alternative, would be higher in September through January, most notably in wet and above normal water year types (Appendix F, Attachment 3-6, Tables 15-2 and 16-2, Figures 15-2, 15-3, 16-2, 16-3). In February through August, monthly average EC levels under Alternative 2 would be similar to or lower than No Action Alternative EC levels (Appendix F, Attachment 3-6, Tables 15-2 and 16-2, Figures 15-8 through 15-14 and 16-8 through 16-14).

While there would be higher monthly average EC levels under Alternative 2 relative to the No Action Alternative, in some months, the CVP/SWP would continue to operate, in real-time, to meet the Bay-Delta WQCP objectives for EC to protect agricultural and fish and wildlife beneficial uses. The western Delta EC objectives for the Sacramento River at Emmaton and San Joaquin River at Jersey Point for agricultural beneficial use protection apply from April through June, July, or August, depending on water year type (SWRCB 2006). The San Joaquin River at Jersey Point objective for fish and wildlife protection also applies during April and May (SWRCB 2006). During these months, the monthly average EC levels under Alternative 2 would be similar to the No Action Alternative (Appendix F, Attachment 3-6, Tables 4-2 and 7-2). The southern Delta EC objectives to protect agricultural uses for the San Joaquin River at Vernalis and the export area for Banks and Jones pumping plant apply year-round. Banks and Jones pumping plants would have higher EC levels in the fall, but lower monthly average EC in spring and summer, relative to the No Action Alternative (Appendix F, Attachment 3-6, Tables 15-2 and 16-2). Monthly average EC levels at Vernalis under Alternative 2 would overall be similar to the No Action Alternative, except in October, when EC levels would be somewhat higher than the No Action Alternative (Appendix F, Attachment 3-6, Table 6-2). Thus, the differences in EC in the Delta under

Alternative 2, relative to the No Action Alternative, would not contribute to agricultural or fish and wildlife beneficial use impairments in the Delta.

Suisun Marsh

In the Sacramento River at Collinsville, which is a Bay-Delta WQCP compliance location for the eastern portion of Suisun Marsh, monthly average EC levels would be substantially higher under Alternative 2, relative to the No Action Alternative, in September through December of wet and above normal water year types (Appendix F, Attachment 3-6, Table 11-2, Figures 11-2 and 11-3). The EC differences would occur primarily at the low end of the modeled EC range; there is little difference between the upper monthly average EC levels at Collinsville under Alternative 2, relative to the No Action Alternative (Appendix F, Attachment 3-6, Figures 11-15 through 11-18). Higher monthly average EC levels would also occur in December through May of all water year types under Alternative 2, relative to the No Action Alternative (Appendix F, Attachment 3-6, Table 11-2, Figures 11-1, 11-7 through 11-11, and 11-18).

Suisun Bay and San Francisco Bay

Based on the modeling results discussed above, the EC of Delta outflow under Alternative 2 may be different than what would occur under the No Action Alternative in certain months of certain water year types. Also, Alternative 2 would result in lower Delta outflow rates relative to the No Action Alternative (Appendix F, Attachment 3-2, *Flow Results (CalSim II)*, Table 41-2). The differences in Delta EC and outflow could cause the freshwater-seawater salinity gradient within Suisun Bay and the northern portion of San Francisco Bay to be different between Alternative 2 and the No Action Alternative. These differences are not expected to result in substantial changes in overall salinity conditions within Suisun Bay and San Francisco Bay, because seawater is the predominant source of the bays' salinity.

Potential Changes in Chloride

The discussion below assesses the differences between chloride at the five assessment locations – Contra Costa Pumping Plant #1, San Joaquin River at Antioch, Banks and Jones pumping plants, and North Bay Aqueduct – under Alternative 2 as compared to the No Action Alternative. The assessment is based on modeling results presented in Appendix F, Attachment 3-10, *Salinity Results (DSM2)*.

Monthly average chloride concentrations at Contra Costa Pumping Plant #1 would often be substantially higher in October through December of wet and above normal water year types, and somewhat higher in September, January, and February of all water year types under Alternative 2, relative to the No Action Alternative (Appendix F, Attachment 3-10, Table 19-2, Figures 19-1 through 19-18). In April and May of all water year types, chloride concentrations would be somewhat lower than would occur under the No Action Alternative (Appendix F, Attachment 3-10, Table 19-2, Figures 19-10 and 19-11). Monthly average chloride concentrations in March, and June through August would be similar to concentrations under the No Action Alternative (Appendix F, Attachment 3-10, Table 19-2, Figures 19-9, and 19-12 through 19-14).

Monthly average chloride concentrations in the San Joaquin River at Antioch would often be substantially higher in September through December of wet and above normal water year types under Alternative 2, relative to the No Action Alternative (Appendix F, Attachment 3-10, Table 20-2, Figures 20-2 and 20-3). In the months of December through May, and August, monthly average chloride concentrations also would be somewhat higher in all water year types (Appendix F, Attachment 3-10, Table 20-2, Figures 20-1, 20-7 through 20-11, 20-14, and 20-18).

Monthly average chloride concentrations in all water year types at Banks and Jones pumping plants would be somewhat higher in the months of September through January under Alternative 2, relative to the No Action Alternative (Appendix F, Attachment 3-10, Table 21-2 and Table 22-2, Figures 21-1 through 21-6 and 22-1 through 22-6). In the months of February through August, monthly average chloride concentrations under Alternative 2 would be similar to or lower than those that would occur under the No Action Alternative (Appendix F, Attachment 3-10, Tables 21-2 and 22-2, Figures 21-8 through 21-14 and 22-8 through 22-14).

Monthly average chloride concentrations in Barker Slough at the North Bay Aqueduct under Alternative 2 would be the same as concentrations that would occur under the No Action Alternative (Appendix F, Attachment 3-10, Table 23-2, Figures 23-1 through 23-18).

In summary, Alternative 2 would generally result in higher monthly average chloride concentrations in the months of September through January, particularly in wet and above normal water year types, and similar or lower concentrations in the remaining months, compared to the No Action Alternative. While there would be higher chloride concentrations under Alternative 2, relative to the No Action Alternative, in some months, the CVP/SWP would continue operation, in real-time, to meet the Bay-Delta WQCP chloride objectives, which aim to protect municipal and industrial beneficial uses. In September through January, when chloride would be higher compared to the No Action Alternative, the maximum mean daily chloride objectives of 250 mg/l would continue to apply at Contra Costa Pumping Plant #1, Banks and Jones pumping plants, and Barker Slough at North Bay Aqueduct (SWRCB 2006:12). Also, the maximum mean daily chloride objective of 150 mg/l would continue to apply at Contra Costa Pumping Plant #1 or San Joaquin River at Antioch for a certain number of days per year, depending on water year type (SWRCB 2006). Thus, Alternative 2 would not contribute to the impairment of Delta waters' municipal and industrial beneficial uses.

Suisun Bay, Suisun Marsh, and San Francisco Bay waters are not designated for municipal and domestic supply uses, and other salinity-related effects in these waters are addressed above in the discussion for EC.

Potential Changes in Bromide

As discussed for Alternative 1, based on the EC levels modeled for Alternative 2, monthly average bromide concentrations at Delta drinking water intakes could be higher than those that would occur under the No Action Alternative, particularly in the fall. However, for the reasons provided for Alternative 1, it is expected that Alternative 2 would not contribute to drinking water impairments related to bromide, relative to those that would occur under the No Action Alternative.

Potential Changes in Methylmercury

Methylmercury concentrations in the Delta, and thus Suisun Bay and Marsh, and San Francisco Bay, could be affected by Alternative 2 through CVP/SWP operation. Unlike Alternative 1, this alternative does not include tidal habitat restoration.

Long-term average water column concentrations of methylmercury in the Delta under Alternative 2 would be the same as, or slightly (0.01 ng/l) lower than, those that would occur under the No Action Alternative (Appendix G, Attachment 1, Table G1.1-2). Thus, Alternative 2 would not contribute to higher concentrations of methylmercury in the Delta through changes in source water inflows to the Delta.

All modeled fish tissue concentrations exceed the water quality objective of 0.24 mg/kg under the No Action Alternative and Alternative 2, as shown by fish tissue concentration results presented in Appendix G, Attachment 1, Table G1.5-3, Methylmercury Concentrations in 350 millimeter Largemouth Bass Fillets for Alternative 2, and Comparison to No Action Alternative, and by the EQs plotted and provided in Appendix G, Attachment 1, Figures G1.5-1 and G1.5-2; all EQs are greater than 1.0. Under Alternative 2, fish tissue methylmercury concentrations would be from 1 to 7 % lower at all modeled locations, except San Joaquin River at Stockton and Barker Slough at North Bay Aqueduct Intake, where concentrations would be 1% higher than the No Action Alternative, for the entire period modeled (Appendix G, Attachment 1, Table G1.5-3). For the drought period modeled, fish tissue methylmercury concentrations would be from 1 to 10% lower at all modeled locations, except San Joaquin River at Stockton, where concentrations would be 1% higher than the No Action Alternative (Appendix G, Attachment 1, Table G1.5-3). Based on the overall lower methylmercury concentrations at almost all modeled Delta locations, water operations under Alternative 2 would not contribute to additional water quality degradation with respect to methylmercury, or increased health risks to wildlife or human consuming wildlife, as compared to the No Action Alternative. Thus, the differences in methylmercury in the Delta under Alternative 2, relative to the No Action Alternative, would not contribute to additional beneficial use impairments in the Delta.

Long-term average methylmercury concentrations in the western Delta under Alternative 2 would be similar to those that would occur under the No Action Alternative (Appendix G, Attachment 1, Table G1.1-2). Alternative 2 would result in lower Delta outflow rates, notably in the months of September, October, November, April, and May (Appendix F, Attachment 3-2, *Flow Results (CalSim II)*, Table 41-2). Thus, water operations under Alternative 2 would not contribute to additional water quality degradation with respect to methylmercury or increased bioaccumulation in biota in Suisun Bay and San Francisco Bay, as compared to the No Action Alternative.

Potential Changes in Selenium

Based on modeled Delta water concentrations, selenium concentrations in the Delta under Alternative 2 would be similar to or lower than those that would occur under the No Action Alternative (Appendix G, Attachment 2, Table G2.2-1). Further, long-term average selenium concentrations in the water column at the three western Delta locations under Alternative 2 would be identical to conditions under the No Action Alternative. Thus, Alternative 2 would not contribute to additional water quality degradation with respect to selenium, as compared to the No Action Alternative.

Modeled selenium concentrations in biota (whole-body fish, bird eggs [invertebrate diet], bird eggs [fish diet], and fish fillets) at all locations in the Delta under Alternative 2 are similar to those modeled for the No Action Alternative, as shown in Appendix G, Attachment 2, Table G2.3-2, Summary Table for Annual Average Selenium Concentrations in Biota for No Action Alternative and Alternative 2. EQs computed for the applicable toxicity benchmarks show that selenium concentrations in biota under both the No Action Alternative and Alternative 2 would be below the thresholds identified for ecological risk (Appendix G, Attachment 2, Tables G2.3-5, Summary Table for Selenium Concentrations in Biota, and Comparisons for No Action Alternative to Benchmarks, and G2.3-7, Summary Table for Selenium Concentrations in Biota, and Comparisons for Alternative 2 to No Action Alternative and Benchmarks, and Figures G2.3-1 through G2.3-4). Thus, Alternative 2 would not result in increased health risks to wildlife or human consuming wildlife associated with whole-body fish, bird eggs (invertebrate diet), bird eggs (fish diet), and fish fillets, as compared to the No Action Alternative.

Modeled selenium concentrations in whole-body Sturgeon in the western Delta under Alternative 2 also are similar to or slightly lower than those modeled for the No Action Alternative (Appendix G, Attachment 2, Table G2.3-10, *Summary of Period Average Selenium Concentrations in Whole-body*

Sturgeon, and G2.3-12*, Percent Change in Selenium Concentrations in Whole Body Sturgeon Relative to No Action Alternative*). Low Toxicity Threshold EQs are less than 1.0 for entire 82-year period modeled and slightly exceed 1.0 for drought period modeled (Appendix G, Attachment 2, Table G2.3-11, Comparison of Annual Average Selenium Concentrations in Whole-body Sturgeon to Toxicity Thresholds, and Figure G2.3-5, Low Toxicity Threshold Exceedance Quotients for Selenium Concentrations in Whole-body Sturgeon for Drought Years), but are similar for Alternative 2 and the No Action Alternative. Modeled EQs for the High Toxicity Threshold at all locations are less than 1.0 for the entire period modeled and the drought period modeled, and are also similar for Alternative 2 and the No Action Alternative. Thus, Alternative 2 would not result in increased health risks to wildlife or human consuming wildlife associated with sturgeon, as compared to the No Action Alternative.

Long-term average water column selenium concentrations in the western Delta under Alternative 2 would be similar to those that would occur under the No Action Alternative (Appendix G, Attachment 2, Table G2.2-1). Alternative 2 would result in lower Delta outflow rates, notably in the months of September, October, November, April, and May (Appendix F, Attachment 3-2, *Flow Results (CalSim II)*, Table 41-2). Thus, Alternative 2 would not contribute to additional water quality degradation with respect to selenium or increased bioaccumulation in biota in Suisun Bay and San Francisco Bay, as compared to the No Action Alternative.

Potential Changes in Trace Metals

For the same reasons described for Alternative 1, Alternative 2 would not affect existing Delta impairments related to trace metals, and would not result in additional trace metals-related impairments in the Delta, Suisun Bay and Marsh, or San Francisco Bay, relative to the No Action Alternative.

Potential Changes in Nutrients

For the same reasons described for Alternative 1, Alternative 2 would not contribute to different Delta nutrient concentrations or nutrient distributions that would result in adverse effects to beneficial uses or substantially degrade the water quality, relative to nutrient conditions that would occur under the No Action Alternative. Further, any potential differences in total nitrogen and phosphorus loading that would occur in Delta outflow to Suisun Bay and Marsh, and San Francisco Bay, relative to the No Action Alternative, are not expected to result in water quality degradation with regard to nutrients that would result in adverse effects to beneficial uses or the further impairment of Suisun Bay and Marsh, or San Francisco Bay.

Potential Changes in Dissolved Oxygen

For the same reasons described for Alternative 1, Alternative 2 would not substantially affect dissolved oxygen concentrations in the Delta, Suisun Bay and Marsh, or San Francisco Bay, or make existing dissolved oxygen impairments in the Delta and Suisun Marsh worse, relative to the No Action Alternative.

Potential Changes in Pathogens

For the same reasons described for Alternative 1, Alternative 2 would not substantially affect pathogen levels in the Delta, Suisun Bay and Marsh, or San Francisco Bay, relative to the No Action Alternative.

Potential Changes in Legacy Contaminants

For the same reasons described for Alternative 1, Alternative 2 would not substantially affect levels of legacy contaminants (e.g., dioxin and furan compounds, PCBs, and PAHs) in the Delta, Suisun Bay and Marsh, or San Francisco Bay, relative to the No Action Alternative.

Potential Changes in Pesticides

For the same reasons described for Alternative 1, Alternative 2 would not substantially affect pesticide concentrations in the Delta, Suisun Bay and Marsh, or San Francisco Bay, relative to the No Action Alternative. Note that under Alternative 2, the Clifton Court Aquatic Weed program discussed in the Alternative 1 pesticides assessment would not be implemented.

Potential Changes in Organic Carbon

For the same reasons described for Alternative 1, Alternative 2 would not result in differences in organic carbon concentrations in the Delta, Suisun Bay and Marsh, or San Francisco Bay, relative to the No Action Alternative, that would adversely affect beneficial uses.

G.2.4.2 *Program-Level Effects*

Alternative 2 does not include program-level components. Thus, there would be no program-level effects to water quality under Alternative 2.

G.2.5 Alternative 3

G.2.5.1 *Project-Level Effects*

Potential Changes in water quality

Alternatives 2 and 3 have almost identical flow changes compared to the No Action Alternative (Figures G.2-1 through G.2-36). The difference between the alternatives is related to the habitat restoration actions included in the program-level analysis. The analysis of project-level impacts for Alternative 2 in the Trinity River, Sacramento River, Clear Creek, Feather River, American River, Stanislaus River, and CVP/SWP service areas is the same as described above for Alternative 2. The analysis below focuses on the Bay-Delta region.

G.2.5.1.1 <u>Bay Delta</u>

Potential Changes in EC

Delta

Monthly average EC levels in the Sacramento River at Emmaton would often be substantially higher in September through December of wet and above normal water year types under Alternative 3, relative to the No Action Alternative (Appendix F, Attachment 3-6, Table 4-3, Figures 4-2, 4-3, 4-15 through 4-18). Monthly average EC levels in January of below normal, dry, and critical water year types also would be substantially higher relative to the No Action Alternative (Appendix F, Attachment 3-6, Table 4-3, Figure 4-7). Monthly average EC levels in February through August under Alternative 3 would be similar to or lower than the No Action Alternative EC levels (Appendix F, Attachment 3-6, Table 4-3, Figures 4-8 through 4-14).

Monthly average EC levels in the San Joaquin River at Vernalis under Alternative 3 would, overall, be similar to levels that would occur under the No Action Alternative, except in October, when EC levels would be substantially higher than the No Action Alternative (Appendix F, Attachment 3-6, Table 6-3, Figures 6-1 through 6-18). Somewhat higher monthly EC levels would occur in March through June under Alternative 3, relative to the No Action Alternative (Appendix F, Attachment 3-6, Table 6-3, Figures 6-9 and 6-12).

Monthly average EC levels in the San Joaquin River at Jersey Point, like the Sacramento River at Emmaton, would often be substantially higher in September through December of wet and above normal water year types under Alternative 3, relative to the No Action Alternative (Appendix F, Attachment 3-6, Table 7-3, Figures 7-2, 7-3, 7-15 through 7-18). February, March, April, May, and June would also see somewhat higher EC levels under Alternative 3, relative to the No Action Alternative (Appendix F, Attachment 3-6, Table 7-3, Figures 7-8 through 7-12).

Monthly average EC levels at the Banks and Jones pumping plants under Alternative 3, relative to the No Action Alternative, would be higher in September through December, most notably in wet and above normal water year types (Appendix F, Attachment 3-6, Tables 15-3 and 16-3, Figures 15-2, 15-3, 16-2, and 16-3). In February through August, monthly average EC levels under Alternative 3 would be similar to or lower than No Action Alternative EC levels (Appendix F, Attachment 3-6, Tables 15-3 and 16-3, Figures 15-8 through 15-14 and 16-8 through 16-14).

While there would be higher monthly average EC levels under Alternative 3 relative to the No Action Alternative, in some months, the CVP/SWP would continue operation, in real-time, to meet the Bay-Delta WQCP EC objectives, which aim to protect agricultural and fish and wildlife beneficial uses. The western Delta EC objectives for the Sacramento River at Emmaton and San Joaquin River at Jersey Point for agricultural beneficial use protection apply from April through June, July, or August, depending on water year type (SWRCB 2006). The San Joaquin River at Jersey Point objective for fish and wildlife protection also applies during April and May (SWRCB 2006). During these months, the monthly average EC levels under Alternative 3 would be similar to the No Action Alternative (Appendix F, Attachment 3-6, Tables 4-3 and 7-3). The southern Delta EC objectives for the protection of agricultural uses for the San Joaquin River at Vernalis and the export area for Banks and Jones pumping plant apply year-round. Banks and Jones pumping plants would have higher EC levels in the fall, but lower monthly average EC in spring and summer, relative to the No Action Alternative (Appendix F, Attachment 3-6, Tables 15-3 and 16-3), and monthly average EC levels at Vernalis under Alternative 3 would overall be similar to the No Action Alternative, except in October, when EC levels would be somewhat higher than the No Action Alternative (Appendix F, Attachment 3-6, Table 6-3). Thus, the differences in EC in the Delta under Alternative 3, relative to the No Action Alternative, would not contribute to agricultural or fish and wildlife beneficial use impairments in the Delta.

Suisun Marsh

In the Sacramento River at Collinsville, a Bay-Delta WQCP compliance location for the eastern portion of Suisun Marsh, monthly average EC levels would be substantially higher under Alternative 3, relative to the No Action Alternative, in September through December of wet and above normal water year types (Appendix F, Attachment 3-6, Table 11-3, Figures 11-2 and 11-3). The EC differences would occur primarily at the low end of the modeled EC range; there is little difference between the upper monthly average EC levels at Collinsville under Alternative 3, relative to the No Action Alternative (Appendix F, Attachment 3-6, Figures 11-15 through 11-18). Higher monthly average EC levels would also occur in December through May of all water year types under Alternative 3, relative to the No Action Alternative (Appendix F, Attachment 3-6, Table 11-3, Figures 11-7 through 11-11, and 11-18).

Suisun Bay and San Francisco Bay

Based on the modeling results discussed above, the EC of Delta outflow under Alternative 3 may be different than what would occur under the No Action Alternative in certain months of certain water year types. Also, Alternative 3 would result in lower Delta outflow rates, relative to the No Action Alternative (Appendix F, Attachment 3-2, *Flow Results (CalSim II)*, Table 41-3). These differences in Delta EC and outflow could cause the freshwater-seawater salinity gradient within Suisun Bay and the northern portion of San Francisco Bay to differ between Alternative 3 and the No Action Alternative. These differences are not expected to result in substantial changes in overall salinity conditions within Suisun Bay and San Francisco Bay, because seawater is the bays' predominant salinity source.

Potential Changes in Chloride

The discussion below assesses the differences between chloride at the five assessment locations – Contra Costa Pumping Plant #1, San Joaquin River at Antioch, Banks and Jones pumping plants, and North Bay Aqueduct – under Alternative 3 as compared to the No Action Alternative. The assessment is based on modeling results presented in Appendix F*,* Attachment 3-10, *Salinity Results (DSM2)*.

Monthly average chloride concentrations at Contra Costa Pumping Plant #1 would often be substantially higher in October through December of wet and above normal water year types, and somewhat higher in September, January, and February of all water year types under Alternative 3, relative to the No Action Alternative (Appendix F, Attachment 3-10, Table 19-3, Figures 19-1 through 19-18). In April and May of all water year types, chloride concentrations would be somewhat lower than would occur under the No Action Alternative (Appendix F, Attachment 3-10, Table 19-3, Figures 19-10 and 19-11). Monthly average chloride concentrations in the months of March and June through August would be similar to concentrations under the No Action Alternative (Appendix F, Attachment 3-10, Table 19-3, Figures 19-9, and 19-12 through 19-14).

Monthly average chloride concentrations in the San Joaquin River at Antioch would often be substantially higher in September through December of wet and above normal water year types under Alternative 3, relative to the No Action Alternative (Appendix F, Attachment 3-10, Table 20-3, Figures 20-2 and 20-3). In the months of December through May, monthly average chloride concentrations would also be somewhat higher in all water year types (Appendix F, Attachment 3-10, Table 20-3, Figures 20-7 through 20-11 and 20-18).

Monthly average chloride concentrations at Banks and Jones pumping plants would be somewhat higher in September through January of all water year types under Alternative 3, relative to the No Action Alternative (Appendix F, Attachment 3-10, Tables 21-3 and 22-3, Figures 21-1 through 21-18 and 22-1 through 22-18). In February through August, monthly average chloride concentrations under Alternative 3 would be similar to or lower than those that would occur under the No Action Alternative (Appendix F, Attachment 3-10, Tables 21-3 and 22-3, Figures 21-8 through 21-14 and 22-8 through 22-14).

Monthly average chloride concentrations in Barker Slough at the North Bay Aqueduct under Alternative 3 would be slightly lower than those that would occur under the No Action Alternative (Appendix F, Attachment 3-10, Table 23-3, Figures 23-1 through 23-18).

In summary, Alternative 3 would generally result in higher monthly average chloride concentrations in the months of September through January, particularly in wet and above normal water year types, and similar or lower concentrations in the remaining months, as compared to the No Action Alternative. While there would be higher chloride concentrations under Alternative 3 relative to the No Action Alternative, in some months, the CVP/SWP would operate in real-time to meet the Bay-Delta WQCP chloride objectives, which aim to protect municipal and industrial beneficial uses. In September through January, when chloride would be higher compared to the No Action Alternative, the maximum mean daily chloride objectives of 250 mg/l would continue to apply at Contra Costa Pumping Plant #1, Banks and Jones pumping plants, and Barker Slough at North Bay Aqueduct (SWRCB 2006). Also, the maximum mean daily chloride objective of 150 mg/l would continue to apply at Contra Costa Pumping Plant #1 or San Joaquin River at Antioch for a certain number of days per year, depending on water year type (SWRCB 2006). Thus, Alternative 3 would not contribute to municipal and industrial beneficial uses of Delta waters impairment.

Suisun Bay, Suisun Marsh, and San Francisco Bay waters are not designated for municipal and domestic supply uses, and other salinity-related effects in these waters are addressed above in the EC discussion.

Potential Changes in Bromide

As discussed for Alternative 1, based on the EC levels modeled for Alternative 3, monthly average bromide concentrations at Delta drinking water intakes could be higher than those that would occur under the No Action Alternative, particularly in the fall. However, for the reasons provided for Alternative 1, Alternative 3 would not be expected to contribute to drinking water impairments related to bromide, relative to those that would occur under the No Action Alternative.

Potential Changes in Methylmercury

Long-term average water column methylmercury concentrations in the Delta under Alternative 3 would be the same as, or slightly (0.01 ng/l) lower than, those that would occur under the No Action Alternative (Appendix G, Attachment 1, Table G1.1-2). Thus, Alternative 3 would not contribute to higher methylmercury concentrations in the Delta through changes in source water inflows.

All modeled fish tissue concentrations exceed the water quality objective of 0.24 mg/kg under the No Action Alternative and Alternative 3, as shown by fish tissue concentration results presented in Appendix G, Attachment 1, Table G1.5-4, Methylmercury Concentrations in 350 millimeter Largemouth Bass Fillets for Alternative 3, and Comparison to No Action Alternative, and the EQs plotted and provided in Appendix G, Attachment 1, Figures G1.5-1 and G1.5-2; all EQs are greater than 1.0. Under Alternative 3, fish tissue methylmercury concentrations would be from 0 to 12% lower at all modeled locations, except San Joaquin River at Stockton, where concentrations would be 0.2% higher, as compared to the No Action Alternative, for the entire period modeled (Appendix G, Attachment 1, Table G1.5-4). For the drought period modeled, fish tissue methylmercury concentrations would be from 0 to 15% lower at all modeled locations, except San Joaquin River at Stockton, where the concentration would be 1% higher, as compared to the No Action Alternative (Appendix G, Attachment 1, Table G1.5-4). Based on the overall lower methylmercury concentrations at almost all modeled Delta locations, water operations under Alternative 3 would not contribute to additional water quality degradation with respect to methylmercury, or in increased health risks to wildlife or humans consuming wildlife, as compared to the No Action Alternative. Thus, the differences in methylmercury in the Delta under Alternative 3, relative to the No Action Alternative, would not contribute to additional beneficial use impairments in the Delta.

Long-term average water column methylmercury concentrations in the western Delta under Alternative 3 would be similar to those that would occur under the No Action Alternative (Appendix G, Attachment 1, Table G1.1-2). Alternative 3 would result in lower Delta outflow rates, notably in September, October, November, April, and May (Appendix F, Attachment 3-2, *Flow Results (CalSim II)*, Table 41-3). Thus, water operations under Alternative 3 would not contribute to additional water quality degradation with respect to methylmercury or increased biota bioaccumulation in Suisun Bay and San Francisco Bay, as compared to the No Action Alternative.

Potential Changes in Selenium

Based on modeled Delta water concentrations, selenium concentrations in the Delta under Alternative 3 would be similar to or lower than those that would occur under the No Action Alternative (Appendix G, Attachment 2, Table G2.2-1). Long-term average selenium concentrations in the water column at the three western Delta locations under Alternative 3 would be the same as or lower than those that would occur under the No Action Alternative. Thus, Alternative 3 would not contribute to additional water quality degradation with respect to selenium, as compared to the No Action Alternative.

Modeled selenium concentrations in biota (whole-body fish, bird eggs [invertebrate diet], bird eggs [fish diet], and fish fillets) at all locations in the Delta under Alternative 3 are similar to those modeled for the No Action Alternative, as shown in Appendix G, Attachment 2, Table G2.3-3, Summary Table for Annual Average Selenium Concentrations in Biota for No Action Alternative and Alternative 3. Also, EQs computed for the applicable toxicity benchmarks show that selenium concentrations in biota under both the No Action Alternative and Alternative 3 would be below the thresholds identified for ecological risk (Appendix G, Attachment 2, Tables G2.3-5, Summary Table for Selenium Concentrations in Biota, and Comparisons for No Action Alternative to Benchmarks, and G2.3-8, Summary Table for Selenium Concentrations in Biota, and Comparisons for Alternative 3 to No Action Alternative and Benchmarks, and Figures G2.3-1 through G2.3-4). Thus, Alternative 3 would not result in increased health risks to wildlife that consuming wildlife associated with whole-body fish, bird eggs (invertebrate diet), bird eggs (fish diet), and fish fillets, as compared to the No Action Alternative.

Modeled selenium concentrations in whole-body sturgeon in the western Delta under Alternative 3 also are similar to or slightly lower than those modeled for the No Action Alternative (Appendix G, Attachment 2, Tables G2.3-10 and G2.3-12). Low Toxicity Threshold EQs are less than 1.0 for entire 82-year period modeled and slightly exceed 1.0 for drought period modeled (Appendix G, Attachment 2, Table G2.3-11, Figure G2.3-5), but are similar for Alternative 3 and the No Action Alternative. Modeled EQs for the High Toxicity Threshold at all locations are less than 1.0 for the entire period modeled and the drought period modeled, and are similar for Alternative 3 and the No Action Alternative. Thus, Alternative 3 would not result in increased health risks to wildlife or human consuming wildlife associated with sturgeon, as compared to the No Action Alternative.

Long-term average water column selenium concentrations in the western Delta under Alternative 3 would be similar to those that would occur under the No Action Alternative (Appendix G, Attachment 2, Table G2.2-1). Alternative 3 would result in lower Delta outflow rates, notably in September, October, November, April, and May (Appendix F, Attachment 3-2, *Flow Results (CalSim II)*, Table 41-3). Thus, Alternative 3 would not contribute to additional water quality degradation with respect to selenium or increased biota bioaccumulation in Suisun Bay and San Francisco Bay, as compared to the No Action Alternative.

Potential Changes in Trace Metals

For the same reasons described for Alternative 1, Alternative 3 would not affect existing Delta impairments related to trace metals, and would not result in additional trace metals-related impairments in the Delta, Suisun Bay and Marsh, or San Francisco Bay, relative to the No Action Alternative.

Potential Changes in Nutrients

For the same reasons described for Alternative 1, Alternative 3 would not contribute to different Delta nutrient concentrations or nutrient distributions that would adversely affect beneficial uses or substantially degrade the water quality, relative to the nutrient conditions that would occur under the No Action

Alternative. Further, any potential differences in total nitrogen and phosphorus loading that would occur in Delta outflow to Suisun Bay and Marsh, and San Francisco Bay, relative to the No Action Alternative, are not expected to degrade water quality with regard to nutrients that would create adverse effects to beneficial uses or further impair Suisun Bay and Marsh, or San Francisco Bay.

Potential Changes in Dissolved Oxygen

For the same reasons described for Alternative 1, Alternative 3 would not substantially affect dissolved oxygen concentrations in the Delta, Suisun Bay and Marsh, or San Francisco Bay, or make existing dissolved oxygen impairments in the Delta and Suisun Marsh worse, relative to the No Action Alternative.

Potential Changes in Pathogens

For the same reasons described for Alternative 1, Alternative 3 would not substantially affect pathogen levels in the Delta, Suisun Bay and Marsh, or San Francisco Bay, relative to the No Action Alternative.

Potential Changes in Legacy Contaminants

For the same reasons described for Alternative 1, Alternative 3 would not substantially affect legacy contaminants levels (e.g., dioxin and furan compounds, PCBs, and PAHs) in the Delta, Suisun Bay and Marsh, or San Francisco Bay, relative to the No Action Alternative.

Potential Changes in Pesticides

For the same reasons described for Alternative 1, Alternative 3 would not substantially affect pesticide concentrations in the Delta, Suisun Bay and Marsh, or San Francisco Bay, relative to the No Action Alternative. Note that under Alternative 3, the Clifton Court Aquatic Weed program discussed in the Alternative 1 pesticides assessment would not be implemented.

Potential Changes in Organic Carbon

For the same reasons described for Alternative 1, Alternative 3 would not result in organic carbon concentration differences in the Delta, Suisun Bay and Marsh, or San Francisco Bay, relative to the No Action Alternative, that would adversely affect beneficial uses.

G.2.5.2 *Program-Level Effects*

Under Alternative 3, program level effects would include effects from intake lowering, habitat restoration, increased aquatic weed removal, the introduction of dredge material for turbidity, and construction activities associated with facility improvements. The Alternative 3 program-level components that would be implemented with the potential to affect water quality are primarily the same as those described for Alternative 1. The one difference is that the tidal habitat restoration area would be larger, thus the potential for methylmercury and organic carbon generation could be greater than the No Action Alternative, depending on the siting and design of the tidal habitat. Construction-related effects to water quality from the facility improvements and habitat restoration construction activities would be similar. While these could have short-term effects on water quality, including increased sedimentation and turbidity, the implementation of Mitigation Measures WQ-1, WQ-2, WQ-3, and WQ-4, described below in Section G.2.7, would reduce or eliminate the effects on water quality. Adverse effects on water quality and violations to water quality standards are not expected from program-level activities.

G.2.6 Alternative 4

G.2.6.1 *Project-Level Effects*

Potential Changes in water quality

G.2.6.1.1 Trinity River

Operations in the Trinity River under Alternative 4 would remain similar to those under the No Action Alternative, but flows may change in the spring of some years because Alternative 4 would increase flow targets on the Sacramento River system. The maximum average change in flows is modeled during February of above normal water year types, when flows are expected to increase by approximately 69%. Figures G.2-1 through G.2-6 illustrate flow changes. Increases in flows would be beneficial to water quality; therefore, no violations of existing water quality standards would occur.

G.2.6.1.2 Sacramento River

Changes in flow under Alternative 4 compared to the No Action Alternative in the Sacramento River would be similar to those seen under Alternatives 1-3, with increases in late winter and early spring and decreases during late fall and early winter. Under Alternative 4, average flows could decrease a maximum of 46% compared to the No Action Alternative. This decrease in flow would occur at Wilkins Slough during above normal water year types. Increases in flow are also expected under Alternative 4 during some months, especially during dry and critical water years. Figures G.2-7 through G.2-12 illustrate flow changes. Flow increases are beneficial to water quality because they dilute constituents of concern. Flow decreases would be relatively small or occur at times when they would not negatively affect water quality and increase the frequency of water quality thresholds exceedances in the Sacramento River.

G.2.6.1.3 Clear Creek

Flows in Clear Creek under Alternative 4 would increase as compared to the No Action Alternative. Under all water year types, flows are expected to increase substantially in the winter and spring. During above normal water years, the maximum average change in flows is expected to increase by approximately 365%. These increases in flow are expected because the flow targets include increased releases from Whiskeytown Lake into Clear Creek. Figures G.2-37 through G.2-42 illustrate changes in flow under Alternative 4. The analysis considers flow increases beneficial to water quality because they make more water available to dilute constituents of concern (i.e., mercury), therefore, no negative changes to existing water quality would occur.

G.2.6.1.4 Feather River

Alternative 4 would include flow targets that change the timing and quantity of the Lake Oroville release for the Feather River below the Thermalito outlet. Increases in flow compared to the No Action Alternative are expected during spring months of all water year types at both Feather River modeling locations. Increases in flow may be as high as 205% in April of below normal water years downstream of Thermalito Afterbay. Similar trends in spring increases in flow are apparent at the Sacramento River confluence, but to a lesser magnitude. Decreases in flow are expected in the summer and early fall, with a maximum decrease of 71% in September of wet water years. Decreases in flow in other water year types are expected to occur in late summer and fall to a lesser magnitude. Figures G.2-13 through G.2-18 illustrate monthly changes in Feather River flow. Flow increases are considered beneficial to water quality because they dilute constituents of concern, and flow decreases are expected when water conditions are wet or above normal and have less impact on water quality. Increased frequency of exceedances of water quality thresholds in the Feather River are not expected.

G.2.6.1.5 American River

In addition to the assumptions outlined under Alternative 1, the flow targets under Alternative 4 would cause changes in flow on the American River due to changes in Folsom Lake release. While decreases in flow are expected to be similar, if not identical to those under Alternative 1, increases in flow would be of greater magnitude than those seen under Alternative 1. Flows are expected to increase to a maximum of 56% during February of critical water years. Figures G.2-19 through G.2-24 present monthly changes in American River flow at H Street for all water year types under Alternative 4 compared to the No Action Alternative. Flow increases are beneficial to water quality because they dilute constituents of concern, and flow decreases would have a minor effect on water quality because they would occur when conditions are wet or above normal. Water quality standards in the American River are not expected to be exceeded with increased frequency.

G.2.6.1.6 Stanislaus River

Changes in flow under Alternative 4 would be identical to those seen under Alternative 1 because Alternative 4 includes the same Stepped Release Plan for the Stanislaus River. Stanislaus River flows at the mouth and below Goodwin Dam are expected to have a maximum increase of approximately 92% and a maximum decrease by approximately 62% compared to the No Action Alternative. Figures G.2-25 through G.2-30 show changes in flow below Goodwin Dam. While the evaluation considers a decrease in flows harmful to water quality because it reduces the dilution of constituents of concern, changes in flows are small enough and at times of year that they would not be expected to result in more water quality thresholds exceedances in Stanislaus River.

G.2.6.1.7 San Joaquin River

Flows in the San Joaquin River under Alternative 4 would be identical to those seen under Alternative 1. Flow change below the confluence with the Merced River and below Sack Dam would be less than 1%. At Vernalis, Alternative 4 would result in a small decrease in flows for all water year types, primarily during the summer months, May through September. Figures G.2-31 through G.2-36 illustrate flow changes at Vernalis. The minimal change in flow under Alternative 4 would not likely increase the frequency of water quality threshold exceedances in the San Joaquin River.

G.2.6.1.8 CVP and SWP Service Area (south to Diamond Valley)

Alternative 4 would generally result in higher monthly average chloride concentrations from September through January, particularly in wet and above normal water year types, and similar or lower concentrations in the remaining months, as compared to the No Action Alternative. Since this water is delivered to reservoirs for storage in the CVP/SWP reservoirs, reservoir chloride concentrations may increase. However, in some months, the CVP/SWP would continue to be operated in real-time to meet the Bay-Delta WQCP objectives for chloride, which aim to protect municipal and industrial beneficial uses. In September through January, when chloride would be higher compared to the No Action Alternative, the maximum mean daily chloride objectives of 250 mg/l would continue to apply at Contra Costa Pumping Plant #1, Banks and Jones pumping plants, and Barker Slough at North Bay Aqueduct (SWRCB 2006). Also, the maximum mean daily chloride objective of 150 mg/l would continue to apply at Contra Costa Pumping Plant #1 or San Joaquin River at Antioch for a certain number of days per year, depending on water year type (SWRCB 2006). Thus, Alternative 4 would not impair municipal and industrial beneficial uses of the CVP/SWP service area.

G.2.6.1.9 Bay Delta

Potential Changes in EC

Delta

Monthly average EC levels in the Sacramento River at Emmaton would often be substantially higher in September through December of wet and above normal water year types under Alternative 4, relative to the No Action Alternative (Appendix F, Attachment 3-6, Table 4-4, Figures 4-2, 4-3, 4-15 through 4-18). Monthly average EC levels in July through October of below normal, dry, and critical water year types also would be higher (Appendix F, Attachment 3-6, Table 4-4). Monthly average EC levels in February through June would be similar to or lower than the No Action Alternative EC levels (Appendix F, Attachment 3-6, Table 4-4, Figures 4-8 through 4-12).

Monthly average EC levels in the San Joaquin River at Vernalis under Alternative 4 would generally be like the levels occurring under the No Action Alternative (Appendix F, Attachment 3-6, Table 6-4, Figures 6-1 through 6-18). Somewhat higher monthly EC levels would occur in April through June of below normal water years, April through August of dry water years, and February through August of critical water years, relative to the No Action Alternative (Appendix F, Attachment 3-6, Table 6-4, and Figures 6-8 through 6-14).

Monthly average EC levels in the San Joaquin River at Jersey Point, like the Sacramento River at Emmaton, would often be substantially higher in September through December of wet and above normal water year types under Alternative 4, relative to the No Action Alternative (Appendix F, Attachment 3-6, Table 7-4, Figures 7-2, 7-3, 7-15 through 7-18). January, February, March, April, and June would also see somewhat higher EC levels relative to the No Action Alternative (Appendix F, Attachment 3-6, Table 7-4, Figures 7-7 through 7-10, and Figure 7-12).

Monthly average EC levels at the Banks and Jones pumping plants under Alternative 4, relative to the No Action Alternative, would be higher in September through December, most notably in wet and above normal water year types (Appendix F, Attachment 3-6, Tables 15-4 and 16-4, Figures 15-2, 15-3, 16-2, and 16-3). Monthly average EC levels in March through May in all water year types also would be higher under Alternative 4 (Appendix F, Attachment 3-6, Tables 15-4 and 16-4). In February, June, July, and August, monthly average EC levels would be similar to or lower than No Action Alternative EC levels (Appendix F, Attachment 3-6, Tables 15-4 and 16-4, Figures 15-8, 15-12 through 15-14, 16-8, and 16-12 through 16-14).

While there would be higher monthly average EC levels under Alternative 4 relative to the No Action Alternative, in some months, the CVP/SWP would continue operation in real-time to meet the Bay-Delta WQCP EC objectives, which aim to protect agricultural and fish and wildlife beneficial uses. The western Delta EC objectives for the Sacramento River at Emmaton and San Joaquin River at Jersey Point for agricultural beneficial use protection apply from April through June, July, or August, depending on water year type (SWRCB 2006:13). The San Joaquin River at Jersey Point objective for fish and wildlife protection also applies during April and May (SWRCB 2006:14). During these months, the monthly average EC levels under Alternative 4 would be similar to the No Action Alternative (Appendix F, Attachment 3-6, Tables 4-4 and 7-4). The southern Delta EC objectives to protect agricultural uses for the San Joaquin River at Vernalis and the export area for the Banks and Jones pumping plants apply year-round. Banks and Jones pumping plants would have higher EC levels in the fall and spring, and generally lower monthly average EC in summer, relative to the No Action Alternative (Appendix F, Attachment 3-6, Tables 15-4 and 16-4), and monthly average EC levels at Vernalis would overall be similar to the No Action Alternative (Appendix F, Attachment 3-6, Table 6-4). Thus, the differences in EC in the Delta under Alternative 4, relative to the No Action Alternative, would not contribute to agricultural or fish and wildlife beneficial use impairments in the Delta.

Suisun Marsh

In the Sacramento River at Collinsville, a Bay-Delta WQCP compliance location for the eastern portion of Suisun Marsh, monthly average EC levels would be substantially higher under Alternative 4, relative to the No Action Alternative, in September through December of wet and above normal water year types (Appendix F, Attachment 3-6, Table 11-4, Figures 11-2 and 11-3). The EC differences would occur primarily at the low end of the modeled EC range; there is little difference between the upper monthly average EC levels at Collinsville relative to the No Action Alternative (Appendix F, Attachment 3-6, Figures 11-15 through 11-18). Monthly average EC levels in January through June would overall be similar to No Action Alternative EC levels (Appendix F, Attachment 3-6, Table 11-4, Figures 11-7 through 11-12).

Suisun Bay and San Francisco Bay

Based on the modeling results discussed above, the EC of Delta outflow under Alternative 4 may be different than what would occur under the No Action Alternative in certain months of certain water year types. Also, Alternative 4 would result in lower Delta outflow rates in June through November and higher outflow rates in December through May (Appendix F, Attachment 3-2, *Flow Results (CalSim II)*, Table 41-4). These differences in Delta EC and outflow could cause the freshwater-seawater salinity gradient within Suisun Bay and the northern portion of San Francisco Bay to differ between Alternative 4 and the No Action Alternative. These differences are not expected to result in substantial changes in overall salinity conditions within Suisun Bay and San Francisco Bay, because seawater is the bays’ predominant salinity source.

Potential Changes in Chloride

The discussion below assesses the differences between chloride at the five assessment locations – Contra Costa Pumping Plant #1, San Joaquin River at Antioch, Banks and Jones pumping plants, and North Bay Aqueduct – under Alternative 4 as compared to the No Action Alternative. The assessment is based on modeling results presented in Appendix F, Attachment 3-10, *Salinity Results (DSM2)*.

Monthly average chloride concentrations at Contra Costa Pumping Plant #1 would often be substantially higher in October through December of wet and above normal water year types, and somewhat higher in March, April, and May of all water year types under Alternative 4, relative to the No Action Alternative (Appendix F, Attachment 3-10, Table 19-4, Figures 19-1 through 19-18). Monthly average chloride concentrations in February and June through August would be similar to or less than concentrations under the No Action Alternative (Appendix F, Attachment 3-10, Table 19-4, Figures 19-8, and 19-12 through 19-14).

Monthly average chloride concentrations in the San Joaquin River at Antioch would often be substantially higher in September through December of wet and above normal water year types under Alternative 4, (Appendix F, Attachment 3-10, Table 20-4, Figures 20-2 and 20-3). In January through August, monthly average chloride concentrations would be similar to or less than No Action Alternative concentrations (Appendix F, Attachment 3-10, Table 20-4, Figures 20-7 through 20-14).

Monthly average chloride concentrations at Banks and Jones pumping plants would be somewhat higher in October through December of wet and above normal water year types under Alternative 4, relative to the No Action Alternative (Appendix F, Attachment 3-10, Table 21-4 and Table 22-4, Figures 21-2, 21-3, 22-2, and 22-3). Monthly average chloride concentrations in March through May would be higher in all water year types (Appendix F, Attachment 3-10, Tables 21-4 and 22-4, Figures 21-1 through 21-6 and 22-1 through 22-6). In February and June through August, monthly average chloride concentrations would be similar to or lower than those that would occur under the No Action Alternative (Appendix F, Attachment 3-10, Tables 21-4 and 22-4, Figures 21-8, 21-12 through 21-14, 22-8, and 22-12 through 22-14).

Monthly average chloride concentrations in Barker Slough at the North Bay Aqueduct under Alternative 4 would be the same as those that would occur under the No Action Alternative (Appendix F, Attachment 3-10, Table 23-4, Figures 23-1 through 23-18).

Alternative 4 would generally result in higher monthly average chloride concentrations in October through December, particularly in wet and above normal water year types, and in March through May of all water year types, as compared to the No Action Alternative. In some months, the CVP/SWP would operate in real-time to meet the Bay-Delta WQCP chloride objectives, which aim to protect municipal and industrial beneficial uses. In October through December and March through May, when chloride would be higher compared to the No Action Alternative, the maximum mean daily chloride objectives of 250 mg/l would continue to apply at Contra Costa Pumping Plant #1, Banks and Jones pumping plants, and Barker Slough at North Bay Aqueduct (SWRCB 2006:12). Also, the maximum mean daily chloride objective of 150 mg/l would continue to apply at Contra Costa Pumping Plant #1 or San Joaquin River at Antioch for a certain number of days per year, depending on water year type (SWRCB 2006:12). Thus, Alternative 4 would not contribute to the impairment of using Delta waters for municipal and industrial beneficial uses.

Suisun Bay, Suisun Marsh, and San Francisco Bay waters are not designated for municipal and domestic supply uses, and other salinity-related effects in these waters are addressed above in the EC discussion.

Potential Changes in Bromide

As discussed for Alternative 1, based on the EC levels modeled for Alternative 4, monthly average bromide concentrations at Delta drinking water intakes could be higher than those that would occur under the No Action Alternative, particularly in the fall. However, for the reasons provided for Alternative 1, Alternative 4 would not be expected to contribute to drinking water impairments related to bromide, relative to those that would occur under the No Action Alternative.

Potential Changes in Methylmercury

Long-term average water column methylmercury concentrations in the Delta under Alternative 4 would be the nearly same (i.e., within 0.003 ng/L) as those that would occur under the No Action Alternative (Appendix G, Attachment 1, Table G1.1-2). Thus, Alternative 4 would not contribute to higher methylmercury concentrations in the Delta through changes in source water inflows.

All modeled fish tissue concentrations exceed the water quality objective of 0.24 mg/kg under the No Action Alternative and Alternative 4, as shown by fish tissue concentration results presented in Appendix G, Attachment 1, Table G1.5-5, *Methylmercury Concentrations in 350 millimeter Largemouth Bass Fillets for Alternative 4, and Comparison to No Action Alternative*, and the EQs plotted and provided in Appendix G, Attachment 1, Figures G1.5-1 and G1.5-2; all EQs are greater than 1.0. Compared to the No Action Alternative, Alternative 4, fish tissue methylmercury concentrations would be from 3.5% higher to 1.6% lower at all modeled locations for the entire period modeled (Appendix G, Attachment 1, Table G1.5-5). For the drought period modeled, fish tissue methylmercury concentrations would be from 1.4% higher to 0.9% lower than the No Action Alternative at all modeled locations (Appendix G, Attachment 1, Table G1.5-5).

The differences between the fish tissue methylmercury concentrations under Alternative 4, relative to the No Action Alternative, are expected to be within the uncertainty inherent in the modeling approach and would likely not be measurable in the environment. The bioaccumulation models contain multiple sources of uncertainty associated with their development related to analytical variability; temporal and/or seasonal variability in Delta source water concentrations of methylmercury; interconversion of mercury species (i.e., the non-conservative nature of methylmercury as a modeled constituent); and limited sample size (both in number of fish and time span over which the measurements were made). Although there is uncertainty in the models used, the results serve as reasonable approximations of a very complex process. Considering the uncertainty, the small (i.e., < 5%) differences in modeled fish tissue mercury concentrations should be interpreted to be within the uncertainty of the overall approach, and not predictive of actual adverse effects.

Based on the overall similar methylmercury concentrations at all modeled Delta locations, water operations under Alternative 4 would not contribute to additional water quality degradation with respect to methylmercury, or in increased health risks to wildlife or humans consuming wildlife, as compared to the No Action Alternative. Thus, the differences in methylmercury in the Delta between Alternative 4 and the No Action Alternative would not contribute to additional beneficial use impairments in the Delta.

Long-term average methylmercury concentrations in the western Delta under Alternative 4 would be similar to those under the No Action Alternative (Appendix G, Attachment 1, Table G1.1-2). Alternative 4 would result in lower Delta outflow rates in June through November and higher outflow rates in December through May (Appendix F, Attachment 3-2, *Flow Results (CalSim II)*, Table 41-4). The long-term average Delta outflow would be similar (Appendix F, Attachment 3-2, *Flow Results (CalSim II)*, Table 41-4). Thus, water operations would not contribute to additional water quality degradation with respect to methylmercury or increased biota bioaccumulation in Suisun Bay and San Francisco Bay, compared to the No Action Alternative.

Potential Changes in Selenium

Based on modeled Delta water concentrations, selenium concentrations in the Delta under Alternative 4 would be nearly the same (i.e., within 0.01 μg/L) those that would occur under the No Action Alternative (Appendix G, Attachment 2, Table G2.2-1). Long-term average selenium concentrations in the water column at the three western Delta locations under Alternative 4 would be the same as those that would occur under the No Action Alternative. Thus, Alternative 4 would not contribute to additional selenium-related water quality degradation, as compared to the No Action Alternative.

Modeled selenium concentrations in biota (whole-body fish, bird eggs [invertebrate diet], bird eggs [fish diet], and fish fillets) at all locations in the Delta under Alternative 4 are similar to those modeled for the No Action Alternative, as shown in Appendix G, Attachment 2, Table G2.3-4, *Summary Table for Annual Average Selenium Concentrations in Biota for No Action Alternative and Alternative 4*. Also, EQs computed for the applicable toxicity benchmarks show that selenium concentrations in biota under both the No Action Alternative and Alternative 4 would be below the thresholds identified for ecological risk (Appendix G, Attachment 2, Tables G2.3-5, *Summary Table for Selenium Concentrations in Biota, and Comparisons for No Action Alternative to Benchmarks* and G2.3-9, *Summary Table for Selenium Concentrations in Biota, and Comparisons for Alternative 4 to No Action Alternative and Benchmarks*, Figures G2.3-1 through G2.3-4). Thus, Alternative 4 would not result in increased health risks to wildlife that consume other wildlife associated with whole-body fish, bird eggs (invertebrate diet), bird eggs (fish diet), and fish fillets, compared to the No Action Alternative.

Modeled selenium concentrations in whole-body Sturgeon in the western Delta under Alternative 4 also are similar to those modeled for the No Action Alternative (Appendix G, Attachment 2, Tables G2.3-10 and G2.3-12). Low Toxicity Threshold EQs are less than 1.0 for entire 82-year period modeled and slightly exceed 1.0 for drought period modeled (Appendix G, Attachment 2, Table G2.3-11, Figure G2.3-5), but are similar for Alternative 4 and the No Action Alternative. Modeled EQs for the High Toxicity Threshold at all locations are less than 1.0 for the entire period modeled and the drought period modeled, and are similar for Alternative 4 and the No Action Alternative. Thus, Alternative 4 would not result in increased health risks to wildlife or humans consuming wildlife associated with sturgeon.

Long-term average water column selenium concentrations in the western Delta under Alternative 4 would be similar to those that would occur under the No Action Alternative (Appendix G, Attachment 2, Table G2.2-1). Alternative 4 would result in lower Delta outflow rates in June through November and higher outflow rates in December through May (Appendix F, Attachment 3-2, *Flow Results (CalSim II)*, Table 41-4). The long-term average Delta outflow would be similar (Appendix F, Attachment 3-2, *Flow Results (CalSim II)*, Table 41-4). Thus, Alternative 4 would not contribute to additional water quality degradation with respect to selenium or increased biota bioaccumulation in Suisun Bay and San Francisco Bay.

Potential Changes in Trace Metals

For the same reasons described for Alternative 1, Alternative 4 would not affect existing Delta impairments related to trace metals and would not result in additional trace metals-related impairments in the Delta, Suisun Bay and Marsh, or San Francisco Bay, relative to the No Action Alternative.

Potential Changes in Nutrients

For the same reasons described for Alternative 1 (see Section G.2.3.1.9), Alternative 4 would not contribute to different Delta nutrient concentrations or nutrient distributions that would adversely affect beneficial uses or substantially degrade the water quality, relative to the conditions that would occur under the No Action Alternative. Further, any potential differences in total nitrogen and phosphorus loading that would occur in Delta outflow to Suisun Bay and Marsh, and San Francisco Bay, relative to the No Action Alternative, are not expected to degrade water quality with regard to nutrients that would create adverse effects to beneficial uses or further impair Suisun Bay and Marsh, or San Francisco Bay.

Potential Changes in Dissolved Oxygen

For the same reasons described for Alternative 1, Alternative 4 would not substantially affect dissolved oxygen concentrations in the Delta, Suisun Bay and Marsh, or San Francisco Bay relative to the No Action Alternative. Alternative 4 would not make existing dissolved oxygen impairments in the Delta and Suisun Marsh worse.

Potential Changes in Pathogens

For the same reasons described for Alternative 1, Alternative 4 would not substantially affect pathogen levels in the Delta, Suisun Bay and Marsh, or San Francisco Bay, relative to the No Action Alternative.

Potential Changes in Legacy Contaminants

For the same reasons described for Alternative 1, Alternative 4 would not substantially affect legacy contaminants levels (e.g., dioxin and furan compounds, PCBs, and PAHs) in the Delta, Suisun Bay and Marsh, or San Francisco Bay, relative to the No Action Alternative.

Potential Changes in Pesticides

For the same reasons described for Alternative 1, Alternative 4 would not substantially affect pesticide concentrations in the Delta, Suisun Bay and Marsh, or San Francisco Bay, relative to the No Action Alternative. Under Alternative 4, the Clifton Court Aquatic Weed program discussed in the Alternative 1 pesticides assessment would not be implemented.

Potential Changes in Organic Carbon

For the same reasons described for Alternative 1, Alternative 4 would not result in organic carbon concentration differences in the Delta, Suisun Bay and Marsh, or San Francisco Bay, relative to the No Action Alternative, that would adversely affect beneficial uses.

G.2.6.2 *Program-Level Effects*

Under Alternative 4, program level effects would include the construction actions related to the increased water use efficiency component. This action would have the potential to similarly affect water quality program-level construction actions as actions under Alternative 1 and Alternative 3. While these could have short-term effects on water quality, including increased sedimentation and turbidity, implementing Mitigation Measures WQ-1, WQ-2, WQ-3, and WQ-4, described below in Section G.2.7, would reduce or eliminate the effects on water quality. Adverse effects on water quality and violations to water quality standards are not expected from Alternative 4 program-level activity.

G.2.7 Mitigation Measures

Mitigation Measure WQ-1: Implement a Spill Prevention, Control, and Countermeasure Plan.

A Spill Prevention, Control, and Countermeasure Plan (SPCCP) shall be developed and implemented to minimize the potential for, and effects from, spills of hazardous, toxic, and petroleum substances during construction and maintenance. The SPCCP will be completed before construction activities begin. SPCCP implementation will comply with State and Federal water quality regulations. The SPCCP will describe spill sources and spill pathways, as well as the actions that would be taken in the event of a spill (e.g., an oil spill from engine refueling will be cleaned up immediately with oil absorbents) or the exposure of an undocumented hazard. The SPCCP will describe containment facilities and practices, such as double-walled tanks, containment berms, emergency shut-offs, drip pans, fueling procedures, and spill response kits. It will also describe how and when employees will be trained in proper handling and spill prevention and response procedures.

The SPCCP will be reviewed and approved before the onset of construction activities and will routinely inspect the construction area to verify that the SPCCP measures are properly implemented and maintained. Contractors will be notified immediately if there is a noncompliance issue and will work to regain compliance.

If a spill is reportable, the construction contractor's superintendent will notify the Lead Agency, and will contact the appropriate safety and cleanup crews to ensure the SPCCP is followed. A written description of reportable releases will be submitted to the RWQCB and the California Department of Toxic Substances Control. This submittal will describe the release, including the type of material and an estimate of the amount spilled, state the date of the release, explain why the spill occurred, and outline the steps taken to prevent and control future releases. The releases will be documented on a spill report form.

Mitigation Measure WQ-2: Implement a Stormwater Pollution and Prevention Plan.

Prior to initiating construction and maintenance activities, the construction contractor will prepare a Stormwater Pollution and Prevention Plan (SWPPP) describing best management practices (BMPs) that will be implemented to control accelerated erosion, sedimentation, and other pollutants during and after project construction. Specific BMPs in the SWPPP will be site-specific and prepared in accordance with the regional water board field manual. The SWPPP will include the following standard erosion- and sediment-control BMPs:

- **Construction timing.** All construction and ongoing operations and maintenance activities will occur from April 15 through November 1 to avoid ground disturbance in the rainy season.
- **Grading spoils stabilization.** Grading spoils generated during construction may be temporarily stockpiled in staging areas. Such staging areas will not contain native or sensitive vegetation communities and will not support sensitive plant or animal species. Silt fences, non-monofilament fiber rolls, or similar devices will be installed around the base of the temporary stockpiles to intercept runoff and sediment during storm events. If necessary, temporary stockpiles may be covered with a geotextile material to increase protection from wind and water erosion. Materials used for stabilizing spoils will be selected to be non-injurious to wildlife
- **Permanent site stabilization.** The construction contractor will install structural or vegetative methods to permanently stabilize all graded or disturbed areas once construction is complete. Structural methods could include installing biodegradable fiber rolls or erosion-control blankets. Vegetative methods could include applying organic mulch and tackifiers, and/or an erosion-control native seed mix.
- **Construction equipment and materials staging.** Equipment and materials will be staged in designated staging areas that meet the requirements identified above for stabilizing grading spoils.
- **Minimizing soil and vegetation disturbance.** The construction contractor will minimize ground disturbance and the disturbance and/or destruction of existing vegetation. This will be accomplished, in part, through establishing designated equipment staging areas, ingress and egress corridors, equipment exclusion zones, and protecting existing trees before beginning grading operations.
- **Installing sediment barriers.** The construction contractor will install silt fences, fiber rolls, or similar devices to prevent sediment-laden water from leaving the construction area to the extent feasible in areas where construction occurs in saturated soils.

Mitigation Measure WQ-3: Develop a turbidity monitoring program.

The Basin Plan for the Sacramento River and San Joaquin River basins (Fourth Edition) (Central Valley RWQCB 2016) contains turbidity objectives. The plan states that where natural turbidity is between five and 50 NTUs, turbidity levels may not be elevated by 20% above ambient conditions; where ambient conditions are between 50 and 100 NTUs, conditions may not be increased by more than 10 NTUs; and where natural turbidity is greater than 100 NTUs, increases will not exceed 10%. A sampling plan shall be developed and implemented based on specific site conditions and in consultation with the RWQCB. If turbidity limits exceed basin plan standards, construction-related earth-disturbing activities will slow to a point that would alleviate the problem.

Mitigation Measure WQ-4: Develop a water quality mitigation and monitoring program.

A program shall be developed and implemented to reduce, minimize, or eliminate increases in water quality constituents. The program will develop a monitoring plan, including frequent sampling and reporting, particularly for existing constituents of concern. Reclamation will coordinate with the implementation of current TMDLs to share monitoring information and contribute to the efforts to reduce constituents of concern. Efforts could include water quality (through the water column), soil, and fish and invertebrate tissue monitoring.

G.2.8 Summary of Impacts

Table G.2-1, *Impact Summary*, includes a summary of impacts, the magnitude and direction of those impacts, and potential mitigation measures to consider.

Table G.2-1. Impact Summary

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
Project-Level Impacts			
Potential changes in water quality	No Action	No Impact	-
	1	Flow reductions in study area rivers from CVP/SWP operation changes would not result in water quality degradation.	-
	2	Flow reductions in Clear Creek and the Stanislaus River could result in water quality degradation.	-
	3	Flow reductions in Clear Creek and the Stanislaus River could result in water quality degradation.	-
	4	Flow reductions in study area rivers from CVP/SWP operation changes would not result water quality degradation.	-
Bay-Delta Region: Potential Changes in EC	No Action	No Impact	-
	1	Higher monthly average EC at certain Delta locations in certain months, relative to No Action Alternative: ● Sacramento River at Emmaton: substantially higher in September through December of wet and above normal water years. ● San Joaquin River at Vernalis: somewhat higher in April and May. ● San Joaquin River at Jersey Point: substantially higher in September through December of wet and above normal water years; somewhat higher in other months. ● Banks and Jones pumping plants: higher in September through January, most notably in wet and above normal years. ● Sacramento River at Collinsville: substantially higher in September through December of wet and above normal water years; somewhat higher in December through May of all water years. No substantial differences in overall Suisun Marsh, Suisun Bay and San Francisco Bay EC conditions expected.	-

<table>
<tr><th>Impact</th><th>Alternative</th><th>Magnitude and Direction of Impacts</th><th>Potential Mitigation Measures</th></tr>
<tr><td></td><td>2</td><td>Higher monthly average EC at certain Delta locations in certain months, relative to No Action Alternative:
Sacramento River at Emmaton: substantially higher in September through December of wet and above normal water years, and January of below normal, dry, and critical water years.
San Joaquin River at Vernalis: substantially higher in October, somewhat higher in March through June.
San Joaquin River at Jersey Point: substantially higher in September through December of wet and above normal water years; somewhat higher in February through June.
Banks and Jones pumping plants: higher in September through January, most notably in wet and above normal years.
Sacramento River at Collinsville: substantially higher in September through December of wet and above normal water years; somewhat higher in December through May of all water years.
No substantial differences in overall Suisun Marsh, Suisun Bay and San Francisco Bay EC conditions expected.</td><td>-</td></tr>
<tr><td></td><td>3</td><td>Higher monthly average EC at certain Delta locations in certain months, relative to No Action Alternative:
Sacramento River at Emmaton: substantially higher in September through December of wet and above normal water years, and January of below normal, dry, and critical water years.
San Joaquin River at Vernalis: substantially higher in October, somewhat higher in March through June.
San Joaquin River at Jersey Point: substantially higher in September through December of wet and above normal water years; somewhat higher in February through June.
Banks and Jones pumping plants: higher in September through January, most notably in wet and above normal years.
Sacramento River at Collinsville: substantially higher in September through December of wet and above normal water years; somewhat higher in December through May of all water years.
No substantial differences in overall Suisun Marsh, Suisun Bay and San Francisco Bay EC conditions expected.</td><td>-</td></tr>
</table>

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
	4	Higher monthly average EC at certain Delta locations in certain months, relative to No Action Alternative: ● Sacramento River at Emmaton: substantially higher in September through December of wet and above normal water years. ● San Joaquin River at Vernalis: somewhat higher in February through August. ● San Joaquin River at Jersey Point: substantially higher in September through December of wet and above normal water years; somewhat higher in February through June. ● Banks and Jones pumping plants: higher in September through December, and March through May. ● Sacramento River at Collinsville: substantially higher in September through December of wet and above normal water years. No substantial differences in overall Suisun Marsh, Suisun Bay and San Francisco Bay EC conditions expected.	-
Bay-Delta Region: Potential Changes in Chloride	No Action	No Impact	-
	1	Higher monthly average chloride at certain Delta locations in certain months, relative to No Action Alternative: ● Contra Costa Pumping Plant #1: substantially higher in October through December of wet and above normal water years; somewhat higher in September and January of all water years. ● San Joaquin River at Antioch: substantially higher in September through December of wet and above normal water years, somewhat higher in January through August of all water years. ● Banks and Jones pumping plants: higher in September through January of all water years. ● Barker Slough at North Bay Aqueduct: little to no difference. Salinity-related effects to Suisun Marsh, Suisun Bay, and San Francisco Bay addressed via evaluating effects to EC.	-

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
	2	Higher monthly average chloride at certain Delta locations in certain months, relative to No Action Alternative: • Contra Costa Pumping Plant #1: substantially higher in October through December of wet and above normal water years; somewhat higher in September, January, and February of all water years. • San Joaquin River at Antioch: substantially higher in September through December of wet and above normal water years, somewhat higher in December through May and August of all water years. • Banks and Jones pumping plants: higher in September through January of all water years. • Barker Slough at North Bay Aqueduct: little to no difference. Salinity-related effects to Suisun Marsh, Suisun Bay, and San Francisco Bay addressed via evaluating effects to EC.	-
	3	Higher monthly average chloride at certain Delta locations in certain months, relative to No Action Alternative: • Contra Costa Pumping Plant #1: substantially higher in October through December of wet and above normal water years; somewhat higher in September, January, and February of all water years. • San Joaquin River at Antioch: substantially higher in September through December of wet and above normal water years, somewhat higher in December through May of all water years. • Banks and Jones pumping plants: higher in September through January of all water years. • Barker Slough at North Bay Aqueduct: little to no difference. Salinity-related effects to Suisun Marsh, Suisun Bay, and San Francisco Bay addressed via evaluating effects to EC.	-

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
	4	Higher monthly average chloride at certain Delta locations in certain months, relative to No Action Alternative: • Contra Costa Pumping Plant #1: substantially higher in October through December of wet and above normal water years. • San Joaquin River at Antioch: substantially higher in September through December of wet and above normal water years. • Banks and Jones pumping plants: higher in October through December of wet and above normal water years, and March through May of all water years. • Barker Slough at North Bay Aqueduct: no difference. Salinity-related effects to Suisun Marsh, Suisun Bay, and San Francisco Bay addressed via evaluating effects to EC.	-
Bay-Delta Region: Potential Changes in Bromide	No Action	No Impact	-
	1	Potentially higher bromide concentrations at Delta export locations, as related to higher EC, relative to the No Action Alternative.	-
	2	Potentially higher bromide concentrations at Delta export locations, as related to higher EC, relative to the No Action Alternative.	-
	3	Potentially higher bromide concentrations at Delta export locations, as related to higher EC, relative to the No Action Alternative.	-
	4	Potentially higher bromide concentrations at Delta export locations, as related to higher EC, relative to the No Action Alternative.	-
Bay-Delta Region: Potential Changes in Methylmercury	No Action	No Impact	-
	1	Long-term average methylmercury concentrations in Delta water and fish tissues would be similar to or slightly lower than No Action Alternative; no additional degradation or bioaccumulation of methylmercury in Suisun Bay or San Francisco Bay, relative to the No Action Alternative.	-
	2	Long-term average methylmercury concentrations in Delta water and fish tissues would be similar to or slightly lower than No Action Alternative; no additional degradation or bioaccumulation of methylmercury in Suisun Bay or San Francisco Bay, relative to the No Action Alternative.	-

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
	3	Long-term average methylmercury concentrations in Delta water and fish tissues would be similar to or slightly lower than No Action Alternative; no additional degradation or bioaccumulation of methylmercury in Suisun Bay or San Francisco Bay, relative to the No Action Alternative.	-
	4	Long-term average methylmercury concentrations in Delta water and fish tissues would be similar to the No Action Alternative; no additional degradation or bioaccumulation of methylmercury in Suisun Bay or San Francisco Bay, relative to the No Action Alternative.	-
Bay-Delta Region: Potential Changes in Selenium	No Action	No Impact	-
	1	Long-term average selenium concentrations in Delta water, and bird egg and fish tissues would be similar to No Action Alternative; no additional degradation or bioaccumulation of selenium in Suisun Bay or San Francisco Bay, relative to the No Action Alternative.	-
	2	Long-term average selenium concentrations in Delta water, and bird egg and fish tissues would be similar to No Action Alternative; no additional degradation or bioaccumulation of selenium in Suisun Bay or San Francisco Bay, relative to the No Action Alternative.	-
	3	Long-term average selenium concentrations in Delta water, and bird egg and fish tissues would be similar to No Action Alternative; no additional degradation or bioaccumulation of selenium in Suisun Bay or San Francisco Bay, relative to the No Action Alternative.	-
	4	Long-term average selenium concentrations in Delta water, and bird egg and fish tissues would be similar to No Action Alternative; no additional degradation or bioaccumulation of selenium in Suisun Bay or San Francisco Bay, relative to the No Action Alternative.	-
Bay-Delta Region: Potential Changes in Trace Metals	No Action	No Impact	-
	1	Existing trace metals impairments would not be affected and no contributions to additional impairments would occur, relative to the No Action Alternative.	-

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
	2	Existing trace metals impairments would not be affected and no contributions to additional impairments would occur, relative to the No Action Alternative.	-
	3	Existing trace metals impairments would not be affected and no contributions to additional impairments would occur, relative to the No Action Alternative.	-
	4	Existing trace metals impairments would not be affected and no contributions to additional impairments would occur, relative to the No Action Alternative.	-
Bay-Delta Region: Potential Changes in Nutrients	No Action	No Impact	-
	1	Nutrients levels and distributions would not be substantially different from No Action Alternative conditions in the Delta; potentially lower nutrient loading to Suisun Marsh, Suisun Bay, and San Francisco Bay.	-
	2	Nutrients levels and distributions would not be substantially different from No Action Alternative conditions in the Delta; potentially lower nutrient loading to Suisun Marsh, Suisun Bay, and San Francisco Bay.	-
	3	Nutrients levels and distributions would not be substantially different from No Action Alternative conditions in the Delta; potentially lower nutrient loading to Suisun Marsh, Suisun Bay, and San Francisco Bay.	-
	4	Nutrients levels and distributions would not be substantially different from No Action Alternative conditions in the Delta; potentially lower nutrient loading to Suisun Marsh, Suisun Bay, and San Francisco Bay.	-
Bay-Delta Region: Potential Changes in Dissolved Oxygen	No Action	No Impact	-
	1	Dissolved oxygen levels in the Delta, Suisun Marsh, Suisun Bay, and San Francisco Bay would not be affected and existing impairments would not be made worse, relative to No Action Alternative conditions.	-
	2	Dissolved oxygen levels in the Delta, Suisun Marsh, Suisun Bay, and San Francisco Bay would not be affected and existing impairments would not be made worse, relative to No Action Alternative conditions.	-

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
	3	Dissolved oxygen levels in the Delta, Suisun Marsh, Suisun Bay, and San Francisco Bay would not be affected and existing impairments would not be made worse, relative to No Action Alternative conditions.	-
	4	Dissolved oxygen levels in the Delta, Suisun Marsh, Suisun Bay, and San Francisco Bay would not be affected and existing impairments would not be made worse, relative to No Action Alternative conditions.	-
Bay-Delta Region: Potential Changes in Pathogens	No Action	No Impact	-
	1	Would not contribute to higher pathogens levels in the Delta, Suisun Marsh, Suisun Bay, and San Francisco Bay, relative to the No Action Alternative.	-
	2	Would not contribute to higher pathogens levels in the Delta, Suisun Marsh, Suisun Bay, and San Francisco Bay, relative to the No Action Alternative.	-
	3	Would not contribute to higher pathogens levels in the Delta, Suisun Marsh, Suisun Bay, and San Francisco Bay, relative to the No Action Alternative.	-
	4	Would not contribute to higher pathogens levels in the Delta, Suisun Marsh, Suisun Bay, and San Francisco Bay, relative to the No Action Alternative.	-
Delta, Suisun Bay and Marsh, and San Francisco Bay: Potential Changes in Legacy Contaminants	No Action	No Impact	-
	1	Levels of legacy contaminants (dioxin and furan compounds, PCBs, and PAHs) in the Delta, Suisun Marsh, Suisun Bay, and San Francisco Bay would not be substantially affected, relative to the No Action Alternative.	-
	2	Levels of legacy contaminants (dioxin and furan compounds, PCBs, and PAHs) in the Delta, Suisun Marsh, Suisun Bay, and San Francisco Bay would not be substantially affected, relative to the No Action Alternative.	-

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
	3	Levels of legacy contaminants (dioxin and furan compounds, PCBs, and PAHs) in the Delta, Suisun Marsh, Suisun Bay, and San Francisco Bay would not be substantially affected, relative to the No Action Alternative.	-
	4	Levels of legacy contaminants (dioxin and furan compounds, PCBs, and PAHs) in the Delta, Suisun Marsh, Suisun Bay, and San Francisco Bay would not be substantially affected, relative to the No Action Alternative.	-
Delta, Suisun Bay and Marsh, and San Francisco Bay: Potential Changes in Pesticides	No Action	No Impact	-
	1	No substantial increased risk of higher pesticide concentrations or pesticide-related toxicity in the Delta, Suisun Marsh, Suisun Bay, and San Francisco Bay, relative to the No Action Alternative.	-
	2	No substantial increased risk of higher pesticide concentrations or pesticide-related toxicity in the Delta, Suisun Marsh, Suisun Bay, and San Francisco Bay, relative to the No Action Alternative.	-
	3	No substantial increased risk of higher pesticide concentrations or pesticide-related toxicity in the Delta, Suisun Marsh, Suisun Bay, and San Francisco Bay, relative to the No Action Alternative.	-
	4	No substantial increased risk of higher pesticide concentrations or pesticide-related toxicity in the Delta, Suisun Marsh, Suisun Bay, and San Francisco Bay, relative to the No Action Alternative.	-
Delta, Suisun Bay and Marsh, and San Francisco Bay: Potential Changes in Organic Carbon	No Action	No Impact	-
	1	No substantial changes in total organic carbon concentrations in the Delta or Suisun Marsh; could result in lower organic carbon loading to Suisun Bay and San Francisco Bay.	-
	2	No substantial changes in total organic carbon concentrations in the Delta or Suisun Marsh; could result in lower organic carbon loading to Suisun Bay and San Francisco Bay.	-

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
	3	No substantial changes in total organic carbon concentrations in the Delta or Suisun Marsh; could result in lower organic carbon loading to Suisun Bay and San Francisco Bay.	-
	4	No substantial changes in total organic carbon concentrations in the Delta or Suisun Marsh; could result in lower organic carbon loading to Suisun Bay and San Francisco Bay.	-
Program-Level Impacts			
Potential changes in water quality	No Action	No Impact	
	1	Program-level actions and construction activities could affect water quality, including turbidity, mercury and selenium bioaccumulation, dissolved organic carbon, and increased sedimentation.	MM WQ-1; MM WQ-2; MM WQ-3; MM WQ-4.
	2	No program-level actions proposed.	-
	3	Program-level actions and construction activities could affect water quality, including turbidity, mercury and selenium bioaccumulation, dissolved organic carbon, and increased sedimentation.	MM WQ-1; MM WQ-2; MM WQ-3; MM WQ-4.
	4	Program-level actions and construction activities could affect water quality, including turbidity and increased sedimentation.	MM WQ-1; MM WQ-2; MM WQ-3; MM WQ-4.

G.2.9 Cumulative Effects

Population growth, climate change, changes in water quality regulations, and past, present, and reasonably foreseeable projects, described in Appendix Y, *Cumulative Methodology,* may change water quality conditions in the study area. The cumulative projects include actions across California to reduce water quality issues, including Bay-Delta Water Quality Control Plan Update, FERC Relicensing Projects, agricultural drainage programs, and San Luis Reservoir Low Point Improvement Project. The cumulative projects also include numerous projects to reduce water quality issues related to nutrients, agricultural drainage, and other discharges of constituents of concern.

Collectively, these cumulative projects are anticipated to generate direct or indirect improvements in local or broader regional water quality conditions. Their construction could generate potential short-term impacts to water quality, but mitigation measures and best management practices will reduce the potential impacts. The combined water quality effects of past, present, and reasonably foreseeable future projects will vary. Some projects will potentially contribute to the degradation of various water quality parameters, whereas other projects will improve water quality in certain areas. Population growth is expected to produce increased constituent loadings to surface waters through increased urban stormwater runoff, increased municipal wastewater treatment plant discharges, and changes in land uses. Regulations, programs, and projects will aim to control pollutant discharges to surface waters and improve or maintain water quality conditions.

The No Action Alternative would generate no changes to water operations and there would be no improvement in the existing limits on water supply availability affecting CVP and SWP water users. There would also be no change to the water quality conditions that currently contribute to the limits on water supply deliveries. This includes water quality concerns within the study area that currently impact beneficial uses. Newly created tidal habitat under the No Action Alternative could potentially lead to new sources of localized organic carbon loading within the Delta. However, the degree to which new tidal habitat areas may be future sources of organic carbon for the Delta's aquatic environment is uncertain. In addition, adding tidal habitat under the No Action Alternative could result in increased mercury methylation within the Delta, increased biotic exposure to and uptake of methylmercury, ultimately resulting in increased mercury bioaccumulation in fish tissues. Tidal habitat design and location considerations would minimize any addition of dissolved organic carbon at drinking water supply intakes and biota methylmercury bioaccumulation. Thus, the No Action Alternative would have no contribution to the cumulative water quality condition.

Alternative 2 would negatively affect water quality in Clear Creek and the Stanislaus River by reducing flows in all water year types. This flow reduction could result in less dilution, causing increased constituents of concern concentrations within Clear Creek and the Stanislaus River compared to current conditions. Flow reductions could lead to an increase in the frequency of exceedances of water quality standards and negatively impact assigned beneficial uses. Alternative 2's contribution to water quality degradation would not be substantial. When considered in combination with the other projects in this assessment, the contribution made by Alternative 2 would not be substantial because these projects are intended to improve overall water quality conditions.

Alternatives 1, 3, and 4 would have similar or less impact compared to Alternative 2. They would not generate substantial contributions to cumulative water quality conditions in the Trinity River, Sacramento River, Clear Creek, Feather River, American River, Stanislaus River, and San Joaquin River areas. When considered in combination with the other projects in this assessment, the contribution made by Alternatives 1, 3, and 4 would not be substantial because these projects are intended to improve overall water quality conditions.

Specific to the CVP and SWP Service Area, all action alternatives would result in high chloride concentrations during some months. However, the CVP/SWP would continue operation, in real-time, to meet the Bay-Delta WQCP objectives for chloride, which aim to protect municipal and industrial beneficial uses. Thus, all action alternatives would not generate substantial contributions to cumulative water quality conditions in the CVP and SWP Service Area.

Specific to the Bay-Delta region, the project alternatives would have negligible, if any, effects on trace metals, dissolved oxygen, pathogens, pesticides, or legacy contaminants (i.e., dioxin and furan compounds, PCBs, and PAHs). Thus, the project alternatives would not have an effect on the future cumulative conditions of these constituents and constituent groups. However, the project alternatives could have some effect on EC, chloride, bromide, methylmercury, selenium, nutrients, and organic carbon, in the Delta, Suisun Marsh, Suisun Bay, and/or San Francisco Bay.

G.2.9.1 *Salinity-Related Parameters: EC, Chloride, and Bromide*

The western, northwestern, southern, and export area portions of the Delta are on the SWRCB's CWA section 303(d) list as impaired due to elevated EC/salinity. Suisun Marsh is listed as impaired due to salinity and chloride (SWRCB 2017a). Bromide is not specifically identified as a constituent contributing to impairment, but is also a salinity-related parameter, so is addressed with EC and chloride. Climate change is anticipated to cause an increase in EC/chloride/salinity in the western and southern due to sea level rise, which would contribute to continued adverse cumulative conditions for EC and chloride, and potentially bromide, in the western Delta.

Several regulatory programs aim to address salinity in the Central Valley and have the potential to reduce salt loads to the Bay-Delta region. The Central Valley RWQCB has adopted a Salt and Nitrate Control Program Basin Plan Amendment to manage salt and nitrate discharges within the Central Valley region (it is pending approval by the SWRCB and U.S. EPA). Further, the Central Valley RWQCB includes requirements in municipal wastewater treatment plant NPDES permits to control salinity discharges to surface waters. While implementing additional controls should reduce salinity in discharges, the cumulative condition for EC and chloride will likely be adverse, primarily because of sea level rise and how that affects EC in the western and southern Delta, and Suisun Marsh. The cumulative condition for bromide also could be adverse, depending on the extent to which sea level rise results in higher bromide concentrations at drinking water treatment plant intakes in the Delta.

All action alternatives also would not contribute to additional adverse effects on Delta EC, chloride, and bromide, and Suisun Marsh salinity/chloride. The CVP and SWP would continue to be operated, in real-time, to meet the Bay-Delta WQCP objectives for EC, which aim to protect agricultural and fish and wildlife beneficial uses, and chloride for the protection of municipal and industrial supply uses. Although there could be some level of water quality degradation for EC and chloride under these alternatives, relative to the No Action Alternative, operations to meet the Bay-Delta WQCP objectives would ensure that beneficial uses would remain protected with regard to EC and chloride levels. While there are no objectives specifically for bromide, bromide concentrations are related to EC and chloride, and thus, all action alternatives would not be expected to contribute to additional adverse effects on beneficial uses because of the operations to meet Bay-Delta WQCP objectives.

G.2.9.2 *Methylmercury*

Numerous regulatory efforts are implemented or under development to control and reduce mercury loading to the Bay-Delta region, including TMDLs, increased restrictions on point-source discharges such as municipal wastewater treatment plants, greater restrictions on suction dredging in Delta tributary watersheds, and continued clean-up actions on mine drainage in the upper watersheds. A key challenge surrounds the pool of mercury deposited in Delta sediments, which cannot be readily or rapidly reduced, despite efforts to reduce future loads in Delta tributaries, and serves as a source for continued methylation and Delta biota methylmercury bioaccumulation. Consequently, methylmercury levels in Bay-Delta waters are considered to be an adverse cumulative condition.

All action alternatives would not contribute to additional adverse effects on Bay-Delta methylmercury. Based on the water and fish tissue modeling performed for the Project-Level analysis, methylmercury concentrations in water and fish tissue are not expected to be substantially affected by water operations under the project alternatives. Implementation of tidal habitat under Alternatives 1 and 3 could create conditions resulting in increased mercury methylation within the Delta and increased biotic exposure to and uptake of methylmercury, resulting in increased mercury bioaccumulation in fish tissues. Increased methylmercury bioaccumulation would contribute to the adverse cumulative condition for methylmercury in the Bay-Delta region. The degree to which newly created tidal habitat will become new sources of methylmercury to Bay-Delta biota will depend on tidal habitat siting and design. Ongoing studies in the Delta (e.g., DWR 2015) will further inform the siting and design of future tidal habitat restoration areas.

G.2.9.3 *Selenium*

Numerous regulatory efforts have been implemented to control and reduce selenium loading to the Bay-Delta region, primarily through TMDLs. Thus, future cumulative selenium conditions in the Bay-Delta region are expected to be no worse, and possibly better, than existing conditions. However, because Suisun Bay and San Francisco Bay are currently listed as impaired for elevated selenium (SWRCB 2017a), it is anticipated that the cumulative condition for selenium will remain adverse.

All action alternatives would not contribute to additional adverse effects on Bay-Delta selenium. Based on the water and fish tissue modeling performed for the Project-Level analysis, long-term average selenium concentrations in water and fish tissue are expected to be affected minimally, if at all, by water operations under the project alternatives.

G.2.9.4 *Nutrients*

Ammonia and nitrate levels in the Bay-Delta region are expected to be reduced in the future as municipal wastewater treatment plants discharging to Bay-Delta waters implement nitrification and de-nitrification processes. The Central Valley RWQCB is currently permitting such requirements with regularity, and thus notable reductions in wastewater treatment plant-related ammonia and nitrate discharges are expected in the future. Other new or greater sources that would offset such point-source reductions are not anticipated. Thus, ammonia and nitrate levels under the cumulative condition are not expected to be adverse.

Primary sources of phosphorus to Delta waters include agriculture, municipal wastewater treatment plants, individual septic treatment systems, urban runoff, stream bank erosion, and decaying plant material. Currently, there is no clear evidence that phosphorous levels adversely affect Bay-Delta beneficial uses. Due to increased regulations and anticipated regulatory monitoring - that may include additional water quality objectives for nutrients, including phosphorus - loading from agriculture, municipal wastewater treatment plants, individual septic treatment systems, and urban runoff are all expected to remain at similar levels to those under current conditions, or decline, under the future cumulative condition. Loadings from stream bank erosion and decaying plants are not expected to change notably in the future. Hence, phosphorus levels are not anticipated to be adverse under the cumulative condition.

G.2.9.5 *Organic Carbon*

Dissolved organic carbon concentrations in Delta waters are at levels of concern due to disinfection byproduct formation risk at drinking water treatment plants that use the Delta as a drinking water supply. However, total organic carbon is a critically important base of the food web in the Bay-Delta region. The loading of total organic carbon to the Bay-Delta waters may increase in the future cumulative condition due to ongoing and future habitat restoration activities. Loading from other sources, such as municipal wastewater treatment plants and storm water, may also be higher in the future cumulative condition. If future drinking water regulations require substantially lower concentrations of disinfection byproducts in drinking water, total and dissolved organic carbon concentrations in the Delta could be considered adverse, relative to drinking water uses, but not relative to aquatic life beneficial uses. Conversely, if in the future regulations for disinfection byproducts in drinking water supplies remain the same as present regulations, then even with some level of organic carbon increases in Delta waters, future cumulative total and dissolved organic carbon concentrations would not be considered adverse, relative to drinking water uses. Total and dissolved organic carbon concentrations in Suisun Bay, Suisun Marsh, and San Francisco Bay would not be adverse, because these water bodies are not drinking water supplies, but the presence of total organic carbon in these water bodies is important for the food web.

In cases where project alternatives are forecast to reduce flows and potentially affect water quality through impacts to beneficial uses and/or increasing concentrations of constituents of concern, the cumulative projects analyzed will cumulatively impact water quality; however, the action alternatives' contribution to cumulative impacts would not be substantial.

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Appendix G- Attachment 1

Appendix G1 Methylmercury Model Documentation

This attachment documents the fish tissue methylmercury modeling performed to estimate methylmercury concentrations in fish throughout the Delta for the assessment presented in Appendix G, Water Quality Technical Appendix, prepared in support of the Reinitiation of Consultation on the long-term operations of the Central Valley Project (CVP) and State Water Project (SWP) Environmental Impact Statement (EIS).

This appendix is organized into the following main sections:

- **Section G.1: Modeling Methodology**. This section provides information about the overall modeling framework, modeling tools, and how model input information was obtained and processed.
- **Section G.2: Modeling Simulations and Assumptions**. This section describes the modeling simulations conducted and input assumptions.
- **Section G.3: Modeling Results.** This section presents the modeling results.
- **Section G.4: Model Limitations and Applicability**. This section describes the limitations associated with the model and appropriate use of model results.

G1.1 Modeling Methodology

This section describes the analytical framework and development and use of the models used to estimate methylmercury concentrations in fish throughout the Delta.

G1.1.1 Overview of the Modeling Approach and Objectives

CalSim II, Delta Simulation Model II (DSM2), and the Central Valley Regional Water Quality Control Board's (CVRWQCB) fish tissue model for Largemouth Bass (*Micropterus salmoides*) developed for the Delta Methylmercury Total Maximum Daily Load (CVRWQCB TMDL Model) (CVRWQCB 2010a) were used in sequence to develop modeled concentrations of methylmercury in fish tissue at select Delta locations. CalSim II simulates CVP and SWP operations and DSM2 simulates one-dimensional hydrodynamics in the Delta. One of the three DSM2 modules, QUAL, simulates one-dimensional source tracking in the Delta and outputs the flow-percentage at DSM2 nodes. The Total Maximum Daily Limit (TMDL) Model is based on a power curve that uses input water column methylmercury concentrations to model methylmercury concentrations in the fish fillets of standard 350-mm-long Largemouth Bass. Figure G1.1-1 shows the relationships among these modeling tools.

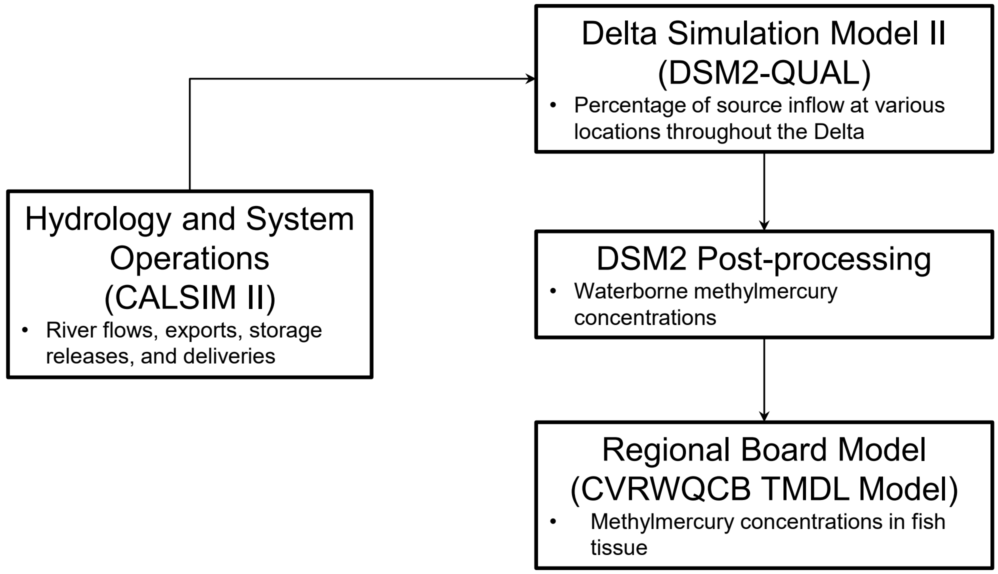

Figure G1.1-1. Relationships among the Different Predictive Modeling Tools

G1.1.2 DSM2 Postprocessing

The period average flow-fraction output from DSM2 was used in mass-balance calculations (processed outside of DSM2) to generate long-term average methylmercury concentrations at selected Delta locations. The flow-fraction output from DSM2 is the percentage of water at each specified Delta location constituted by the six primary source waters—Sacramento River, Yolo Bypass, San Joaquin River, eastside tributaries, San Francisco Bay, and in-Delta agriculture. Water column methylmercury concentrations for each Delta location were calculated using the following mass-balance equation:

$$C_{water} = [(I_1 * C_1)+(I_2 * C_2)+ (I_3 * C_3)+ (I_4 * C_4)+ (I_5 * C_5)+ (I_6 * C_6)]/100$$

Where:

- C_{water} = methylmercury concentration in water (nanograms/liter [ng/L]) at a DSM2 output location
- $I_{1\text{-}6}$ = modeled daily inflow from each of the six sources of water to the Delta for each DSM2 output location (percentage)
- $C_{1\text{-}6}$ = methylmercury concentration in water (ng/L) from each of the six inflow sources to the Delta

The Delta source water concentrations used in the mass-balance calculations are summarized in Table G1.1-1.

Water column methylmercury concentrations from the mass balance calculations are shown in Table G1.1-2. Average concentrations are presented for the entire (1922–2003) period modeled and drought (1987–1991) period modeled by DSM2. A key assumption for the mass-balance calculation of water column concentrations of methylmercury is that the methylmercury acts in a conservative manner as the various source waters mix and flow through the Delta, which it does not.

Table G1.1-1. Methylmercury (Total) Concentrations in Water in Inflow Sources to the Delta

Source Water	Station	Concentration in Water (ng/L)	Years	Source
Sacramento River	Sacramento River at Freeport	0.10	2000–2003	CVRWQCB 2010b
Yolo Bypass	Prospect Slough (Yolo Bypass)	0.35	2000–2003	CVRWQCB 2010b
San Joaquin River	San Joaquin River at Vernalis	0.16	2000–2004	CVRWQCB 2010b
East Side Tributaries	Mokelumne River at I-5	0.17	2000–2004	CVRWQCB 2010b
In-Delta Agriculture	Various Delta locations	0.35	2000, 2003	CVRWQCB 2010b
San Francisco Bay	Suisun Bay	0.033	2007–2011; 2013; 2015	SFEI 2019

ng/L = nanogram(s) per liter

G1.1.3 CVRWQCB TMDL Model

The CVRWQCB TMDL Model is an empirical power curve that uses water column concentrations of methylmercury to estimate methylmercury concentrations in the fish fillets of standard 350-mm-long Largemouth Bass (CVRWQCB 2010a). The CVRWQCB developed the nonlinear model based on Largemouth Bass as grouped in large regions of the Delta (rather than specific locations) compared to average methylmercury concentrations in water for those same general regions (CVRWQCB 2010a). Data were grouped by subareas of the Delta such as Sacramento River, Mokelumne River, Central Delta, San Joaquin River, and West Delta (CVRWQCB 2010a).

Largemouth Bass are excellent indicators of mercury contamination because they have a relatively high level of mercury compared to other species, are piscivorous, are abundantly distributed throughout the Delta, are popular gamefish, and have high site fidelity. Largemouth Bass are therefore representative of spatial patterns of tissue mercury concentrations throughout the aquatic food web, including exposure to humans.

The CVRWQCB TMDL Model used for estimating fish tissue concentrations of methylmercury in Largemouth Bass is presented below.

$$\textit{Fish methylmercury (milligrams/kilogram, wet weight)} = 20.365 \times (\textit{methylmercury in water, ng/L})^{1.6374}$$

(with r^2=0.91, and P less than 0.05)

The water column methylmercury concentrations presented in Table G1.1-2 were input into the above equation to generate the fish tissue methylmercury concentrations. The overall construction and calibration of the model were unchanged for the simulations described herein.

Table G1.1-2. Modeled Methylmercury Concentrations in Water

Location	Period[1]	Period Average Concentration (ng/L)				
		No Action Alternative	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Delta Interior						
San Joaquin River at Stockton	All	0.17	0.17	0.17	0.17	0.17
	Drought	0.18	0.18	0.18	0.18	0.18
Turner Cut	All	0.17	0.17	0.17	0.17	0.17
	Drought	0.17	0.17	0.17	0.17	0.17
San Joaquin River at San Andreas Landing	All	0.12	0.11	0.11	0.12	0.12
	Drought	0.11	0.11	0.11	0.11	0.11
San Joaquin River at Jersey Point	All	0.12	0.12	0.12	0.12	0.12
	Drought	0.11	0.11	0.11	0.11	0.11
Victoria Canal	All	0.15	0.15	0.15	0.15	0.16
	Drought	0.15	0.15	0.14	0.15	0.15
Western Delta						
Sacramento River at Emmaton	All	0.12	0.12	0.12	0.12	0.12
	Drought	0.11	0.11	0.11	0.11	0.11
San Joaquin River at Antioch	All	0.11	0.11	0.11	0.11	0.11
	Drought	0.10	0.10	0.10	0.10	0.10
Montezuma Slough at Hunter Cut/ Beldon's Landing	All	0.10	0.09	0.09	0.09	0.10
	Drought	0.08	0.08	0.07	0.07	0.08
Major Diversions (Pumping Stations)						
Barker Slough at North Bay Aqueduct Intake	All	0.14	0.14	0.14	0.14	0.14
	Drought	0.13	0.13	0.13	0.12	0.13
Contra Costa Pumping Plant #1	All	0.14	0.14	0.13	0.14	0.14
	Drought	0.13	0.13	0.13	0.13	0.13
Banks Pumping Plant	All	0.15	0.14	0.14	0.14	0.15
	Drought	0.15	0.14	0.14	0.14	0.15
Jones Pumping Plant	All	0.15	0.15	0.15	0.15	0.15
	Drought	0.15	0.15	0.14	0.14	0.15

[1] "All" water years 1922–2003 represent the 82-year period modeled using DSM2; "drought" represents a 5-consecutive-year (water years 1987-1991) drought period consisting of dry and critical water year types (as defined by the Sacramento Valley 40-30-30 water year hydrologic classification index).
ng/L = nanograms per liter

G1.2 Modeling Simulations and Assumptions

This section describes the assumptions for the CVRWQCB TMDL Model simulations.

G1.2.1 Location Assumptions

The CVRWQCB TMDL Model was based on data for Largemouth Bass as grouped in large regions of the Delta, rather than specific locations, compared to average methylmercury concentrations in water for those same general regions (CVRWQCB 2010a). As such, the model provides a Delta-specific, general, long-term average relationship between co-located water column methylmercury concentrations and methylmercury concentrations in Largemouth Bass fillets.

G1.2.2 Normalization and Tissue Type Assumptions

As discussed above, Largemouth Bass are excellent indicators of long-term average mercury exposure, risk, and the spatial pattern for both ecological and human health effects. A fish tissue mercury dataset was available for Largemouth Bass from locations across the Delta. It is important to standardize concentrations to the same length fish for establishment of the model and for model predictions because of the well-established positive relationship between fish length and age and tissue mercury concentrations (e.g., Alpers et al. 2008). This same normalization technique was used by the CVRWQCB for the TMDL Model (CVRWQCB 2010a). The 350-mm size fish is an appropriate size representative of human health consumption and risk. The standardized size allows the best comparison among locations and alternatives. The fillet concentrations predicted by the TMDL Model are expected to be slightly different from whole-body fish concentrations as consumed by wildlife, but allow for comparison between alternative to determine relative effects to fish and wildlife as well as estimating effects to human consumers.

G1.2.3 Model Application

To evaluate differences between the No Action Alternative and Alternatives 1 through 4, modeled fish tissue methylmercury concentrations were compared directly for percent change relative to the No Action Alternative and to the CVRWQCB's fish tissue objective of 0.24 milligrams per kilogram (mg/kg), wet weight, for trophic level 4 fish (CVRWQCB 2018). The comparison of each fish tissue concentration to the fish tissue objective is expressed as an exceedance quotient (EQ).

G1.3 Modeling Results

Output data resulting from the TMDL Model simulations for each alternative are presented in Tables G1.5-1 through G1.5-5 and Figures G1.5-1 and G1.5-2. Outputs from the TMDL Model are average fish tissue methylmercury concentrations for the entire (1922–2003) period modeled and the five-year (1987–1991) drought period modeled using DSM2.

G1.4 Model Limitations and Applicability

CalSim II and DSM2 are planning level models, not predictive models. Further, mathematical models like DSM2 can only approximate processes of physical systems. Models are inherently inexact because the mathematical description of the physical system is imperfect and the understanding of interrelated physical processes is incomplete.

The goal of the CVRWQCB TMDL Model was to establish the linkage between the 0.24 mg/kg tissue mercury TMDL target (which is now the Delta water quality objective for trophic level 4 fish) to a water column concentration goal for methylmercury of 0.066 ng/l. The model results are presented with the recognition of the imprecision of predicting fish tissue concentrations from estimates of methylmercury concentrations for specific Delta locations, but with the knowledge that Largemouth Bass are probably the best indicator of fish tissue contamination. Results provide an estimated mean tissue concentration as would be expected based on the input water column concentration.

Mercury concentrations for inflow sources to the Delta (for example, agriculture in the Delta, Yolo Bypass, Eastside Tributaries) also present uncertainty in the modeling because of limited data.

For the reasons discussed above, the water column concentration and fish tissue concentration results presented herein are not predictive in nature. Rather, they are for comparative assessment to identify the effect the alternatives would have on fish tissue methylmercury concentrations relative to the No Action Alternative.

G1.5 References

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CVRWQCB (Central Valley Regional Water Quality Control Board). 2010a. *Amendments to the Water Quality Control Plan for the Sacramento River and San Joaquin River Basins for the Control of Methylmercury and Total Mercury in the Sacramento-San Joaquin Delta Estuary, Staff Report*. Rancho Cordova, CA. April. Available: https://www.waterboards.ca.gov/rwqcb5/water_issues/tmdl/central_valley_projects/delta_hg/. Site accessed March 13, 2019.

_____. *Sacramento–San Joaquin Delta Estuary TMDL for Methylmercury, Final Staff Report*. April. Rancho Cordova, CA. Available: https://www.waterboards.ca.gov/rwqcb5/water_issues/tmdl/central_valley_projects/delta_hg/. Site accessed March 13, 2019.

_____. 2018. *Water Quality Control Plan (Basin Plan) for the California Regional Water Quality Control Board Central Valley Region, Fifth Edition, Revised May 2018 (With Approved Amendments), The Sacramento River Basin and The San Joaquin River Basin.* Available: https://www.waterboards.ca.gov/centralvalley/water_issues/basin_plans/#basinplans. Site accessed March 13, 2019.

SFEI (San Francisco Estuary Institute). 2019. *Regional Data Center*. Available: http://www.sfei.org/data. Site accessed February 28, 2019.

Table G1.5-1. Methylmercury Concentrations in 350 millimeter Largemouth Bass Fillets for the No Action Alternative

Location	Period[1]	Estimated Concentrations of Methylmercury (mg/kg, wet weight)	Exceedance Quotients[2]
		No Action Alternative	No Action Alternative
Delta Interior			
San Joaquin River at Stockton	All	1.12	4.7
	Drought	1.20	5.0
Turner Cut	All	1.10	4.6
	Drought	1.13	4.7
San Joaquin River at San Andreas Landing	All	0.60	2.5
	Drought	0.57	2.4
San Joaquin River at Jersey Point	All	0.63	2.6
	Drought	0.56	2.3
Victoria Canal	All	0.95	4.0
	Drought	0.93	3.9
Western Delta			
Sacramento River at Emmaton	All	0.62	2.6
	Drought	0.53	2.2
San Joaquin River at Antioch	All	0.57	2.4
	Drought	0.47	2.0
Montezuma Slough at Hunter Cut/Beldon's Landing	All	0.44	1.8
	Drought	0.30	1.3
Major Diversions (Pumping Stations)			
Barker Slough at North Bay Aqueduct Intake	All	0.84	3.5
	Drought	0.69	2.9
Contra Costa Pumping Plant #1	All	0.81	3.4
	Drought	0.75	3.1
Banks Pumping Plant	All	0.88	3.7
	Drought	0.89	3.7
Jones Pumping Plant	All	0.93	3.9
	Drought	0.93	3.9

[1] "All" water years 1922–2003 represent the 82-year period modeled using DSM2; "drought" represents a 5-consecutive-year (water years 1987–1991) drought period consisting of dry and critical water year types (as defined by the Sacramento Valley 40 30-30 water year hydrologic classification index)
[2] Exceedance Quotient = tissue concentration / 0.24 mg/kg
mg/kg - milligrams per kilogram

Table G1.5-2. Methylmercury Concentrations in 350 millimeter Largemouth Bass Fillets for Alternative 1, and Comparison to No Action Alternative

Location	Period[1]	Estimated Concentrations of Methylmercury (mg/kg, wet weight)	% Change In Methylmercury Concentrations Compared to No Action Alternative[2]	Exceedance Quotients[3]
		Alternative 1	Alternative 1	Alternative 1
Delta Interior				
San Joaquin River at Stockton	All	1.13	1	4.7
	Drought	1.22	2	5.1
Turner Cut	All	1.09	-1	4.5
	Drought	1.09	-3	4.5
San Joaquin River at San Andreas Landing	All	0.58	-2	2.4
	Drought	0.56	-2	2.3
San Joaquin River at Jersey Point	All	0.61	-3	2.5
	Drought	0.55	-2	2.3
Victoria Canal	All	0.92	-4	3.8
	Drought	0.87	-7	3.6
Western Delta				
Sacramento River at Emmaton	All	0.61	-1	2.5
	Drought	0.52	-1	2.2
San Joaquin River at Antioch	All	0.55	-4	2.3
	Drought	0.46	-3	1.9
Montezuma Slough at Hunter Cut/Beldon's Landing	All	0.42	-3	1.8
	Drought	0.29	-3	1.2
Major Diversions (Pumping Stations)				
Barker Slough at North Bay Aqueduct Intake	All	0.85	1	3.5
	Drought	0.69	-0.3	2.9
Contra Costa Pumping Plant #1	All	0.78	-4	3.2
	Drought	0.71	-5	3.0
Banks Pumping Plant	All	0.85	-4	3.5
	Drought	0.82	-7	3.4
Jones Pumping Plant	All	0.91	-2	3.8
	Drought	0.89	-4	3.7

[1] "All" water years 1922–2003 represent the 82-year period modeled using DSM2; "drought" represents a 5-consecutive-year (water years 1987–1991) drought period consisting of dry and critical water year types (as defined by the Sacramento Valley 40 30-30 water year hydrologic classification index)
[2] % change indicates a negative change (increased concentrations) relative to the No Action Alternative when values are positive and a positive change (lowered concentrations) relative to the No Action Alternative when values are negative.
[3] Exceedance Quotient = tissue concentration / 0.24 mg/kg
mg/kg - milligrams per kilogram

Table G1.5-3. Methylmercury Concentrations in 350 millimeter Largemouth Bass Fillets for Alternative 2, and Comparison to No Action Alternative

Location	Period[1]	Estimated Concentrations of Methylmercury (mg/kg, wet weight)	% Change In Methylmercury Concentrations Compared to No Action Alternative[2]	Exceedance Quotients[3]
		Alternative 2	Alternative 2	Alternative 2
Delta Interior				
San Joaquin River at Stockton	All	1.13	1	4.7
	Drought	1.22	1	5.1
Turner Cut	All	1.08	-2	4.5
	Drought	1.08	-4	4.5
San Joaquin River at San Andreas Landing	All	0.58	-3	2.4
	Drought	0.55	-2	2.3
San Joaquin River at Jersey Point	All	0.61	-3	2.5
	Drought	0.55	-3	2.3
Victoria Canal	All	0.89	-6	3.7
	Drought	0.85	-9	3.5
Western Delta				
Sacramento River at Emmaton	All	0.61	-1	2.5
	Drought	0.52	-2	2.2
San Joaquin River at Antioch	All	0.54	-5	2.3
	Drought	0.45	-4	1.9
Montezuma Slough at Hunter Cut/Beldon's Landing	All	0.42	-5	1.7
	Drought	0.29	-4	1.2
Major Diversions (Pumping Stations)				
Barker Slough at North Bay Aqueduct Intake	All	0.85	1	3.5
	Drought	0.69	-0.3	2.9
Contra Costa Pumping Plant #1	All	0.75	-7	3.1
	Drought	0.69	-7	2.9
Banks Pumping Plant	All	0.82	-7	3.4
	Drought	0.80	-10	3.3
Jones Pumping Plant	All	0.88	-6	3.7
	Drought	0.85	-8	3.5

[1] "All" water years 1922–2003 represent the 82-year period modeled using DSM2; "drought" represents a 5-consecutive-year (water years 1987–1991) drought period consisting of dry and critical water year types (as defined by the Sacramento Valley 40 30-30 water year hydrologic classification index)
[2] % change indicates a negative change (increased concentrations) relative to the No Action Alternative when values are positive and a positive change (lowered concentrations) relative to the No Action Alternative when values are negative.
[3] Exceedance Quotient = tissue concentration / 0.24 mg/kg
mg/kg - milligrams per kilogram

Table G1.5-4. Methylmercury Concentrations in 350 millimeter Largemouth Bass Fillets for Alternative 3, and Comparison to No Action Alternative

Location	Period[1]	Estimated Concentrations of Methylmercury (mg/kg, wet weight)	% Change In Methylmercury Concentrations Compared to No Action Alternative[2]	Exceedance Quotients[3]
		Alternative 3	Alternative 3	Alternative 3
Delta Interior				
San Joaquin River at Stockton	All	1.12	0.2	4.7
	Drought	1.21	1	5.1
Turner Cut	All	1.10	0	4.6
	Drought	1.12	-1	4.7
San Joaquin River at San Andreas Landing	All	0.59	-1	2.5
	Drought	0.57	0	2.4
San Joaquin River at Jersey Point	All	0.62	-2	2.6
	Drought	0.55	-2	2.3
Victoria Canal	All	0.91	-4	3.8
	Drought	0.87	-7	3.6
Western Delta				
Sacramento River at Emmaton	All	0.61	-1	2.5
	Drought	0.52	-1	2.2
San Joaquin River at Antioch	All	0.56	-3	2.3
	Drought	0.46	-2	1.9
Montezuma Slough at Hunter Cut/Beldon's Landing	All	0.39	-12	1.6
	Drought	0.26	-15	1.1
Major Diversions (Pumping Stations)				
Barker Slough at North Bay Aqueduct Intake	All	0.78	-8	3.2
	Drought	0.60	-14	2.5
Contra Costa Pumping Plant #1	All	0.77	-5	3.2
	Drought	0.71	-5	2.9
Banks Pumping Plant	All	0.83	-6	3.5
	Drought	0.81	-9	3.4
Jones Pumping Plant	All	0.89	-5	3.7
	Drought	0.86	-7	3.6

[1] "All" water years 1922–2003 represent the 82-year period modeled using DSM2; "drought" represents a 5-consecutive-year (water years 1987–1991) drought period consisting of dry and critical water year types (as defined by the Sacramento Valley 40 30-30 water year hydrologic classification index)
2 % change indicates a negative change (increased concentrations) relative to the No Action Alternative when values are positive and a positive change (lowered concentrations) relative to the No Action Alternative when values are negative.
[3] Exceedance Quotient = tissue concentration / 0.24 mg/kg
mg/kg - milligrams per kilogram

Table G1.5-5. Methylmercury Concentrations in 350 millimeter Largemouth Bass Fillets for Alternative 4, and Comparison to No Action Alternative

Location	Period[1]	Estimated Concentrations of Methylmercury (mg/kg, wet weight)	% Change In Methylmercury Concentrations Compared to No Action Alternative[2]	Exceedance Quotients[3]
		Alternative 4	Alternative 4	Alternative 4
Delta Interior				
San Joaquin River at Stockton	All	1.13	0.4	4.7
	Drought	1.22	1.1	5.1
Turner Cut	All	1.10	0.3	4.6
	Drought	1.12	-0.7	4.7
San Joaquin River at San Andreas Landing	All	0.60	0.1	2.5
	Drought	0.57	0.3	2.4
San Joaquin River at Jersey Point	All	0.63	0.0	2.6
	Drought	0.56	0.1	2.3
Victoria Canal	All	0.97	2.0	4.0
	Drought	0.93	-0.1	3.9
Western Delta				
Sacramento River at Emmaton	All	0.62	0.0	2.6
	Drought	0.53	0.0	2.2
San Joaquin River at Antioch	All	0.56	-1.6	2.3
	Drought	0.47	-0.7	2.0
Montezuma Slough at Hunter Cut/Beldon's Landing	All	0.44	-0.7	1.8
	Drought	0.30	-0.4	1.3
Major Diversions (Pumping Stations)				
Barker Slough at North Bay Aqueduct Intake	All	0.85	1.0	3.5
	Drought	0.69	-0.9	2.9
Contra Costa Pumping Plant #1	All	0.84	3.5	3.5
	Drought	0.76	1.4	3.2
Banks Pumping Plant	All	0.89	0.9	3.7
	Drought	0.89	-0.1	3.7
Jones Pumping Plant	All	0.93	-0.1	3.9
	Drought	0.92	-0.4	3.8

[1] “All” water years 1922–2003 represent the 82-year period modeled using DSM2; “drought” represents a 5-consecutive-year (water years 1987–1991) drought period consisting of dry and critical water year types (as defined by the Sacramento Valley 40 30-30 water year hydrologic classification index)
[2] % change indicates a negative change (increased concentrations) relative to the No Action Alternative when values are positive and a positive change (lowered concentrations) relative to the No Action Alternative when values are negative.
[3] Exceedance Quotient = tissue concentration / 0.24 mg/kg
mg/kg - milligrams per kilogram

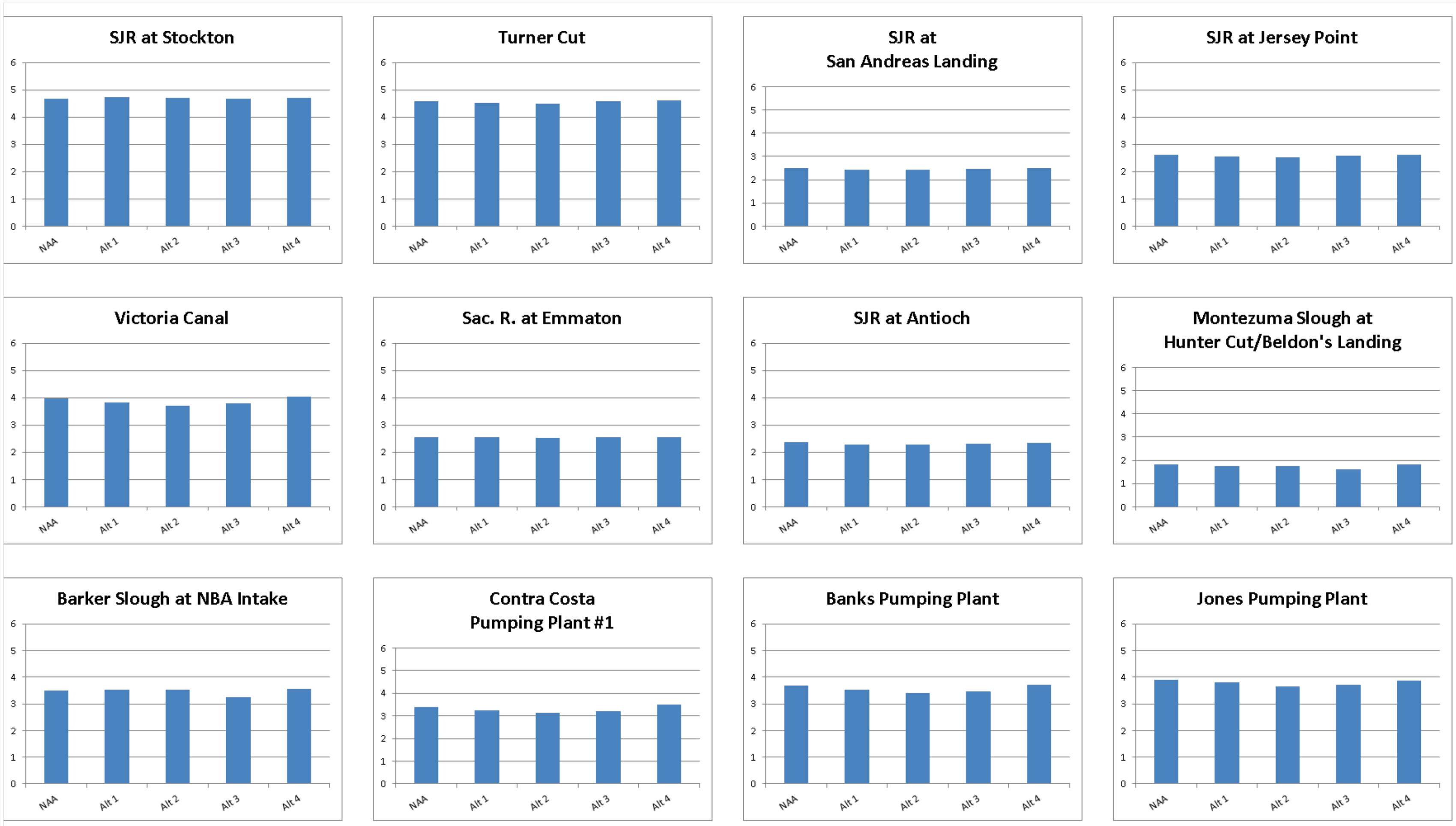

Figure G1.5-1. Level of Concern Exceedance Quotients for Mercury Concentrations in 350 millimeter Largemouth Bass Fillets for All Years

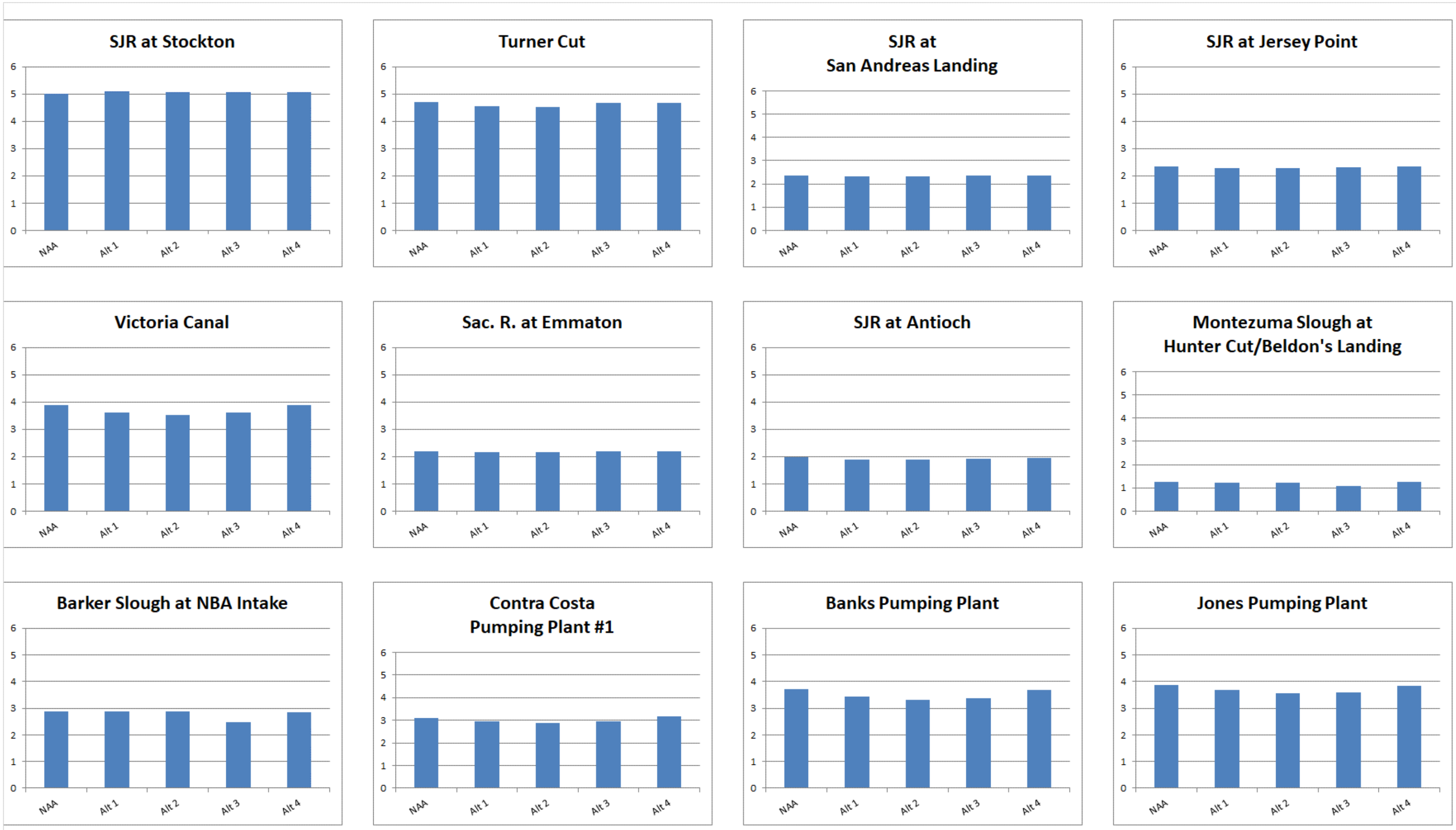

Figure G1.5-2. Level of Concern Exceedance Quotients for Mercury Concentrations in 350 millimeter Largemouth Bass Fillets for Drought Years

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Appendix G - Attachment 2

Appendix G2 Selenium Model Documentation

This attachment documents the selenium bioaccumulation modeling performed to estimate selenium concentrations in fish and bird eggs throughout the Delta for the assessment presented in Appendix G, Water Quality Technical Appendix, prepared in support of the Reinitiation of Consultation on the long-term operations of the Central Valley Project (CVP) and State Water Project (SWP) Environmental Impact Statement (EIS).

This attachment is organized into three main sections:

- **Section G2.1: Modeling Methodology.** This section provides information about the overall modeling framework, modeling tools, and how model input information was obtained and processed.
- **Section G2.2: Modeling Simulations and Assumptions.** This section provides a description of the assumptions for the selenium model simulations.
- **Section G2.3: Modeling Results.** This section presents the modeling results. The limitations and applicability of the results are also addressed.

G2.1 Modeling Methodology

This section describes the analytical framework and development and use of the models used to estimate selenium concentrations in fish and bird eggs throughout the Delta.

G2.1.1 Overview of the Modeling Approach and Objectives

CalSim II, Delta Simulation Model II (DSM2), and bioaccumulation modeling were used in sequence to estimate the effects of CVP and SWP operations on water quality relative to selenium in the Delta. CalSim II, which simulates flow in California's waterways, and DSM2, which simulates one-dimensional hydrodynamics in California's Delta. One of the three DSM2 modules, QUAL, simulates one-dimensional source tracking in the Delta. Results from DSM2 were multiplied by source concentrations (shown in Table G2.1-1) to determine annual average water column selenium concentrations in the Delta for all year types and drought years.

Table G2.1-1. Selenium Concentrations in Water at Inflow Sources to the Delta

Delta Sources	Representative Inflow Site	Geometric Mean Selenium Concentration in Water (µg/L)[1]	Years	Source
Delta Agriculture	Mildred Island, Center	0.11	2000	Lucas and Stewart 2007
East Delta Tributaries	Mokelumne, Calaveras, and Cosumnes Rivers	0.10 [2]	None	None
Martinez/Suisun Bay	San Joaquin River near Mallard Island	0.10	02/2000 – 08/2008	SFEI 2014
Sacramento River	Sacramento River at Freeport	0.09	11/2007 – 07/2014	USGS 2014
San Joaquin River	San Joaquin River at Vernalis (Airport Way)	0.45 [3]	11/2007 – 08/2014	USGS 2014
San Joaquin River	San Joaquin River at Vernalis (Airport Way)	0.83 [4]	1999 – 2000	SWAMP 2009
		0.85	2004 – 2005	SWAMP 2009
		0.58	2006 – 2007	SWAMP 2009
Yolo Bypass	Sacramento River below Knights Landing	0.23 [5]	2004, 2007, 2008	DWR 2009

[1] Selenium concentrations are in the dissolved fraction unless otherwise noted.
[2] Dissolved selenium concentration is assumed to be 0.1 µg/L due to lack of available data and lack of sources that would be expected to result in concentrations greater than 0.1 µg/L.
[3] Data used to represent conditions for comparison of alternatives.
[4] Not specified whether total or dissolved selenium; data for 1999-2000 used for bioaccumulation by bass in 2000; data for 2004-2005 for bass in 2005; and data for 2006-2007 for bass in 2007.
[5] Total selenium concentration in water.
µg/L = microgram(s) per liter

Operations-related changes in water column selenium concentrations in the Delta may result in increased selenium bioaccumulation or toxicity (or both) to aquatic and semi-aquatic receptors using the Delta. Historical fish tissue data from 2000, 2005, and 2007 (Foe 2010a) and measured (for Sacramento River below Knights Landing and for San Joaquin River at Vernalis) or DSM2-modeled (other locations) water column selenium concentrations for selected locations in 2000, 2005, and 2007 were used to model water-to-tissue relationships. This modeling generally followed procedures described by Presser and Luoma (2010a, 2010b).

Implementation of the Grassland Bypass Project (GBP) has led to a 60 percent decrease in selenium loads from the Grassland Drainage Area compared to pre-project conditions (San Francisco Bay RWQCB 2008). These changes are reflected in data for the San Joaquin River at Vernalis, where water quality is monitored frequently because the river is a primary source of selenium to the Delta. Vernalis water data over two years (1999–2000, 2004–2005, and 2006–2007) was paired with each year when fish data were available, because of the GBP-related changes and because the lag time for selenium bioaccumulation in the piscivorous Largemouth Bass (*Micropterus salmoides*, the species for which the Delta-wide bioaccumulation model was calibrated) may be more than one year (Beckon 2014).

Output from the DSM2-QUAL model (expressed as percentage of inflow from different sources) was used in combination with the available measured water column selenium concentrations (Table G2.1-1) to model concentrations of selenium at locations throughout the Delta. These modeled water column selenium concentrations were used in the relationship model to estimate bioaccumulation of selenium in whole-body fish and in bird eggs. Selenium concentrations in fish fillets were then estimated from those in whole-body fish. The following sections provide detailed information about the modeling approach for selenium.

In addition to the Delta-wide modeling for fish and birds (calibrated with data for Largemouth Bass), selenium uptake and food-chain transfer information from the ecosystem-scale selenium model for the San Francisco Bay-Delta Regional Ecosystem Restoration Implementation Plan (Presser and Luoma 2013) informed the selenium bioaccumulation model for the western Delta. The Largemouth Bass has lower selenium bioaccumulation rates than those observed for sturgeon (Green Sturgeon [*Acipenser medirostris]* and White Sturgeon, [*A. transmontanus]*) and is not an appropriate model species that would be protective of sturgeon. Sturgeon differ by feeding, in part, on Overbite Clams (*Corbula* [*Potamocorbula*] *amurensis*) in Suisun Bay and may do so in the western portion of the Delta under future conditions. Therefore, DSM2-modeled water column selenium concentrations from three western-most locations in the Delta (Sacramento River at Emmaton, San Joaquin River at Antioch, and Montezuma Slough at Hunter Cut/Beldon's Landing) were used to model selenium bioaccumulation for sturgeon at those three locations to supplement the modeling done for Largemouth Bass.

The results from this suite of physical and biological models are used to inform the understanding of effects of each alternative considered in this EIS on selenium. Modeling objectives included evaluation of the following:

- Percent changes in water column selenium concentrations under the alternatives as compared to the No Action Alternative.
- Exceedances of fish, wildlife, or human thresholds for selenium effects.

G2.1.2 Key Components of the Selenium Modeling

To fulfill the objectives of the selenium modeling effort, DSM2 output data were used in combination with source water concentrations to estimate water column selenium concentrations at representative locations throughout the Delta (Tables G2.1-2 through G2.1-4, located at end of this attachment). Water column selenium concentrations were then used to estimate tissue selenium concentrations in Largemouth Bass (as a representative higher trophic-level fish) throughout the Delta and in sturgeon in the western Delta. Estimation of concentrations in Largemouth Bass throughout the Delta included the development and calibration of a bioaccumulation model using measured concentrations in bass (Foe 2010a). In contrast, modeling for sturgeon in the western Delta relied on literature-based model parameters (Presser and Luoma 2013), because data were not available to calibrate the model.

G2.1.2.1 DSM2 Post-processing

Dissolved or total selenium data were available for six inflow locations to the Delta (Table G2.1-1):

- Sacramento River below Knights Landing (just upstream of Yolo Bypass, representing the Bypass source)
- Sacramento River at Freeport (mainstem flow to Delta)
- San Joaquin River at Vernalis (Airport Way) (mainstem flow to Delta)
- Mokelumne, Calaveras, and Cosumnes Rivers (for East Delta tributaries)
- Mildred Island, Center (for Delta Agriculture)
- San Joaquin River near Mallard Island (for Martinez/Suisun Bay)

Both dissolved and total selenium data were considered suitable for purposes of the modeling conducted for the Delta, because they typically do not differ greatly in the Delta. Statements related to water column selenium concentrations in this attachment would be applicable to either dissolved or total concentrations.

Whole-body Largemouth Bass data for selenium were available from the following DSM2 output locations:

- Big Break
- Cache Slough Ryer
- Franks Tract
- Middle River Bullfrog
- Old River Near Paradise Cut
- Sacramento River Mile (RM) 44
- San Joaquin River Potato Slough

Largemouth Bass data also were available from the Veterans Bridge on the Sacramento River and from Vernalis on the San Joaquin River, but DSM2 data were not available for those locations. Therefore, historical data for selenium concentrations in water collected nearby (Table G2.1-1) were used to calculate quarterly average water column selenium concentrations from these locations. The geometric mean of total selenium concentrations in water collected from the Sacramento River below Knights Landing in 2004, 2007, and 2008 (DWR 2009) were used to represent quarterly averages of selenium concentrations in water for Veterans Bridge in all years. The geometric means of selenium concentrations (total or dissolved was not specified) in water collected from Vernalis in 1999–2000, 2004-2005, and 2006-2007 (SWAMP 2009) were used to represent quarterly averages for selenium concentrations in water during 2000, 2005, and 2007, respectively.

For DSM2 output locations, the geometric mean selenium concentrations from the inflow locations were combined with the modeled quarterly average percent inflow for each DSM2 output location to estimate water column selenium concentrations at those locations. The quarterly average mix of water from the six inflow sources (Table G2.1-1) was calculated from daily percent inflows provided by the DSM2 model output for the DSM2 output locations for which fish data were available. The quarterly water column selenium concentrations at DSM2 locations were calculated using Equation 1:

$$C_{water\ quarterly} = ([I_1*C_1] + [I_2*C_2] + [I_3*C_3] + [I_4*C_4] + [I_5*C_5] + [I_6*C_6])/100$$

Where:

- $C_{water\ quarterly}$ = quarterly average selenium concentration in water (micrograms/liter [µg/L]) at a DSM2 output location
- $I_{1\text{-}6}$ = modeled quarterly inflow from each of the six sources of water to the Delta for each DSM2 output location (percentage)
- $C_{1\text{-}6}$ = selenium concentration in water (µg/L) from each of the six inflow sources to the Delta (1-6)

Example Calculation: Modeled Selenium Concentration at Franks Tract Year 2000, First Quarter:

- (43.94 [% inflow from Sacramento River water source at Franks Tract] × 0.09 µg/L [selenium concentration at Sacramento River at Freeport]) + (11.56 [% inflow from East Delta Tributaries water source at Franks Tract] × 0.10 µg/L [selenium concentration at Mokelumne, Calaveras, and

Cosumnes Rivers]) + (15.79 [% inflow from San Joaquin River water source at Franks Tract] × 0.83 µg/L [selenium concentration at San Joaquin River at Vernalis]) + (0.02 [% inflow from Martinez/Suisun Bay water source at Franks Tract] × 0.10 µg/L [selenium concentration at San Joaquin River near Mallard Island]) + (0.32 [% inflow from Yolo Bypass water source at Franks Tract] × 0.23 µg/L [selenium concentration at Sacramento River below Knights Landing]) + (5.06 [% inflow from Delta Agriculture water source at Franks Tract] × 0.11 µg/L [selenium concentration at Mildred Island, Center])/100 = 0.19 µg/L

The quarterly and average annual water column selenium concentrations for the DSM2 output locations are shown in Table G2.1-2 (Year 2000), Table G2.1-3 (Year 2005), and Table G2.1-4 (Year 2007).

G2.1.2.2 Delta-wide Selenium Model Development

Selenium concentrations in whole-body fish and in bird eggs were calculated using ecosystem-scale models developed by Presser and Luoma (2010a, 2010b, 2013). The models were based on biogeochemical and physiological factors from laboratory and field studies; loading rates, chemical speciation, and transformation to particulate material; bioavailability; bioaccumulation in invertebrates; and trophic transfer to predators. Important components of the methodology included (1) empirically determined environmental partitioning factors between water and particulate material that quantify the effects of dissolved speciation and phase transformation; (2) concentrations of selenium in living and non-living particulates at the base of the food web that determine selenium bioavailability to invertebrates; and (3) selenium biodynamic food web transfer factors that quantify the physiological potential for bioaccumulation from particulate matter to consumer organisms and from prey to their predators.

G2.1.2.2.1 Selenium Concentration in Particulates

Phase transformation reactions from dissolved to particulate selenium are the primary form by which selenium enters the food web. Presser and Luoma (2010a, 2010b, 2013) used field observations to quantify the relationship between particulate material and dissolved selenium as indicated in Equation 2.

$$C_{particulate} = K_d * C_{water\ column}$$

Where:

- $C_{particulate}$ = selenium concentration in particulate material (micrograms/kilogram, dry weight [µg/kg dw])
- K_d = particulate/water ratio
- $C_{water\ column}$ = selenium concentration in water column (µg/L)

The K_d (also called an “enrichment factor”) describes the particulate/water ratio at the moment the sample was taken and should not be interpreted as an equilibrium constant (as it sometimes is mistaken to be). It can vary widely among hydrologic environments and potentially among seasons (Presser and Luoma 2010a, 2010b, 2013; Young et al. 2010). In addition, other factors such as selenium speciation, water residence time, and particle type affect K_d. Selenium typically enters a stream primarily as selenate. If the stream flows into a wetland and the water is retained there with sufficient residence time, recycling of selenium may occur. This results in generation of particulate selenium and conversion to more bioaccumulative selenite and organo-selenium from the less-bioaccumulative dissolved selenate.

Residence time of water containing selenium is usually the most influential factor on the conditions in the receiving aquatic environment. Short water residence times (such as in streams and rivers) limit partitioning of selenium into particulate material. Conversely, longer residence times (such as in sloughs, lakes, and estuaries) allow greater uptake by plants, algae, and microorganisms. Furthermore, environments in downstream portions of a watershed can receive cumulative contributions of upstream recycling in a hydrologic system. Because of its high variability, K_d is a large source of uncertainty in any selenium model where extrapolations from selenium concentrations in the water column to those in aquatic organism tissues, or from tissue to water column concentrations, are necessary.

In developing the Delta-wide bioaccumulation model for bass, the particulate selenium concentration initially was estimated using Equation 2 and a default K_d of 1,000 (Presser and Luoma 2010a). Because the K_d is typically much more variable than other steps in the bioaccumulation model, the K_d was then adjusted to calibrate the model so that the modeled concentrations for fish approximated the measured concentrations in bass for normal and wet years (2000 and 2005) and for drought years (2007), as described in more detail in Section 6D.1.2.3.

G2.1.2.2.2 Selenium Concentrations in Invertebrates

Trophic transfer factors (TTFs) describing the transfer of selenium from particulates to prey and to predators were developed using data from laboratory experiments and field studies (Presser and Luoma 2010a, 2010b, 2013). TTFs are species-specific, but the range of TTFs for freshwater invertebrates was found to be similar to TTFs for marine invertebrates determined in laboratory experiments.

TTFs for estimating selenium concentrations in invertebrates were calculated using Equation 3:

$$TTF_{invertebrate} = (C_{invertebrate})/(C_{particulate})$$

Where:

- $TTF_{invertebrate}$ = trophic transfer factor from particulate material to invertebrate
- $C_{invertebrate}$ = concentration of selenium in invertebrate (µg/g dw)
- $C_{particulate}$ = concentration of selenium in particulate material (µg/g dw)

An average aquatic insect TTF was calculated from TTFs for aquatic insect species with similar bioaccumulative potential, including Mayfly (Baetidae; Heptageniidae; Ephemerellidae), Caddisfly (Rhyacophilidae; Hydropsychidae), Crane Fly (Tipulidae), Stonefly (Perlodidae/Perlidae; Chloroperlidae), Damselfly (Coenagrionidae), Corixid (*Cenocorixa* spp.), and Chironomid (Chironomus spp.) aquatic life stages. Species-specific TTFs ranged from 2.1 to 3.2; the average TTF of 2.8 was used in the Delta-wide model.

G2.1.2.2.3 Selenium Concentrations in Whole-body Fish

The mechanistic equation for modeling selenium bioaccumulation in fish tissue is similar to that for invertebrates if whole-body concentrations are the endpoint (Presser and Luoma 2010a, 2010b, 2013), as shown in Equation 4:

$$TTF_{fish} = C_{fish}/ C_{invertebrate}$$

where:

$$C_{invertebrate} = C_{particulate} * TTF_{invertebrate}$$

therefore:

$$C_{fish} = C_{particulate} * TTF_{invertebrate} * TTF_{fish}$$

Where:

- C_{fish} = concentration of selenium in fish (µg/g dw)
- $C_{particulate}$ = concentration of selenium in particulate material (µg/g dw)
- $C_{invertebrate}$ = concentration of selenium in invertebrate (µg/g dw)
- $TTF_{invertebrate}$ = trophic transfer factor from particulate material to invertebrates
- TTF_{fish} = trophic transfer factor from invertebrates to fish

Modeling selenium bioaccumulation into a particular fish species considers organism physiology and its preferred foods. However, variability in fish tissue selenium concentrations for the present modeling is driven more by dietary choices and their respective levels of bioaccumulation (that is, $TTF_{invertebrate}$) than by differences in fish physiology or the dietary transfer to the fish (TTF_{fish}). A diet of mixed prey (including invertebrates or other fish) can be modeled as shown in Equation 5:

$$C_{fish} = TTF_{fish} * ([C_1 * F_1] + [C_2 * F_2] + [C_3 * F_3])$$

Where:

- C_{fish} = concentration of selenium in fish (µg/g dw)
- TTF_{fish} = trophic transfer factor for fish species
- $C_{1\text{-}3}$ = concentration of selenium in invertebrates or fish prey items 1, 2, and 3 (µg/g dw)
- $F_{1\text{-}3}$ = fraction of diet composed of prey items 1, 2, and 3

Modeling selenium concentrations in more complex food webs with higher trophic levels (for example, predator fish such as bass consuming forage fish) can be completed by incorporating additional TTFs, as shown in Equation 6:

$$C_{predatorfish} = C_{particulate} * TTF_{invertebrate} * TTF_{foragefish} * TTF_{predatorfish}$$

Where:

- $C_{predatorfish}$ = concentration of selenium in fish (µg/g dw)
- $C_{particulate}$ = concentration of selenium in particulate material (µg/g dw)
- $TTF_{invertebrate}$ = trophic transfer factor from particulate material to invertebrates
- $TTF_{foragefish}$ = trophic transfer factor for invertebrates to foraging fish species
- $TTF_{predatorfish}$ = trophic transfer factor for forage fish to predator species

The fish TTFs reported in Presser and Luoma (2010a) ranged from 0.5 to 1.6, so the average fish TTF of 1.1 was used for all trophic levels of fish in the Delta-wide model.

Modeled selenium concentrations in whole-body fish were used to estimate selenium concentrations in fish fillets, as described in Section 6D.1.2.2.5.

G2.1.2.2.4 Selenium Concentrations in Bird Eggs

Selenium concentrations in bird tissues can be estimated, but the transfer of selenium into bird eggs is more meaningful for evaluating reproductive endpoints (Presser and Luoma 2010a; Ohlendorf and Heinz 2011). Examples of models for selenium transfer to bird eggs are as shown in Equations 7 and 8:

$$C_{birdegg} = C_{particulate} * TTF_{invertebrate} * TTF_{birdegg}$$

(this equation is based on birds, such as shorebirds, eating invertebrates)

or:

$$C_{birdegg} = C_{particulate} * TTF_{invertebrate} * TTF_{fish} * TTF_{birdegg}$$

(this equation is based on birds, such as herons or terns, feeding on small fish)

Where:

- $C_{birdegg}$ = concentration of selenium in bird egg (µg/g dw)
- $C_{particulate}$ = concentration of selenium in particulate material (µg/g dw)
- $TTF_{invertebrate}$ = trophic transfer factor from particulate material to invertebrate
- TTF_{fish} = trophic transfer factor from invertebrate to fish
- $TTF_{birdegg}$ = trophic transfer factor from invertebrate or fish (depending on diet) to bird egg

Presser and Luoma (2010b, 2013) reviewed the available data for selenium bioaccumulation from diet to bird eggs and concluded that the mean $TTF_{birdegg}$ = 2.6 was most appropriate for modeling. This TTF was based on laboratory studies in which Mallards (*Anas platyrhynchos*) were fed selenium-fortified diets to evaluate reproductive effects. Mallards are considered sensitive to selenium based on reproductive endpoints. In their previous evaluation of those data, Presser and Luoma (2010a) concluded that a $TTF_{birdegg}$ = 1.8 was appropriate. The form of selenium included in the Mallard diet (selenomethionine) has been used as a surrogate in many laboratory studies to represent exposure of fish and birds under field conditions. Other laboratory studies were conducted with Black-crowned Night-herons (*Nycticorax nycticorax)* by Smith et al (1988), for Eastern Screech-owls (*Otus asio)* by Wiemeyer and Hoffman (1996), and for American Kestrels (*Falco sparverius)* by Santolo et al. (1999). In each of these studies, the experimental groups also received supplemental selenium in the form of selenomethionine. Transfer factors for the selenium-supplemented birds varied from approximately 1.0 to 2.2, with a mean of 1.5.

In field studies conducted at Kesterson Reservoir and the Volta Wildlife Area reference site, extensive sampling of food-chain biota and bird eggs was conducted from 1983 through 1985, and birds were collected to determine qualitatively the kinds of aquatic organisms they had eaten (Saiki and Lowe 1987; Hothem and Ohlendorf 1989; Schuler et al. 1990; Ohlendorf and Hothem 1995). Based on the kinds of food items found in each of the sampled species and the mean selenium concentrations in those kinds of organisms, a mean selenium concentration was estimated for each species at each site during each nesting season. In contrast to the findings with selenomethionine-supplemented diets in the laboratory, TTFs from diet to eggs were almost always less than 2.0. At the Volta Wildlife Area, where diet and egg selenium concentrations were representative of “background” conditions, transfer factors ranged from 0.63 to 2.0, with a mean of 1.35. At Kesterson, the transfer factors ranged from less than 0.2 to 0.48.

Because selenomethionine in the Mallard diet is probably more readily transferred to eggs than are the selenium forms in field-collected food-chain biota, the $TTF_{birdegg}$ = 1.8 value from Presser and Luoma (2010a) was used in the bioaccumulation model.

G2.1.2.2.5 Selenium Concentrations in Fish Fillets

Selenium concentrations in whole-body fish from the bioaccumulation model were converted to selenium concentrations in skinless fish fillets for evaluation of potential human health effects. The regression equation provided in Saiki et al. (1991) for Largemouth Bass from the San Joaquin River system was considered to be the most representative of fish in the Delta and was used for the conversion of these selenium concentrations, as shown in Equation 9:

$$SF = (-0.388) + (1.322 * WB)$$

Where:

- *SF* = selenium concentration in skinless fish fillet (µg/g dw)
- *WB* = selenium concentration in whole-body fish (µg/g dw)

Fish fillet data were compared to the Advisory Tissue Level (2.5 micrograms per gram [µg/g]) in wet weight (ww) (OEHHA 2008); therefore, wet-weight concentrations were estimated from dry-weight concentrations using the equation provided by Saiki et al. (1991) as shown in Equation 10:

$$WW = DW * (100 - Moist)/100$$

Where:

- *WW* = selenium concentration in wet weight (µg/g ww)
- *DW* = selenium concentration in dry weight (µg/g dw)
- *Moist* = mean moisture content of the species

Because moisture content in fish varies among species, sample handling, and locations, the mean moisture content of 70 percent used by Foe (2010b) was assumed for fish in the Delta. The final equation used to estimate selenium concentration in skinless fish fillets (wet weight) from selenium concentration in whole-body fish (dry weight) is as shown in Equation 11:

$$SF = ([-0.388] + [1.322 * WB]) * 0.3$$

Where:

- *SF* = selenium concentrations in skinless fish fillet (µg/g ww)
- *WB* = selenium concentration in whole-body fish (µg/g dw)

G2.1.2.3 Delta-wide Selenium Model Calibration

Several models were evaluated and refined to estimate selenium uptake in fish and in bird eggs from waters in the Delta. Input parameters to the model (K_ds and the number of trophic levels) were iterated among the models as refinements were made. Data for Largemouth Bass collected in the Delta from areas near DSM2 output locations were used to calculate the geometric mean selenium concentration in whole-body fish (Foe 2010a). The ratio of the estimated (modeled) selenium concentration in fish to measured selenium in whole-body bass was used to evaluate each fish model and to focus refinements of the model. These Delta-wide models are presented in the following subsections.

Characteristics of water flow in the Delta affect selenium bioaccumulation and the model refinements, because longer residence time for the water can be expected to increase bioaccumulation by increasing K_d. Foe (2010a) reported the water year type for 2000 as "above normal" in both the Sacramento River and San Joaquin River watersheds. Water year 2000 came after "wet" water years and was followed by "dry" water years. Year 2005 was wetter than 2000 and was reported as "above normal" for the Sacramento River watershed and "wet" for the San Joaquin River watershed. Year 2005 occurred between periods of wet water years. Water Year 2007 was reported as "dry" (Sacramento River watershed) and "critically dry" (San Joaquin River watershed). It came after wet water years and was followed by critically dry water years.

There were no differences in bass selenium concentrations in the Sacramento River at Rio Vista in comparison to the San Joaquin River at Vernalis in 2000, 2005, and 2007 (Foe 2010a). The lack of a difference in bioaccumulated selenium between the two river systems was unexpected because the San Joaquin River is considered a significant source of selenium to the Delta.

Differences in modeled tissue selenium concentrations among years were related to hydrology and water flow through the Delta. Year 2005 selenium concentrations in bass were comparatively lower than those estimated for Year 2000. As expected in a wet water year, the water residence time was shorter, resulting in less selenium recycling, lower K_d values, and lower concentrations of selenium entering the food web. The dry water year (2007) resulted in a longer water residence time, higher K_d values, greater selenium recycling, and higher concentrations of bioavailable selenium entering the food web. These differences among years were considered when refining the selenium bioaccumulation model.

G2.1.2.3.1 Bioaccumulation in Whole-body Fish

Models estimating whole-body selenium concentrations in fish were refined by modifying dietary composition and input parameters to closely represent measured conditions in the Delta. Each model is described in this section.

Model 1 was a basic representative of uptake by a forage fish, while Model 2 calculated sequential bioaccumulation in a more complex food web that included predatory fish eating forage fish, as shown below:

Model 1: Trophic level 3 (TL-3) fish eating invertebrates (Equation 12):

$$C_{fish} = C_{particulate} * TTF_{invertebrate} * TTF_{fish}$$

Model 2: Trophic level 4 (TL-4) fish eating TL-3 fish (Equation 13):

$$C_{predatorfish} = C_{particulate} * TTF_{invertebrate} * TTF_{foragefish} * TTF_{predatorfish}$$

Where:

- C_{fish} = concentration of selenium in fish (µg/g dw)
- $C_{particulate}$ = concentration of selenium in particulate material (µg/g dw)
- $TTF_{invertebrate}$ = Trophic transfer factor from particulate material to invertebrate
- TTF_{fish} = Trophic transfer factor from invertebrate to forage fish or forage fish to predator fish

Equation 12 is the same as Equation 4 and Equation 13 is the same as Equation 6 that were described previously for the generalized model. In both Models 1 and 2, the particulate selenium concentration was estimated using Equation 2 and a default K_d of 1,000. The average TTFs for invertebrates (2.8) and fish (1.1) were used in each model. The outputs of estimated selenium concentrations and the ratios of predicted-to-observed bass selenium concentrations for Models 1 and 2 are presented in Table G2.1-5 and Figure G2.1-1 (all figures are provided at the end of this attachment).

Models 1 and 2 tended to substantially underestimate the whole-body selenium concentrations in fish compared to bass data reported in Foe (2010a). This was partly because Model 1 was estimating selenium concentration in a forage fish (TL-3), whereas bass are a predatory fish with expected higher dietary exposure. Consequently, Model 1 was not further developed as the selenium bioaccumulation model to represent fish in the Delta.

Model 2 is representative of predatory fish, but Model 2 was very similar to Model 1 in distribution of data and in underestimating bass data, even though an additional trophic-level transfer was included in the model. As noted in Section 6D.1.2.2.1 and described in much greater detail by Presser and Luoma (2010a, 2010b, 2013), the K_d values for uptake from water are far more variable than the TTFs for invertebrates or fish. Models 1 and 2 also apparently reflect the tendency of selenium (as an essential nutrient) to be more bioaccumulative when water column concentrations are low (as described by Stewart et al. [2010]), which they were for the DSM2-modeled concentrations (that is, 0.09 to 0.85 µg/L). Available K_d values from various sampling efforts in the Delta provided by Presser and Luoma (2010b) were reviewed for potential applicability in the modeling effort. Those values varied on the basis of locations within the Delta and Suisun Bay and also by water year and flow characteristics (often greater than 5,000 and sometimes exceeding 10,000). However, efforts to incorporate various selected K_d values (for example, 2,000 or 3,000) into the model uniformly for different DSM2 locations failed to produce ratios of modeled-to-measured fish selenium concentrations that approximated 1 (they either over- or underestimated fish selenium concentrations because of variability in site conditions).

The available bass data and the assumed TTFs for invertebrates (2.8) and fish (1.1) were used to back-calculate a location and sample-specific K_d. It is recognized that some of the variability in bioaccumulation may be associated with the TTFs, but there were no reasonable assumptions for selection of alternative values to consider in the model.

When TTFs were held constant, back-calculation of K_d values revealed a concentration-related influence on the values. For water column selenium concentrations in the range of 0.09 to 0.13 µg/L (N = 50), the median K_d was 5,575; when water column selenium concentrations were in the range of 0.14 to 0.40 µg/L (N = 19), the median K_d was 2,431; for water column selenium concentrations in the range of 0.41 to 0.85 µg/L (N = 19), the median K_d was 748. These observations are consistent with an inverse relationship between water column selenium concentrations and bioaccumulation in aquatic organisms (Stewart et al. 2010, USEPA 2016).

Figure G2.1-2 shows the log-log regression relation of K_d to water column selenium concentration when all years are included and the TTFs are held constant, while Figure G2.1-3 shows the relationship for normal/wet years (2000 and 2005) and Figure G2.1-4 shows the regression for dry years (2007), when the K_ds were generally higher.

Model 3 is a refinement of Model 2 (with TTFs as described previously) by including the K_d estimated from the log-log regression relation for all years (Figure G2.2-2). This produced a median ratio of predicted-to-observed whole-body selenium in bass that slightly exceeded 1 (Figure G2.1-1); details are provided in Table G2.1-6. Because of the noticeable differences between 2007 (the dry year) and the other 2 years, the next step in modeling was to evaluate 2007 separately from 2000 and 2005.

Model 4 incorporates the log-log relationship between K_d and water selenium concentrations for 2000 and 2005 (Figure G2.1-3). Model 5 incorporates log-log relationship between K_d and water selenium concentrations for 2007 (Figure G2.1-4 and Table G2.1-7). These two models produced ratios of predicted-to-observed whole-body selenium in bass approximating 1, as shown in Figure G2.1-1.

As expected in a large, complex, and diverse ecological habitat such as the Delta, variations in the data distribution and in the outputs of the models are not surprising. However, it should be noted that the estimated K_d values for Model 3 (674-6,060; Table G2.1-6), Model 4 (651-4,997; Table G2.1-7), and Model 5 (1,206-8,064; Table G2.1-7) are consistent with those summarized by Presser and Luoma (2010b) for the Delta.

Figures G2.1-5 and G2.1-6 illustrate the distribution of data for selenium concentrations in Largemouth Bass (Foe 2010a) relative to the measured or DSM2-modeled water column selenium concentrations (Tables G2.1-2 through G2.1-4) and Models 3, 4, and 5 to complement the boxplots shown in Figure G2.1-1. There is notably more variability in selenium concentrations in bass between 0.09 and 0.13 µg/L than at higher water column selenium concentrations (as shown in both Figures G2.1-5 and G2.1-6); most of the higher values are from 2007 and most of the lower ones are from 2005.

Figure G2.1-5 shows the available data for 2000, 2005, and 2007 plotted with the Model 3 prediction of selenium concentrations. As noted previously in text and in Figure G2.1-1, the model slightly over-predicts the median concentrations in fish on the basis of water column selenium concentrations. This effect is reflected in Figure G2.1-1 by the outliers above the 90th percentile bar (that is, the higher over-predictions for fish, which are those from 2000 and 2005). However, overall, the model is within 1 µg/g for all values less than the prediction, and within about 1.2 µg/g for the values greater than the prediction (Figure G2.1-5).

Because of the notable differences between data for 2007 compared to combined 2000 and 2005 data, Model 4 was developed for 2000 and 2005 and Model 5 was developed for 2007. Figure G2.1-6 shows those model predictions compared to the data. These two models improved the predictions; although, the figure shows greater differences between measured and modeled fish tissue data at lower water column concentrations (that is, less than 0.30 µg/L) than at higher ones. The divergence is generally less than 0.5 µg/g at the higher water column concentrations. The outliers for Model 4 are mostly above the 90th percentile (that is, over-predicting concentrations in fish), rather than below, as shown in Figure G2.1-1. For Model 5, the predictions are “tighter” with just a few outliers above or below the 90th percentile.

Evaluation of water-year effects on selenium concentration in bass concluded that Model 4 was relatively predictive of selenium concentration in whole-body bass during normal to wet water years. Model 5 was considered predictive for dry water years (such as 2007). Model 3 incorporates the varying bioaccumulation when all years are considered (that is, 2000, 2005, and 2007). Although Model 3 tends to slightly overestimate selenium bioaccumulation (Table G2.1-6 and Figure G2.1-1), it was used for estimating selenium concentrations in whole-body fish for “All” years, and Model 5 was used for “Drought” years.

G2.1.2.3.2 Selenium Bioaccumulation in Bird Eggs

The K_d, invertebrate TTF, and fish TTFs developed for use in fish bioaccumulation Models 4 and 5 also were used to estimate selenium uptake into bird eggs using the following two bird egg models (Table G2.1-8):

Bird Egg: Uptake from invertebrates (Equation 14):

$$C_{birdegg} = C_{particulate} * TTF_{invertebrate} * TTF_{birdegg}$$

where:

$$C_{particulate} = K_d * C_{water}$$

Bird Egg: Uptake from fish (Equation 15):

$$C_{birdegg} = C_{particulate} * TTF_{invertebrate} * TTF_{fish} * TTF_{fish} * TTF_{birdegg}$$

where:

$$C_{particulate} = K_d * C_{water}$$

Where:

- $C_{birdegg}$ = concentration of selenium in bird egg (µg/g dw)
- $C_{particulate}$ = concentration of selenium in particulate material (µg/g dw)
- C_{water} = selenium concentration in water column (µg/L)
- K_d = particulate/water ratio
- $TTF_{invertebrate}$ = trophic transfer factor from particulate material to invertebrate
- TTF_{fish} = trophic transfer factor from invertebrate or fish to fish
- $TTF_{birdegg}$ = trophic transfer factor from invertebrate or fish (depending on diet) to bird egg

Equation 14 is the same as Equation 7, but Equation 15 differs from Equation 8 in that it assumes birds are eating larger predatory fish such as bass.

G2.1.2.4 Western Delta Sturgeon Model

Presser and Luoma (2013) determined K_d values for San Francisco Bay (including Carquinez Strait – Suisun Bay) during "low flow" conditions (5,986) and "average" conditions (3,317). These values were used to model selenium concentrations in particulates in bioaccumulation modeling for sturgeon under "Drought" and "All" year conditions at the three western Delta locations. By comparison, calibration of the Delta-wide model for two western-most location from which bass had been collected (Big Break) resulted in an average K_d = 3,736 for 2000/2005 (Model 4, normal/wet years) and average K_d = 7,166 for 2007 (Model 5, dry year).

Sturgeon in the western Delta, Carquinez Strait, and Suisun Bay typically prey on a mix of clams including *Corbula* (*Potamocorbula*) *amurensis*, which is known to be an efficient bioaccumulator of selenium (Stewart et al. 2010) and crustaceans. Presser and Luoma (2013) assumed a sturgeon diet of 50 percent clams and 50 percent amphipods and other crustaceans in their model. Based on this diet, the authors reported a TTF of 9.2 (identified as TTF_{prey} in Table 1 of Presser and Luoma [2013]). This TTF was used to calculate concentrations in sturgeon invertebrate prey for the Sacramento River at Emmaton, San Joaquin River at Antioch, and Montezuma Slough at Hunter Cut/Beldon's Landing locations.

A TTF of 1.3 from diet to fish (identified as $TTF_{predator}$) was reported for sturgeon in Presser and Luoma (2013) and was used to calculate concentrations of selenium in sturgeon for the three western Delta locations.

Modeling sturgeon tissue selenium concentrations at the three western Delta locations did not require refinement because it relied on recent data provided by Presser and Luoma (2013) and because field data to refine the model were not available.

G2.2 Modeling Simulations and Assumptions

This section describes the assumptions for the selenium model simulations. The general selenium modeling assumptions described in the following subsection pertain to all alternative model runs.

G2.2.1 Delta-wide Assumptions

The calibrated Delta-wide selenium bioaccumulation models (Models 3, 4, and 5) are considered representative of conditions in the Delta under current and likely future conditions, because they incorporate realistic concentrations of water column selenium and they predict selenium concentrations in predatory fish that approximate measured concentrations in Largemouth Bass. The calibrated models take into account the variable nature of selenium bioaccumulation in relation to water column concentrations, which is reflected by the inverse relationship between K_d and water column selenium concentrations.

Models are not available to quantitatively estimate the level of changes in selenium bioaccumulation as related to residence time, but the effects of residence time are incorporated in the bioaccumulation modeling for selenium through higher K_d values in drought years compared to wet, normal, or all years. If increases in fish tissue or bird egg selenium were to occur, the increases would likely be of concern only where fish tissues or bird eggs are already near or above thresholds of concern. That is, where biota concentrations are currently low and not approaching thresholds of concern (which is the case throughout the Delta, except for sturgeon in the western Delta), changes in residence time alone would not be expected to cause them to then approach or exceed thresholds of concern. In consideration of this factor, although monitoring data for fish tissue or bird eggs in the Delta are sparse, the most likely areas in which biota tissue selenium concentrations would be high enough that additional bioaccumulation due to increased residence time from restoration areas would be a concern are the western Delta and Suisun Bay (discussed below for sturgeon), and the south Delta in areas that receive San Joaquin River water.

The South Delta receives elevated selenium loads from the San Joaquin River. In contrast to Suisun Bay and possibly the western Delta in the future, the south Delta lacks the Overbite Clam (*Corbula* [*Potamocorbula*] *amurensis*), which is considered a key driver of selenium bioaccumulation in Suisun Bay because of its high bioaccumulation of selenium and its role in the benthic food web that includes long-lived sturgeon. The Asian Clam, *Corbicula fluminea,* occur in the south Delta. This bivalve also bioaccumulates selenium, but it is not as widespread as the Overbite Clam and thus likely makes up a smaller fraction of sturgeon diet.

Nonpoint sources of selenium in the San Joaquin Valley that contribute selenium to the Delta are being controlled through a Total Maximum Daily Load (TMDL) developed by the Central Valley Regional Water Quality Control Board (CVRWQCB) for the lower San Joaquin River, established limits for the Grassland Bypass Project, and Basin Plan objectives (CVRWQCB 2001, 2010; SWRCB 2010a, 2010b; USEPA 2015) that have resulted in decreasing discharges of selenium from the San Joaquin River to the Delta.

G2.2.2 Western Delta Sturgeon Assumptions

Modeling for selenium bioaccumulation by sturgeon in the western Delta was based on the most appropriate uptake factors available, which were published recently by Presser and Luoma (2013) specifically for sturgeon in northern San Francisco Bay estuary. The disparity between larger estimated changes for sturgeon and smaller changes for other biota (that is, whole-body fish, bird eggs, and fish fillets) is attributable largely to differences in modeling approaches, as described previously. The model for most biota was calibrated to account for the varying concentration-dependent uptake from water column selenium concentrations (expressed as the K_d, which is the ratio of selenium concentrations in particulates [as the lowest level of the food chain] relative to the water column concentration) that was exhibited in data for Largemouth Bass in 2000, 2005, and 2007 at various locations across the Delta. In contrast, the sturgeon modeling could not be similarly calibrated at the three western Delta locations and used literature-derived uptake factors and TTFs for the estuary from Presser and Luoma (2013).

There was a significant negative log-log relationship of K_d to water column selenium concentration that reflected greater bioaccumulation rates for bass at low water column selenium than at higher concentrations. There was no difference in bass selenium concentrations in the Sacramento River at Rio Vista compared to the San Joaquin River at Vernalis in 2000, 2005, and 2007 (Foe 2010a), despite a nearly 10-fold difference in water column selenium concentrations. It is unknown whether this might also occur in the sturgeon food web. Thus, there is more confidence in the site-specific modeling based on the Delta-wide model that was calibrated for bass data than in the estimates for sturgeon based on “fixed” K_d values for all years and for drought years without regard to water column selenium concentration at the three locations in different time periods.

The western Delta and Suisun Bay receive elevated selenium loads from North San Francisco Bay (including San Pablo Bay, Carquinez Strait, and Suisun Bay) and from the San Joaquin River. Point sources of selenium in North San Francisco Bay (that is, refineries) that contribute selenium to Suisun Bay are expected to be reduced through a TMDL developed by the San Francisco Bay Regional Water Quality Control Board (SFBRWQCB 2016) that is expected to result in decreasing discharges of selenium. Nonpoint sources of selenium in the San Joaquin Valley that contribute selenium to the San Joaquin River, and thus the Delta and Suisun Bay, will be controlled through a TMDL developed by the CVRWQCB (2001) for the lower San Joaquin River, established limits for the GBP, and Basin Plan objectives (CVRWQCB 2010; SWRCB 2010a, 2010b; USEPA 2015) that are expected to result in decreasing discharges of selenium from the San Joaquin River to the Delta. If selenium levels are not sufficiently reduced via these efforts, it is expected that the SWRCB and the San Francisco Bay and Central Valley regional Water Quality Control Boards would initiate additional actions to further control sources of selenium.

G2.2.3 Model Application Methodology

Modeled whole-body fish, bird egg, or fish fillet data were compared directly (for percent change) to the following threshold effect benchmarks:

- Whole-body fish for the Delta-wide model were compared to the Level of Concern (4 milligrams per kilogram [mg/kg] dw; Beckon 2017) and the Toxicity Level (8.5 mg/kg dw; USEPA 2016, 2018) for fish tissue.
- Modeled bird egg selenium concentrations were compared to Level of Concern (6 mg/kg dw) and Toxicity Level (10 mg/kg dw) values from Beckon (2017).
- Fish fillet data were compared to the Advisory Tissue Level (2.5 µg/g ww) for human consumption of fish (OEHHA 2008).

- Whole-body selenium concentrations in sturgeon were compared to Low Effect (5 mg/kg dw) and High Effect (8 mg/kg dw) guidelines from Presser and Luoma (2013) and the North San Francisco Bay TMDL target (8 mg/kg dw; SFBRWQCB 2016).

Results of comparisons to these benchmarks are expressed as Exceedance Quotients (EQs) in some of the tables and figures. Annual average selenium concentrations in water did not exceed the 1.5 µg/L criterion for lentic aquatic systems or the 3.1 µg/L criterion for lotic aquatic systems (USEPA 2016), so no EQs were calculated for modeled water concentrations.

G2.2.3.1 No Action Alternative Model

- The No Action Alternative model was completed for five Delta interior, three western Delta, and four major Delta diversion locations. DSM2 post-processing output provided estimates of the water column selenium concentration at each of those 12 locations (Table G2.2-1). The Delta-specific selenium bioaccumulation model that was calibrated using Largemouth Bass data from the Delta was then used to estimate selenium concentrations in whole-body fish and then in bird eggs and fish fillets. Selenium concentrations in sturgeon inhabiting the western Delta (represented by three locations) were estimated using recently published literature parameters. Modeled selenium concentrations in whole-body fish (predatory fish throughout the Delta or sturgeon in the western Delta), bird egg, or fish fillet data were compared to the threshold effect benchmarks listed previously. The modeled tissue selenium concentrations themselves and the EQs (based on comparisons to thresholds) both served as a basis for comparison of other alternatives.

G2.2.3.2 Alternative Models

For each of the alternative model simulations, the same procedure as described for the No Action Alternative model was used, with similar assumptions, to estimate water column selenium concentrations and selenium concentrations in fish and in bird eggs. Each alternative model simulation for each type of biota (whole-body fish [either using the Delta-wide model for bass or the western Delta sturgeon model], bird eggs, or fish fillets) was compared to the No Action Alternative.

G2.3 Modeling Results

G2.3.1 Results: Delta-wide Model

Modeled concentrations of selenium in whole-body fish, bird eggs (invertebrate diet and fish diet), and fish fillets are for the alternatives are summarized in Tables G2.3-1 through G2.3-9. Outputs are average selenium concentrations for the entire (1922–2003) period modeled and the five-year (1987–1991) drought period modeled using DSM2. Figures G2.3-1 through G2.3-4 present the EQs for the five year drought period for whole-body fish, bird eggs (invertebrate diet), bird eggs (fish diet), and fish fillets.

G2.3.2 Results: Western Delta Sturgeon Model

Modeling results for selenium in whole-body sturgeon are summarized in Tables G2.3-10 through G2.3-12. Outputs are average selenium concentrations for the entire (1922–2003) period modeled and the five-year (1987–1991) drought period modeled using DSM2. Figure G2.3-5 presents the Low Toxicity Threshold EQs in whole-body sturgeon for the five-year drought period.

G2.3.3 Model Limitations and Applicability

CalSim II and DSM2 are planning level models, not predictive models. Further, mathematical models like DSM2 can only approximate processes of physical systems. Models are inherently inexact because the mathematical description of the physical system is imperfect, and the understanding of interrelated physical processes is incomplete.

The selenium model for sturgeon has greater uncertainty than the selenium model for bass because the sturgeon model was not as finely calibrated for varying K_d relative to water column selenium concentrations in the western Delta, as discussed in Section 6D.2.2. Selenium concentrations for inflow sources to the Delta (for example, agriculture in the Delta, Yolo Bypass, Eastside Tributaries) also present uncertainty in the modeling because of limited data. However, the selenium models are powerful tools that provide estimated selenium concentrations in biota that, when used in a comparative manner, can provide useful insight into how physical system changes could affect selenium bioaccumulation.

G2.4 References

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Table G2.1-2. Calculation of Quarterly Average Selenium Concentrations for DSM2 Output Locations Based on Percentage of Flow at Each Location from Different Sources: Year 2000

		First Quarter Inflow Percentage						Second Quarter Inflow Percentage					
	Inflow Source □	**Delta Ag.**	**East Delta Tributaries**	**Sac. R.**	**San Joaq. R.**	**Martinez/ Suisun Bay**	**Yolo Bypass**	**Delta Ag.**	**East Delta Tributaries**	**Sac. R.**	**San Joaq. R.**	**Martinez/ Suisun Bay**	**Yolo Bypass**
	Inflow Location □	***Mildred Island, Center***	***Mokelumne Calaveras Cosumnes Rivers***	***Freeport***	***Vernalis***	***San Joaq. R. near Mallard Island***	***Sac. R. below Knights Landing***	***Mildred Island, Center***	***Mokelumne Calaveras Cosumnes Rivers***	***Freeport***	***Vernalis***	***San Joaq. R. near Mallard Island***	***Sac. R. below Knights Landing***
	Selenium (µg/L) □	0.11	0.10	0.09	0.83	0.10	0.23	0.11	0.10	0.09	0.83	0.10	0.23
DSM2 Output Water Location	**Location ID**												
Big Break	BIGBRK_MID	2.94	6.88	53.15	6.59	0.18	5.70	2.95	6.37	73.59	13.55	0.27	3.12
Cache Slough	CACHS_LEN	1.46	0	53.38	0	0	31.91	1.24	1.5E-05	85.07	2.5E-05	0	13.25
Cache Slough Ryer	CACHSR_MID	2.88	0	54.86	0	0	20.48	3.36	9.8E-07	79.75	1.9E-06	0	16.25
Cosumnes R.	COSR_LEN	8.1E-06	98.82	0	0	0	0	0	100.00	0	0	0	0
Franks Tract	FRANKST_MID	5.06	11.56	43.94	15.79	0.02	0.32	4.17	9.42	61.16	23.89	0.01	1.22
Little Holland Tract	LHOLND_L0	72.35	0	5.06	0	0	6.50	23.38	8.2E-07	63.10	1.6E-06	0	13.03
Middle R Bullfrog	MIDRBULFRG_LEN	10.54	13.07	18.37	32.20	1.9E-03	3.2E-03	5.49	9.19	14.96	70.17	4.2E-04	0.10
Mildred Island	MILDDRISL_MID	7.47	14.31	22.79	30.23	2.4E-03	1.8E-03	4.77	10.05	18.48	66.48	6.7E-04	0.13
Mok. R. below Cosum.	MOKBCOS_LEN	2.07	96.19	0	0	0	0	1.65	98.35	0	0	0	0
Mok. R. downstream Cosum.	MOKDCOS_MID	2.07	96.43	0	0	0	0	1.68	98.32	0	0	0	0
Old R near Paradise Cut	OLDRNPARADSEC_MID	6.24	0	0	87.26	0	0	14.40	1.67	5.21	78.66	1.2E-05	0.04
Paradise Cut	PARADSECUT_LEN	4.69	0	0	91.37	0	0	2.62	0.06	0.15	97.16	1.5E-07	1.1E-03
Port of Stockton	PORTOSTOCK_L0	1.67	0	0	18.85	0	0	2.22	0	0	60.73	0	0
Sac. R. at Isleton	SACRISLTON_L0	0.33	0	95.77	0	0	0	0.31	0.00	99.60	0	0	5.5E-05
Sac River RM 44	SACR44_L0	0.14	0	97.93	0	0	0	0.11	0	99.81	0	0	0
Sandmound Sl.	SANDMND_MID	6.36	10.51	43.82	12.90	0.03	0.57	5.22	8.81	63.78	20.40	0.03	1.63
Sherman Island	SHERMNILND_L0	1.64	3.45	52.71	3.93	0.60	12.10	2.48	4.95	76.80	10.96	0.96	3.67
SJR Bowman	SJRBOWMN_MID	1.40	0	0	94.03	0	0	1.52	0	0	98.48	0	0
SJR N Hwy4	SJRNHWY4_MID	3.49	0	0	89.96	0	0	1.87	0	0	98.13	0	0
SJR Naval st	SJRNAVLST_L0	8.89	12.70	0.00	65.44	0	0	2.69	6.26	0	90.94	0	0
SJR Potato Slough	SJRPOTSL_MID	3.15	12.62	55.38	12.40	0.01	0.06	3.05	10.32	65.93	19.73	0.01	0.86
SJR Turner	SJRTURNR_MID	8.81	9.28	2.55	56.31	5.3E-05	1.0E-05	3.33	5.77	0.41	90.39	6.3E-06	2.4E-03
SJR/Pt. Antioch/fish pier	ASRANTFSH_MID	1.92	4.35	55.13	4.50	0.44	10.23	2.45	4.72	77.70	10.28	0.76	3.91
Suisun Bay	SUISNB_LEN	0.81	1.22	45.93	1.24	16.49	15.94	0.92	1.66	49.51	3.61	41.10	2.95
Sycamore Slough	SYCAMOR_MID	6.50	50.69	15.18	0	0	0	5.89	76.86	16.89	2.8E-07	0	0
White Slough	WHITESL_L0	22.32	11.88	17.97	25.51	1.7E-08	6.0E-11	16.54	12.10	16.87	54.46	3.7E-09	6.1E-05
White Slough DS Disappointment Sl.	WHTSLDISPONT_LEN	14.83	22.63	29.02	22.45	5.4E-08	0	12.45	13.97	21.21	52.32	2.2E-09	2.3E-04

Table G2.1-2. Continued: Calculation of Quarterly Average Selenium Concentrations for DSM2 Output Locations Based on Percentage of Flow at Each Location from Different Sources: Year 2000

DSM2 Output Water Location		Third Quarter Inflow Percentage						Fourth Quarter Inflow Percentage						Estimated Waterborne Selenium Concentrations (µg/L)				
	Inflow Source □	Delta Ag.	East Delta Tributaries	Sac. R.	San Joaq. R.	Martinez/ Suisun Bay	Yolo Bypass	Delta Ag.	East Delta Tributaries	Sac. R.	San Joaq. R.	Martinez/ Suisun Bay	Yolo Bypass					
	Inflow Location □	*Mildred Island, Center*	*Mokelumne Calaveras Cosumnes Rivers*	*Freeport*	*Vernalis*	*San Joaq. R. near Mallard Island*	*Sac. R. below Knights Landing*	*Mildred Island, Center*	*Mokelumne Calaveras Cosumnes Rivers*	*Freeport*	*Vernalis*	*San Joaq. R. near Mallard Island*	*Sac. R. below Knights Landing*	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter	Annual
	Selenium (µg/L) □	0.11	0.10	0.09	0.83	0.10	0.23	0.11	0.10	0.09	0.83	0.10	0.23					
	Location ID																	
Big Break	BIGBRK_MID	3.13	0.45	85.63	0.44	4.15	6.12	2.13	0.20	84.85	0.02	8.76	3.96	0.13	0.20	0.10	0.10	0.13
Cache Slough	CACHS_LEN	1.66	4.7E-07	85.95	4.3E-07	5.9E-07	12.23	1.32	2.8E-06	89.83	1.1E-07	2.3E-05	8.67	0.12	0.11	0.11	0.10	0.11
Cache Slough Ryer	CACHSR_MID	1.90	9.3E-08	84.53	1.8E-07	9.2E-12	13.38	1.81	1.0E-07	89.45	6.2E-10	3.0E-06	8.54	0.10	0.11	0.11	0.10	0.11
Cosumnes R.	COSR_LEN	0	100.00	0	0	0	0	0	100.00	0	0	0	0	0.10	0.10	0.10	0.10	0.10
Franks Tract	FRANKST_MID	4.04	0.57	90.34	0.41	0.80	3.78	2.76	0.62	91.38	0.12	2.42	2.64	0.19	0.27	0.10	0.10	0.16
Little Holland Tract	LHOLND_L0	18.48	2.2E-07	68.67	4.2E-07	7.2E-13	12.68	19.63	2.6E-09	72.79	0	0	7.42	0.10	0.11	0.11	0.10	0.11
Middle R Bullfrog	MIDRBULFRG_LEN	7.81	6.43	69.63	14.94	0.12	1.02	4.86	6.31	59.79	27.84	1	0.68	0.31	0.61	0.20	0.30	0.36
Mildred Island	MILDDRISL_MID	6.57	4.57	83.28	4.14	0.15	1.25	4.50	6.63	71.28	16.13	0.61	0.82	0.29	0.58	0.12	0.21	0.30
Mok. R. below Cosum.	MOKBCOS_LEN	7.23	92.77	4.7E-09	0	0	0	2.47	97.53	0	0	0	0	0.10	0.10	0.10	0.10	0.10
Mok. R. downstream Cosum.	MOKDCOS_MID	7.08	92.92	0	0	0	0	2.34	97.66	0	0	0	0	0.10	0.10	0.10	0.10	0.10
Old R near Paradise Cut	OLDRNPARADSEC_MID	10.56	3.9E-05	1.3E-04	89.44	8.8E-28	3.0E-07	2.50	1.1E-04	3.5E-04	97.50	2.8E-20	1.7E-07	0.73	0.68	0.75	0.81	0.74
Paradise Cut	PARADSECUT_LEN	3.43	0	0	96.57	0	0	0.96	0	0	99.04	0	0	0.76	0.81	0.81	0.82	0.80
Port of Stockton	PORTOSTOCK_L0	3.09	0	0	81.32	0	0	2.70	0	0	89.89	0	0	0.16	0.51	0.68	0.75	0.52
Sac. R. at Isleton	SACRISLTON_L0	0.44	0	99.55	0	0	1.3E-05	0.28	0	99.72	0	0	1.1E-03	0.09	0.09	0.09	0.09	0.09
Sac River RM 44	SACR44_L0	0.13	0	99.86	0	0	0	0.05	0	99.94	0	0	0	0.09	0.09	0.09	0.09	0.09
Sandmound Sl.	SANDMND_MID	5.24	0.61	87.78	0.49	1.22	4.59	3.31	0.43	89.58	0.06	3.44	3.11	0.17	0.25	0.10	0.10	0.15
Sherman Island	SHERMNILND_L0	2.60	0.40	81.69	0.46	8.21	6.56	1.77	0.11	77.64	0.01	16.46	3.94	0.11	0.18	0.10	0.10	0.12
SJR Bowman	SJRBOWMN_MID	3.00	0	0	97.00	0	0	0.33	0	0	99.67	0	0	0.78	0.82	0.81	0.83	0.81
SJR N Hwy4	SJRNHWY4_MID	3.91	0	0	96.09	0	0	0.72	0	0	99.28	0	0	0.75	0.82	0.80	0.82	0.80
SJR Naval st	SJRNAVLST_L0	5.98	10.89	0	83.00	0	0	2.02	3.10	0.00	94.84	0	0	0.57	0.76	0.71	0.79	0.71
SJR Potato Slough	SJRPOTSL_MID	2.63	0.35	93.54	0.20	0.45	2.79	2.06	0.80	93.46	0.06	1.47	2.11	0.17	0.24	0.10	0.09	0.15
SJR Turner	SJRTURNR_MID	8.69	13.75	17.87	59.41	0.01	0.16	3.23	4.83	7.34	84.49	0.03	0.05	0.49	0.76	0.53	0.72	0.62
SJR/Pt. Antioch/fish pier	ASRANTFSH_MID	2.64	0.35	83.38	0.38	6.66	6.52	1.82	0.12	80.54	0.01	13.33	4.11	0.12	0.17	0.10	0.10	0.12
Suisun Bay	SUISNB_LEN	0.80	0.23	27.56	0.40	68.55	2.42	0.60	0.03	28.62	0.01	69.16	1.54	0.11	0.13	0.10	0.10	0.11
Sycamore Slough	SYCAMOR_MID	5.04	14.29	80.66	1.2E-31	0	0	4.23	31.10	64.66	0	0	0	0.07	0.10	0.09	0.09	0.09
White Slough	WHITESL_L0	9.89	7.76	82.34	3.8E-03	3.0E-05	5.3E-04	11.19	12.92	75.64	0.24	4.2E-04	6.4E-04	0.26	0.50	0.09	0.10	0.24
White Slough DS Disappointment Sl.	WHTSLDISPONT_LEN	8.74	7.78	83.47	2.4E-03	4.0E-05	5.6E-04	5.28	14.84	79.82	0.05	5.0E-04	7.3E-04	0.25	0.48	0.09	0.09	0.23

Table G2.1-3. Calculation of Quarterly Average Selenium Concentrations for DSM2 Output Locations Based on Percentage of Flow at Each Location from Different Sources: Year 2005

DSM2 Output Water Location		First Quarter Inflow Percentage						Second Quarter Inflow Percentage					
	Inflow Source □	Delta Ag.	East Delta Tributaries	Sac. R.	San Joaq. R.	Martinez/ Suisun Bay	Yolo Bypass	Delta Ag.	East Delta Tributaries	Sac. R.	San Joaq. R.	Martinez/ Suisun Bay	Yolo Bypass
	Inflow Location □	*Mildred Island, Center*	*Mokelumne Calaveras Cosumnes Rivers*	*Freeport*	*Vernalis*	*San Joaq. R. near Mallard Island*	*Sac. R. below Knights Landing*	*Mildred Island, Center*	*Mokelumne Calaveras Cosumnes Rivers*	*Freeport*	*Vernalis*	*San Joaq. R. near Mallard Island*	*Sac. R. below Knights Landing*
	Selenium (µg/L) □	0.11	0.10	0.09	0.85	0.10	0.23	0.11	0.10	0.09	0.85	0.10	0.23
	Location ID												
Big Break	BIGBRK_MID	5.87	7.57	83.73	2.41	0.24	0.18	2.90	17.21	52.77	26.69	1.6E-03	0.43
Cache Slough	CACHS_LEN	4.89	2.2E-07	93.64	8.E-07	3.8E-07	1.47	1.48	7.1E-07	94.13	8.0E-07	1.1E-08	4.38
Cache Slough Ryer	CACHSR_MID	8.13	3.0E-07	91.14	1.2E-06	1.3E-06	0.73	3.74	2.5E-08	91.89	1.0E-07	2.9E-08	4.38
Cosumnes R.	COSR_LEN	0	100.00	0	0	0	0	0.00	100.00	0.00	0	0	0
Franks Tract	FRANKST_MID	8.65	11.65	72.50	7.E+00	0.19	0.05	4.63	16.63	26.97	51.74	1.1E-04	0.03
Little Holland Tract	LHOLND_L0	97.11	3.2E-09	2.88	9.E-09	3.9E-09	0.01	44.12	6.5E-09	53.25	2E-08	1.2E-08	2.63
Middle R Bullfrog	MIDRBULFRG_LEN	13.67	9.76	28.26	48.24	0.08	0.01	5.55	5.64	2.70	86.11	7.1E-05	8.4E-04
Mildred Island	MILDDRISL_MID	12.36	11.39	32.28	43.87	8.4E-02	0.01	4.81	6.98	2.78	85.43	3.6E-05	6.7E-04
Mok. R. below Cosum.	MOKBCOS_LEN	2.18	97.82	0	0.00	0	0	0.53	99.47	0	0	0	0
Mok. R. downstream Cosum.	MOKDCOS_MID	2.22	97.78	0	0.00	0	0	0.53	99.47	0	0	0	0
Old R near Paradise Cut	OLDRNPARADSEC_MID	8.95	4.7E-05	1.5E-03	91.05	1.4E-05	1.4E-06	1.43	1.7E-07	1.6E-05	98.57	1.7E-08	3.5E-10
Paradise Cut	PARADSECUT_LEN	10.28	1.6E-07	6.8E-07	89.72	1.6E-11	1.7E-08	0.82	0	0	99.18	0	0
Port of Stockton	PORTOSTOCK_L0	4.70	0	0	95.30	0	0	2.83	0	0	97.16	0	0
Sac. R. at Isleton	SACRISLTON_L0	0.55	0	99.45	0.00	0	0	0.18	0	99.82	0.00	0	0
Sac River RM 44	SACR44_L0	0.21	0	99.79	0.00	0	0	0.07	0	99.93	0.00	0	0
Sandmound Sl.	SANDMND_MID	10.51	10.17	74.35	4.65	0.25	0.07	5.35	18.03	32.15	44.41	1.5E-04	0.06
Sherman Island	SHERMNILND_L0	4.89	5.04	87.74	1.52	0.56	0.23	2.43	14.17	61.17	21.31	0.03	0.89
SJR Bowman	SJRBOWMN_MID	1.10	0	0.00	98.90	0	0	0.45	0	0	99.55	0	0
SJR N Hwy4	SJRNHWY4_MID	1.89	0	0.00	98.11	0	0	0.59	0	0	99.41	0	0
SJR Naval st	SJRNAVLST_L0	4.70	5.45	0.00	89.85	0	0	1.06	5.10	0	93.84	0	0
SJR Potato Slough	SJRPOTSL_MID	6.24	16.03	71.18	6.45	0.07	0.03	2.65	23.15	38.61	35.59	1.1E-05	0.01
SJR Turner	SJRTURNR_MID	6.75	4.55	1.37	87.31	0.01	0	1.49	3.20	0.00	95.31	0	0
SJR/Pt. Antioch/fish pier	ASRANTFSH_MID	4.87	5.29	87.53	1.67	0.37	0.27	2.37	13.56	62.61	20.61	0.02	0.84
Suisun Bay	SUISNB_LEN	2.63	1.36	66.87	0.33	28.58	0.23	1.35	6.21	59.91	8.33	22.38	1.82
Sycamore Slough	SYCAMOR_MID	14.41	68.02	17.57	8.8E-17	0	3.5E-29	3.66	95.02	1.31	1.E-18	0	3.9E-33
White Slough	WHITESL_L0	47.62	12.39	33.06	6.93	8.2E-04	2.7E-06	15.95	8.06	2.95	73.04	1.4E-05	1.5E-07
White Slough DS Disappointment Sl.	WHTSLDISPONT_LEN	20.77	29.09	44.03	6.11	2.4E-04	3.6E-06	14.40	8.89	3.00	73.72	7.9E-06	0

Table G2.1-3. Continued: Calculation of Quarterly Average Selenium Concentrations for DSM2 Output Locations Based on Percentage of Flow at Each Location from Different Sources: Year 2005

DSM2 Output Water Location		Third Quarter Inflow Percentage						Fourth Quarter Inflow Percentage						Estimated Waterborne Selenium Concentrations (µg/L)				
	Inflow Source □	**Delta Ag.**	**East Delta Tributaries**	**Sac. R.**	**San Joaq. R.**	**Martinez/ Suisun Bay**	**Yolo Bypass**	**Delta Ag.**	**East Delta Tributaries**	**Sac. R.**	**San Joaq. R.**	**Martinez/ Suisun Bay**	**Yolo Bypass**					
	Inflow Location □	***Mildred Island, Center***	***Mokelumne Calaveras Cosumnes Rivers***	***Freeport***	***Vernalis***	***San Joaq. R. near Mallard Island***	***Sac. R. below Knights Landing***	***Mildred Island, Center***	***Mokelumne Calaveras Cosumnes Rivers***	***Freeport***	***Vernalis***	***San Joaq. R. near Mallard Island***	***Sac. R. below Knights Landing***	**1st Quarter**	**2nd Quarter**	**3rd Quarter**	**4th Quarter**	**Annual**
	Selenium (µg/L) □	0.11	0.10	0.09	0.85	0.10	0.23	0.11	0.10	0.09	0.85	0.10	0.23					
	Location ID																	
Big Break	BIGBRK_MID	3.31	2.21	88.77	1.70	3.98	0.03	2.39	0.24	90.17	0.01	6.48	0.70	0.11	0.30	0.10	0.09	0.15
Cache Slough	CACHS_LEN	1.94	1.7E-05	98.02	1.0E-05	1.6E-06	0.05	2.30	1.2E-05	92.72	4.6E-07	0.00	4.98	0.09	0.10	0.09	0.10	0.09
Cache Slough Ryer	CACHSR_MID	2.15	5.6E-07	97.77	2.6E-07	4.5E-09	0.08	2.66	8.8E-07	96.37	1.9E-08	7.6E-06	0.97	0.09	0.10	0.09	0.09	0.09
Cosumnes R.	COSR_LEN	0	100	0	0	0	0	1.2E-04	100.00	0	0	0	0	0.10	0.10	0.10	0.10	0.10
Franks Tract	FRANKST_MID	4.27	3.20	89.93	1.81	0.77	0.02	3.17	0.81	94.16	0.06	1.74	0.05	0.15	0.49	0.11	0.09	0.21
Little Holland Tract	LHOLND_L0	18.61	5.6E-07	81.24	0.00	0.00	0.16	46.22	6.1E-08	53.77	2.8E-08	2.6E-09	0.01	0.11	0.10	0.09	0.10	0.10
Middle R Bullfrog	MIDRBULFRG_LEN	7.43	12.50	53.07	26.88	0.12	3.1E-03	5.54	8.75	65.65	19.67	0.39	1.1E-03	0.46	0.75	0.30	0.24	0.44
Mildred Island	MILDDRISL_MID	6.73	12.68	65.46	14.98	0.15	3.9E-03	4.81	7.16	77.85	9.71	0.47	1.8E-03	0.43	0.74	0.21	0.17	0.38
Mok. R. below Cosum.	MOKBCOS_LEN	3.05	96.95	0	0	0	0	3.00	97.00	0	0	0	0	0.10	0.10	0.10	0.10	0.10
Mok. R. downstream Cosum.	MOKDCOS_MID	3.05	96.95	0	0	0	0	2.93	97.07	0	0	0	0	0.10	0.10	0.10	0.10	0.10
Old R near Paradise Cut	OLDRNPARADSEC_MID	6.64	0	5.E-09	93.36	0	0	14.49	0.24	3.16	82.09	0.02	8.1E-05	0.78	0.84	0.80	0.72	0.79
Paradise Cut	PARADSECUT_LEN	2.39	0	0	97.61	0	0	1.08	0	0	98.92	0	0	0.77	0.84	0.83	0.84	0.82
Port of Stockton	PORTOSTOCK_L0	2.20	0	0	97.80	0	0	2.20	0	0	97.79	0	0	0.82	0.83	0.83	0.83	0.83
Sac. R. at Isleton	SACRISLTON_L0	0.45	0	99.55	0.00	0	0	0.41	0	99.59	0	0	8.2E-08	0.09	0.09	0.09	0.09	0.09
Sac River RM 44	SACR44_L0	0.14	0	99.86	0.00	0	0	0.17	0	99.83	0	0	0	0.09	0.09	0.09	0.09	0.09
Sandmound Sl.	SANDMND_MID	5.61	3.13	87.97	2.10	1.17	0.02	3.93	0.55	92.97	0.03	2.45	0.07	0.13	0.43	0.11	0.09	0.19
Sherman Island	SHERMNILND_L0	2.76	1.84	86.03	1.72	7.62	0.04	1.95	0.11	84.69	0.01	11.76	1.48	0.10	0.26	0.10	0.09	0.14
SJR Bowman	SJRBOWMN_MID	2.06	0	0	97.94	0	0	0.80	0	0	99.20	0	0	0.84	0.85	0.83	0.84	0.84
SJR N Hwy4	SJRNHWY4_MID	2.64	0	0	97.36	0	0	1.94	0.00	0	98.06	0	0	0.84	0.85	0.83	0.84	0.84
SJR Naval st	SJRNAVLST_L0	4.11	9.43	0	86.46	0	0	4.97	12.46	0	82.57	0	0	0.77	0.80	0.75	0.72	0.76
SJR Potato Slough	SJRPOTSL_MID	2.75	2.58	93.40	0.83	0.42	0.01	2.16	1.30	95.35	0.02	1.04	0.13	0.14	0.36	0.10	0.09	0.17
SJR Turner	SJRTURNR_MID	6.05	11.77	4.90	77.27	0.01	8.4E-05	5.55	16.96	10.99	66.44	0.06	7.4E-05	0.76	0.81	0.68	0.60	0.71
SJR/Pt. Antioch/fish pier	ASRANTFSH_MID	2.82	1.68	87.76	1.46	6.24	0.03	2.05	0.14	86.70	0.01	9.68	1.42	0.10	0.25	0.10	0.09	0.14
Suisun Bay	SUISNB_LEN	0.83	0.82	31.47	1.16	65.65	0.07	0.68	0.05	32.01	0.03	66.56	0.68	0.10	0.16	0.11	0.10	0.11
Sycamore Slough	SYCAMOR_MID	4.79	40.41	54.81	2.9E-20	0	1.1E-32	5.24	32.04	62.72	2.6E-18	7.7E-14	1.0E-30	0.10	0.10	0.09	0.09	0.10
White Slough	WHITESL_L0	10.03	26.20	63.17	0.61	3.0E-05	8.1E-08	9.32	12.33	78.34	0.01	4.6E-04	4.6E-08	0.15	0.65	0.10	0.09	0.25
White Slough DS Disappointment Sl.	WHTSLDISPONT_LEN	9.10	26.19	64.27	0.45	3.1E-05	0	6.26	14.39	79.35	1.9E-03	6.8E-04	0	0.14	0.65	0.10	0.09	0.25

Table G2.1-4. Calculation of Quarterly Average Selenium Concentrations for DSM2 Output Locations Based on Percentage of Flow at Each Location from Different Sources: Year 2007

		First Quarter Inflow Percentage						Second Quarter Inflow Percentage					
	Inflow Source □	**Delta Ag.**	**East Delta Tributaries**	**Sac. R.**	**San Joaq. R.**	**Martinez/ Suisun Bay**	**Yolo Bypass**	**Delta Ag.**	**East Delta Tributaries**	**Sac. R.**	**San Joaq. R.**	**Martinez/ Suisun Bay**	**Yolo Bypass**
	Inflow Location □	***Mildred Island, Center***	***Mokelumne Calaveras Cosumnes Rivers***	***Freeport***	***Vernalis***	***San Joaq. R. near Mallard Island***	***Sac. R. below Knights Landing***	***Mildred Island, Center***	***Mokelumne Calaveras Cosumnes Rivers***	***Freeport***	***Vernalis***	***San Joaq. R. near Mallard Island***	***Sac. R. below Knights Landing***
	Selenium (μg/L) □	0.11	0.10	0.09	0.58	0.10	0.23	0.11	0.10	0.09	0.58	0.10	0.23
DSM2 Output Water Location	**Location ID**												
Big Break	BIGBRK_MID	2.66	1.75	93.01	0.07	2.30	0.21	4.40	3.10	84.13	4.24	1.24	2.89
Cache Slough	CACHS_LEN	1.86	1.4E-05	97.14	2.2E-07	2.8E-05	1.01	1.99	5.1E-04	88.84	8.8E-04	1.6E-05	9.17
Cache Slough Ryer	CACHSR_MID	2.85	1.8E-06	96.46	4.7E-08	1.5E-05	0.68	2.66	1.2E-04	88.76	1.8E-04	1.4E-06	8.58
Cosumnes R.	COSR_LEN	0.00	100.00	0	0	0	0.00	0.01	99.99	0	0	0	0
Franks Tract	FRANKST_MID	3.85	4.08	90.69	0.32	0.94	0.11	6.16	5.35	77.86	9.10	0.16	1.38
Little Holland Tract	LHOLND_L0	29.80	0.00	69.38	1.2E-07	5.3E-05	0.81	22.80	8.0E-05	71.18	1.1E-04	5.2E-06	6.02
Middle R Bullfrog	MIDRBULFRG_LEN	8.32	10.69	59.08	21.39	0.48	0.04	9.69	10.67	38.75	40.64	0.03	0.22
Mildred Island	MILDDRISL_MID	7.42	11.13	68.24	12.63	0.54	0.04	8.53	10.39	42.57	38.23	0.03	0.25
Mok. R. below Cosum.	MOKBCOS_LEN	1.46	98.54	0	0	0	0	6.32	93.68	6.5E-04	0	0	0
Mok. R. downstream Cosum.	MOKDCOS_MID	1.46	98.54	0	0	0	0	6.42	93.58	0	0	0	0
Old R near Paradise Cut	OLDRNPARADSEC_MID	3.95	5E-12	3E-06	96.05	1.7E-16	2.5E-17	15.73	1.81	12.66	69.68	0.02	0.10
Paradise Cut	PARADSECUT_LEN	1.91	0	0	98.09	0	0	4.98	0.11	0.61	94.29	6.7E-04	3.7E-03
Port of Stockton	PORTOSTOCK_L0	1.48	0	0	98.52	0	0	2.29	0	0	97.71	0	0
Sac. R. at Isleton	SACRISLTON_L0	0.45	0	99.55	0	0	2.1E-06	0.63	8.8E-05	99.36	5.7E-08	0	0.01
Sac River RM 44	SACR44_L0	0.20	0	99.80	0	0	0	0.30	0	99.70	0	0	0
Sandmound Sl.	SANDMND_MID	4.47	3.23	90.83	0.17	1.17	0.13	7.20	4.64	79.23	6.98	0.23	1.71
Sherman Island	SHERMNILND_L0	2.14	0.95	92.16	0.04	4.49	0.23	3.69	2.31	83.94	2.94	4.01	3.11
SJR Bowman	SJRBOWMN_MID	0.88	0	0	99.12	0	0	3.52	0	0	96.48	0	0
SJR N Hwy4	SJRNHWY4_MID	1.82	2.8E-08	0	98.18	0	0	4.35	1.4E-07	0	95.65	0	0
SJR Naval st	SJRNAVLST_L0	4.83	6.83	0	88.35	0	0	5.86	11.12	1.3E-06	83.02	0	0
SJR Potato Slough	SJRPOTSL_MID	2.91	5.22	91.00	0.15	0.61	0.10	4.89	5.67	79.70	8.49	0.10	1.16
SJR Turner	SJRTURNR_MID	7.22	10.11	10.82	71.76	0.08	0.01	7.49	11.95	7.23	73.31	2.9E-03	0.02
SJR/Pt. Antioch/fish pier	ASRANTFSH_MID	2.17	1.01	92.90	0.04	3.62	0.26	3.74	2.30	84.37	3.04	3.24	3.31
Suisun Bay	SUISNB_LEN	0.87	0.23	46.77	0.01	51.97	0.14	0.94	0.51	31.58	0.43	65.55	0.98
Sycamore Slough	SYCAMOR_MID	10.20	72.58	17.22	5.1E-10	9.7E-14	4.3E-29	13.62	50.90	35.47	0.01	4.0E-09	1.1E-07
White Slough	WHITESL_L0	20.35	16.73	61.67	1.25	4.8E-03	2.4E-04	33.31	13.41	23.49	29.78	3.9E-04	3.2E-03
White Slough DS Disappointment Sl.	WHTSLDISPONT_LEN	10.09	24.12	65.07	0.71	4.1E-03	1.9E-04	17.00	13.60	32.29	37.10	1.4E-03	0.01

Table G2.1-4. Continued: Calculation of Quarterly Average Selenium Concentrations for DSM2 Output Locations Based on Percentage of Flow at Each Location from Different Sources: Year 2007

DSM2 Output Water Location		Third Quarter Inflow Percentage						Fourth Quarter Inflow Percentage						Estimated Waterborne Selenium Concentrations (µg/L)				
	Inflow Source □	Delta Ag.	East Delta Tributaries	Sac. R.	San Joaq. R.	Martinez/ Suisun Bay	Yolo Bypass	Delta Ag.	East Delta Tributaries	Sac. R.	San Joaq. R.	Martinez/ Suisun Bay	Yolo Bypass					
	Inflow Location □	*Mildred Island, Center*	*Mokelumne Calaveras Cosumnes Rivers*	*Freeport*	*Vernalis*	*San Joaq. R. near Mallard Island*	*Sac. R. below Knights Landing*	*Mildred Island, Center*	*Mokelumne Calaveras Cosumnes Rivers*	*Freeport*	*Vernalis*	*San Joaq. R. near Mallard Island*	*Sac. R. below Knights Landing*	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter	Annual
	Selenium (µg/L) □	0.11	0.10	0.09	0.58	0.10	0.23	0.11	0.10	0.09	0.58	0.10	0.23					
	Location ID																	
Big Break	BIGBRK_MID	3.58	0.32	81.60	0.79	9.45	4.27	2.60	0.11	84.06	0.04	8.53	4.65	0.09	0.12	0.10	0.10	0.10
Cache Slough	CACHS_LEN	1.92	9.1E-06	89.20	1.9E-05	1.6E-06	8.88	1.64	1.9E-05	91.73	8.5E-06	5.1E-04	6.62	0.09	0.10	0.10	0.10	0.10
Cache Slough Ryer	CACHSR_MID	2.16	1.5E-05	88.35	3.1E-05	3.1E-07	9.49	1.96	4.5E-06	90.83	2.8E-06	1.9E-04	7.21	0.09	0.10	0.10	0.10	0.10
Cosumnes R.	COSR_LEN	0.09	99.91	0	0	0	0	0	100.00	0	0	0	0.00	0.10	0.10	0.10	0.10	0.10
Franks Tract	FRANKST_MID	4.86	0.34	88.03	0.84	2.96	2.98	3.19	0.32	91.15	0.17	2.23	2.95	0.09	0.14	0.10	0.10	0.11
Little Holland Tract	LHOLND_L0	18.52	2.4E-05	73.18	0.00	4.9E-07	8.30	21.64	5.2E-07	71.72	1.4E-06	4.9E-05	6.64	0.10	0.10	0.11	0.10	0.10
Middle R Bullfrog	MIDRBULFRG_LEN	8.41	3.92	81.16	4.51	0.87	1.14	5.81	4.90	72.42	15.36	0.57	0.94	0.20	0.29	0.12	0.17	0.19
Mildred Island	MILDDRISL_MID	6.49	1.12	88.25	1.83	1.00	1.30	4.91	4.55	80.81	7.99	0.66	1.08	0.15	0.28	0.10	0.13	0.17
Mok. R. below Cosum.	MOKBCOS_LEN	15.09	84.81	0.10	6.2E-35	0	0	2.30	97.70	0	0	0	0	0.10	0.10	0.10	0.10	0.10
Mok. R. downstream Cosum.	MOKDCOS_MID	15.19	84.81	3.2E-04	0	0	0	2.27	97.73	0	0	0	0	0.10	0.10	0.10	0.10	0.10
Old R near Paradise Cut	OLDRNPARADSEC_MID	10.18	1.9E-05	1.6E-04	89.82	6.9E-08	6.5E-07	2.31	9.2E-04	0.01	97.68	0	9.7E-05	0.56	0.43	0.53	0.57	0.52
Paradise Cut	PARADSECUT_LEN	7.14	0	0	92.86	0	0	1.24	4.1E-03	0.05	98.71	4.1E-04	4.5E-04	0.57	0.55	0.55	0.57	0.56
Port of Stockton	PORTOSTOCK_L0	6.32	0.04	0	93.64	0	0	7.16	0.05	0	92.78	0	0	0.57	0.57	0.55	0.55	0.56
Sac. R. at Isleton	SACRISLTON_L0	0.49	0	99.51	0	0	2.9E-04	0.39	1.0E-08	99.61	0	6.7E-07	0.01	0.09	0.09	0.09	0.09	0.09
Sac River RM 44	SACR44_L0	0.15	0	99.85	0	0	0	0.11	0	99.89	0	0	0	0.09	0.09	0.09	0.09	0.09
Sandmound Sl.	SANDMND_MID	6.15	0.39	84.96	0.98	4.06	3.46	3.79	0.22	89.26	0.10	3.11	3.51	0.09	0.13	0.10	0.10	0.10
Sherman Island	SHERMNILND_L0	2.99	0.32	77.36	0.77	14.22	4.34	2.22	0.06	75.89	0.03	17.11	4.68	0.09	0.11	0.10	0.10	0.10
SJR Bowman	SJRBOWMN_MID	8.49	2.5E-04	0	91.51	0	0	0.91	0	0	99.09	0	0	0.58	0.56	0.54	0.58	0.56
SJR N Hwy4	SJRNHWY4_MID	12.54	0.08	4.0E-26	87.39	0	0	1.89	1.3E-04	0	98.11	0	0	0.57	0.56	0.52	0.57	0.56
SJR Naval st	SJRNAVLST_L0	12.06	40.15	3.4E-03	47.78	6.2E-07	6.3E-06	4.73	6.37	2.5E-04	88.90	5.4E-09	7.0E-09	0.52	0.50	0.33	0.53	0.47
SJR Potato Slough	SJRPOTSL_MID	3.16	0.19	91.86	0.46	1.88	2.44	2.37	0.33	93.43	0.10	1.44	2.33	0.09	0.13	0.10	0.09	0.10
SJR Turner	SJRTURNR_MID	11.09	11.29	65.50	11.02	0.46	0.63	6.16	6.57	36.18	50.55	0.19	0.35	0.44	0.45	0.15	0.34	0.35
SJR/Pt. Antioch/fish pier	ASRANTFSH_MID	3.00	0.27	79.62	0.65	12.05	4.40	2.27	0.07	78.73	0.03	14.08	4.82	0.09	0.11	0.10	0.10	0.10
Suisun Bay	SUISNB_LEN	0.84	0.16	21.30	0.36	76.08	1.25	0.59	0.02	21.39	0.01	76.63	1.36	0.10	0.10	0.10	0.10	0.10
Sycamore Slough	SYCAMOR_MID	5.33	3.90	90.77	1.9E-16	3.8E-25	1.1E-22	3.69	20.36	75.95	6.0E-19	1.1E-37	2.4E-31	0.10	0.10	0.09	0.09	0.10
White Slough	WHITESL_L0	15.53	1.33	83.05	0.09	1.2E-03	2.0E-03	9.35	8.62	81.98	0.04	3.7E-04	7.1E-04	0.10	0.24	0.09	0.09	0.13
White Slough DS Disappointment Sl.	WHTSLDISPONT_LEN	7.70	1.46	90.83	1.5E-03	1.3E-03	2.2E-03	5.21	9.69	85.06	0.03	9.7E-04	2.1E-03	0.10	0.28	0.09	0.09	0.14

Table G2.1-5. Selenium Bioaccumulation from Water (μg/L) to Particulates and Fish (μg/g, dry weight) Using Models 1 and 2

DSM2 Delta Water Location	Year 2000 Concentration: DSM2 Water	Year 2000 Concentration: Particulate from Water	Year 2000 Concentration: Invert. from Particulate	Year 2000 Concentration: Model 1 Fish	Year 2000 Concentration: Model 2 Fish	Year 2000 Whole-body Bass[1]	Year 2000 Fish-to-Bass Ratio: Model 1	Year 2000 Fish-to-Bass Ratio: Model 2	Year 2005 Concentration: DSM2 Water[5]	Year 2005 Concentration: Particulate from Water	Year 2005 Concentration: Invert. from Particulate	Year 2005 Concentration: Model 1 Fish	Year 2005 Concentration: Model 2 Fish	Year 2005 Whole-body Bass[1]	Year 2005 Fish-to-Bass Ratio: Model 1	Year 2005 Fish-to-Bass Ratio: Model 2	Year 2007 Concentration: DSM2 Water[5]	Year 2007 Concentration: Particulate from Water	Year 2007 Concentration: Invert. from Particulate	Year 2007 Concentration: Model 1 Fish	Year 2007 Concentration: Model 2 Fish	Year 2007 Whole-body Bass[1]	Year 2007 Fish-to-Bass Ratio: Model 1	Year 2007 Fish-to-Bass Ratio: Model 2
First Quarter																								
Sacramento River RM 44	0.09	0.09	0.25	0.27	0.30	2.6	0.10	0.11	0.09	0.09	0.25	0.28	0.31	1.5	0.19	0.21	0.09	0.09	0.25	0.28	0.31	1.8	0.15	0.17
Cache Slough Ryer[2]	0.10	0.10	0.28	0.31	0.34	1.5	0.21	0.23	0.09	0.09	0.26	0.29	0.31	1.7	0.17	0.18	0.09	0.09	0.26	0.28	0.31	2.5	0.11	0.12
San Joaquin River Potato Slough	0.17	0.17	0.47	0.52	0.57	1.4	0.38	0.42	0.14	0.14	0.40	0.44	0.48	1.3	0.33	0.37	0.09	0.09	0.26	0.28	0.31	2.5	0.11	0.13
Franks Tract	0.19	0.19	0.53	0.58	0.64	1.6	0.35	0.39	0.15	0.15	0.41	0.45	0.49	1.1	0.39	0.43	0.09	0.09	0.26	0.29	0.32	3.0	0.10	0.11
Big Break	0.13	0.13	0.35	0.39	0.43	1.6	0.25	0.28	0.11	0.11	0.31	0.34	0.37	1.0	0.33	0.37	0.09	0.09	0.26	0.28	0.31	2.8	0.10	0.11
Middle River Bullfrog	0.31	0.31	0.86	0.95	1.05	NA	NA	NA	0.46	0.46	1.29	1.42	1.56	1.9	0.7	0.8	0.20	0.20	0.55	0.61	0.67	2.1	0.3	0.3
Old River near Paradise Cut[3]	0.73	0.73	2.05	2.25	2.48	NA	NA	NA	0.78	0.78	2.19	2.41	2.66	2.4	1.0	1.1	0.56	0.56	1.57	1.73	1.90	NA	NA	NA
Knights Landing[4]	0.23	0.23	0.64	0.71	0.78	NA	NA	NA	0.23	0.23	0.64	0.71	0.78	2.2	0.3	0.4	0.23	0.23	0.64	0.71	0.78	NA	NA	NA
Vernalis[5]	0.83	0.83	2.32	2.56	2.81	1.7	1.50	1.65	0.85	0.85	2.38	2.62	2.88	1.9	1.38	1.52	0.58	0.58	1.62	1.79	1.97	2.4	0.74	0.82
Second Quarter																								
Sacramento River RM 44	0.09	0.09	0.25	0.28	0.30	2.6	0.11	0.12	0.09	0.09	0.25	0.28	0.30	1.5	0.19	0.21	0.09	0.09	0.25	0.28	0.31	1.8	0.15	0.17
Cache Slough Ryer[2]	0.11	0.11	0.32	0.35	0.38	1.5	0.23	0.26	0.10	0.10	0.27	0.30	0.33	1.7	0.17	0.19	0.10	0.10	0.29	0.32	0.35	2.5	0.12	0.14
San Joaquin River Potato Slough	0.24	0.24	0.67	0.74	0.81	1.4	0.54	0.60	0.36	0.36	1.02	1.12	1.23	1.3	0.86	0.94	0.13	0.13	0.38	0.42	0.46	2.5	0.17	0.18
Franks Tract	0.27	0.27	0.76	0.83	0.92	1.6	0.51	0.56	0.49	0.49	1.36	1.50	1.65	1.1	1.31	1.44	0.14	0.14	0.39	0.43	0.47	3.0	0.14	0.16
Big Break	0.20	0.20	0.55	0.60	0.66	1.6	0.39	0.43	0.30	0.30	0.83	0.91	1.00	1.0	0.89	0.98	0.12	0.12	0.33	0.36	0.39	2.8	0.13	0.14
Middle River Bullfrog	0.61	0.61	1.71	1.88	2.07	NA	NA	NA	0.75	0.75	2.09	2.30	2.53	1.9	1.2	1.3	0.29	0.29	0.82	0.90	0.99	2.1	0.4	0.5
Old River near Paradise Cut[3]	0.68	0.68	1.89	2.08	2.29	NA	NA	NA	0.84	0.84	2.35	2.59	2.84	2.4	1.1	1.2	0.43	0.43	1.22	1.34	1.47	NA	NA	NA
Knights Landing[4]	0.23	0.23	0.64	0.71	0.78	NA	NA	NA	0.23	0.23	0.64	0.71	0.78	2.2	0.3	0.4	0.23	0.23	0.64	0.71	0.78	NA	NA	NA
Vernalis[5]	0.83	0.83	2.32	2.56	2.81	1.7	1.50	1.65	0.85	0.85	2.38	2.62	2.88	1.9	1.38	1.52	0.58	0.58	1.62	1.79	1.97	2.4	0.74	0.82
Third Quarter																								
Sacramento River RM 44	0.09	0.09	0.25	0.28	0.30	2.6	0.11	0.12	0.09	0.09	0.25	0.28	0.31	1.5	0.19	0.21	0.09	0.09	0.25	0.28	0.31	1.8	0.15	0.17
Cache Slough Ryer[2]	0.11	0.11	0.31	0.34	0.37	1.5	0.22	0.25	0.09	0.09	0.25	0.28	0.31	1.7	0.16	0.18	0.10	0.10	0.29	0.32	0.35	2.5	0.13	0.14
San Joaquin River Potato Slough	0.10	0.10	0.27	0.30	0.32	1.4	0.22	0.24	0.10	0.10	0.27	0.30	0.33	1.3	0.23	0.25	0.10	0.10	0.27	0.30	0.33	2.5	0.12	0.13
Franks Tract	0.10	0.10	0.28	0.31	0.34	1.6	0.19	0.20	0.11	0.11	0.29	0.32	0.36	1.1	0.28	0.31	0.10	0.10	0.28	0.31	0.34	3.0	0.10	0.11
Big Break	0.10	0.10	0.29	0.32	0.35	1.6	0.20	0.22	0.10	0.10	0.29	0.32	0.35	1.0	0.31	0.35	0.10	0.10	0.28	0.31	0.34	2.8	0.11	0.12
Middle River Bullfrog	0.20	0.20	0.57	0.63	0.69	NA	NA	NA	0.30	0.30	0.83	0.91	1.01	1.9	0.5	0.5	0.12	0.12	0.32	0.36	0.39	2.1	0.2	0.2
Old River near Paradise Cut[3]	0.75	0.75	2.11	2.32	2.55	NA	NA	NA	0.80	0.80	2.24	2.47	2.71	2.4	1.0	1.1	0.53	0.53	1.49	1.64	1.80	NA	NA	NA
Knights Landing[4]	0.23	0.23	0.64	0.71	0.78	NA	NA	NA	0.23	0.23	0.64	0.71	0.78	2.2	0.3	0.4	0.23	0.23	0.64	0.71	0.78	NA	NA	NA
Vernalis[5]	0.83	0.83	2.32	2.56	2.81	1.7	1.50	1.65	0.85	0.85	2.38	2.62	2.88	1.9	1.38	1.52	0.58	0.58	1.62	1.79	1.97	2.4	0.74	0.82
Fourth Quarter																								
Sacramento River RM 44	0.09	0.09	0.25	0.28	0.30	2.6	0.11	0.12	0.09	0.09	0.25	0.28	0.31	1.5	0.19	0.21	0.09	0.09	0.25	0.28	0.30	1.8	0.15	0.17
Cache Slough Ryer[2]	0.10	0.10	0.29	0.31	0.35	1.5	0.21	0.23	0.09	0.09	0.26	0.28	0.31	1.7	0.16	0.18	0.10	0.10	0.28	0.31	0.34	2.5	0.12	0.13
San Joaquin River Potato Slough	0.09	0.09	0.26	0.29	0.32	1.4	0.21	0.23	0.09	0.09	0.25	0.28	0.31	1.3	0.21	0.24	0.09	0.09	0.26	0.29	0.32	2.5	0.12	0.13

DSM2 Delta Water Location	Year 2000								Year 2005								Year 2007							
	Concentration					Whole-body Bass[1]	Fish-to-Bass Ratio		Concentration					Whole-body Bass[1]	Fish-to-Bass Ratio		Concentration					Whole-body Bass[1]	Fish-to-Bass Ratio	
	DSM2 Water	Particulate from Water	Invert. from Particulate	Model 1 Fish	Model 2 Fish		Model 1	Model 2	DSM2 Water [5]	Particulate from Water	Invert. from Particulate	Model 1 Fish	Model 2 Fish		Model 1	Model 2	DSM2 Water [5]	Particulate from Water	Invert. from Particulate	Model 1 Fish	Model 2 Fish		Model 1	Model 2
Franks Tract	0.10	0.10	0.27	0.29	0.32	1.6	0.18	0.20	0.09	0.09	0.26	0.28	0.31	1.1	0.25	0.27	0.10	0.10	0.27	0.30	0.32	3.0	0.10	0.11
Big Break	0.10	0.10	0.27	0.30	0.33	1.6	0.19	0.21	0.09	0.09	0.26	0.28	0.31	1.0	0.28	0.31	0.10	0.10	0.27	0.30	0.33	2.8	0.11	0.12
Middle River Bullfrog	0.30	0.30	0.84	0.92	1.01	NA	NA	NA	0.24	0.24	0.68	0.74	0.82	1.9	0.4	0.4	0.17	0.17	0.47	0.52	0.57	2.1	0.2	0.3
Old River near Paradise Cut [3]	0.81	0.81	2.27	2.50	2.75	NA	NA	NA	0.72	0.72	2.01	2.21	2.43	2.4	0.9	1.0	0.57	0.57	1.59	1.75	1.93	NA	NA	NA
Knights Landing [4]	0.23	0.23	0.64	0.71	0.78	NA	NA	NA	0.23	0.23	0.64	0.71	0.78	2.2	0.3	0.4	0.23	0.23	0.64	0.71	0.78	NA	NA	NA
Vernalis [5]	0.83	0.83	2.32	2.56	2.81	1.7	1.50	1.65	0.85	0.85	2.38	2.62	2.88	1.9	1.38	1.52	0.58	0.58	1.62	1.79	1.97	2.4	0.74	0.82

Equations from Presser and Luoma (2010a, 2010b) were used to calculate selenium concentrations for fish. Models 1 and 2 used the default Kd (1000) and the average selenium trophic transfer factors to aquatic insects (2.8) and fish (1.1 for all trophic levels).
Model 1 = TL-3 Fish Eating Invertebrates.
Model 2 = TL-4 Fish Eating TL-3 Fish
[1] Geometric mean calculated from whole-body largemouth bass data presented in Foe (2010a).
[2] Fish data collected at Rio Vista (Foe 2010a) were used to calculate geometric mean whole-body largemouth bass and ratios.
[3] Fish data collected at Old River near Tracy (Foe 2010a) were used to calculate geometric mean whole-body largemouth bass and ratios.
[4] Geometric mean of total selenium concentrations in water collected from years 2004, 2007, and 2008 (DWR Website 2009) was used to estimate selenium concentrations in particulates and biota (DSM2 data were not available). Fish data collected from Sacramento River at Veterans Bridge (Foe 2010a) were used to calculate geometric mean whole-body largemouth bass and ratios.
[5] Geometric mean of selenium concentrations (total or dissolved was not specified) in water collected from years 1999–2000 (SWAMP Website 2009) was used to estimate Year 2000 selenium concentrations in particulates and biota (DSM2 data were not available); years 2004-2005 were used for Year 2005 estimates; and years 2006-2007 were used for Year 2007 estimates.
Invert. = invertebrate
Kd = particulate concentration/water concentration ratio
NA = not available; bass not collected here
RM = river mile
TL = trophic level
µg/g = micrograms per gram

Table G2.1-6. Selenium Bioaccumulation from Water (µg/L) to Particulates and Fish (µg/g, dw) Using Model 2 with Estimated K_d from All Years Regression for Model 3

	Year 2000							Year 2005							Year 2007						
	Concentration					Whole-body Bass[1]	Fish-to-Bass Ratio	Concentration					Whole-body Bass[1]	Fish-to-Bass Ratio	Concentration					Whole-body Bass[1]	Fish-to-Bass Ratio
DSM2 Delta Water Location	DSM2 Water	Particulate from Water	Inveretebrate from Particulate	Model 3 Fish	Kd		Model 3	DSM2 Water	Particulate from Water	Inverebrate from Particulate	Model 3 Fish	Kd		Model 3	DSM2 Water	Particulate from Water	Inverebrate from Particulate	Model 3 Fish	K_d		Model 3
First Quarter																					
Sacramento River RM 44	0.09	0.54	1.50	1.81	6061	2.6	0.69	0.09	0.54	1.50	1.81	5945	1.5	1.25	0.09	0.54	1.50	1.81	5946	1.8	0.98
Cache Slough Ryer[2]	0.10	0.54	1.50	1.82	5389	1.5	1.22	0.09	0.54	1.50	1.82	5783	1.7	1.05	0.09	0.54	1.50	1.81	5852	2.5	0.71
San Joaquin River Potato Slough	0.17	0.55	1.50	1.85	3229	1.4	1.36	0.14	0.54	1.52	1.84	3724	1.3	1.41	0.09	0.54	1.50	1.81	5819	2.5	0.73
Franks Tract	0.19	0.55	1.53	1.85	2904	1.6	1.13	0.15	0.54	1.52	1.84	3724	1.1	1.61	0.09	0.54	1.50	1.82	5762	3.0	0.61
Big Break	0.13	0.54	1.51	1.83	4295	1.6	1.18	0.11	0.54	1.51	1.82	4873	1.0	1.79	0.09	0.54	1.50	1.81	5850	2.8	0.64
Middle River Bullfrog	0.31	0.56	1.56	1.88	1801	NA	NA	0.46	0.56	1.57	1.90	1221	1.9	1.0	0.20	0.55	1.53	1.86	2773	2.1	0.87
Old River near Paradise Cut[3]	0.73	0.57	1.60	1.93	780	NA	NA	0.78	0.57	1.60	1.94	729	2.4	0.8	0.56	0.57	1.58	1.95	1007	NA	NA
Knights Landing[4]	0.23	0.55	1.54	1.87	2394	NA	NA	0.23	0.55	1.64	1.87	2394	2.2	0.8	0.23	0.55	1.54	1.87	2394	NA	NA
Vernalis[5]	0.83	0.57	1.60	1.94	689	1.7	1.14	0.85	0.57	1.60	1.94	674	1.9	1.02	0.58	0.57	1.59	1.92	976	2.4	0.80
Second Quarter																					
Sacramento River RM 44	0.09	0.54	1.50	1.81	5952	2.6	0.69	0.09	0.54	1.50	1.81	5947	1.5	1.25	0.09	0.54	1.50	1.81	5944	1.8	0.98
Cache Slough Ryer[2]	0.11	0.54	1.51	1.83	4777	1.5	1.22	0.10	0.54	1.50	1.82	5538	1.7	1.05	0.10	0.54	1.50	1.82	5241	2.5	0.72
San Joaquin River Potato Slough	0.24	0.55	1.54	1.87	2309	1.4	1.38	0.36	0.56	1.56	1.89	1537	1.3	1.45	0.13	0.54	1.52	1.84	4020	2.5	0.74
Franks Tract	0.27	0.55	1.55	1.87	2048	1.6	1.14	0.49	0.56	1.58	1.91	1159	1.1	1.67	0.14	0.54	1.52	1.84	3921	3.0	0.61
Big Break	0.20	0.55	1.53	1.86	2800	1.6	1.20	0.30	0.55	1.55	1.88	1876	1.0	1.84	0.12	0.54	1.51	1.83	4645	2.8	0.64
Middle River Bullfrog	0.61	0.57	1.59	1.92	928	NA	NA	0.75	0.57	1.60	1.93	764	1.9	1.0	0.29	0.55	1.55	1.88	1896	2.1	0.9
Old River near Paradise Cut[3]	0.68	0.57	1.59	1.93	842	NA	NA	0.84	0.57	1.60	1.94	682	2.4	0.8	0.43	0.56	1.57	1.90	1291	NA	NA
Knights Landing[4]	0.23	0.55	1.54	1.87	2394	NA	NA	0.23	0.55	1.54	1.87	2394	2.2	0.8	0.23	0.55	1.54	1.87	2394	NA	NA
Vernalis[5]	0.83	0.57	1.60	1.94	689	1.7	1.14	0.85	0.57	1.60	1.94	674	1.9	1.02	0.58	0.57	1.59	1.92	976	2.4	0.80
Third Quarter																					
Sacramento River RM 44	0.09	0.54	1.50	1.81	5947	2.6	0.69	0.09	0.54	1.50	1.81	5946	1.5	1.25	0.09	0.54	1.50	1.81	5946	1.8	0.98
Cache Slough Ryer[2]	0.11	0.54	1.51	1.82	4942	1.5	1.22	0.09	0.54	1.50	1.81	5914	1.7	1.05	0.10	0.54	1.51	1.82	5184	2.5	0.72
San Joaquin River Potato Slough	0.10	0.54	1.50	1.82	5592	1.4	1.34	0.10	0.54	1.50	1.82	5523	1.3	1.39	0.10	0.54	1.50	1.82	5557	2.5	0.73
Franks Tract	0.10	0.54	1.50	1.82	5412	1.6	1.10	0.11	0.54	1.51	1.82	5121	1.1	1.59	0.10	0.54	1.50	1.82	5393	3.0	0.61
Big Break	0.10	0.54	1.50	1.82	5227	1.6	1.17	0.10	0.54	1.51	1.82	5159	1.0	1.79	0.10	0.54	1.50	1.82	5291	2.8	0.64
Middle River Bullfrog	0.20	0.55	1.54	1.86	2688	NA	NA	0.30	0.55	1.55	1.88	1868	1.9	1.0	0.12	0.54	1.51	1.83	4656	2.1	0.86
Old River near Paradise Cut[3]	0.75	0.57	1.60	1.93	757	NA	NA	0.80	0.57	1.60	1.94	714	2.4	0.8	0.53	0.56	1.58	1.91	1061	NA	NA
Knights Landing[4]	0.23	0.55	1.54	1.87	2394	NA	NA	0.23	0.55	1.54	1.87	2394	2.2	0.8	0.23	0.55	1.54	1.87	2394	NA	NA
Vernalis[5]	0.83	0.57	1.60	1.94	689	1.7	1.14	0.85	0.57	1.60	1.94	674	1.9	1.02	0.58	0.57	1.59	1.92	976	2.4	0.80
Fourth Quarter																					
Sacramento River RM 44	0.09	0.54	1.50	1.81	5948	2.6	0.69	0.09	0.54	1.50	1.82	5946	1.5	1.25	0.09	0.54	1.50	1.81	5947	1.8	0.98
Cache Slough Ryer[2]	0.10	0.54	1.50	1.82	5261	1.5	1.22	0.09	0.54	1.50	1.81	5830	1.7	1.05	0.10	0.54	1.50	1.82	5345	2.5	0.71
San Joaquin River Potato Slough	0.09	0.54	1.50	1.82	5704	1.4	1.34	0.09	0.54	1.50	1.81	5885	1.3	1.39	0.09	0.54	1.50	1.82	5678	2.5	0.73
Franks Tract	0.10	0.54	1.50	1.82	5621	1.6	1.10	0.09	0.54	1.50	1.81	5859	1.1	1.59	0.10	0.54	1.50	1.82	5678	3.0	0.61
Big Break	0.10	0.54	1.50	1.82	5534	1.6	1.17	0.09	0.54	1.50	1.82	5809	1.0	1.78	0.10	0.54	1.50	1.82	5470	2.8	0.64

DSM2 Delta Water Location	Year 2000							Year 2005							Year 2007						
	Concentration				Kd	Whole-body Bass [1]	Fish-to-Bass Ratio	Concentration				Kd	Whole-body Bass [1]	Fish-to-Bass Ratio	Concentration				K_d	Whole-body Bass [1]	Fish-to-Bass Ratio
	DSM2 Water	Particulate from Water	Inveretebrate from Particulate	Model 3 Fish			Model 3	DSM2 Water	Particulate from Water	Inverebrate from Particulate	Model 3 Fish			Model 3	DSM2 Water	Particulate from Water	Inverebrate from Particulate	Model 3 Fish			Model 3
Middle River Bullfrog	0.30	0.55	1.55	1.88	1859	NA	NA	0.24	0.55	1.54	1.87	2283	1.9	1.0	0.17	0.55	1.53	1.85	3241	2.1	0.87
Old River near Paradise Cut [3]	0.81	0.57	1.60	1.94	704	NA	NA	0.72	0.57	1.60	1.93	794	2.4	0.8	0.57	0.57	1.58	1.92	994	NA	NA
Knights Landing [4]	0.23	0.55	1.54	1.87	2394	NA	NA	0.23	0.55	1.54	1.87	2394	2.2	0.8	0.23	0.55	1.54	1.87	2394	NA	NA
Veranlis [5]	0.83	0.57	1.60	1.94	689	1.7	1.14	0.85	0.57	1.60	1.94	676	1.9	1.02	0.58	0.57	1.59	1.92	976	2.4	0.80

Equations from Presser and Luoma (2010a, 2010b) were used to calculate selenium concentrations for fish. Model 3 used the average selenium trophic transfer factors to aquatic insects (2.8) and fish (1.1 for all trophic levels).

Model 3 = Model 2 (TL-4 Fish Eating TL-3 Fish) with Kd estimated using all years regression (log Kd = 2.76-0.97(logDSM2))

[1] Geometric mean calculated from whole-body largemouth bass data presented in Foe (2010a).

[2] Fish data collected at Rio Vista (Foe 2010a) were used to calculate geometric mean whole-body largemouth bass and ratios.

[3] Fish data collected at Old River near Tracy (Foe 2010a) were used to calculate geometric mean whole-body largemouth bass and ratios.

[4] Geometric mean of total selenium concentrations in water collected from years 2004, 2007, and 2008 (DWR Website 2009) was used to estimate selenium concentrations in particulates and biota (DSM2 data were not available). Fish data collected from Sacramento River at Veterans Bridge (Foe 2010a) were used to calculate geometric mean whole-body largemouth bass and ratios.

[5] Geometric mean of selenium concentrations (total or dissolved was not specified) in water collected from years 1999–2000 (SWAMP Website 2009) was used to estimate Year 2000 selenium concentrations in particulates and biota (DSM2 data were not available); years 2004-2005 were used for Year 2005 estimates; and years 2006-2007 were used for Year 2007 estimates.

K_d = particulate concentration/water concentration ratio

NA = not available; bass not collected here

RM = river mile

TL = trophic level

µg/g = micrograms per gram

Table G2.1-7. Selenium Bioaccumulation from Water (µg/L) to Particulates and Fish (µg/g, dw) Using Model 2 with Estimated K_d from Normal/Wet Years Regression for Model 4 and Dry Years Regression for Model 5

DSM2 Delta Water Location	Year 2000 Concentration DSM2 Water	Year 2000 Concentration Particulate from Water	Year 2000 Concentration Invert. from Particulate	Year 2000 Concentration Model 4 Fish	Year 2000 K_d	Year 2000 Whole-body Bass [1]	Year 2000 Fish-to-Bass Ratio Model 4	Year 2005 Concentration DSM2 Water	Year 2005 Concentration Particulate from Water	Year 2005 Concentration Invert. from Particulate	Year 2005 Concentration Model 4 Fish	Year 2005 K_d	Year 2005 Whole-body Bass [1]	Year 2005 Fish-to-Bass Ratio Model 4	Year 2007 Concentration DSM2 Water	Year 2007 Concentration Particulate from Water	Year 2007 Concentration Invert. from Particulate	Year 2007 Concentration Model 5 Fish	Year 2007 K_d	Year 2007 Whole-body Bass [1]	Year 2007 Fish-to-Bass Ratio Model 5
First Quarter																					
Sacramento River RM 44	0.09	0.44	1.24	1.49	4997	2.6	0.57	0.09	0.44	1.24	1.50	4909	1.5	1.03	0.09	0.73	2.03	2.46	8063	1.8	1.33
Cache Slough Ryer [2]	0.10	0.45	1.25	1.51	4481	1.5	1.01	0.09	0.44	1.24	1.50	4784	1.7	0.87	0.09	0.73	2.03	2.46	7929	2.5	0.97
San Joaquin River Potato Slough	0.17	0.47	1.32	1.59	2786	1.4	1.17	0.14	0.46	1.30	1.57	3260	1.3	1.20	0.09	0.73	2.03	2.46	7883	2.5	0.99
Franks Tract	0.19	0.48	1.33	1.61	2525	1.6	0.98	0.15	0.46	1.30	1.57	3181	1.1	1.37	0.09	0.73	2.03	2.46	7802	3.0	0.82
Big Break	0.13	0.46	1.28	1.55	3630	1.6	1.00	0.11	0.45	1.26	1.53	4082	1.0	1.50	0.09	0.73	2.03	2.46	7926	2.8	0.87
Middle River Bullfrog	0.31	0.50	1.40	1.69	1621	NA	NA	0.46	0.52	1.46	1.76	1130	1.9	0.90	0.20	0.71	2.00	2.42	3616	2.1	1.14
Old River near Paradise Cut [3]	0.73	0.55	1.53	1.85	745	NA	NA	0.78	0.55	1.54	1.86	700	2.4	0.80	0.56	0.70	1.96	2.37	1247	NA	NA
Knights Landing [4]	0.23	0.49	1.36	1.64	2111	NA	NA	0.23	0.49	1.36	1.64	2111	2.2	0.70	0.23	0.71	1.99	2.41	3098	NA	NA
Vernalis [5]	0.83	0.52	1.55	1.87	665	1.7	1.10	0.85	0.55	1.55	1.87	651	1.9	0.99	0.58	0.70	1.96	2.37	1206	2.4	0.99
Second Quarter																					
Sacramento River RM 44	0.09	0.44	1.24	1.50	4914	2.6	0.57	0.09	0.44	1.24	1.50	4910	1.5	1.03	0.09	0.73	2.03	2.46	8061	1.8	1.33
Cache Slough Ryer [2]	0.11	0.45	1.27	1.53	4007	1.5	1.03	0.10	0.45	1.25	1.51	4596	1.7	0.87	0.10	0.72	2.03	2.45	7061	2.5	0.96
San Joaquin River Potato Slough	0.24	0.49	1.36	1.65	2041	1.4	1.22	0.36	0.51	1.42	1.72	1399	1.3	1.32	0.13	0.72	2.02	2.44	5343	2.5	0.98
Franks Tract	0.27	0.49	1.38	1.67	1826	1.6	1.02	0.49	0.52	1.46	1.77	1077	1.1	1.55	0.14	0.72	2.02	2.44	5204	3.0	0.82
Big Break	0.20	0.48	1.34	1.62	2441	1.6	1.04	0.30	0.50	1.39	1.69	1683	1.0	1.65	0.12	0.72	2.02	2.45	6220	2.8	0.86
Middle River Bullfrog	0.61	0.54	1.50	1.81	876	NA	NA	0.75	0.55	1.53	1.85	732	1.9	1.00	0.29	0.71	1.99	2.40	2424	2.1	1.1
Old River near Paradise Cut [3]	0.68	0.54	1.51	1.83	801	NA	NA	0.84	0.55	1.55	1.87	658	2.4	0.80	0.43	0.70	1.97	2.38	1617	NA	NA
Knights Landing [4]	0.23	0.49	1.36	1.64	2111	NA	NA	0.23	0.49	1.36	1.64	2111	2.2	0.70	0.23	0.71	1.99	2.41	3098	NA	NA
Vernalis [5]	0.83	0.55	1.55	1.87	665	1.7	1.10	0.85	0.55	1.55	1.87	651	1.9	0.99	0.58	0.70	1.96	2.37	1206	2.4	0.99
Third Quarter																					
Sacramento River RM 44	0.09	0.44	1.24	1.50	4910	2.6	0.57	0.09	0.44	1.24	1.50	4910	1.5	1.03	0.09	0.73	2.03	2.46	8064	1.8	1.33
Cache Slough Ryer [2]	0.11	0.45	1.26	1.53	4135	1.5	1.02	0.09	0.44	1.24	1.50	4885	1.7	0.87	0.10	0.72	2.03	2.45	6980	2.5	0.96
San Joaquin River Potato Slough	0.10	0.44	1.25	1.51	4637	1.4	1.11	0.10	0.45	1.25	1.51	4584	1.3	1.15	0.10	0.72	2.03	2.46	7510	2.5	0.99
Franks Tract	0.10	0.45	1.25	1.51	4499	1.6	0.92	0.11	0.45	1.26	1.52	4274	1.1	1.33	0.10	0.72	2.03	2.45	7276	3.0	0.82
Big Break	0.10	0.45	1.25	1.52	4356	1.6	0.98	0.10	0.45	1.26	1.52	4304	1.0	1.49	0.10	0.72	2.03	2.45	7131	2.8	0.87
Middle River Bullfrog	0.20	0.48	1.34	1.63	2350	NA	NA	0.30	0.50	1.39	1.69	1677	1.9	0.90	0.12	0.72	2.02	2.45	6235	2.1	1.15
Old River near Paradise Cut [3]	0.75	0.55	1.53	1.85	725	NA	NA	0.80	0.55	1.54	1.86	687	2.4	0.80	0.53	0.70	1.96	2.37	1317	NA	NA
Knights Landing [4]	0.23	0.49	1.36	1.64	2111	NA	NA	0.23	0.49	1.36	1.64	2111	2.2	0.70	0.23	0.71	1.99	2.41	3098	NA	NA
Vernalis [5]	0.83	0.55	1.55	1.87	665	1.7	1.10	0.85	0.55	1.55	1.87	651	1.9	0.99	0.58	0.70	1.96	2.37	1206	2.4	0.99
Fourth Quarter																					
Sacramento River RM 44	0.09	0.44	1.24	1.50	4911	2.6	0.57	0.09	0.44	1.24	1.50	4909	1.5	1.03	0.09	0.73	2.03	2.46	8064	1.8	1.33
Cache Slough Ryer [2]	0.10	0.45	1.25	1.52	4383	1.5	1.02	0.09	0.44	1.24	1.50	4820	1.7	0.87	0.10	0.72	2.03	2.45	7209	2.5	0.96
San Joaquin River Potato Slough	0.09	0.44	1.24	1.50	4723	1.4	1.11	0.09	0.44	1.24	1.50	4862	1.3	1.15	0.09	0.73	2.03	2.46	7682	2.5	0.99
Franks Tract	0.10	0.44	1.24	1.51	4660	1.6	0.91	0.09	0.44	1.24	1.50	4843	1.1	1.31	0.10	0.73	2.03	2.46	7564	3.0	0.82
Big Break	0.10	0.45	1.25	1.51	4593	1.6	0.97	0.09	0.44	1.24	1.50	4804	1.0	1.47	0.10	0.72	2.03	2.46	7386	2.8	0.87

DSM2 Delta Water Location	Year 2000							Year 2005							Year 2007						
	Concentration				K_d	Whole-body Bass [1]	Fish-to-Bass Ratio	Concentration				K_d	Whole-body Bass [1]	Fish-to-Bass Ratio	Concentration				K_d	Whole-body Bass [1]	Fish-to-Bass Ratio
	DSM2 Water	Particulate from Water	Invert. from Particulate	Model 4 Fish			Model 4	DSM2 Water	Particulate from Water	Invert. from Particulate	Model 4 Fish			Model 4	DSM2 Water	Particulate from Water	Invert. from Particulate	Model 5 Fish			Model 5
Middle River Bullfrog	0.30	0.50	1.40	1.69	1669	NA	NA	0.24	0.49	1.37	1.65	2020	1.9	0.90	0.17	0.72	2.01	2.43	4260	2.1	1.14
Old River near Paradise Cut [3]	0.81	0.55	1.54	1.87	678	NA	NA	0.72	0.54	1.52	1.84	759	2.4	0.80	0.57	0.70	1.96	2.37	1229	NA	NA
Knights Landing [4]	0.23	0.49	1.36	1.64	2111	NA	NA	0.23	0.49	1.36	1.64	2111	2.2	0.70	0.23	0.71	1.99	2.41	3098	NA	NA
Vernalis [5]	0.83	0.55	1.55	1.87	665	1.27	1.10	0.85	0.55	1.55	1.87	651	1.9	0.99	0.58	0.70	1.96	2.37	1206	2.4	0.99

Equations from Presser and Luoma (2010a, 2010b) were used to calculate selenium concentrations for fish. Models 4 and 5 used the average selenium trophic transfer factors to aquatic insects (2.8) and fish (1.1 for all trophic levels).
Model 4 = Model 2 (TL-4 Fish Eating TL-3 Fish) with Kd estimated using normal/wet years regression (log Kd = 2.75-0.90(logDSM2))
Model 5 = Model 2 (TL-4 Fish Eating TL-3 Fish) with Kd estimated using dry years (2007) regression (log Kd = 2.84-1.02(logDSM2))
[1] Geometric mean calculated from whole-body largemouth bass data presented in Foe (2010a).
[2] Fish data collected at Rio Vista (Foe 2010a) were used to calculate geometric mean whole-body largemouth bass and ratios.
[3] Fish data collected at Old River near Tracy (Foe 2010a) were used to calculate geometric mean whole-body largemouth bass and ratios.
[4] Geometric mean of total selenium concentrations in water collected from years 2004, 2007, and 2008 (DWR Website 2009) was used to estimate selenium concentrations in particulates and biota (DSM2 data were not available). Fish data collected from Sacramento River at Veterans Bridge (Foe 2010a) were used to calculate geometric mean whole-body largemouth bass and ratios.
[5] Geometric mean of selenium concentrations (total or dissolved was not specified) in water collected from years 1999–2000 (SWAMP Website 2009) was used to estimate Year 2000 selenium concentrations in particulates and biota (DSM2 data were not available); years 2004-2005 were used for Year 2005 estimates; and years 2006-2007 were used for Year 2007 estimates.
K_d = particulate concentration/water concentration ratio
NA = not available; bass not collected here
RM = river mile
TL = trophic level
µg/g = micrograms per gram

Table G2.1-8. Selenium Bioaccumulation from Water (µg/L) to Particulates, Whole-body Fish (µg/g, dw), and Bird Eggs (µg/g, dw) Using Model 2 with Estimated K_d from Normal/Wet Years Regression for Model 4 and Dry Years Regression for Model 5

DSM2 Delta Water Location	Year 2000									Year 2005								
	Concentration					Whole-body Bass[1]	Fish-to-Bass Ratio	Bird Eggs		Concentration					Whole-body Bass[1]	Fish-to-Bass Ratio	Bird Eggs	
	DSM2 Water	Particulate from Water	Invertebrate from Particulate	Model 4 Fish	K_d		Model 4	From Invertebrate	From Fish	DSM2 Water	Particulate from Water	Invertebrate from Particulate	Model 4 Fish	K_d		Model 4	From Invertebrate	From Fish
	First Quarter									First Quarter								
Sacramento River RM 44	0.09	0.44	1.24	1.49	4997	2.6	0.57	2.22	2.69	0.09	0.44	1.24	1.50	4909	1.5	1.03	2.23	2.70
Cache Slough Ryer [2]	0.10	0.45	1.25	1.51	4481	1.5	1.01	2.25	2.72	0.09	0.44	1.24	1.50	4784	1.7	0.87	2.23	2.70
San Joaquin River Potato Slough	0.17	0.47	1.32	1.59	2786	1.4	1.17	2.37	2.87	0.14	0.46	1.30	1.57	3260	1.3	1.20	2.33	2.82
Franks Tract	0.19	0.48	1.33	1.61	2525	1.6	0.98	2.40	2.90	0.15	0.46	1.30	1.57	3181	1.1	1.37	2.34	2.83
Big Break	0.13	0.46	1.28	1.55	3630	1.6	1.00	2.30	2.79	0.11	0.45	1.26	1.53	4082	1.0	1.50	2.27	2.75
Middle River Bullfrog	0.31	0.50	1.40	1.69	1621	NA	NA	2.52	3.05	0.46	0.52	1.46	1.76	1130	1.9	0.9	2.62	3.17
Old River near Paradise Cut [3]	0.73	0.55	1.53	1.85	745	NA	NA	2.75	3.32	0.78	0.55	1.54	1.86	700	2.4	0.8	2.77	3.35
Knights Landing [4]	0.23	0.49	1.36	1.64	2111	NA	NA	2.45	2.96	0.23	0.49	1.36	1.64	2111	2.2	0.7	2.45	2.96
Vernalis [5]	0.83	0.55	1.55	1.87	665	1.7	1.10	2.78	3.37	0.85	0.55	1.55	1.87	651	1.9	0.99	2.79	3.37
	Second Quarter									Second Quarter								
Sacramento River RM 44	0.09	0.44	1.24	1.50	4914	2.6	0.57	2.23	2.70	0.09	0.44	1.24	1.50	4910	1.5	1.03	2.23	2.70
Cache Slough Ryer [2]	0.11	0.45	1.27	1.53	4007	1.5	1.03	2.28	2.76	0.10	0.45	1.25	1.51	4596	1.7	0.87	2.24	2.72
San Joaquin River Potato Slough	0.24	0.49	1.36	1.65	2041	1.4	1.22	2.46	2.97	0.36	0.51	1.42	1.72	1399	1.3	1.32	2.56	3.10
Franks Tract	0.27	0.49	1.38	1.67	1826	1.6	1.02	2.49	3.01	0.49	0.52	1.46	1.77	1077	1.1	1.55	2.64	3.19
Big Break	0.20	0.48	1.34	1.62	2441	1.6	1.04	2.41	2.91	0.30	0.50	1.39	1.69	1683	1.0	1.65	2.51	3.04
Middle River Bullfrog	0.61	0.54	1.50	1.81	876	NA	NA	2.70	3.26	0.75	0.55	1.53	1.85	732	1.9	1.0	2.75	3.33
Old River near Paradise Cut [3]	0.68	0.54	1.51	1.83	801	NA	NA	2.73	3.30	0.84	0.55	1.55	1.87	658	2.4	0.8	2.79	3.37
Knights Landing [4]	0.23	0.49	1.36	1.64	2111	NA	NA	2.45	2.96	0.23	0.49	1.36	1.64	2111	2.2	0.7	2.45	2.96
Vernalis [5]	0.83	0.55	1.55	1.87	665	1.7	1.10	2.78	3.37	0.85	0.55	1.55	1.87	651	1.9	0.99	2.79	3.37
	Third Quarter									Third Quarter								
Sacramento River RM 44	0.09	0.44	1.24	1.50	4910	2.6	0.57	2.23	2.70	0.09	0.44	1.24	1.50	4910	1.5	1.03	2.23	2.70
Cache Slough Ryer [2]	0.11	0.45	1.26	1.53	4135	1.5	1.02	2.27	2.75	0.09	0.44	1.24	1.50	4885	1.7	0.87	2.23	2.70
San Joaquin River Potato Slough	0.10	0.44	1.25	1.51	4637	1.4	1.11	2.24	2.71	0.10	0.45	1.25	1.51	4584	1.3	1.15	2.24	2.72
Franks Tract	0.10	0.45	1.25	1.51	4499	1.6	0.92	2.25	2.72	0.11	0.45	1.26	1.52	4274	1.1	1.33	2.26	2.74
Big Break	0.10	0.45	1.25	1.52	4356	1.6	0.98	2.26	2.73	0.10	0.45	1.26	1.52	4304	1.0	1.49	2.26	2.74
Middle River Bullfrog	0.20	0.48	1.34	1.63	2350	NA	NA	2.42	2.93	0.30	0.50	1.39	1.69	1677	1.9	0.9	2.51	3.04
Old River near Paradise Cut [3]	0.75	0.55	1.53	1.85	725	NA	NA	2.76	3.33	0.80	0.55	1.54	1.86	687	2.4	0.8	2.77	3.35
Knights Landing [4]	0.23	0.49	1.36	1.64	2111	NA	NA	2.45	2.96	0.23	0.49	1.36	1.64	2111	2.2	0.7	2.45	2.96
Vernalis [5]	0.83	0.55	1.55	1.87	665	1.7	1.10	2.78	3.37	0.85	0.55	1.55	1.87	651	1.9	0.99	2.79	3.37
	Fourth Quarter									Fourth Quarter								
Sacramento River RM 44	0.09	0.44	1.24	1.50	4911	2.6	0.57	2.23	2.70	0.09	0.44	1.24	1.50	4909	1.5	1.03	2.23	2.70
Cache Slough Ryer [2]	0.10	0.45	1.25	1.52	4383	1.5	1.02	2.26	2.73	0.09	0.44	1.24	1.50	4820	1.7	0.87	2.23	2.70
San Joaquin River Potato Slough	0.09	0.44	1.24	1.50	4723	1.4	1.11	2.24	2.71	0.09	0.44	1.24	1.50	4862	1.3	1.15	2.23	2.70
Franks Tract	0.10	0.44	1.24	1.51	4660	1.6	0.91	2.24	2.71	0.09	0.44	1.24	1.50	4843	1.1	1.31	2.23	2.70
Big Break	0.10	0.45	1.25	1.51	4593	1.6	0.97	2.24	2.72	0.09	0.44	1.24	1.50	4804	1.0	1.47	2.23	2.70
Middle River Bullfrog	0.30	0.50	1.40	1.69	1669	NA	NA	2.51	3.04	0.24	0.49	1.37	1.65	2020	1.9	0.9	2.46	2.98
Old River near Paradise Cut [3]	0.81	0.55	1.54	1.87	678	NA	NA	2.78	3.36	0.72	0.54	1.52	1.84	759	2.4	0.8	2.74	3.32
Knights Landing [4]	0.23	0.49	1.36	1.64	2111	NA	NA	2.45	2.96	0.23	0.49	1.36	1.64	2111	2.2	0.7	2.45	2.96
Vernalis [5]	0.83	0.55	1.55	1.87	665	1.7	1.10	2.78	3.37	0.85	0.55	1.55	1.87	651	1.9	0.99	2.79	3.37

Table G2.1-8. Continued: Selenium Bioaccumulation from Water (µg/L) to Particulates, Whole-body Fish (µg/g, dw), and Bird Eggs (µg/g, dw) Using Model 2 with Estimated K_d from Normal/Wet Years Regression for Model 4 and Dry Years Regression for Model 5

DSM2 Delta Water Location	Year 2007								
	Concentration					Whole-body Bass[1]	Fish-to-Bass Ratio	Bird Eggs	
	DSM2 Water	Particulate from Water	Invertebrate from Particulate	Model 5 Fish	K_d		Model 5	From Invertebrate	From Fish
	First Quarter								
Sacramento River RM 44	0.09	0.73	2.03	2.46	8063	1.8	1.33	3.66	4.43
Cache Slough Ryer [2]	0.09	0.73	2.03	2.46	7929	2.5	0.97	3.66	4.43
San Joaquin River Potato Slough	0.09	0.73	2.03	2.46	7883	2.5	0.99	3.66	4.43
Franks Tract	0.09	0.73	2.03	2.46	7802	3.0	0.82	3.66	4.42
Big Break	0.09	0.73	2.03	2.46	7926	2.8	0.87	3.66	4.43
Middle River Bullfrog	0.20	0.71	2.00	2.42	3616	2.1	1.14	3.60	4.36
Old River near Paradise Cut [3]	0.56	0.70	1.96	2.37	1247	NA	NA	3.53	4.27
Knights Landing [4]	0.23	0.71	1.99	2.41	3098	NA	NA	3.59	4.34
Vernalis [5]	0.58	0.70	1.96	2.37	1206	2.4	0.99	3.53	4.27
	Second Quarter								
Sacramento River RM 44	0.09	0.73	2.03	2.46	8061	1.8	1.33	3.66	4.43
Cache Slough Ryer [2]	0.10	0.72	2.03	2.45	7061	2.5	0.96	3.65	4.42
San Joaquin River Potato Slough	0.13	0.72	2.02	2.44	5343	2.5	0.98	3.63	4.39
Franks Tract	0.14	0.72	2.02	2.44	5204	3.0	0.82	3.63	4.39
Big Break	0.12	0.72	2.02	2.45	6220	2.8	0.86	3.64	4.40
Middle River Bullfrog	0.29	0.71	1.99	2.40	2424	2.1	1.1	3.57	4.32
Old River near Paradise Cut [3]	0.43	0.70	1.97	2.38	1617	NA	NA	3.55	4.29
Knights Landing [4]	0.23	0.71	1.99	2.41	3098	NA	NA	3.59	4.34
Vernalis [5]	0.58	0.70	1.96	2.37	1206	2.4	0.99	3.53	4.27
	Third Quarter								
Sacramento River RM 44	0.09	0.73	2.03	2.46	8064	1.8	1.33	3.66	4.43
Cache Slough Ryer [2]	0.10	0.72	2.03	2.45	6980	2.5	0.96	3.65	4.41
San Joaquin River Potato Slough	0.10	0.72	2.03	2.46	7510	2.5	0.99	3.65	4.42
Franks Tract	0.10	0.72	2.03	2.45	7276	3.0	0.82	3.65	4.42
Big Break	0.10	0.72	2.03	2.45	7131	2.8	0.87	3.65	4.42
Middle River Bullfrog	0.12	0.72	2.02	2.45	6235	2.1	1.15	3.64	4.40
Old River near Paradise Cut [3]	0.53	0.70	1.96	2.37	1317	NA	NA	3.53	4.27
Knights Landing [4]	0.23	0.71	1.99	2.41	3098	NA	NA	3.59	4.34
Vernalis [5]	0.58	0.70	1.96	2.37	1206	2.4	0.99	3.53	4.27
	Fourth Quarter								
Sacramento River RM 44	0.09	0.73	2.03	2.46	8064	1.8	1.33	3.66	4.43
Cache Slough Ryer [2]	0.10	0.72	2.03	2.45	7209	2.5	0.96	3.65	4.42
San Joaquin River Potato Slough	0.09	0.73	2.03	2.46	7682	2.5	0.99	3.66	4.42
Franks Tract	0.10	0.73	2.03	2.46	7564	3.0	0.82	3.65	4.42
Big Break	0.10	0.72	2.03	2.46	7386	2.8	0.87	3.65	4.42
Middle River Bullfrog	0.17	0.72	2.01	2.43	4260	2.1	1.14	3.61	4.37
Old River near Paradise Cut [3]	0.57	0.70	1.96	2.37	1229	NA	NA	3.53	4.27

DSM2 Delta Water Location	Year 2007								
	Concentration				K_d	Whole-body Bass[1]	Fish-to-Bass Ratio	Bird Eggs	
	DSM2 Water	Particulate from Water	Invertebrate from Particulate	Model 5 Fish			Model 5	From Invertebrate	From Fish
Knights Landing [4]	0.23	0.71	1.99	2.41	3098	NA	NA	3.59	4.34
Vernalis [5]	0.58	0.70	1.96	2.37	1206	2.4	0.99	3.53	4.27

[1] Geometric mean calculated from whole-body largemouth bass data presented in Foe (2010a).
[2] Fish data collected at Rio Vista (Foe 2010a) were used to calculate geometric mean whole-body largemouth bass and ratios.
[3] Fish data collected at Old River near Tracy (Foe 2010a) were used to calculate geometric mean whole-body largemouth bass and ratios.
[4] Geometric mean of total selenium concentrations in water collected from years 2004, 2007, and 2008 (DWR Website 2009) was used to estimate selenium concentrations in particulates and biota (DSM2 data were not available). Fish data collected from Sacramento River at Veterans Bridge (Foe 2010a) were used to calculate geometric mean whole-body largemouth bass and ratios.
[5] Geometric mean of selenium concentrations (total or dissolved was not specified) in water collected from years 1999–2000 (SWAMP Website 2009) was used to estimate Year 2000 selenium concentrations in particulates and biota (DSM2 data were not available); years 2004-2005 were used for Year 2005 estimates; and years 2006-2007 were used for Year 2007 estimates.
K_d = particulate concentration/water concentration ratio
NA = not available; bass not collected here
RM = river mile
TL = trophic level
µg/g = micrograms per gram

Table G2.2-1. Modeled Period Average Selenium Concentrations in Water for No Action Alternative and Alternatives 1 through 4

Location	Period [1]	Selenium: Period Average Concentration (µg/L)				
		No Action Alternative	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Delta Interior						
San Joaquin River at Stockton	ALL	0.42	0.42	0.42	0.42	0.42
	DROUGHT	0.40	0.39	0.40	0.40	0.40
Turner Cut	ALL	0.35	0.33	0.34	0.34	0.35
	DROUGHT	0.31	0.28	0.28	0.30	0.30
San Joaquin River at San Andreas Landing	ALL	0.11	0.10	0.10	0.10	0.11
	DROUGHT	0.09	0.09	0.09	0.09	0.10
San Joaquin River at Jersey Point	ALL	0.12	0.11	0.11	0.11	0.12
	DROUGHT	0.10	0.09	0.09	0.09	0.10
Victoria Canal	ALL	0.23	0.21	0.21	0.21	0.23
	DROUGHT	0.17	0.15	0.15	0.15	0.17
Western Delta						
Sacramento River at Emmaton	ALL	0.10	0.10	0.10	0.10	0.10
	DROUGHT	0.09	0.09	0.09	0.09	0.09
San Joaquin River at Antioch	ALL	0.11	0.11	0.11	0.11	0.11
	DROUGHT	0.10	0.10	0.10	0.09	0.10
Montezuma Slough at Hunter Cut/Beldon's Landing	ALL	0.11	0.11	0.11	0.11	0.11
	DROUGHT	0.10	0.10	0.10	0.10	0.10
Major Diversions (Pumping Stations)						
Barker Slough at North Bay Aqueduct Intake	ALL	0.11	0.11	0.11	0.11	0.11
	DROUGHT	0.10	0.10	0.10	0.10	0.10
Contra Costa Pumping Plant #1	ALL	0.15	0.13	0.13	0.13	0.15
	DROUGHT	0.11	0.10	0.10	0.10	0.11
Banks Pumping Plant	ALL	0.21	0.19	0.18	0.18	0.22
	DROUGHT	0.15	0.14	0.13	0.14	0.16
Jones Pumping Plant	ALL	0.28	0.27	0.25	0.25	0.28
	DROUGHT	0.24	0.22	0.20	0.20	0.24

[1] All: Water years 1922–2003 represent the 82-year period modeled using DSM2. Drought: Represents a five consecutive year (water years 1987-1991) drought period consisting of dry and critical water year types (as defined by the Sacramento Valley 40-30-30 water year hydrologic classification index)
µg/L = microgram per liter

Table G2.3-1. Summary Table for Annual Average Selenium Concentrations in Biota for No Action Alternative and Alternative 1

Location	Period [1]	Estimated Concentrations of Selenium (mg/kg, Dry Weight[2])							
		Whole-body Fish		Bird Eggs (Invertebrate Diet)		Bird Eggs (Fish Diet)		Fish Fillets (Wet Weight)	
		No Action Alternative	Alternative 1	No Action Alternative	Alternative 1	No Action Alternative	Alternative 1	No Action Alternative	Alternative 1
Delta Interior									
San Joaquin River at Stockton	ALL	1.90	1.90	2.83	2.83	3.42	3.42	0.64	0.64
	DROUGHT	2.39	2.39	3.55	3.55	4.30	4.30	0.83	0.83
Turner Cut	ALL	1.89	1.89	2.81	2.81	3.40	3.40	0.63	0.63
	DROUGHT	2.40	2.40	3.57	3.58	4.32	4.33	0.84	0.84
San Joaquin River at San Andreas Landing	ALL	1.82	1.82	2.71	2.71	3.28	3.28	0.61	0.61
	DROUGHT	2.46	2.46	3.65	3.66	4.42	4.42	0.86	0.86
San Joaquin River at Jersey Point	ALL	1.83	1.82	2.72	2.71	3.29	3.28	0.61	0.61
	DROUGHT	2.46	2.46	3.65	3.66	4.42	4.42	0.86	0.86
Victoria Canal	ALL	1.87	1.86	2.78	2.77	3.36	3.35	0.62	0.62
	DROUGHT	2.43	2.43	3.61	3.62	4.37	4.38	0.85	0.85
Western Delta									
Sacramento River at Emmaton	ALL	1.82	1.82	2.71	2.71	3.28	3.28	0.61	0.61
	DROUGHT	2.46	2.46	3.66	3.66	4.42	4.42	0.86	0.86
San Joaquin River at Antioch	ALL	1.83	1.82	2.72	2.71	3.29	3.28	0.61	0.61
	DROUGHT	2.46	2.46	3.65	3.65	4.42	4.42	0.86	0.86
Montezuma Slough at Hunter Cut/Beldon's Landing	ALL	1.82	1.82	2.71	2.71	3.28	3.28	0.61	0.61
	DROUGHT	2.46	2.46	3.65	3.65	4.42	4.42	0.86	0.86
Major Diversions (Pumping Stations)									
Barker Slough at North Bay Aqueduct Intake	ALL	1.82	1.82	2.71	2.71	3.28	3.28	0.61	0.61
	DROUGHT	2.46	2.46	3.65	3.65	4.42	4.42	0.86	0.86
Contra Costa Pumping Plant #1	ALL	1.84	1.83	2.74	2.73	3.31	3.30	0.61	0.61
	DROUGHT	2.45	2.46	3.65	3.65	4.41	4.42	0.86	0.86
Banks Pumping Plant	ALL	1.86	1.85	2.77	2.76	3.35	3.34	0.62	0.62
	DROUGHT	2.43	2.44	3.62	3.63	4.38	4.39	0.85	0.85
Jones Pumping Plant	ALL	1.88	1.87	2.79	2.79	3.38	3.37	0.63	0.63
	DROUGHT	2.41	2.42	3.59	3.59	4.34	4.35	0.84	0.84

[1] All: Water years 1922-2003 represent the 82-year period modeled using DSM2. Drought: Represents a five consecutive year (water years 1987-1991) drought period consisting of dry and critical water year types (as defined by the Sacramento Valley 40-30-30 water year hydrologic classification index)
[2] Dry weight, except as noted for fish fillets
mg/kg = milligram per kilogram

Table G2.3-2. Summary Table for Annual Average Selenium Concentrations in Biota for No Action Alternative and Alternative 2

Location	Period [1]	Estimated Concentrations of Selenium (mg/kg, Dry Weight[2])							
		Whole-body Fish		Bird Eggs (Invertebrate Diet)		Bird Eggs (Fish Diet)		Fish Fillets (Wet Weight)	
		No Action Alternative	Alternative 2	No Action Alternative	Alternative 2	No Action Alternative	Alternative 2	No Action Alternative	Alternative 2
Delta Interior									
San Joaquin River at Stockton	ALL	1.90	1.90	2.83	2.83	3.42	3.42	0.64	0.64
	DROUGHT	2.39	2.39	3.55	3.55	4.30	4.30	0.83	0.83
Turner Cut	ALL	1.89	1.89	2.81	2.81	3.40	3.40	0.63	0.63
	DROUGHT	2.40	2.40	3.57	3.58	4.32	4.33	0.84	0.84
San Joaquin River at San Andreas Landing	ALL	1.82	1.82	2.71	2.71	3.28	3.28	0.61	0.61
	DROUGHT	2.46	2.46	3.65	3.66	4.42	4.42	0.86	0.86
San Joaquin River at Jersey Point	ALL	1.83	1.82	2.72	2.71	3.29	3.28	0.61	0.61
	DROUGHT	2.46	2.46	3.65	3.66	4.42	4.42	0.86	0.86
Victoria Canal	ALL	1.87	1.86	2.78	2.77	3.36	3.35	0.62	0.62
	DROUGHT	2.43	2.43	3.61	3.62	4.37	4.38	0.85	0.85
Western Delta									
Sacramento River at Emmaton	ALL	1.82	1.82	2.71	2.71	3.28	3.28	0.61	0.61
	DROUGHT	2.46	2.46	3.66	3.66	4.42	4.42	0.86	0.86
San Joaquin River at Antioch	ALL	1.83	1.82	2.72	2.71	3.29	3.28	0.61	0.61
	DROUGHT	2.46	2.46	3.65	3.65	4.42	4.42	0.86	0.86
Montezuma Slough at Hunter Cut/Beldon's Landing	ALL	1.82	1.82	2.71	2.71	3.28	3.28	0.61	0.61
	DROUGHT	2.46	2.46	3.65	3.65	4.42	4.42	0.86	0.86
Major Diversions (Pumping Stations)									
Barker Slough at North Bay Aqueduct Intake	ALL	1.82	1.82	2.71	2.71	3.28	3.28	0.61	0.61
	DROUGHT	2.46	2.46	3.65	3.65	4.42	4.42	0.86	0.86
Contra Costa Pumping Plant #1	ALL	1.84	1.83	2.74	2.73	3.31	3.30	0.61	0.61
	DROUGHT	2.45	2.46	3.65	3.65	4.41	4.42	0.86	0.86
Banks Pumping Plant	ALL	1.86	1.85	2.77	2.76	3.35	3.34	0.62	0.62
	DROUGHT	2.43	2.44	3.62	3.63	4.38	4.39	0.85	0.85
Jones Pumping Plant	ALL	1.88	1.87	2.79	2.78	3.38	3.37	0.63	0.63
	DROUGHT	2.41	2.42	3.59	3.60	4.34	4.35	0.84	0.84

[1] All: Water years 1922-2003 represent the 82-year period modeled using DSM2. Drought: Represents a five consecutive year (water years 1987-1991) drought period consisting of dry and critical water year types (as defined by the Sacramento Valley 40-30-30 water year hydrologic classification index)
[2] Dry weight, except as noted for fish fillets
mg/kg = milligram per kilogram
ww = wet weight

Table G2.3-3. Summary Table for Annual Average Selenium Concentrations in Biota for No Action Alternative and Alternative 3

Location	Period [1]	Estimated Concentrations of Selenium (mg/kg, Dry Weight [2])							
		Whole-body Fish		Bird Eggs (Invertebrate Diet)		Bird Eggs (Fish Diet)		Fish Fillets (Wet Weight)	
		No Action Alternative	Alternative 3	No Action Alternative	Alternative 3	No Action Alternative	Alternative 3	No Action Alternative	Alternative 3
Delta Interior									
San Joaquin River at Stockton	ALL	1.90	1.90	2.83	2.83	3.42	3.42	0.64	0.64
	DROUGHT	2.39	2.39	3.55	3.55	4.30	4.30	0.83	0.83
Turner Cut	ALL	1.89	1.89	2.81	2.81	3.40	3.40	0.63	0.63
	DROUGHT	2.40	2.40	3.57	3.57	4.32	4.32	0.84	0.84
San Joaquin River at San Andreas Landing	ALL	1.82	1.82	2.71	2.71	3.28	3.27	0.61	0.61
	DROUGHT	2.46	2.46	3.65	3.66	4.42	4.42	0.86	0.86
San Joaquin River at Jersey Point	ALL	1.83	1.82	2.72	2.71	3.29	3.28	0.61	0.61
	DROUGHT	2.46	2.46	3.65	3.66	4.42	4.42	0.86	0.86
Victoria Canal	ALL	1.87	1.86	2.78	2.77	3.36	3.35	0.62	0.62
	DROUGHT	2.43	2.43	3.61	3.62	4.37	4.38	0.85	0.85
Western Delta									
Sacramento River at Emmaton	ALL	1.82	1.82	2.71	2.71	3.28	3.28	0.61	0.61
	DROUGHT	2.46	2.46	3.66	3.66	4.42	4.42	0.86	0.86
San Joaquin River at Antioch	ALL	1.83	1.82	2.72	2.71	3.29	3.28	0.61	0.61
	DROUGHT	2.46	2.46	3.65	3.65	4.42	4.42	0.86	0.86
Montezuma Slough at Hunter Cut/Beldon's Landing	ALL	1.82	1.82	2.71	2.71	3.28	3.28	0.61	0.61
	DROUGHT	2.46	2.46	3.65	3.65	4.42	4.42	0.86	0.86
Major Diversions (Pumping Stations)									
Barker Slough at North Bay Aqueduct Intake	ALL	1.82	1.82	2.71	2.71	3.28	3.28	0.61	0.61
	DROUGHT	2.46	2.46	3.65	3.65	4.42	4.42	0.86	0.86
Contra Costa Pumping Plant #1	ALL	1.84	1.83	2.74	2.73	3.31	3.30	0.61	0.61
	DROUGHT	2.45	2.46	3.65	3.65	4.41	4.42	0.86	0.86
Banks Pumping Plant	ALL	1.86	1.85	2.77	2.76	3.35	3.34	0.62	0.62
	DROUGHT	2.43	2.44	3.62	3.63	4.38	4.39	0.85	0.85
Jones Pumping Plant	ALL	1.88	1.87	2.79	2.78	3.38	3.37	0.63	0.63
	DROUGHT	2.41	2.42	3.59	3.60	4.34	4.36	0.84	0.84

[1] All: Water years 1922-2003 represent the 82-year period modeled using DSM2. Drought: Represents a 5 consecutive year (water years 1987-1991) drought period consisting of dry and critical water year types (as defined by the Sacramento Valley 40-30-30 water year hydrologic classification index)
[2] Dry weight, except as noted for fish fillets
mg/kg = milligram per kilogram

Table G2.3-4. Summary Table for Annual Average Selenium Concentrations in Biota for No Action Alternative and Alternative 4

Location	Period [1]	Estimated Concentrations of Selenium (mg/kg, Dry Weight[2])							
		Whole-body Fish		Bird Eggs (Invertebrate Diet)		Bird Eggs (Fish Diet)		Fish Fillets (Wet Weight)	
		No Action Alternative	Alternative 4	No Action Alternative	Alternative 4	No Action Alternative	Alternative 4	No Action Alternative	Alternative 4
Delta Interior									
San Joaquin River at Stockton	ALL	1.90	1.90	2.83	2.83	3.42	3.42	0.64	0.64
	DROUGHT	2.39	2.39	3.55	3.55	4.30	4.30	0.83	0.83
Turner Cut	ALL	1.89	1.89	2.81	2.81	3.40	3.40	0.63	0.63
	DROUGHT	2.40	2.40	3.57	3.57	4.32	4.32	0.84	0.84
San Joaquin River at San Andreas Landing	ALL	1.82	1.82	2.71	2.71	3.28	3.28	0.61	0.61
	DROUGHT	2.46	2.46	3.65	3.65	4.42	4.42	0.86	0.86
San Joaquin River at Jersey Point	ALL	1.83	1.83	2.72	2.72	3.29	3.29	0.61	0.61
	DROUGHT	2.46	2.46	3.65	3.65	4.42	4.42	0.86	0.86
Victoria Canal	ALL	1.87	1.86	2.78	2.77	3.36	3.36	0.62	0.62
	DROUGHT	2.43	2.43	3.61	3.61	4.37	4.37	0.85	0.85
Western Delta									
Sacramento River at Emmaton	ALL	1.82	1.82	2.71	2.71	3.28	3.28	0.61	0.61
	DROUGHT	2.46	2.46	3.66	3.65	4.42	4.42	0.86	0.86
San Joaquin River at Antioch	ALL	1.83	1.83	2.72	2.72	3.29	3.29	0.61	0.61
	DROUGHT	2.46	2.46	3.65	3.65	4.42	4.42	0.86	0.86
Montezuma Slough at Hunter Cut/Beldon's Landing	ALL	1.82	1.82	2.71	2.71	3.28	3.28	0.61	0.61
	DROUGHT	2.46	2.46	3.65	3.65	4.42	4.42	0.86	0.86
Major Diversions (Pumping Stations)									
Barker Slough at North Bay Aqueduct Intake	ALL	1.82	1.82	2.71	2.71	3.28	3.28	0.61	0.61
	DROUGHT	2.46	2.46	3.65	3.65	4.42	4.42	0.86	0.86
Contra Costa Pumping Plant #1	ALL	1.84	1.84	2.74	2.74	3.31	3.31	0.61	0.61
	DROUGHT	2.45	2.45	3.65	3.65	4.41	4.41	0.86	0.86
Banks Pumping Plant	ALL	1.86	1.86	2.77	2.77	3.35	3.35	0.62	0.62
	DROUGHT	2.43	2.43	3.62	3.62	4.38	4.38	0.85	0.85
Jones Pumping Plant	ALL	1.88	1.88	2.79	2.79	3.38	3.38	0.63	0.63
	DROUGHT	2.41	2.41	3.59	3.59	4.34	4.34	0.84	0.84

[1] All: Water years 1922-2003 represent the 82-year period modeled using DSM2. Drought: Represents a 5 consecutive year (water years 1987-1991) drought period consisting of dry and critical water year types (as defined by the Sacramento Valley 40-30-30 water year hydrologic classification index)

[2] Dry weight, except as noted for fish fillets

mg/kg = milligram per kilogram

Table G2.3-5. Summary Table for Selenium Concentrations in Biota, and Comparisons for No Action Alternative to Benchmarks

Location	Period [1]	Estimated Concentrations of Selenium (mg/kg, dry weight [2])				Exceedance Quotients [3]						
		Whole-body Fish	Bird Eggs (Invertebrate Diet)	Bird Eggs (Fish Diet)	Fish Fillets (ww)	Whole-body Fish		Bird Eggs (Invertebrate Diet)		Bird Eggs (Fish Diet)		Fish Fillets (wet weight)
						Level of Concern [4]	Toxicity Level [5]	Level of Concern [6]	Toxicity Level [7]	Level of Concern [6]	Toxicity Level [7]	Advisory Tissue Level [8]
Delta Interior												
San Joaquin River at Stockton	ALL	1.90	2.83	3.42	0.64	0.47	0.22	0.47	0.28	0.57	0.34	0.25
	DROUGHT	2.39	3.55	4.30	0.83	0.60	0.28	0.59	0.36	0.72	0.43	0.33
Turner Cut	ALL	1.89	2.81	3.40	0.63	0.47	0.22	0.47	0.28	0.57	0.34	0.25
	DROUGHT	2.40	3.57	4.32	0.84	0.60	0.28	0.59	0.36	0.72	0.43	0.33
San Joaquin River at San Andreas Landing	ALL	1.82	2.71	3.28	0.61	0.46	0.21	0.45	0.27	0.55	0.33	0.24
	DROUGHT	2.46	3.65	4.42	0.86	0.61	0.29	0.61	0.37	0.74	0.44	0.34
San Joaquin River at Jersey Point	ALL	1.83	2.72	3.29	0.61	0.46	0.21	0.45	0.27	0.55	0.33	0.24
	DROUGHT	2.46	3.65	4.42	0.86	0.61	0.29	0.61	0.37	0.74	0.44	0.34
Victoria Canal	ALL	1.87	2.78	3.36	0.62	0.47	0.22	0.46	0.28	0.56	0.34	0.25
	DROUGHT	2.43	3.61	4.37	0.85	0.61	0.29	0.60	0.36	0.73	0.44	0.34
Western Delta												
Sacramento River at Emmaton	ALL	1.82	2.71	3.28	0.61	0.46	0.21	0.45	0.27	0.55	0.33	0.24
	DROUGHT	2.46	3.66	4.42	0.86	0.61	0.29	0.61	0.37	0.74	0.44	0.34
San Joaquin River at Antioch	ALL	1.83	2.72	3.29	0.61	0.46	0.21	0.45	0.27	0.55	0.33	0.24
	DROUGHT	2.46	3.65	4.42	0.86	0.61	0.29	0.61	0.37	0.74	0.44	0.34
Montezuma Slough at Hunter Cut/Beldon's Landing	ALL	1.82	2.71	3.28	0.61	0.46	0.21	0.45	0.27	0.55	0.33	0.24
	DROUGHT	2.46	3.65	4.42	0.86	0.61	0.29	0.61	0.37	0.74	0.44	0.34
Major Diversions (Pumping Stations)												
Barker Slough at North Bay Aqueduct Intake	ALL	1.82	2.71	3.28	0.61	0.46	0.21	0.45	0.27	0.55	0.33	0.24
	DROUGHT	2.46	3.65	4.42	0.86	0.61	0.29	0.61	0.37	0.74	0.44	0.34
Contra Costa Pumping Plant #1	ALL	1.84	2.74	3.31	0.61	0.46	0.22	0.46	0.27	0.55	0.33	0.25
	DROUGHT	2.45	3.65	4.41	0.86	0.61	0.29	0.61	0.36	0.74	0.44	0.34
Banks Pumping Plant	ALL	1.86	2.77	3.35	0.62	0.46	0.22	0.46	0.28	0.56	0.33	0.25
	DROUGHT	2.43	3.62	4.38	0.85	0.61	0.29	0.60	0.36	0.73	0.44	0.34
Jones Pumping Plant	ALL	1.88	2.79	3.38	0.63	0.47	0.22	0.47	0.28	0.56	0.34	0.25
	DROUGHT	2.41	3.59	4.34	0.84	0.60	0.28	0.60	0.36	0.72	0.43	0.34

[1] All: Water years 1922-2003 represent the 82-year period modeled using DSM2. Drought: Represents a 5 consecutive year (water years 1987-1991) drought period consisting of dry and critical water year types (as defined by the Sacramento Valley 40-30-30 water year hydrologic classification index).
[2] Dry weight, except as noted for fish fillets.
[3] Exceedance Quotient = tissue concentration/benchmark
[4] Level of Concern for fish tissue (lower end of range) = 4 mg/kg dw (Beckon 2017)
[5] Toxicity Level for fish tissue = 8.5 mg/kg dw (USEPA 2016, 2018)
[6] Level of Concern for bird eggs (lower end of range) = 6 mg/kg dw (Beckon 2017)
[7] Toxicity Level for bird eggs = 10 mg/kg dw (Beckon 2017)
[8] Advisory Tissue Level = 2.5 mg/kg ww (OEHHA 2008)
mg/kg - milligram per kilogram

Table G2.3-6. Summary Table for Selenium Concentrations in Biota, and Comparisons for Alternative 1 to No Action Alternative and Benchmarks

Location	Period [1]	Estimated Concentrations of Selenium (mg/kg, dry weight [2])				% Change In Selenium Concentrations Compared to No Action Alternative [3]				Exceedance Quotients [4]						
		Whole-body Fish	Bird Eggs (Invertebrate Diet)	Bird Eggs (Fish Diet)	Fish Fillets (wet weight)	Whole-body Fish	Bird Eggs (Invertebrate Diet)	Bird Eggs (Fish Diet)	Fish Fillets (wet weight)	Whole-body Fish		Bird Eggs (Fish Diet)		Bird Eggs (Fish Diet)		Fish Fillets (wet weight)
		Alternative 1	Alternative 1	Alternative 1	Alternative 1	No Action Alternative	No Action Alternative	No Action Alternative	No Action Alternative	Level of Concern [5]	Toxicity Level [6]	Level of Concern [7]	Toxicity Level [8]	Level of Concern [7]	Toxicity Level [8]	Advisory Tissue Level [9]
Delta Interior																
San Joaquin River at Stockton	ALL	1.90	2.83	3.42	0.64	-0.02	-0.02	-0.02	-0.03	0.47	0.22	0.47	0.28	0.57	0.34	0.25
	DROUGHT	2.39	3.55	4.30	0.83	0.04	0.04	0.04	0.05	0.60	0.28	0.59	0.36	0.72	0.43	0.33
Turner Cut	ALL	1.89	2.81	3.40	0.63	-0.14	-0.14	-0.14	-0.17	0.47	0.22	0.47	0.28	0.57	0.34	0.25
	DROUGHT	2.40	3.58	4.33	0.00	0.21	0.21	0.21	0.24	0.60	0.28	0.60	0.36	0.72	0.43	0.33
San Joaquin River at San Andreas Landing	ALL	1.82	2.71	3.28	0.61	-0.15	-0.15	-0.15	-0.18	0.46	0.21	0.45	0.27	0.55	0.33	0.24
	DROUGHT	2.46	3.66	4.42	0.86	0.05	0.05	0.05	0.05	0.61	0.29	0.61	0.37	0.74	0.44	0.34
San Joaquin River at Jersey Point	ALL	1.82	2.71	3.28	0.61	-0.17	-0.17	-0.17	-0.20	0.46	0.21	0.45	0.27	0.55	0.33	0.24
	DROUGHT	2.46	3.66	4.42	0.86	0.04	0.04	0.04	0.05	0.61	0.29	0.61	0.37	0.74	0.44	0.34
Victoria Canal	ALL	1.86	2.77	3.35	0.62	-0.27	-0.27	-0.27	-0.32	0.47	0.22	0.46	0.28	0.56	0.33	0.25
	DROUGHT	2.43	3.62	4.38	0.85	0.28	0.28	0.28	0.32	0.61	0.29	0.60	0.36	0.73	0.44	0.34
Western Delta																
Sacramento River at Emmaton	ALL	1.82	2.71	3.28	0.61	-0.06	-0.06	-0.06	-0.07	0.46	0.21	0.45	0.27	0.55	0.33	0.24
	DROUGHT	2.46	3.66	4.42	0.86	0.01	0.01	0.01	0.01	0.61	0.29	0.61	0.37	0.74	0.44	0.34
San Joaquin River at Antioch	ALL	1.82	2.71	3.28	0.61	-0.14	-0.14	-0.14	-0.16	0.46	0.21	0.45	0.27	0.55	0.33	0.24
	DROUGHT	2.46	3.65	4.42	0.86	0.02	0.02	0.02	0.02	0.61	0.29	0.61	0.37	0.74	0.44	0.34
Montezuma Slough at Hunter Cut/Beldon's Landing	ALL	1.82	2.71	3.28	0.61	-0.06	-0.06	-0.06	-0.07	0.46	0.21	0.45	0.27	0.55	0.33	0.24
	DROUGHT	2.46	3.65	4.42	0.86	0.01	0.01	0.01	0.01	0.61	0.29	0.61	0.37	0.74	0.44	0.34
Major Diversions (Pumping Stations)																
Barker Slough at North Bay Aqueduct Intake	ALL	1.82	2.71	3.28	0.61	0.01	0.01	0.01	0.01	0.46	0.21	0.45	0.27	0.55	0.33	0.24
	DROUGHT	2.46	3.65	4.42	0.86	0.00	0.00	0.00	0.00	0.61	0.29	0.61	0.37	0.74	0.44	0.34
Contra Costa Pumping Plant #1	ALL	1.83	2.73	3.30	0.61	-0.39	-0.39	-0.39	-0.46	0.46	0.22	0.45	0.27	0.55	0.33	0.24
	DROUGHT	2.46	3.65	4.42	0.86	0.16	0.16	0.16	0.18	0.61	0.29	0.61	0.37	0.74	0.44	0.34
Banks Pumping Plant	ALL	1.85	2.76	3.34	0.62	-0.31	-0.31	-0.31	-0.36	0.46	0.22	0.46	0.28	0.56	0.33	0.25
	DROUGHT	2.44	3.63	4.39	0.85	0.26	0.26	0.26	0.29	0.61	0.29	0.60	0.36	0.73	0.44	0.34
Jones Pumping Plant	ALL	1.87	2.79	3.37	0.63	-0.13	-0.13	-0.13	-0.15	0.47	0.22	0.46	0.28	0.56	0.34	0.25
	DROUGHT	2.42	3.59	4.35	0.84	0.20	0.20	0.20	0.22	0.60	0.28	0.60	0.36	0.72	0.43	0.34

[1] All: Water years 1922-2003 represent the 82-year period modeled using DSM2. Drought: Represents a 5 consecutive year (water years 1987-1991) drought period consisting of dry and critical water year types (as defined by the Sacramento Valley 40-30-30 water year hydrologic classification index).
[2] Dry weight, except as noted for fish fillets.
[3] % change indicates a negative change (increased concentrations) relative to the No Action Alternative when values are positive and a positive change (lowered concentrations) relative to the No Action Alternative when values are negative.
[4] Exceedance Quotient = tissue concentration/benchmark
[5] Level of Concern for fish tissue (lower end of range) = 4 mg/kg dw (Beckon 2017)
[6] Toxicity Level for fish tissue = 8.5 mg/kg dw (USEPA 2016, 2018)
[7] Level of Concern for bird eggs (lower end of range) = 6 mg/kg dw (Beckon 2017)
[8] Toxicity Level for bird eggs = 10 mg/kg dw (Beckon 2017)
[9] Advisory Tissue Level = 2.5 mg/kg ww (OEHHA 2008)
mg/kg - milligram per kilogram

Table G2.3-7. Summary Table for Selenium Concentrations in Biota, and Comparisons for Alternative 2 to No Action Alternative and Benchmarks

Location	Period [a]	Estimated Concentrations of Selenium (mg/kg, dry weight [2])				% Change In Selenium Concentrations Compared to No Action Alternative [3]				Exceedance Quotients [4]						
		Whole-body Fish	Bird Eggs (Invertebrate Diet)	Bird Eggs (Fish Diet)	Fish Fillets (wet weight)	Whole-body Fish	Bird Eggs (Invertebrate Diet)	Bird Eggs (Fish Diet)	Fish Fillets (wet weight)	Whole-body Fish		Bird Eggs (Fish Diet)		Bird Eggs (Fish Diet)		Fish Fillets (wet weight)
		Alternative 2	Alternative 2	Alternative 2	Alternative 2	No Action Alternative	No Action Alternative	No Action Alternative	No Action Alternative	Level of Concern [5]	Toxicity Level [6]	Level of Concern [7]	Toxicity Level [8]	Level of Concern [7]	Toxicity Level [8]	Advisory Tissue Level [9]
Delta Interior																
San Joaquin River at Stockton	ALL	1.90	2.83	3.42	0.64	-0.02	-0.02	-0.02	-0.02	0.47	0.22	0.47	0.28	0.57	0.34	0.25
	DROUGHT	2.39	3.55	4.30	0.83	0.03	0.03	0.03	0.03	0.60	0.28	0.59	0.36	0.72	0.43	0.33
Turner Cut	ALL	1.89	2.81	3.40	0.63	-0.13	-0.13	-0.13	-0.15	0.47	0.22	0.47	0.28	0.57	0.34	0.25
	DROUGHT	2.40	3.58	4.33	0.00	0.16	0.16	0.16	0.18	0.60	0.28	0.60	0.36	0.72	0.43	0.33
San Joaquin River at San Andreas Landing	ALL	1.82	2.71	3.28	0.61	-0.19	-0.19	-0.19	-0.23	0.45	0.21	0.45	0.27	0.55	0.33	0.24
	DROUGHT	2.46	3.66	4.42	0.86	0.05	0.05	0.05	0.05	0.61	0.29	0.61	0.37	0.74	0.44	0.34
San Joaquin River at Jersey Point	ALL	1.82	2.71	3.28	0.61	-0.20	-0.20	-0.20	-0.24	0.46	0.21	0.45	0.27	0.55	0.33	0.24
	DROUGHT	2.46	3.66	4.42	0.86	0.04	0.04	0.04	0.04	0.61	0.29	0.61	0.37	0.74	0.44	0.34
Victoria Canal	ALL	1.86	2.77	3.35	0.62	-0.32	-0.32	-0.32	-0.38	0.46	0.22	0.46	0.28	0.56	0.33	0.25
	DROUGHT	2.43	3.62	4.38	0.85	0.25	0.25	0.25	0.28	0.61	0.29	0.60	0.36	0.73	0.44	0.34
Western Delta																
Sacramento River at Emmaton	ALL	1.82	2.71	3.28	0.61	-0.07	-0.07	-0.07	-0.09	0.45	0.21	0.45	0.27	0.55	0.33	0.24
	DROUGHT	2.46	3.66	4.42	0.86	0.01	0.01	0.01	0.02	0.61	0.29	0.61	0.37	0.74	0.44	0.34
San Joaquin River at Antioch	ALL	1.82	2.71	3.28	0.61	-0.15	-0.15	-0.15	-0.18	0.46	0.21	0.45	0.27	0.55	0.33	0.24
	DROUGHT	2.46	3.65	4.42	0.86	0.02	0.02	0.02	0.02	0.61	0.29	0.61	0.37	0.74	0.44	0.34
Montezuma Slough at Hunter Cut/Beldon's Landing	ALL	1.82	2.71	3.28	0.61	-0.07	-0.07	-0.07	-0.08	0.46	0.21	0.45	0.27	0.55	0.33	0.24
	DROUGHT	2.46	3.65	4.42	0.86	0.01	0.01	0.01	0.01	0.61	0.29	0.61	0.37	0.74	0.44	0.34
Major Diversions (Pumping Stations)																
Barker Slough at North Bay Aqueduct Intake	ALL	1.82	2.71	3.28	0.61	0.01	0.01	0.01	0.01	0.46	0.21	0.45	0.27	0.55	0.33	0.24
	DROUGHT	2.46	3.65	4.42	0.86	0.00	0.00	0.00	0.00	0.61	0.29	0.61	0.37	0.74	0.44	0.34
Contra Costa Pumping Plant #1	ALL	1.83	2.73	3.30	0.61	-0.48	-0.48	-0.48	-0.57	0.46	0.22	0.45	0.27	0.55	0.33	0.24
	DROUGHT	2.46	3.65	4.42	0.86	0.16	0.16	0.16	0.19	0.61	0.29	0.61	0.37	0.74	0.44	0.34
Banks Pumping Plant	ALL	1.85	2.76	3.34	0.62	-0.39	-0.39	-0.39	-0.46	0.46	0.22	0.46	0.28	0.56	0.33	0.25
	DROUGHT	2.44	3.63	4.39	0.85	0.27	0.27	0.27	0.30	0.61	0.29	0.60	0.36	0.73	0.44	0.34
Jones Pumping Plant	ALL	1.87	2.79	3.37	0.63	-0.35	-0.35	-0.35	-0.41	0.47	0.22	0.46	0.28	0.56	0.34	0.25
	DROUGHT	2.42	3.59	4.35	0.84	0.36	0.36	0.36	0.41	0.61	0.28	0.60	0.36	0.73	0.44	0.34

[1] All: Water years 1922-2003 represent the 82-year period modeled using DSM2. Drought: Represents a 5 consecutive year (water years 1987-1991) drought period consisting of dry and critical water year types (as defined by the Sacramento Valley 40-30-30 water year hydrologic classification index).
[2] Dry weight, except as noted for fish fillets.
[3] % change indicates a negative change (increased concentrations) relative to the No Action Alternative when values are positive and a positive change (lowered concentrations) relative to the No Action Alternative when values are negative.
[4] Exceedance Quotient = tissue concentration/benchmark
[5] Level of Concern for fish tissue (lower end of range) = 4 mg/kg dw (Beckon 2017)
[6] Toxicity Level for fish tissue = 8.5 mg/kg dw (USEPA 2016, 2018)
[7] Level of Concern for bird eggs (lower end of range) = 6 mg/kg dw (Beckon 2017)
[8] Toxicity Level for bird eggs = 10 mg/kg dw (Beckon 2017)
[9] Advisory Tissue Level = 2.5 mg/kg ww (OEHHA 2008)
mg/kg - milligram per kilogram

Table G2.3-8. Summary Table for Selenium Concentrations in Biota, and Comparisons for Alternative 3 to No Action Alternative and Benchmarks

Location	Period [1]	Estimated Concentrations of Selenium (mg/kg, dry weight [2])				% Change In Selenium Concentrations Compared to No Action Alternative [3]				Exceedance Quotients [4]						
		Whole-body Fish	Bird Eggs (Invertebrate Diet)	Bird Eggs (Fish Diet)	Fish Fillets (wet weight)	Whole-body Fish	Bird Eggs (Invertebrate Diet)	Bird Eggs (Fish Diet)	Fish Fillets (wet weight)	Whole-body Fish		Bird Eggs (Fish Diet)		Bird Eggs (Fish Diet)		Fish Fillets (wet weight)
		Alternative 3	Alternative 3	Alternative 3	Alternative 3	No Action Alternative	No Action Alternative	No Action Alternative	No Action Alternative	Level of Concern [5]	Toxicity Level [6]	Level of Concern [7]	Toxicity Level [8]	Level of Concern [7]	Toxicity Level [8]	Advisory Tissue Level [9]
Delta Interior																
San Joaquin River at Stockton	ALL	1.90	2.83	3.42	0.64	0.00	0.00	0.00	-0.01	0.47	0.22	0.47	0.28	0.57	0.34	0.25
	DROUGHT	2.39	3.55	4.30	0.83	0.02	0.02	0.02	0.02	0.60	0.28	0.59	0.36	0.72	0.43	0.33
Turner Cut	ALL	1.89	2.81	3.40	0.63	-0.06	-0.06	-0.06	-0.07	0.47	0.22	0.47	0.28	0.57	0.34	0.25
	DROUGHT	2.40	3.57	4.32	0.84	0.08	0.08	0.08	0.10	0.60	0.28	0.60	0.36	0.72	0.43	0.33
San Joaquin River at San Andreas Landing	ALL	1.82	2.71	3.27	0.61	-0.22	-0.22	-0.22	-0.26	0.45	0.21	0.45	0.27	0.55	0.33	0.24
	DROUGHT	2.46	3.66	4.42	0.86	0.04	0.04	0.04	0.05	0.61	0.29	0.61	0.37	0.74	0.44	0.34
San Joaquin River at Jersey Point	ALL	1.82	2.71	3.28	0.61	-0.18	-0.18	-0.18	-0.22	0.46	0.21	0.45	0.27	0.55	0.33	0.24
	DROUGHT	2.46	3.66	4.42	0.86	0.04	0.04	0.04	0.05	0.61	0.29	0.61	0.37	0.74	0.44	0.34
Victoria Canal	ALL	1.86	2.77	3.35	0.62	-0.26	-0.26	-0.26	-0.31	0.47	0.22	0.46	0.28	0.56	0.33	0.25
	DROUGHT	2.43	3.62	4.38	0.85	0.21	0.21	0.21	0.24	0.61	0.29	0.60	0.36	0.73	0.44	0.34
Western Delta																
Sacramento River at Emmaton	ALL	1.82	2.71	3.28	0.61	-0.08	-0.08	-0.08	-0.09	0.45	0.21	0.45	0.27	0.55	0.33	0.24
	DROUGHT	2.46	3.66	4.42	0.86	0.02	0.02	0.02	0.02	0.61	0.29	0.61	0.37	0.74	0.44	0.34
San Joaquin River at Antioch	ALL	1.82	2.71	3.28	0.61	-0.14	-0.14	-0.14	-0.17	0.46	0.21	0.45	0.27	0.55	0.33	0.24
	DROUGHT	2.46	3.65	4.42	0.86	0.02	0.02	0.02	0.03	0.61	0.29	0.61	0.37	0.74	0.44	0.34
Montezuma Slough at Hunter Cut/Beldon's Landing	ALL	1.82	2.71	3.28	0.61	-0.08	-0.08	-0.08	-0.09	0.46	0.21	0.45	0.27	0.55	0.33	0.24
	DROUGHT	2.46	3.65	4.42	0.86	0.00	0.00	0.00	0.00	0.61	0.29	0.61	0.37	0.74	0.44	0.34
Major Diversions (Pumping Stations)																
Barker Slough at North Bay Aqueduct Intake	ALL	1.82	2.71	3.28	0.61	0.02	0.02	0.02	0.02	0.46	0.21	0.45	0.27	0.55	0.33	0.24
	DROUGHT	2.46	3.65	4.42	0.86	0.02	0.02	0.02	0.02	0.61	0.29	0.61	0.37	0.74	0.44	0.34
Contra Costa Pumping Plant #1	ALL	1.83	2.73	3.30	0.61	-0.47	-0.47	-0.47	-0.56	0.46	0.22	0.45	0.27	0.55	0.33	0.24
	DROUGHT	2.46	3.65	4.42	0.86	0.19	0.19	0.19	0.21	0.61	0.29	0.61	0.37	0.74	0.44	0.34
Banks Pumping Plant	ALL	1.85	2.76	3.34	0.62	-0.36	-0.36	-0.36	-0.43	0.46	0.22	0.46	0.28	0.56	0.33	0.25
	DROUGHT	2.44	3.63	4.39	0.85	0.26	0.26	0.26	0.30	0.61	0.29	0.60	0.36	0.73	0.44	0.34
Jones Pumping Plant	ALL	1.87	2.78	3.37	0.63	-0.33	-0.33	-0.33	-0.39	0.47	0.22	0.46	0.28	0.56	0.34	0.25
	DROUGHT	2.42	3.60	4.36	0.84	0.38	0.38	0.38	0.43	0.61	0.28	0.60	0.36	0.73	0.44	0.34

[1] All: Water years 1922-2003 represent the 82-year period modeled using DSM2. Drought: Represents a 5 consecutive year (water years 1987-1991) drought period consisting of dry and critical water year types (as defined by the Sacramento Valley 40-30-30 water year hydrologic classification index).
[2] Dry weight, except as noted for fish fillets.
[3] % change indicates a negative change (increased concentrations) relative to the No Action Alternative when values are positive and a positive change (lowered concentrations) relative to the No Action Alternative when values are negative.
[4] Exceedance Quotient = tissue concentration/benchmark
[5] Level of Concern for fish tissue (lower end of range) = 4 mg/kg dw (Beckon 2017)
[6] Toxicity Level for fish tissue = 8.5 mg/kg dw (USEPA 2016, 2018)
[7] Level of Concern for bird eggs (lower end of range) = 6 mg/kg dw (Beckon 2017)
[8] Toxicity Level for bird eggs = 10 mg/kg dw (Beckon 2017)
[9] Advisory Tissue Level = 2.5 mg/kg ww (OEHHA 2008)
mg/kg - milligram per kilogram

Table G2.3-9. Summary Table for Selenium Concentrations in Biota, and Comparisons for Alternative 4 to No Action Alternative and Benchmarks

Location	Period [1]	Estimated Concentrations of Selenium (mg/kg, dry weight [2])				% Change In Selenium Concentrations Compared to No Action Alternative [3]				Exceedance Quotients [4]						
		Whole-body Fish	Bird Eggs (Invertebrate Diet)	Bird Eggs (Fish Diet)	Fish Fillets (wet weight)	Whole-body Fish	Bird Eggs (Invertebrate Diet)	Bird Eggs (Fish Diet)	Fish Fillets (wet weight)	Whole-body Fish		Bird Eggs (Fish Diet)		Bird Eggs (Fish Diet)		Fish Fillets (wet weight)
		Alternative 3	Alternative 3	Alternative 3	Alternative 3	No Action Alternative	No Action Alternative	No Action Alternative	No Action Alternative	Level of Concern [5]	Toxicity Level [6]	Level of Concern [7]	Toxicity Level [8]	Level of Concern [7]	Toxicity Level [8]	Advisory Tissue Level [9]
Delta Interior																
San Joaquin River at Stockton	ALL	1.90	2.83	3.42	0.64	-0.01	-0.01	-0.01	-0.01	0.47	0.22	0.47	0.28	0.57	0.34	0.25
	DROUGHT	2.39	3.55	4.30	0.83	0.02	0.02	0.02	0.02	0.60	0.28	0.59	0.36	0.72	0.43	0.33
Turner Cut	ALL	1.89	2.81	3.40	0.63	-0.02	-0.02	-0.02	-0.02	0.47	0.22	0.47	0.28	0.57	0.34	0.25
	DROUGHT	2.40	3.57	4.32	0.84	0.07	0.07	0.07	0.08	0.60	0.28	0.60	0.36	0.72	0.43	0.33
San Joaquin River at San Andreas Landing	ALL	1.82	2.71	3.28	0.61	0.02	0.02	0.02	0.02	0.45	0.21	0.45	0.27	0.55	0.33	0.24
	DROUGHT	2.46	3.65	4.42	0.86	-0.01	-0.01	-0.01	-0.01	0.61	0.29	0.61	0.37	0.74	0.44	0.34
San Joaquin River at Jersey Point	ALL	1.83	2.72	3.29	0.61	0.02	0.02	0.02	0.02	0.46	0.21	0.45	0.27	0.55	0.33	0.24
	DROUGHT	2.46	3.65	4.42	0.86	-0.01	-0.01	-0.01	-0.01	0.61	0.29	0.61	0.37	0.74	0.44	0.34
Victoria Canal	ALL	1.86	2.77	3.36	0.62	-0.04	-0.04	-0.04	-0.04	0.47	0.22	0.46	0.28	0.56	0.33	0.25
	DROUGHT	2.43	3.61	4.37	0.85	0.07	0.07	0.07	0.08	0.61	0.29	0.60	0.36	0.73	0.44	0.34
Western Delta																
Sacramento River at Emmaton	ALL	1.82	2.71	3.28	0.61	0.00	0.00	0.00	0.00	0.45	0.21	0.45	0.27	0.55	0.33	0.24
	DROUGHT	2.46	3.65	4.42	0.86	-0.01	-0.01	-0.01	-0.01	0.61	0.29	0.61	0.37	0.74	0.44	0.34
San Joaquin River at Antioch	ALL	1.83	2.72	3.29	0.61	0.02	0.02	0.02	0.02	0.46	0.21	0.45	0.27	0.55	0.33	0.24
	DROUGHT	2.46	3.65	4.42	0.86	-0.01	-0.01	-0.01	-0.01	0.61	0.29	0.61	0.37	0.74	0.44	0.34
Montezuma Slough at Hunter Cut/Beldon's Landing	ALL	1.82	2.71	3.28	0.61	0.01	0.01	0.01	0.01	0.46	0.21	0.45	0.27	0.55	0.33	0.24
	DROUGHT	2.46	3.65	4.42	0.86	-0.01	-0.01	-0.01	-0.01	0.61	0.29	0.61	0.37	0.74	0.44	0.34
Major Diversions (Pumping Stations)																
Barker Slough at North Bay Aqueduct Intake	ALL	1.82	2.71	3.28	0.61	0.01	0.01	0.01	0.02	0.46	0.21	0.45	0.27	0.55	0.33	0.24
	DROUGHT	2.46	3.65	4.42	0.86	0.01	0.01	0.01	0.01	0.61	0.29	0.61	0.37	0.74	0.44	0.34
Contra Costa Pumping Plant #1	ALL	1.84	2.74	3.31	0.61	0.00	0.00	0.00	0.00	0.46	0.22	0.45	0.27	0.55	0.33	0.24
	DROUGHT	2.45	3.65	4.41	0.86	-0.02	-0.02	-0.02	-0.02	0.61	0.29	0.61	0.37	0.74	0.44	0.34
Banks Pumping Plant	ALL	1.86	2.77	3.35	0.62	0.11	0.11	0.11	0.13	0.46	0.22	0.46	0.28	0.56	0.33	0.25
	DROUGHT	2.43	3.62	4.38	0.85	-0.04	-0.04	-0.04	-0.05	0.61	0.29	0.60	0.36	0.73	0.44	0.34
Jones Pumping Plant	ALL	1.88	2.79	3.38	0.63	0.03	0.03	0.03	0.03	0.47	0.22	0.46	0.28	0.56	0.34	0.25
	DROUGHT	2.41	3.59	4.34	0.84	0.01	0.01	0.01	0.01	0.61	0.28	0.60	0.36	0.73	0.44	0.34

Table G2.3-10. Summary of Period Average Selenium Concentrations in Whole-body Sturgeon

Location	Period [1]	Estimated Concentrations of Selenium in Whole-body Sturgeon (mg/kg, dry weight) No Action Alternative	Estimated Concentrations of Selenium in Whole-body Sturgeon (mg/kg, dry weight) Alternative 1	Estimated Concentrations of Selenium in Whole-body Sturgeon (mg/kg, dry weight) Alternative 2	Estimated Concentrations of Selenium in Whole-body Sturgeon (mg/kg, dry weight) Alternative 3	Estimated Concentrations of Selenium in Whole-body Sturgeon (mg/kg, dry weight) Alternative 4
Sacramento River	ALL	4.09	4.01	3.99	3.98	4.09
at Emmaton	DROUGHT	6.77	6.72	6.72	6.71	6.79
San Joaquin River	ALL	4.49	4.29	4.26	4.28	4.52
at Antioch	DROUGHT	6.87	6.80	6.80	6.79	6.92
Montezuma Slough at Hunter Cut /	ALL	4.28	4.19	4.18	4.17	4.29
Beldon's Landing	DROUGHT	6.96	6.94	6.94	6.97	6.98

[1] All: Water years 1922-2003 represent the 82-year period modeled using DSM2. Drought: Represents a 5-consecutive-year (Water Years 1987-1991) drought period consisting of dry and critical water-year types (as defined by the Sacramento Valley 40-30-30 water year hydrologic classification index).
mg/kg = milligram per kilogram

Table G2.3-11. Comparison of Annual Average Selenium Concentrations in Whole-body Sturgeon to Toxicity Thresholds, expressed as Exceedance Quotients [1]

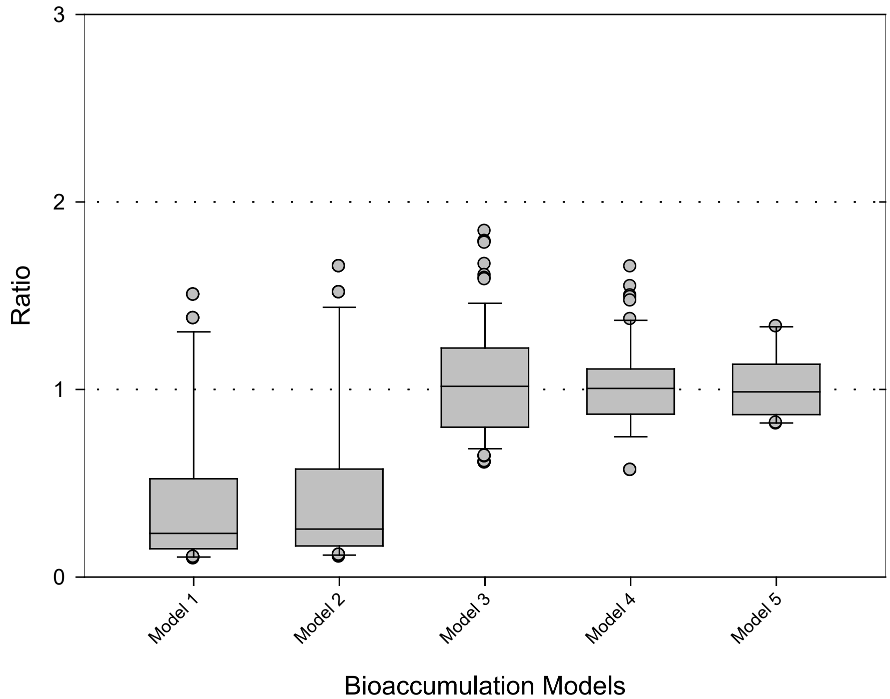
Location	Period 2	No Action Alternative		Alternative 1		Alternative 2		Alternative 3		Alternative 4	
		Low	High	Low	High	Low	High	Low	High	Low	High
Sacramento River at Emmaton	ALL	0.82	0.51	0.80	0.50	0.80	0.50	0.80	0.50	0.82	0.51
	DROUGHT	**1.4**	0.85	**1.3**	0.84	**1.3**	0.84	**1.3**	0.84	**1.4**	0.85
San Joaquin River at Antioch	ALL	0.90	0.56	0.86	0.54	0.85	0.53	0.86	0.54	0.90	0.56
	DROUGHT	**1.4**	0.86	**1.4**	0.85	**1.4**	0.85	**1.4**	0.85	**1.4**	0.86
Montezuma Slough at Hunter Cut/Beldon's Landing	ALL	0.86	0.53	0.84	0.52	0.84	0.52	0.83	0.52	0.86	0.54
	DROUGHT	**1.4**	0.87	**1.4**	0.87	**1.4**	0.87	**1.4**	0.87	**1.4**	0.87

[1] Toxicity thresholds are Low = 5 mg/kg, dw and High = 8 mg/kg, dw as reported in Presser and Luoma (2013) and 8 mg/kg, dw from the TMDL for North San Francisco Bay (San Francisco Bay RWQCB 2016).
[2] All: Water years 1922-2003 represent the 82-year period modeled using DSM2. Drought: Represents a 5 consecutive year (water years 1987-1991) drought period consisting of dry and critical water year types (as defined by the Sacramento Valley 40-30-30 water year hydrologic classification index).
bold and highlighted = estimated whole-body sturgen exceeded toxicity threshold
dw - dry weight
mg/kg - milligram per kilogram

Table G2.3-12. Percent Change in Selenium Concentrations in Whole Body Sturgeon Relative to No Action Alternative

Location	Period [1]	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Sacramento River at Emmaton	ALL	-1.9	-2.4	-2.5	0.1
	DROUGHT	-0.6	-0.7	-0.8	0.4
San Joaquin River at Antioch	ALL	-4.4	-5.0	-4.6	0.6
	DROUGHT	-1.0	-1.0	-1.1	0.6
Montezuma Slough at Hunter Cut/Beldon's Landing	ALL	-2.0	-2.3	-2.5	0.3
	DROUGHT	-0.3	-0.3	0.1	0.3

[1] All: Water years 1922-2003 represent the 82-year period modeled using DSM2. Drought: Represents a 5-consecutive-year (Water Years 1987-1991) drought period consisting of dry and critical water-year types (as defined by the Sacramento Valley 40-30-30 water year hydrologic classification index).



For Models 1 and 2, default values (K_d = 1000, TTF_{invert} = 2.8, TTF_{fish} = 1.1) were used in calculations as follows:

Model 1=Trophic level 3 (TL-3) fish eating invertebrates
Model 2= TL-4 fish eating TL-3 fish

Model 3=Model 2 with K_d estimated using all years regression (log Kd = 2.76-0.97(logDSM2))
Model 4=Model 2 with K_d estimated using normal/wet years (2000/2005) regression (log Kd = 2.75-0.90(logDSM2))
Model 5=Model 2 with K_d estimated using dry years (2007) regression (logKd = 2.84-1.02(logDSM2))

Figure G2.1-1. Ratios of Predicted Selenium Concentrations in Fish Models 1 through 5 to Observed Selenium Concentrations in Largemouth Bass

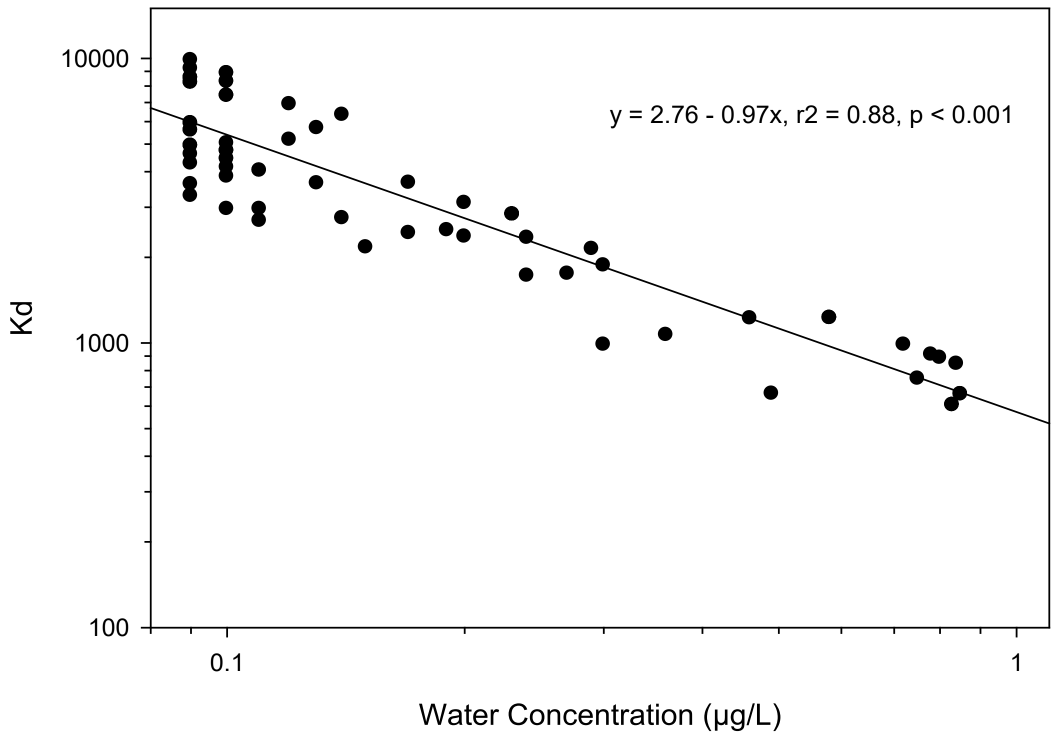


Figure G2.1-2. Log-log Regression Relation of Estimated K_d to Water column Selenium Concentration for Model 3 in All Years (Based on Years 2000, 2005, and 2007)

To predict the K_d (y) from water concentrations using the regression equation, take the log of the water concentration (x), multiply it by the slope (-0.97), which gives a positive number for x<1 (i.e., water column selenium concentrations less than 1 µg/L); then add this number to the intercept (2.76) and take the antilog.

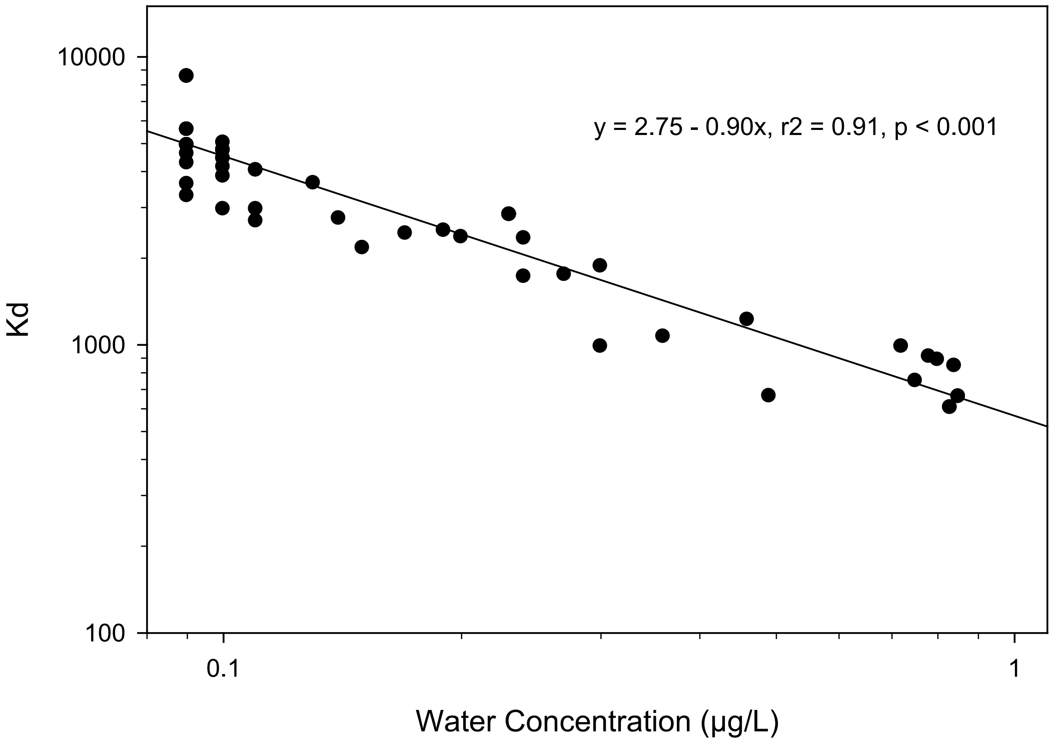


Figure G2.1-3. Log-log Regression Relation of Estimated K_d to Water column Selenium Concentration for Model 4 in Normal/Wet Years (Based on Years 2000 and 2005)

To predict the K_d (y) from water concentrations using the regression equation, take the log of the water concentration (x), multiply it by the slope (-0.90), which gives a positive number for x<1 (i.e., water column selenium concentrations less than 1 µg/L); then add this number to the intercept (2.75) and take the antilog.

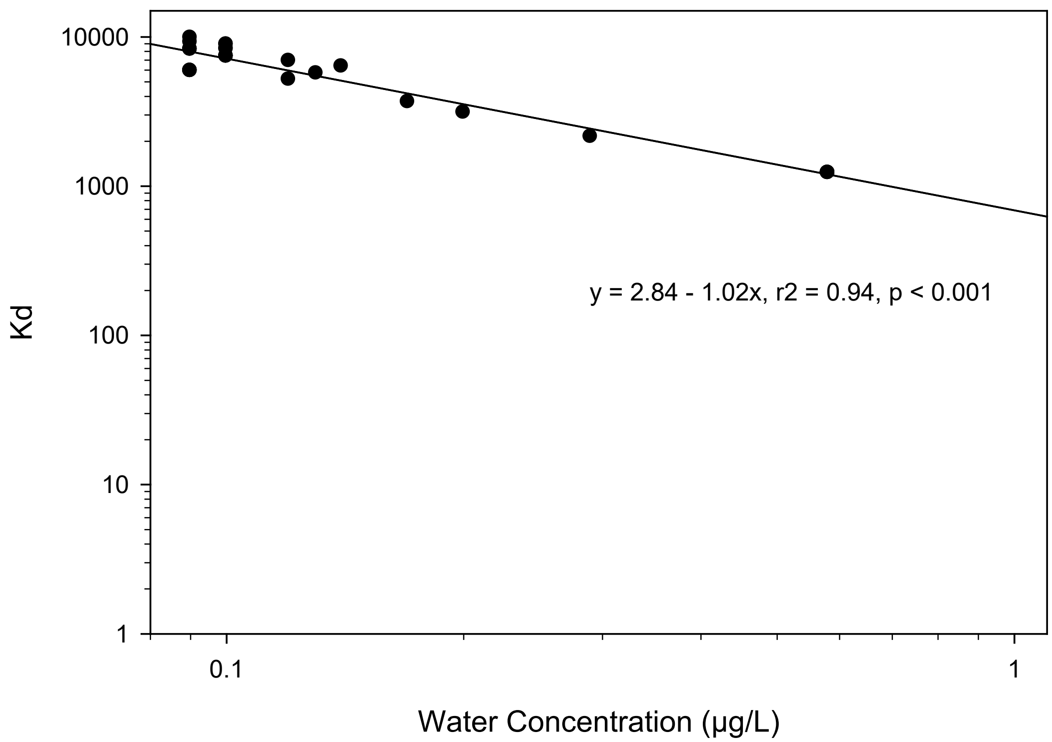


Figure G2.1-4. Log-log Regression Relation of Estimated K_d to Water column Selenium Concentration for Model 5 in Dry Years (Based on Year 2007)

To predict the K_d (y) from water concentrations using the regression equation, take the log of the water concentration (x), multiply it by the slope (-1.02), which gives a positive number for x<1 (i.e., water column selenium concentrations less than 1 µg/L); then add this number to the intercept (2.84) and take the antilog.

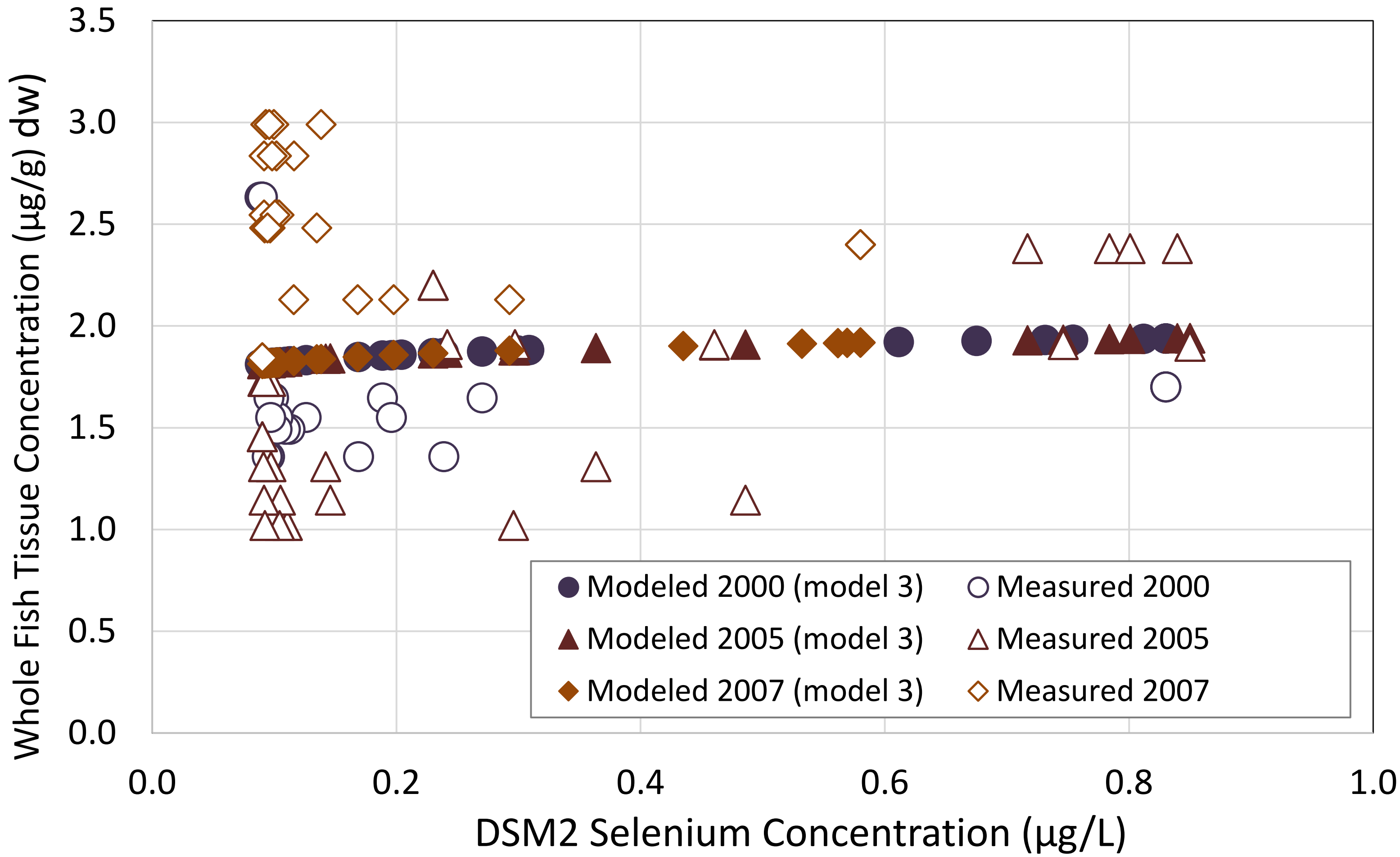


Figure G2.1-5. Distribution of Data for Selenium Concentrations in Largemouth Bass Relative to Water column Selenium for Model 3

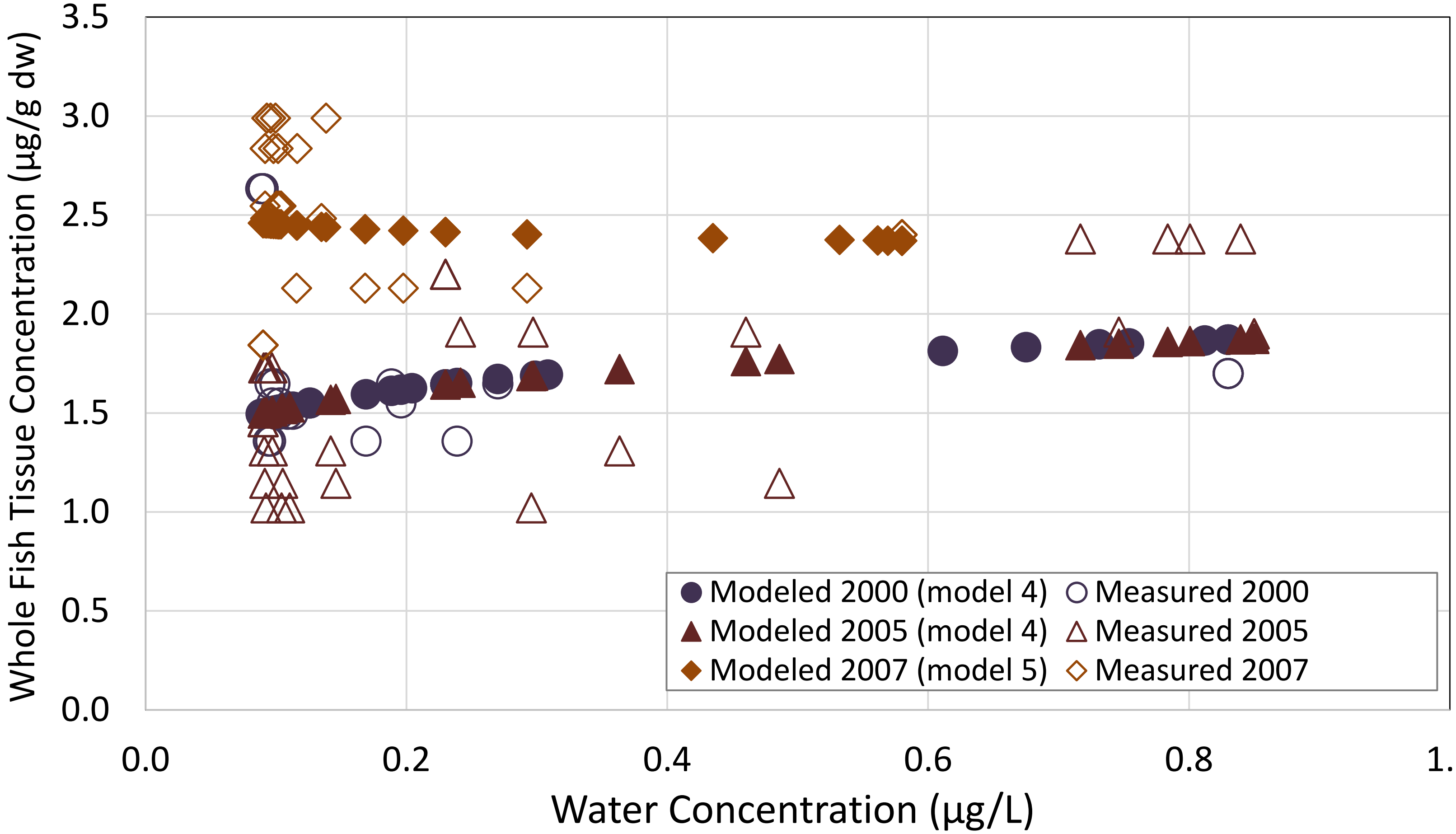


Figure G2.1-6. Distribution of Data for Selenium Concentrations in Largemouth Bass Relative to Water column Selenium for Model 4 and Model 5

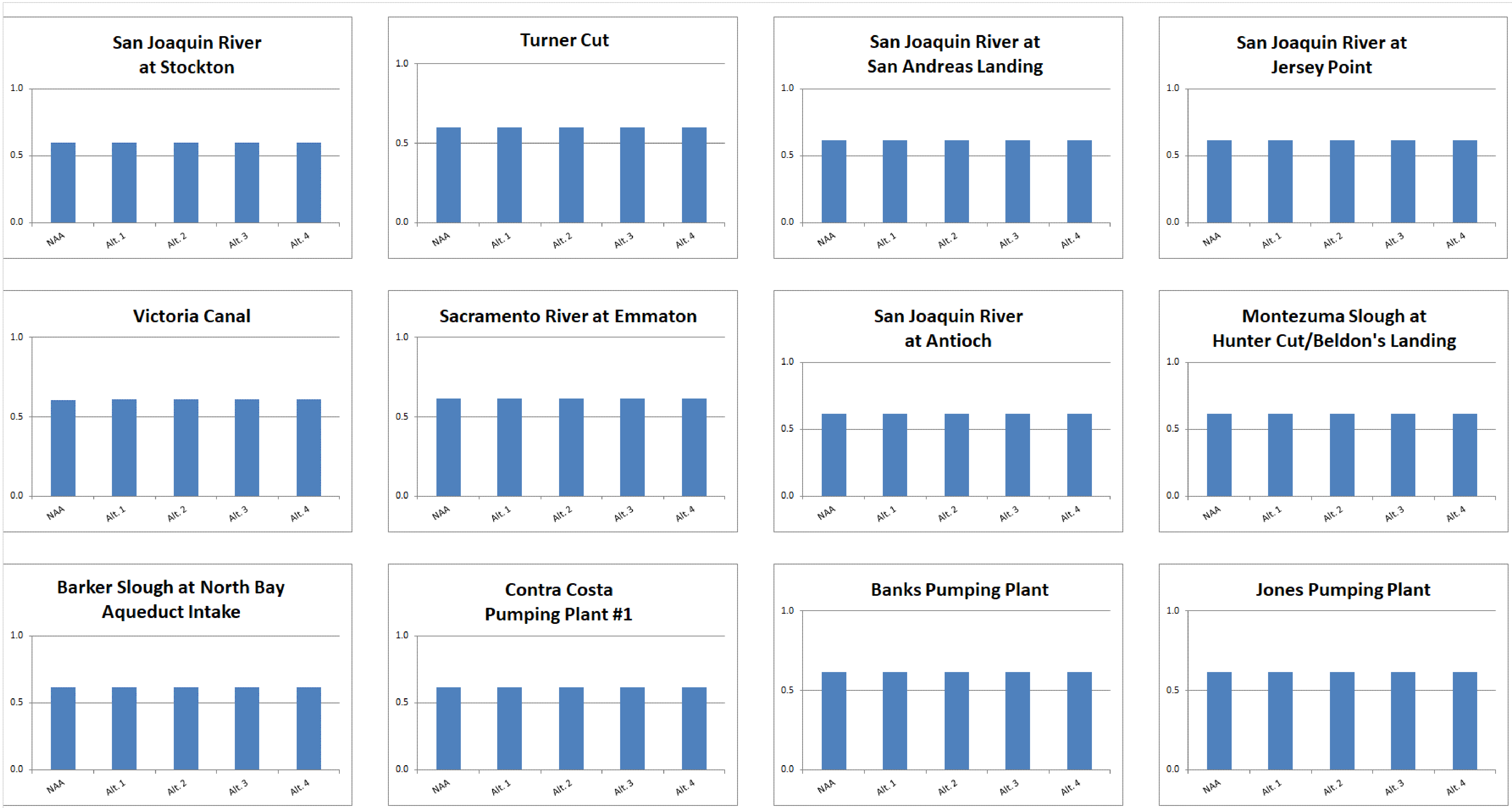


Figure G2.3-1. Level of Concern Exceedance Quotients for Selenium Concentrations in Whole-Body Fish for Drought Years

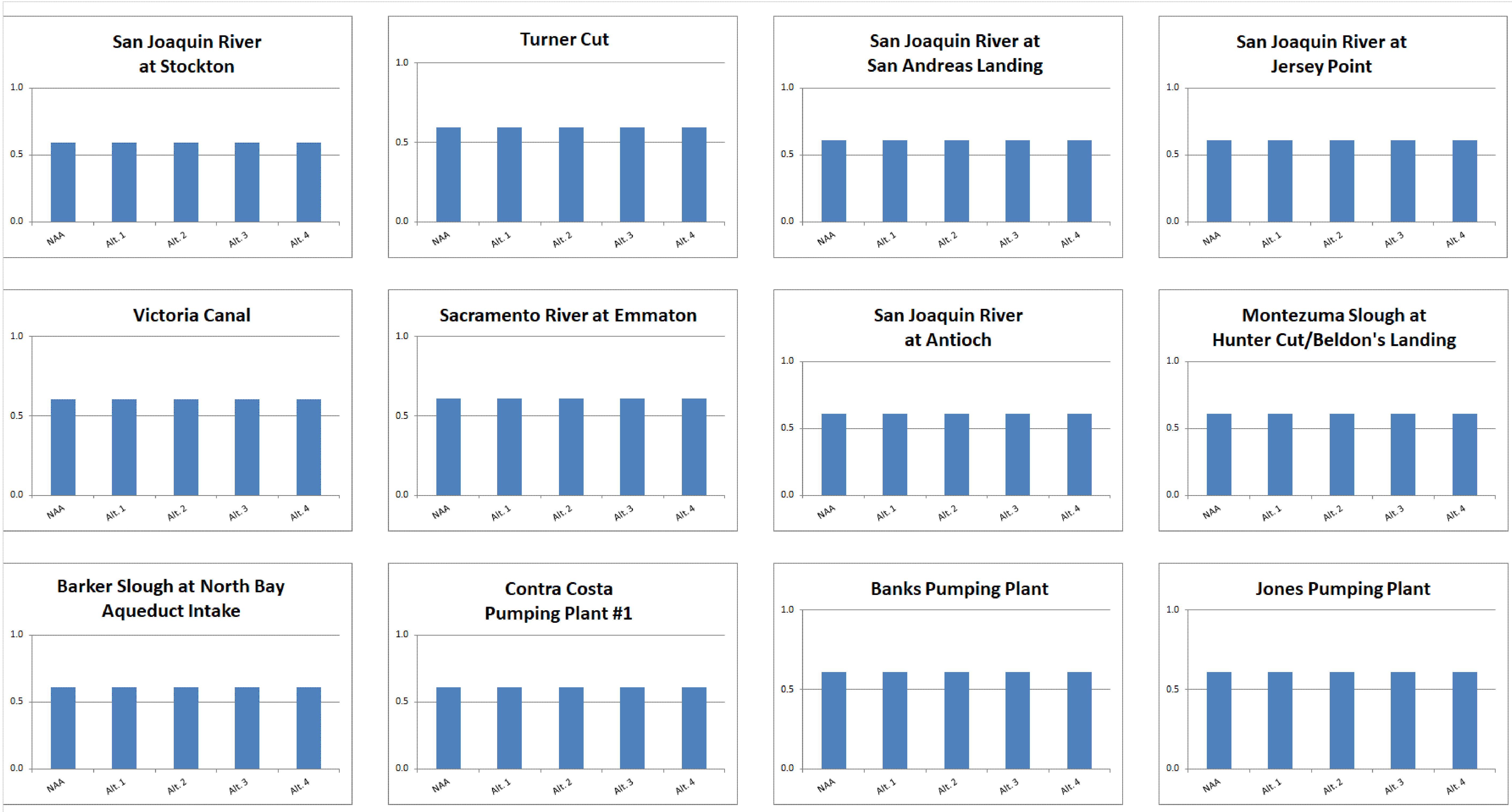


Figure G2.3-2. Level of Concern Exceedance Quotients for Selenium Concentrations in Bird Eggs (Invertebrate Diet) for Drought Years

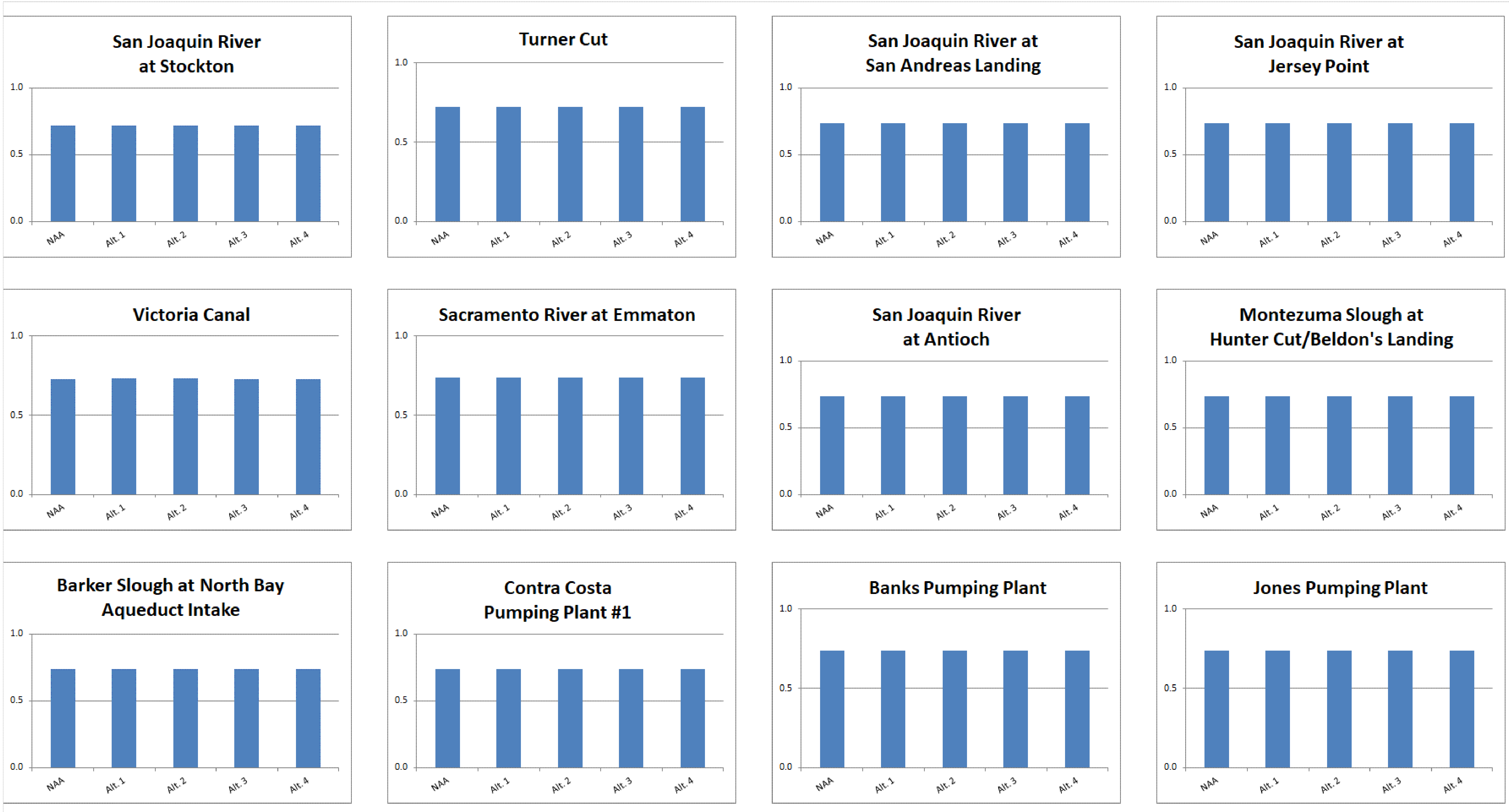


Figure G2.3-3. Level of Concern Exceedance Quotients for Selenium Concentrations in Bird Eggs (Fish Diet) for Drought Years

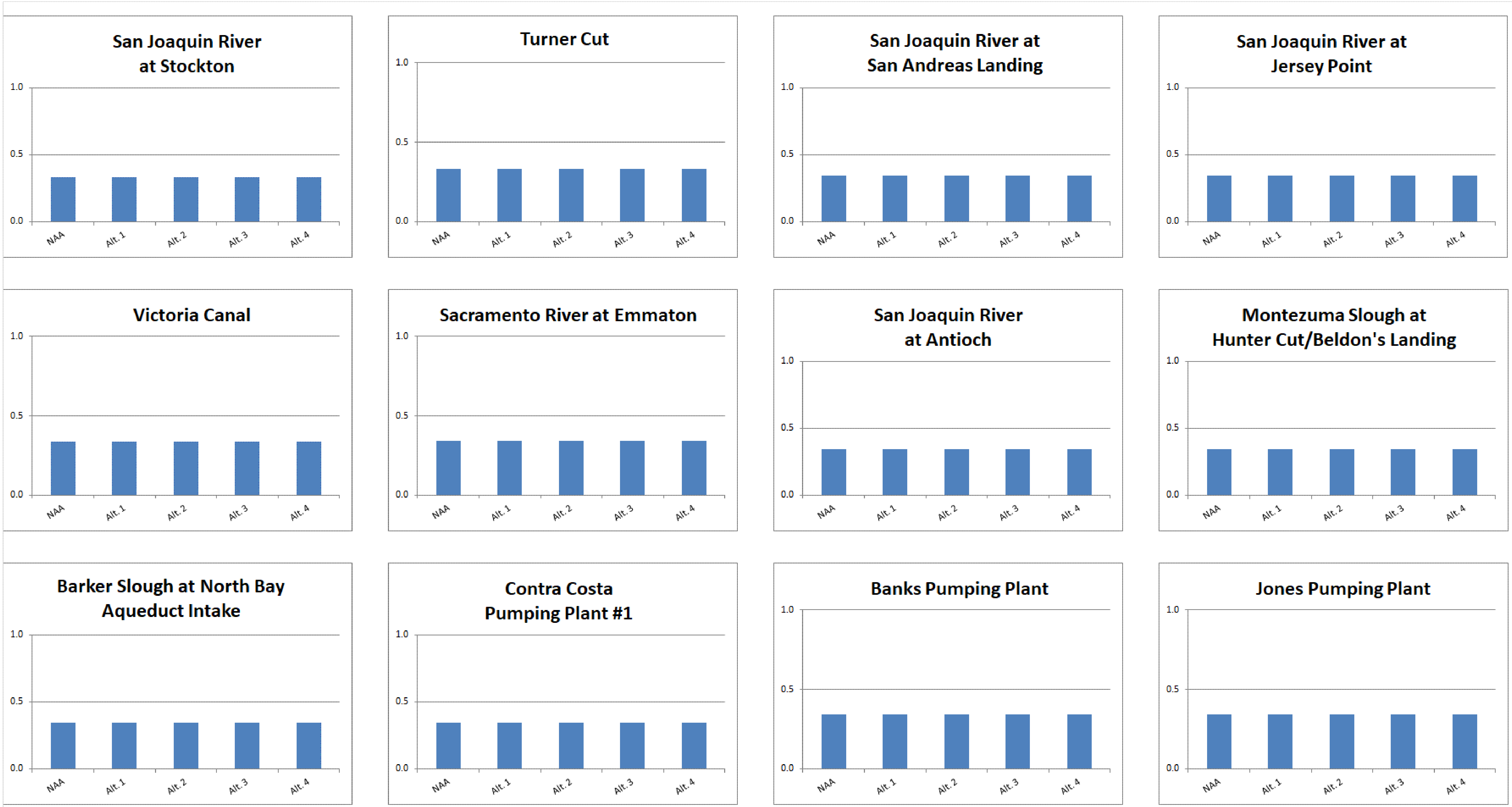


Figure G2.3-4. Level of Concern Exceedance Quotients for Selenium Concentrations in Fish Fillets (wet weight) for Drought Years

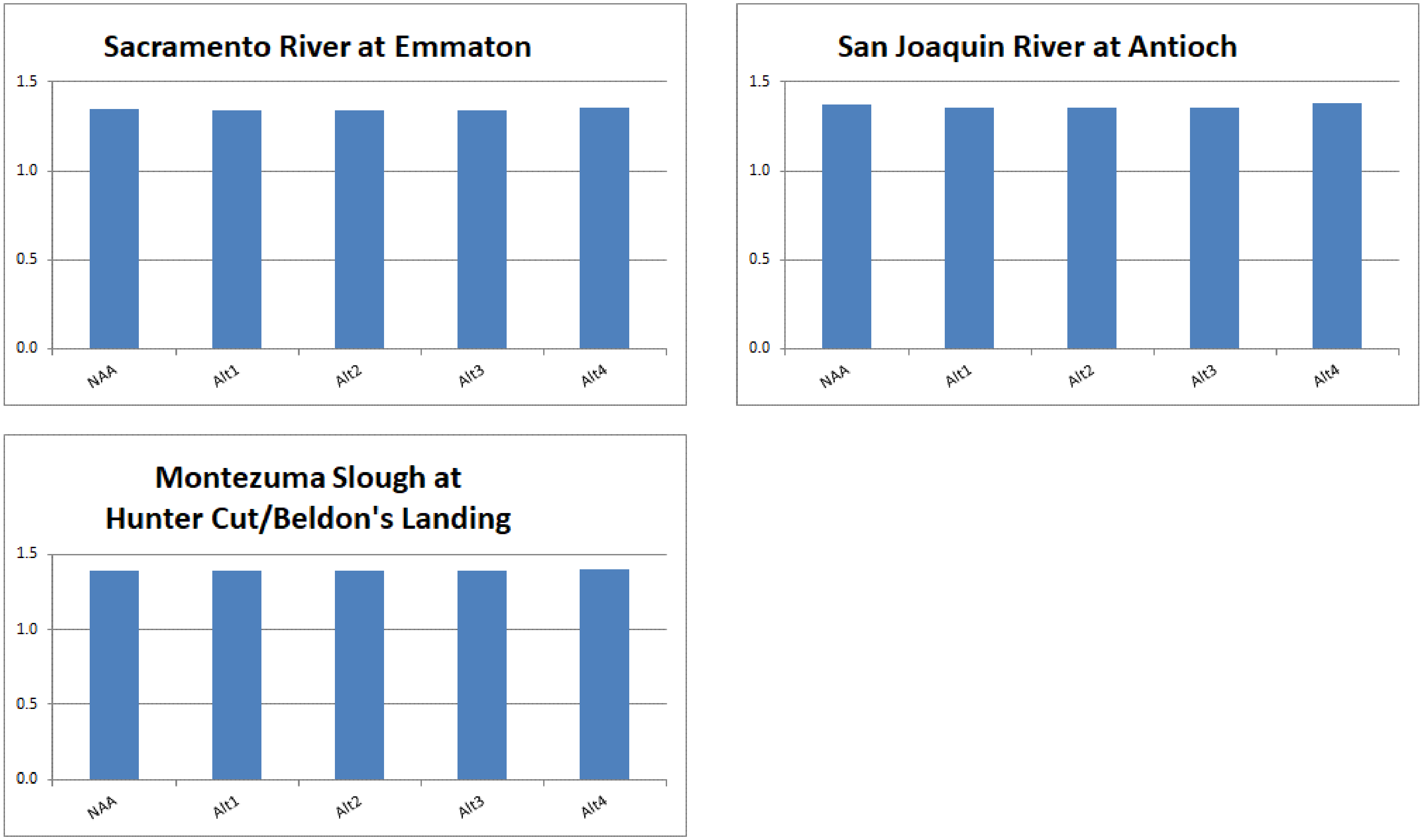


Figure G2.3-5. Low Toxicity Threshold Exceedance Quotients for Selenium Concentrations in Whole-body Sturgeon for Drought Years

Appendix H Water Supply Technical Appendix

This appendix documents the water supply technical analysis to support impact analysis in the environmental impact statement (EIS).

H.1 Background Information

This section describes surface water resources and water supplies that could be potentially affected by implementation of alternatives considered in this EIS, including:

- **Surface Water Hydrology:** Changes in surface water hydrology may occur in Trinity, Sacramento, Clear Creek, Feather, American, Stanislaus, and San Joaquin Rivers, the San Francisco Bay and Sacramento and San Joaquin river delta (Bay-Delta), and the Central Valley Project (CVP) and State Water Project (SWP) Service Area (south to Diamond Valley) due to changes in CVP and SWP operations. Full descriptions of CVP and SWP facilities and their operation are described in Appendix C, *Facility Descriptions and Operations,* and are not repeated in this section.
- **Overview of CVP and SWP Water Users:** Water users that may be affected by changes in CVP and SWP operations are located in Trinity, Sacramento, Clear Creek, Feather, American, Stanislaus, and San Joaquin Rivers, Bay-Delta, and CVP and SWP Service Area (south to Diamond Valley) regions.

H.1.1 Overview of California Water Supply and Water Management Facilities

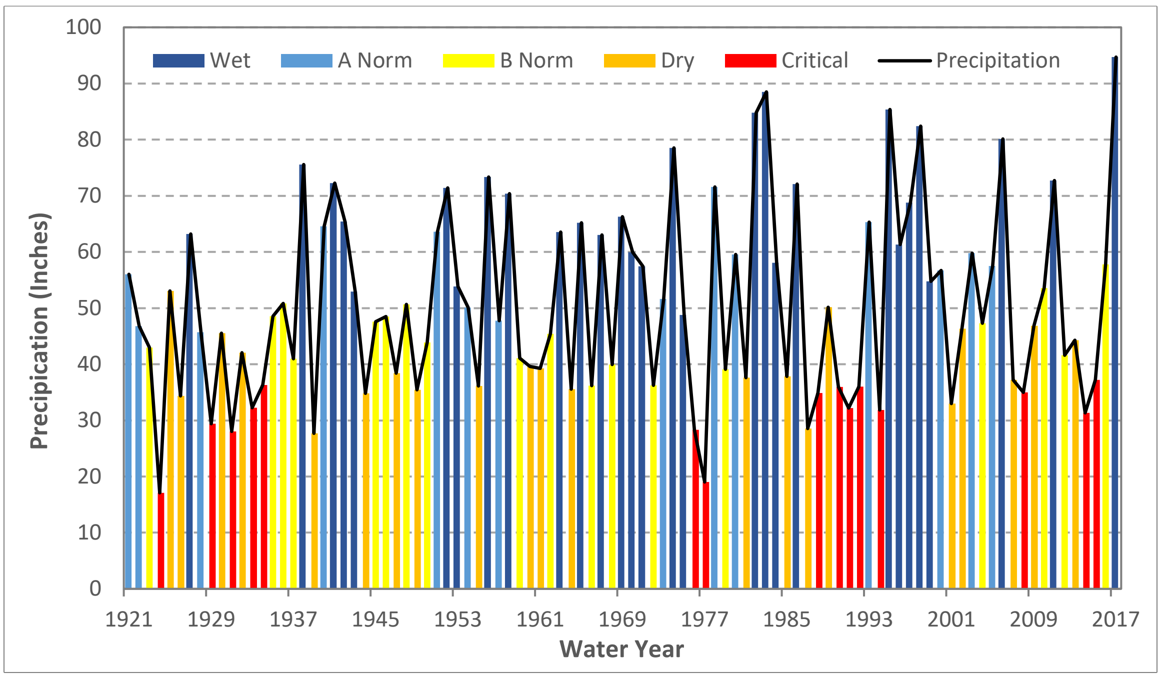
H.1.1.1 *Sources of Water in California*

Variability and uncertainty are dominant characteristics of California's water resources. Precipitation is the primary source of California's water supply (DWR 2018). It varies greatly from year to year, as well as by season and location within the state. Unpredictability and geographic variation in precipitation that California receives make it challenging to manage available runoff to meet urban, agricultural, and environmental water needs. With climate change, precipitation patterns are expected to become even more unpredictable, as described in Appendix F, *Model Documentation*.

In an average water year, California receives approximately 200 million acre-feet (MAF) of water from precipitation and imports from Colorado, Oregon, and Mexico (DWR 2013). The total volume of water the state receives from precipitation can vary dramatically between dry and wet years. California may receive less than 100 MAF of water during a dry year and more than 300 MAF in a wet year (Western Regional Climate Center 2011).

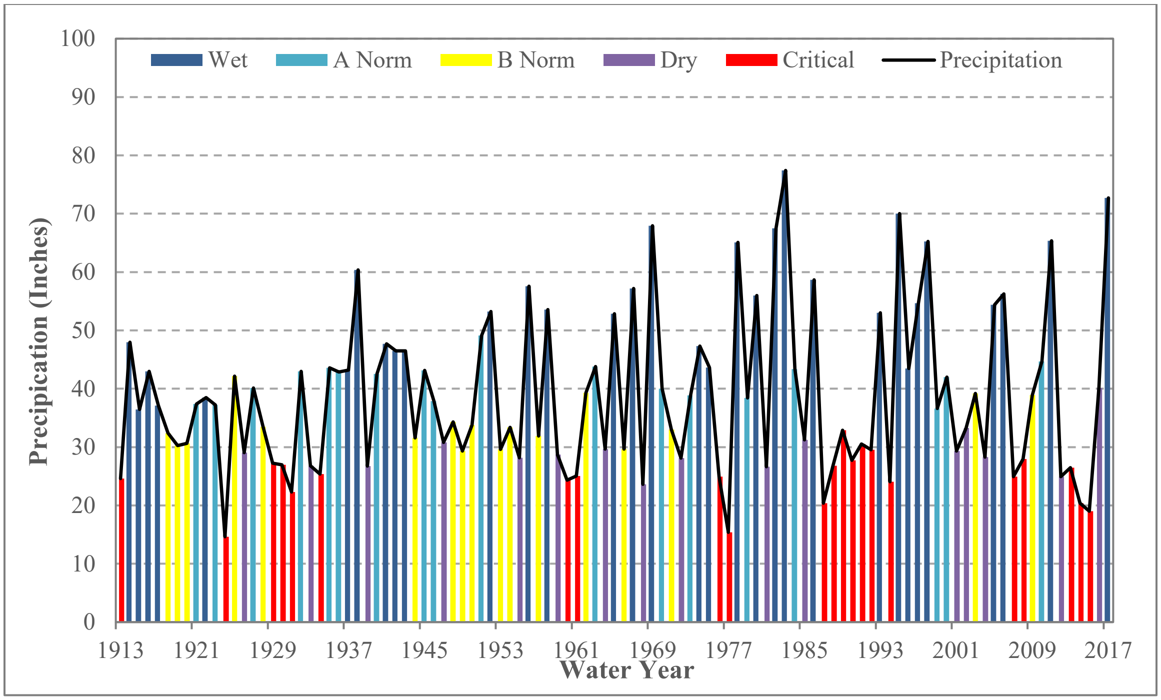
The majority of California's precipitation occurs between November and April, while most of the state's demand for water is in the summer months (Western Regional Climate Center 2011). In addition, most precipitation falls in the northern portion of the state and much of the demand comes from central and southern portions of the state where major agricultural and population centers are located. In some years, northern regions of the state can receive 100 inches or more of precipitation, while southern regions receive only a few inches.

Over time, annual precipitation trends have been changing and continue to change, as shown on Figure H.1-1, Sacramento River Hydrologic Region Precipitation Trends and Figure H.1-2, San Joaquin River Hydrologic Region Precipitation Trends. From 1906 to 1960, the California Department of Water Resources (DWR) classified 33% of water years in California as “dry” or “critically dry”; that percentage increased to 46% from 1961 to 2017 (DWR 2018). From 1906 to 1960, DWR classified 45% of water years in California as “above normal” or “wet” and that percentage increased to 48% from 1961 to 2017. Additionally, the 1906 to 1960 period had 42% of water years classified as extreme (“critically dry” or “wet”) and that percentage increased to 59% after 1960.



Source: DWR 2019

Figure H.1-1. Sacramento River Hydrologic Region Precipitation Trends



Source: DWR 2019

Figure H.1-2. San Joaquin River Hydrologic Region Precipitation Trends

Although there were more extreme water year classifications in the later period, overall precipitation averages in pre-1960 years and post 1960 years have little differences. Despite having similar precipitation averages, year to year variation and patterns of extreme condition occurrences are substantially different between time periods. Year to year statewide precipitation variation is larger and more frequent since 1961 when compared to the 1906 to 1960 period. Also, occurrence of a year to year change of more than 10 inches of precipitation is three times higher post 1960 as compared to pre 1960. There are also more occurrences of sequential “critically dry” years and sequential “wet” years after 1960.

Approximately 50% of precipitation that California receives evaporates, is used consumptively by native vegetation and crops (not including irrigation water supplies) and by managed wetlands, flows into streams within Oregon or Nevada and into saline water bodies (such as Salton Sea), or percolates into saline groundwater aquifers (DWR 2013). Therefore, less than 50% of water that enters California, or less than 100 MAF per year, is available for use by urban, agricultural, and other environmental uses, collectively.

H.1.1.2 *Development of Major California Water Management Facilities*

Due to hydrologic variability that ranges from dry summers and fall months to floods in winter and spring, water from precipitation in winter and spring must be stored for use in summer and fall. During an average hydrological year, approximately 15 MAF of water is stored in the Sierra Nevada snowpack (DWR 2013). However, not all snowpack becomes available in a timely manner for uses throughout the state. Therefore, federal, state, and local agencies and private entities have constructed reservoirs, aqueducts, pipelines, and water diversion facilities to capture and use rainfall and subsequent snowmelt.

H.1.1.2.1 Water Facilities Development through Early 1900s

Spanish settlements were initially established in late 1700s in southern California, including conveyance systems to bring water to the pueblos. The first water storage and diversion project in California was constructed in 1772, including a 12-foot high dam on San Diego River and 6 miles of canals to deliver water to San Diego Mission (Reclamation 1999). Over the next 80 years, other irrigation systems were constructed to provide water for communities and irrigated lands. The first major levee was constructed in Delta in 1840 along Grand Island to protect agricultural lands from floods.

After California became a state in 1850, the state legislature adopted English Common Law, which included the doctrine of riparian rights to provide water supplies to lands adjacent to rivers and streams (Reclamation 1999). The California legislature at this time also recognized "pueblo water rights" granted under both Spanish and Mexican governments, including water rights on Los Angeles and San Diego rivers. Water rights also were influenced by the practice of miners of "posting notice" at their points of diversion to substantiate water rights as an "appropriative right" for areas not adjacent to rivers and streams. This set of appropriative rights was catalogued with respect to "first in time, first in right." Appropriative water rights were given statutory recognition in 1872.

Between the 1850s and early 1900s, miners, agricultural water users, and communities constructed numerous dams and canals (Reclamation 1999). In the 1870s, the first wells were constructed with wood-burning engines. By the late 1890s, natural gas engines and electricity became available to power pumps. Between 1906 and 1910, over 4,000 natural gas or electric groundwater pumps were installed in San Joaquin Valley. Substantial use of groundwater caused extensive groundwater aquifer depletions and land subsidence in some areas of Central Valley. Availability of electricity to communities also resulted in more hydroelectric generation facilities and associated dams being constructed throughout the Sierra Nevada.

H.1.1.2.2 Conceptual Development of Central Valley Project and State Water Project

The need for coordinated water development was evaluated in the 1870s when Congress authorized the Alexander Commission to evaluate water supply concepts in Sacramento and San Joaquin Rivers watersheds, including reservoirs and large-scale irrigation water supply projects (Reclamation 1999).

1919 Marshall Plan

In 1919, Colonel Robert Marshall, chief geographer for the U.S. Geological Survey, proposed a major water storage and conveyance plan to irrigate lands in the Central Valley and San Francisco Bay Area and provide water to communities in San Francisco Bay Area and southern California (Marshall 1919). The Marshall Plan recommended two major dams on San Joaquin River near Friant and Stanislaus Rivers between the present locations of Tulloch and Goodwin dams to serve eastern San Joaquin Valley and reduce groundwater overdraft in Tulare and Kern counties. The plan identified four dams on Kern River to serve the Los Angeles area; and dams on Sacramento River near Red Bluff. On the Klamath River the plan identified a new dam downstream of Klamath Falls. The plan also identified dams along Sacramento River tributaries to provide stored water into two canals along the western and eastern sides of Central Valley to provide exchange water to San Joaquin River water rights holders affected by San Joaquin River dam, water to other San Joaquin Valley users, and water to communities in Contra Costa, Alameda, Santa Clara, and San Francisco counties.

1930s State Water Plan

During the 1920s, California State Legislature commissioned a series of investigations to further evaluate the Marshall Plan (Reclamation 1999). The 1930 Division of Water Resources Bulletin No. 25 outlined a statewide water plan, including the concept that became CVP and SWP. The plan included 37 water supply and flood management reservoirs, including a dam on San Joaquin River near Friant, and canals to distribute water along eastern San Joaquin Valley to reduce groundwater overdraft in Tulare and Kern counties; 14 dams along Trinity River, Sacramento River, and Sacramento River tributaries to provide water to San Joaquin River water rights contractors affected by the dam on San Joaquin River and water users on the west side of San Joaquin Valley and in Contra Costa County; and eight dams on San Joaquin Valley rivers to provide water to San Joaquin Valley. These dams included recommended facilities near present CVP, Trinity, Shasta, Folsom, New Melones, and Friant Dams and present SWP Oroville Dam. Recommendations also included a Delta Cross Channel canal to improve south Delta water quality; a canal from a south Delta pumping plant to a regulating reservoir and pumping plant near Mendota; canals from Mendota to San Joaquin Valley; a canal from Delta into Contra Costa County; and expansion of San Joaquin River and associated channels with five operable barriers along San Joaquin River.

The study also addressed use of aquifer storage, improved navigation along Sacramento and San Joaquin Rivers, flood management, salt water barrier along the western Delta, recycled wastewater and stormwater in Southern California, and importation of Colorado River water to Southern California.

In 1933, the state authorized the Central Valley Project Act. However, during the 1930s depression, the state could not raise funds. The state appealed to the federal government for assistance. The state legislature approved the overall SWP in 1941.

As described above, six of 37 dams in SWP were included in CVP and SWP facilities (Reclamation 1999). However, U.S. Army Corps of Engineers (USACE), local or regional water supply and/or flood management agencies, and hydropower entities constructed most of the recommended dams on Yuba, Bear, Feather, American, Mokelumne, Calaveras, Chowchilla, Fresno, Merced, Tuolumne, Stanislaus, Kings, Kaweah, Tule, and Kern Rivers. USACE initially developed dams on Fresno and Chowchilla rivers; however, Hidden and Buchanan Dams, respectively, were integrated into CVP to supply water to portions of the eastern side of San Joaquin Valley (Reclamation 1999).

H.1.1.2.3 Overview of Central Valley Project

With passage of Rivers and Harbors Act of 1935, Congress appropriated funds and authorized construction of CVP by USACE (Reclamation 1999). When the Rivers and Harbors Act was reauthorized in 1937, construction and operation of CVP was assigned to Reclamation, and CVP became subject to Reclamation Law (as defined in the Reclamation Act of 1902 and subsequent legislation). A full description of CVP facilities that were ultimately developed their operation today is presented in Appendix C.

H.1.1.2.4 Overview of State Water Project

As CVP facilities were being constructed after World War II, the state began investigations to meet additional water needs through development of the California Water Plan. In 1957, DWR published Bulletin Number 3 that identified new facilities to provide flood control in northern California and water supplies to San Francisco Bay Area, San Joaquin Valley, San Luis Obispo and Santa Barbara counties in the Central Coast Region, and southern California (DWR 1957, 2012; Reclamation 2011). The study identified a seasonal deficiency of 2.675 MAF/year in 1950 that resulted in groundwater overdraft throughout many portions of California. The report described facilities to meet water demands and reduce groundwater overdraft, including facilities that would become part of SWP. In 1960, California voters authorized the Burns-Porter Act to construct initial SWP facilities. A full description of SWP facilities that were ultimately developed their operation today is presented in Appendix C.

H.1.1.2.5 Other Major Water Supply and Flood Management Reservoirs

During the past 100 years, numerous water supply, flood management, and hydroelectric generation reservoirs were constructed throughout California. Many of these projects were constructed on tributaries to Sacramento and San Joaquin rivers and tributaries to Tulare Lake Basin. Operations of these non-CVP and non-SWP reservoirs affect flow patterns into Sacramento and San Joaquin rivers and Delta. However, implementation of alternatives evaluated in this EIS would not result in changes in operations in most of these reservoirs, except on lower Stanislaus River.

Major non-CVP and non-SWP reservoirs in Sacramento Valley and San Joaquin Valley watersheds, generally with storage capacities greater than 100,000 acre-feet, which could affect operations of CVP or SWP reservoirs or Delta facilities or could be affected by implementation of alternatives evaluated in this EIS, are detailed in Appendix C.

H.1.2 CVP and SWP Water Users

This section provides an overview of CVP and SWP water users potentially affected by changes in surface water hydrology with implementation of the alternatives. Appendix C describes in detail hydrologic conditions in Trinity, Sacramento, Clear Creek, Feather, American, Stanislaus, and San Joaquin Rivers, Bay-Delta, and CVP and SWP Service Area (south to Diamond Valley) that could be changed by implementation of the alternatives. Figure H.1-3 displays CVP and SWP water users, rivers and reservoirs whose hydrologic conditions could change, and DWR hydrologic regions by which effects to CVP and SWP water users are organized.

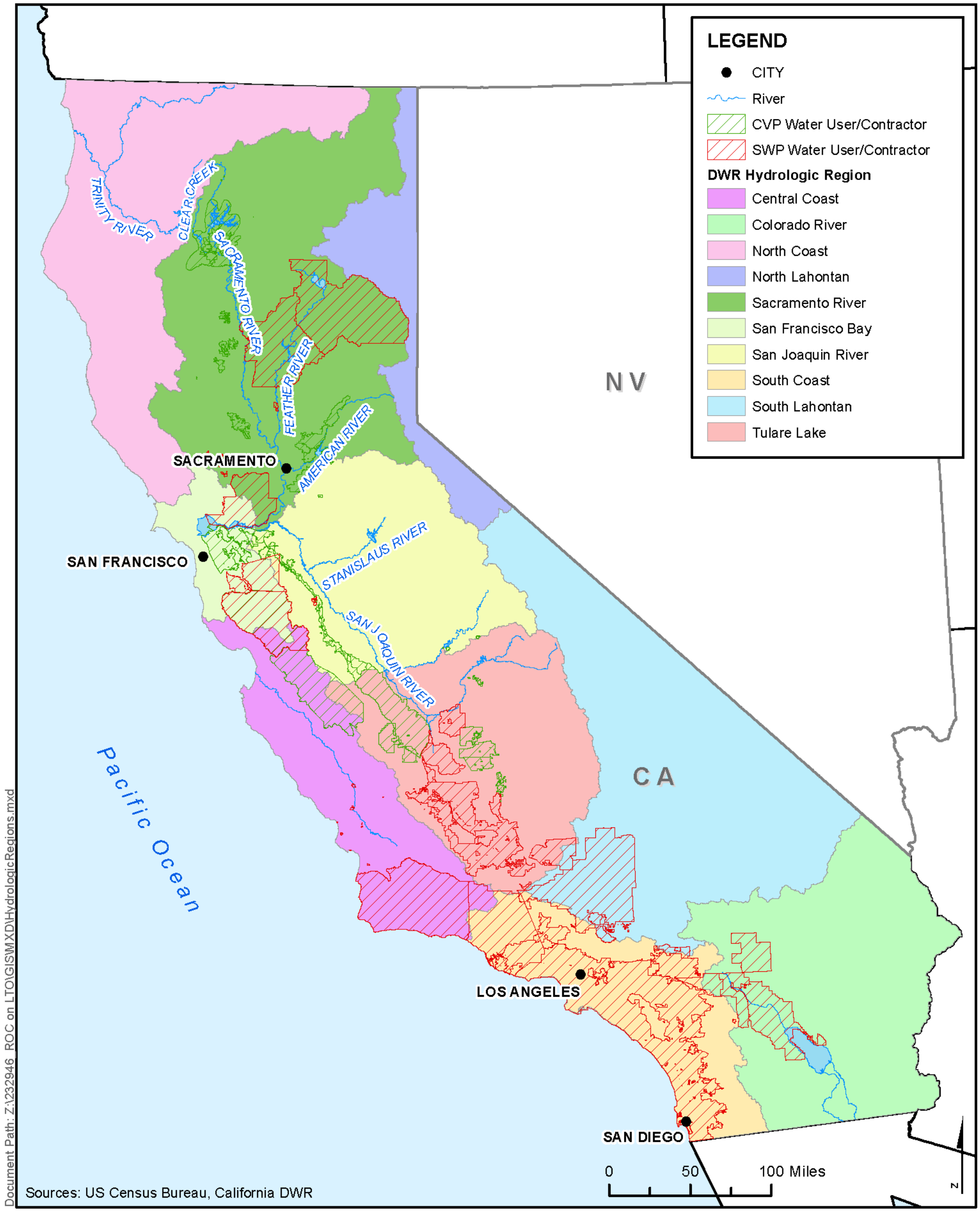


Figure H.1-3. CVP and SWP Water Users and DWR Hydrologic Regions

CVP serves a total of 271 water contracts, of which 88 are water service contracts with Reclamation for delivery of CVP water (Table H.1-1 below lists agencies with CVP contracts). CVP water allocations for agricultural, environmental/refuges, and M&I users vary based on factors such as hydrology, runoff forecast, prior water right commitments, reservoir storage, required water quality releases, required environmental releases, and operational limitations. Each year Reclamation determines the amount of water that can be allocated to each CVP water service contractor based on conditions for that year. In most cases, these allocations are expressed as a percentage of CVP water service contractors' contract total (for contracts that allow use of both agricultural and M&I water) or historical use (for M&I only contracts). North of Delta, there are 42 water service contractors across three CVP divisions that deliver water to agricultural water service contractors, M&I water users, or both agricultural and M&I water users. In Delta and south of Delta there are 31 water service contractors across three CVP Divisions and one unit that deliver water to agricultural water users, M&I water users, or both agricultural and M&I water users.

Table H.1-1. CVP Water Contractors

Contractor	M&I	AG	CVP Division	Hydrologic Region
Water Service Contracts North of Delta				
4-E Water District		X	Sacramento River Div	Sacramento River
Stony Creek Water District	X	X	Sacramento River Div	Sacramento River
U.S. Forest Service (Salt Creek)	X		Sacramento River Div	Sacramento River
Whitney Construction, Inc.	X		Sacramento River Div	Sacramento River
U.S. Forest Service	X		Sacramento River Div	Sacramento River
Colusa, County of (Stonyford)	X	X	Sacramento River Div	Sacramento River
Colusa Drain Mutual Water Company		X	Sacramento River Div	Sacramento River
Corning Water District	X	X	Sacramento River Div	Sacramento River
Proberta Water District	X	X	Sacramento River Div	Sacramento River
Thomes Creek Water District	X	X	Sacramento River Div	Sacramento River
Colusa County Water District	X	X	Sacramento River Div	Sacramento River
County of Colusa	X	X	Sacramento River Div	Sacramento River
4-M Water District	X	X	Sacramento River Div	Sacramento River
Colusa County Water District	X	X	Sacramento River Div	Sacramento River
Cortina Water District	X	X	Sacramento River Div	Sacramento River
Glenn Valley Water District	X	X	Sacramento River Div	Sacramento River
Holthouse Water District	X	X	Sacramento River Div	Sacramento River
La Grande Water District	X	X	Sacramento River Div	Sacramento River
Myers-Marsh Mutual Water Company	X	X	Sacramento River Div	Sacramento River
Davis Water District	X	X	Sacramento River Div	Sacramento River
Dunnigan Wd	X	X	Sacramento River Div	Sacramento River
Glide Water District	X	X	Sacramento River Div	Sacramento River
Kanawha Water District	X	X	Sacramento River Div	Sacramento River
Kirkwood Water District	X	X	Sacramento River Div	Sacramento River
La Grande Water District	X	X	Sacramento River Div	Sacramento River
Orland-Artois Water District	X	X	Sacramento River Div	Sacramento River
Westside Water District	X	X	Sacramento River Div	Sacramento River

Contractor	M&I	AG	CVP Division	Hydrologic Region
Feather Water District	X	X	Sacramento River Div	Sacramento River
Centerville Community Services District	X		Sacramento River Div	Sacramento River
Mountain Gate Community Services District	X		Sacramento River Div	Sacramento River
City of Redding	X		Sacramento River Div	Sacramento River
Shasta County Water Agency	X		Sacramento River Div	Sacramento River
City of Shasta Lake	X		Sacramento River Div	Sacramento River
Bella Vista Water District	X	X	Trinity River Div	Sacramento River
Clear Creek Community Services District	X	X	Trinity River Div	Sacramento River
Shasta Community Services District	X		Trinity River Div	Sacramento River
American River M&I Contracts				
El Dorado Irrigation District	X		American River Div	Sacramento River
City of Roseville	X		American River Div	Sacramento River
City of Folsom	X		American River Div	Sacramento River
Sacramento County Water Agency	X		American River Div	Sacramento River
San Juan Water District	X		American River Div	Sacramento River
East Bay Municipal Utility District	X		American River Div	Sacramento River
Sacramento Municipal Utility District	X		American River Div	Sacramento River
Sacramento County (assignment from Sacramento Municipal Utilities District)	X		American River Div	Sacramento River
Placer County Water Agency	X	X	American River Div	Sacramento River
North of Delta - Sacramento River Settlement Contracts				
Alexander, Thomas & Karen		X	Sacramento River Div	Sacramento River
Anderson, Arthur L., et al.		X	Sacramento River Div	Sacramento River
Anderson, R. & J., Properties, L.P.		X	Sacramento River Div	Sacramento River
Anderson, R. & J., Properties, L.P.		X	Sacramento River Div	Sacramento River
Anderson-Cottonwood Irrigation District	X	X	Sacramento River Div	Sacramento River
Andreotti, Beverly F., et al.		X	Sacramento River Div	Sacramento River
Baber, Jack W., et al.		X	Sacramento River Div	Sacramento River
Cranmore Farms (Assigned to Pelger Road 1700)		X	Sacramento River Div	Sacramento River
Beckley, Ralph & Ophelia (Assigned to Mary Kristine Charter)		X	Sacramento River Div	Sacramento River
Butler, Dianne E., Revocable Intervivos Trust		X	Sacramento River Div	Sacramento River
Butte Creek Farms, Inc.		X	Sacramento River Div	Sacramento River
Butte Creek Farms, Inc.		X	Sacramento River Div	Sacramento River
Butte Creek Farms, Inc.		X	Sacramento River Div	Sacramento River
Butte Creek Farms, Inc.		X	Sacramento River Div	Sacramento River

Contractor	**M&I**	**AG**	**CVP Division**	**Hydrologic Region**
Byrd, Anna C. & Osborne, Jane		X	Sacramento River Div	Sacramento River
Byrd, Anna C. & Osborne, Jane		X	Sacramento River Div	Sacramento River
Cachil Dehe Band of Wintun Indians		X	Sacramento River Div	Sacramento River
Carter Mutual Water Company		X	Sacramento River Div	Sacramento River
Chesney, Adona, Trustee		X	Sacramento River Div	Sacramento River
Churkin, Michael, Jr., et al.		X	Sacramento River Div	Sacramento River
Conaway Preservation Group, LLC (10,000 AF assigned to Woodland-Davis)		X	Sacramento River Div	Sacramento River
Cummings, William C.		X	Sacramento River Div	Sacramento River
Daniell, Harry W.		X	Sacramento River Div	Sacramento River
Davis, Ina M.		X	Sacramento River Div	Sacramento River
Driscoll Strawberry Associates, Inc.		X	Sacramento River Div	Sacramento River
Driver, Gary, et al.		X	Sacramento River Div	Sacramento River
Driver, Gregory E.		X	Sacramento River Div	Sacramento River
Driver, John A. & Clare M., Trustees		X	Sacramento River Div	Sacramento River
Driver, John A. & Clare M., Trustees		X	Sacramento River Div	Sacramento River
Driver, William A., et al.		X	Sacramento River Div	Sacramento River
Dyer, Jeffrey E. & Wing-Dyer, Jan		X	Sacramento River Div	Sacramento River
E.L.H. Sutter Properties		X	Sacramento River Div	Sacramento River
Eastside Mutual Water Company		X	Sacramento River Div	Sacramento River
Eggleston, Ronald H., et ux.		X	Sacramento River Div	Sacramento River
Ehrke, Allen A. & Bonnie E.		X	Sacramento River Div	Sacramento River
Exchange Bank (Nature Conservancy)		X	Sacramento River Div	Sacramento River
Fedora, Sibley G. & Margaret L., Trustees		X	Sacramento River Div	Sacramento River
Forry, Laurie & Adams, Lois		X	Sacramento River Div	Sacramento River
Furlan, Emile & Simone, Family Trust		X	Sacramento River Div	Sacramento River
Gillaspy, William F., Trustee		X	Sacramento River Div	Sacramento River
Giovannetti, B. E.		X	Sacramento River Div	Sacramento River
Giusti, Richard J. & Sandra A., Trustees		X	Sacramento River Div	Sacramento River
Gjermann, Hal		X	Sacramento River Div	Sacramento River
Glenn-Colusa Irrigation District		X	Sacramento River Div	Sacramento River
Gomes, Judith A., Trustee		X	Sacramento River Div	Sacramento River
Green Valley Corporation		X	Sacramento River Div	Sacramento River
Green Valley Corporation		X	Sacramento River Div	Sacramento River
Griffin, Joseph & Prater, Sharon		X	Sacramento River Div	Sacramento River
Hale, Judith. A. & Marks, Alice K.		X	Sacramento River Div	Sacramento River
Hale, Judith. A. & Marks, Alice K.		X	Sacramento River Div	Sacramento River

Contractor	M&I	AG	CVP Division	Hydrologic Region
Hatfield Robert and Bonnie		X	Sacramento River Div	Sacramento River
Heidrick, Joe Jr., Trustee		X	Sacramento River Div	Sacramento River
Heidrick, Mildred M, Trustee		X	Sacramento River Div	Sacramento River
Heidrick, Mildred M, Trustee		X	Sacramento River Div	Sacramento River
Henle, Thomas N., Trustee		X	Sacramento River Div	Sacramento River
Hiatt, Thomas & Illerich, Phillip, Trustees		X	Sacramento River Div	Sacramento River
Hiatt, Thomas, Trustee		X	Sacramento River Div	Sacramento River
Howald Farms, Inc.		X	Sacramento River Div	Sacramento River
Howard, Theodore W. & Linda M.		X	Sacramento River Div	Sacramento River
J.B. Unlimited, Inc.		X	Sacramento River Div	Sacramento River
Jaeger, William L. & Patricia A.		X	Sacramento River Div	Sacramento River
Jansen, Peter & Sandy		X	Sacramento River Div	Sacramento River
Kary, Carol, Trustee		X	Sacramento River Div	Sacramento River
Kary, Carol, Trustee		X	Sacramento River Div	Sacramento River
King, Benjamin & Laura		X	Sacramento River Div	Sacramento River
King, Laura		X	Sacramento River Div	Sacramento River
KLSY, LLC		X	Sacramento River Div	Sacramento River
Knaggs Walnut Ranches Company, L.P. (Assigned to Yolo Land Trust)		X	Sacramento River Div	Sacramento River
Knights Landing Investors, LLC		X	Sacramento River Div	Sacramento River
Lake California Property Owners Association, Inc.	X		Sacramento River Div	Sacramento River
Lauppe, Burton H. & Kathryn L.		X	Sacramento River Div	Sacramento River
Lauppe, Burton H. & Kathryn L.		X	Sacramento River Div	Sacramento River
Leiser, Dorothy L.		X	Sacramento River Div	Sacramento River
Leviathan, Inc.		X	Sacramento River Div	Sacramento River
Lockett, William P. & Jean B.		X	Sacramento River Div	Sacramento River
Lomo Cold Storage & Micheli, Justin J.		X	Sacramento River Div	Sacramento River
Lonon, Michael E.		X	Sacramento River Div	Sacramento River
Maxwell Irrigation District		X	Sacramento River Div	Sacramento River
MCM Properties, Inc.		X	Sacramento River Div	Sacramento River
Mehrhof Montgomery, Susan & John McPherson Montgomery		X	Sacramento River Div	Sacramento River
Meridian Farms Water Company		X	Sacramento River Div	Sacramento River
Mesquite Investors, LLC (McClatchy/Riverby Limited)		X	Sacramento River Div	Sacramento River
Meyer Crest, Ltd.	X		Sacramento River Div	Sacramento River
Micke, Daniel H. & Nina J.		X	Sacramento River Div	Sacramento River
Morehead, Joseph A. & Brenda		X	Sacramento River Div	Sacramento River

Contractor	M&I	AG	CVP Division	Hydrologic Region
Munson, James T. & Delmira		X	Sacramento River Div	Sacramento River
Natomas Basin Conservancy		X	Sacramento River Div	Sacramento River
Natomas Central Mutual Water Company	X	X	Sacramento River Div	Sacramento River
Nelson, Thomas L., Jr. & Hazel H.		X	Sacramento River Div	Sacramento River
Nene Ranch, LLC		X	Sacramento River Div	Sacramento River
O'Brien, Frank J. & Janice C.		X	Sacramento River Div	Sacramento River
Odysseus Farms Partnership		X	Sacramento River Div	Sacramento River
Oji Brothers Farms, Inc.		X	Sacramento River Div	Sacramento River
Oji, Mitsue, Family Partnership, et al.		X	Sacramento River Div	Sacramento River
Otterson, Mike, Trustee		X	Sacramento River Div	Sacramento River
Pacific Realty Associates. LP (dba M&T Chico Ranch, Inc.)		X	Sacramento River Div	Sacramento River
Pelger Mutual Water Company		X	Sacramento River Div	Sacramento River
Penner, Roger & Leona		X	Sacramento River Div	Sacramento River
Pleasant Grove Verona Mutual Water Company		X	Sacramento River Div	Sacramento River
Princeton-Codora-Glenn Irrigation District		X	Sacramento River Div	Sacramento River
Provident Irrigation District		X	Sacramento River Div	Sacramento River
Quad-H Ranches, Inc.		X	Sacramento River Div	Sacramento River
Rauf, Abdul & Tahmina		X	Sacramento River Div	Sacramento River
Reclamation District Nos. 900 & 1000		X	Sacramento River Div	Sacramento River
Reclamation District No. 1004		X	Sacramento River Div	Sacramento River
Reclamation District No. 108		X	Sacramento River Div	Sacramento River
Redding Rancheria Tribe		X	Sacramento River Div	Sacramento River
Redding, City of	X		Sacramento River Div	Sacramento River
Reische, Eric L.		X	Sacramento River Div	Sacramento River
Reische, Laverne C., et al.		X	Sacramento River Div	Sacramento River
Richter, Henry D., et al.		X	Sacramento River Div	Sacramento River
River Garden Farms Company		X	Sacramento River Div	Sacramento River
Riverview Golf & Country Club	X		Sacramento River Div	Sacramento River
Roberts Ditch Irrigation Company, Inc.		X	Sacramento River Div	Sacramento River
Rubio, Exequiel P. & Elsa A.		X	Sacramento River Div	Sacramento River
Sacramento River Ranch, LLC		X	Sacramento River Div	Sacramento River
Sacramento, County of		X	Sacramento River Div	Sacramento River
Seaver, Charles W. & Barbara J., Trustees		X	Sacramento River Div	Sacramento River
Schreiner (Sioux Creek Property, LLC)		X	Sacramento River Div	Sacramento River
Sutter Mutual Water Company		X	Sacramento River Div	Sacramento River
Sycamore Family Trust		X	Sacramento River Div	Sacramento River

Contractor	M&I	AG	CVP Division	Hydrologic Region
Tarke, Stephen E. & Debra F., Trustees		X	Sacramento River Div	Sacramento River
Tisdale Irrigation & Drainage Company		X	Sacramento River Div	Sacramento River
Tuttle, Charles, Jr. & Noack, Sue T., Trustees		X	Sacramento River Div	Sacramento River
Wakida, Haruye, Trustee		X	Sacramento River Div	Sacramento River
Wakida, Haruye, Trustee		X	Sacramento River Div	Sacramento River
Wallace, Kenneth L. Living Trust		X	Sacramento River Div	Sacramento River
West Sacramento, City of	X		Sacramento River Div	Sacramento River
Willey, Edwin A. & Marjorie E.		X	Sacramento River Div	Sacramento River
Wilson Ranch Partnership		X	Sacramento River Div	Sacramento River
Wilson, Dennis, Farms, Inc.(Assigned to Wallace, Joseph V. & Janice C.)		X	Sacramento River Div	Sacramento River
Windswept Land & Livestock Company		X	Sacramento River Div	Sacramento River
Wisler, John W., Jr.		X	Sacramento River Div	Sacramento River
Young, Russell L., et al.		X	Sacramento River Div	Sacramento River
Zelmar Ranch, Inc.		X	Sacramento River Div	Sacramento River
Anderson-Cottonwood Irrigation District	X	X	Sacramento River Div	Sacramento River
Water Service Contracts South of Delta				
Banta-Carbona Irrigation District	X	X	Delta Div	San Francisco Bay, San Joaquin River
Byron-Bethany Irrigation District 1	X	X	Delta Div	San Joaquin River
Del Puerto Water District	X	X	Delta Div	San Joaquin River
Eagle Field Water District	X	X	Delta Div	San Joaquin River
Mercy Springs Water District	X	X	Delta Div	San Joaquin River
Oro Loma Water District	X	X	Delta Div	San Joaquin River
Pajaro Valley Water Management Agency, Santa Clara Valley Water District	X	X	Delta Div	Central Coast
Pajaro Valley Water Management Agency, Westlands Water District	X	X	Delta Div	Central Coast, San Joaquin River
Patterson Irrigation District	X	X	Delta Div	San Joaquin River
The West Side Irrigation District	X	X	Delta Div	San Joaquin River
Tracy, City of	X	X	Delta Div	San Joaquin River
U.S. Department of Veteran Affairs	X		Delta Div	San Joaquin River
West Stanislaus Irrigation District		X	Delta Div	San Joaquin River
Westlands Water District Distribution District 1	X	X	Delta Div	San Joaquin River
Westlands Water District Distribution District 1	X	X	Delta Div	San Joaquin River
Westlands Water District Distribution District 1	X	X	Delta Div	San Joaquin River
Westlands Water District Distribution District 2	X	X	Delta Div	San Joaquin River

Contractor	M&I	AG	CVP Division	Hydrologic Region
Coelho Family Trust	X	X	Delta Div	Tulare Lake
Fresno Slough Water District	X	X	Delta Div	Tulare Lake
James Irrigation District	X	X	Delta Div	Tulare Lake
Laguna Water District	X	X	Delta Div	Tulare Lake
Reclamation District No. 1606	X	X	Delta Div	Tulare Lake
Tranquillity Irrigation District	X	X	Delta Div	Tulare Lake
Tranquillity Public Utility District	X	X	Delta Div	Tulare Lake
Westlands Water District (Assigned from Oro Loma)		X	Delta Div	Tulare Lake
County of Fresno	X	X	Miscellaneous	Tulare Lake
Hills Valley Irrigation District	X	X	Miscellaneous	Tulare Lake
Kern-Tulare Water District	X	X	Miscellaneous	Tulare Lake
Lower Tule River Irrigation District	X	X	Miscellaneous	Tulare Lake
Pixley Irrigation District	X	X	Miscellaneous	Tulare Lake
Kern-Tulare Water District	X	X	Miscellaneous	Tulare Lake
Tri-Valley Water District	X	X	Miscellaneous	Tulare Lake
Tulare, County of	X	X	Miscellaneous	Tulare Lake
San Benito County Water District	X	X	San Felipe Div	Central Cost
Santa Clara Valley Water District	X	X	San Felipe Div	San Francisco Bay, Central Coast
City of Avenal	X		West San Joaquin Div	Tulare Lake
State of California	X		West San Joaquin Div	San Joaquin River
State of California (Parks and Recreation)	X		West San Joaquin Div	San Joaquin River
City of Coalinga	X		West San Joaquin Div	Tulare Lake
City of Huron	X		West San Joaquin Div	Tulare Lake
Pacheco Water District	X	X	West San Joaquin Div	San Joaquin River
Panoche Water District	X	X	West San Joaquin Div	San Joaquin River
San Luis Water District	X	X	West San Joaquin Div	San Joaquin River, Tulare Lake
Westlands Water District	X	X	West San Joaquin Div	San Joaquin River, Tulare Lake
South of Delta - Exchange Contracts				
Central California Irrigation District		X	Delta Div	San Joaquin River
Columbia Canal Company		X	Delta Div	San Joaquin River
Firebaugh Canal Company		X	Delta Div	San Joaquin River
San Luis Canal Company		X	Delta Div	San Joaquin River
South of Delta - Settlement Contracts				
Dudley & Indart/Coelho/Hansen			Delta Div	San Joaquin River
Coelho Family Trust			Delta Div	San Joaquin River
Fresno Slough Water District			Delta Div	San Joaquin River
James Irrigation District			Delta Div	San Joaquin River

Contractor	M&I	AG	CVP Division	Hydrologic Region
Lempesis, Virginia L-Trustee			Delta Div	San Joaquin River
Meyers Farms Family Trust			Delta Div	San Joaquin River
Reclamation District No. 1606			Delta Div	San Joaquin River
Tranquillity Irrigation District			Delta Div	San Joaquin River
Tranquillity Public Utility District			Delta Div	San Joaquin River
In Delta				
Contra Costa Water District	X		Delta Div	San Francisco Bay, Sacramento River, San Joaquin River
Eastside Contracts/Agreement				
Central San Joaquin Water Conservation Dist.	X	X	East Side Div	San Joaquin River
Stockton-East Water District	X	X	East Side Div	San Joaquin River
Oakdale Irrigation District			East Side Div	San Joaquin River
South San Joaquin Irrigation District			East Side Div	San Joaquin River
Refuges - Contracts/Agreements				
North of Delta Refuges				Sacramento River
South of Delta Refuges				San Joaquin River

Ag – Agricultural
Div - Division
M&I – Municipal and Industrial

SWP delivers water to 29 public water agencies in Northern, Central and Southern California that hold long-term contracts for surface water deliveries. Table H.1-2 below list agencies with long-term SWP contracts. Agencies deliver water for both urban and agricultural use, representing over 25 million municipal water users and 750,000 acres of irrigated farmland. Five agencies use SWP water primarily for agricultural uses and the remaining 24 use SWP water primarily for municipal use. As noted above, Alameda County Flood Control and Water Conservation District (Zone 7), Alameda County Water District, and SCVWD all receive their SWP supplies through SBA.

Water supplies for agencies include imported SWP water, groundwater, local surface water, and for some agencies other imported supplies. The agencies collectively have received deliveries ranging from approximately 1.4 MAF in dry water years to approximately 4.0 MAF in wet years.

Table H.1-2. SWP Long-term Water Supply Contracting Agencies

Contractor	Hydrologic Region	Contractor	Hydrologic Region
Upper Feather River Area		**Central Coastal Area**	
City of Yuba City	Sacramento River	San Luis Obispo County Flood Control and Water Conservation District	Central Coast
County of Butte	Sacramento River	Santa Barbara County Flood Control and Water Conservation District	Central Coast, South Coast
Plumas County Flood Control and Water Conservation District	North Lahontan, Sacramento River	**Southern California Area**	
North Bay Area		Antelope Valley-East Kern Water Agency	South Coast, South Lahontan, Tulare Lake
Napa County Flood Control and Water Conservation District	Sacramento River	Castaic Lake Water Agency	South Coast,
Solano County Water Agency	Sacramento River, San Francisco Bay	Coachella Valley Water District	Colorado River
South Bay Area		Crestline-Lake Arrowhead Water Agency	South Coast, South Lahontan
Alameda County Flood Control and Water Conservation District – Zone 7	San Francisco Bay	Desert Water Agency	Colorado River, South Coast
Alameda County Water District	San Francisco Bay	Littlerock Creek Irrigation District	South Lahontan
Santa Clara Valley Water District	Central Coast, San Francisco Bay, San Joaquin River	The Metropolitan WD of Southern California	South Coast
San Joaquin Valley Area		Mojave Water Agency	Colorado River
County of Kings	Tulare Lake	Palmdale Water District	South Coast, South Lahontan
Castaic Lake Water Agency		San Bernardino Valley Municipal Water District	South Coast, South Lahontan
Dudley Ridge Water District	Tulare Lake	San Gabriel Valley Municipal Water District	South Coast
Empire West Side Irrigation District	Tulare Lake	San Gorgonio Pass Water Agency	South Coast, Colorado River
Kern County Water Agency	South Coast, South Lahontan, Tulare Lake	Santa Clarita Valley Water Agency	South Coast
Oak Flat Water District	Tulare Lake	Ventura County Watershed Protection District	Central Coast, South Coast, Tulare Lake
Tulare Lake Basin Water Storage District	Tulare Lake		

Sources: DWR 2017

H.2 Evaluation of Alternatives

This section describes the technical background for evaluation of environmental consequences associated with action alternatives and the No Action Alternative.

H.2.1 Methods and Tools

The impact assessment considers changes in water supply conditions related to changes in CVP and SWP operations under the alternatives as compared to the No Action Alternative. This section details methods and tools used to evaluate those effects.

H.2.2 Changes in CVP and SWP Deliveries

Changes in CVP and SWP operations under the alternatives as compared to the No Action Alternative would result in changes water supply deliveries to CVP and SW contractors. Numerical models are available to quantitatively analyze changes in CVP and SWP systems proposed under the alternatives to determine potential impacts to delivery of CVP and SWP water. With the exception of the changes to reservoir conditions in the CVP Trinity River Division, changes in reservoirs that store CVP and SWP water outside of Central Valley are not included in CVP and SWP numerical models and are evaluated qualitatively.

Surface water supply analysis was conducted using the CalSim II model, as described in Appendix F, to simulate operational assumptions of each alternative that was described in Chapter 3, *Description of Alternatives*.

H.2.2.1 *Use of CalSim II Model*

DWR and Reclamation developed the CalSim II reservoir-river basin planning model to simulate operation of CVP and SWP over a range of different hydrologic conditions. Inputs to CalSim II include water demands (including water rights), stream accretions and depletions, reservoir inflows, irrigation efficiencies, and parameters to calculate return flows, nonrecoverable losses and groundwater operations. Sacramento Valley and tributary rim basin hydrology uses an adjusted historical sequence of monthly stream flows over an 82-year period (1922 to 2003) to represent a sequence of flows at a future level of development and accounting for climate change. Adjustments to historic water supplies are imposed based on future land use conditions. The resulting hydrology represents water supply available from Central Valley streams to CVP and SWP at a future level of development. Water rights deliveries to non-CVP and non-SWP water rights holders are not modified in CalSim II simulations of alternatives. CalSim II produces outputs for river flows and diversions, reservoir storage, Delta flows and exports, Delta inflow and outflow, deliveries to project and nonproject users, and controls on project operations.

The CalSim II model monthly simulation of an actual daily (or even hourly) operation of CVP and SWP results in several limitations in use of model results. Model results must be used in a comparative manner to reduce effects of use of monthly and other assumptions that are indicative of real-time operations, but do not specifically match real-time observations. CalSim II model output is based upon a monthly time step. CalSim II model output includes minor fluctuations of up to 5% due to model assumptions and approaches. Therefore, if quantitative changes between a specific alternative and the No Action Alternative are 5% or less, conditions under the specific alternative would be considered to be “similar” to conditions under the No Action Alternative.

Under extreme hydrologic and operational conditions where there is not enough water supply to meet all requirements, CalSim II utilizes a series of operating rules to reach a solution to allow for continuation of the simulation. It is recognized that these operating rules are a simplified version of very complex decision processes that CVP and SWP operators would use in actual extreme conditions. Therefore, model results and potential changes under these extreme conditions should be evaluated on a comparative basis between alternatives and are an approximation of extreme operational conditions.

H.2.2.2 *Analysis of Changes in Water Supply Deliveries*

CalSim II outputs for the alternatives are compared to CalSim II outputs for the No Action Alternative to evaluate changes in water supply deliveries to CVP and SWP water users by hydrologic region: Sacramento River, San Joaquin River, San Francisco Bay, Central Coast, Tulare Lake (not including Friant-Kern Canal and Madera Canal water users), South Lahontan, and South Coast.

The analyses presented in this EIS do not include specific analysis for Millerton Lake and deliveries to Friant-Kern Canal and Madera Canal water users under Alternatives 1 through 4 compared to the No Action Alternative. Results of these analyses (presented in Appendix F) indicated that there were no differences in Millerton Lake storage or deliveries from Millerton Lake to Friant-Kern and Madera Canals between Alternatives 1 through 4 compared to the No Action Alternative because implementation of the alternatives would not affect operations of Millerton Lake. Therefore, conditions at Millerton Lake and Friant Division are not analyzed in this EIS.

The CalSim II outputs for Alternative 1 presented in this appendix do not include the operations of the Suisun Marsh Salinity Control Gates (SMSCG) in some years or a fall action to maintain the X2 position at 80 kilometers in some above normal and wet years included as elements of the Summer-Fall Delta Smelt Habitat action due to uncertainty in the future frequency of these actions. Generally, the potential impacts and benefits of Alternative 1 could range between what is described in this appendix and the No Action Alternative, which includes a Fall X2 action in above normal and wet years. If the Summer-Fall Delta Smelt Habitat action includes operations of the SMSCG or a Fall X2 action, the water requirements in summer and fall could be greater than shown for Alternative 1 in this appendix. Alternative 1 indicates water supply benefits for CVP and SWP contractors. In years with the summer or fall actions, the water supply benefits would be less than indicated in the Alternative 1 modeling.

H.2.3 No Action Alternative

The No Action Alternative would generate no changes to water operations and there would be no improvement in existing limits to water supply availability that impact CVP and SWP water users. Therefore, in comparison to existing conditions there would be no impact to water supply.

H.2.4 Alternative 1

H.2.4.1 *Project-Level Effects*

H.2.4.1.1 Potential changes in water supply deliveries

Trinity River, Sacramento River, Clear Creek, Feather River, and American River

CVP and SWP deliveries to contractors in Trinity, Sacramento, Clear Creek, Feather, and American Rivers watersheds under Alternative 1 are detailed in Table H.2-1. As indicated in Table H.2-1, all contract delivery types, with the exception of deliveries to CVP Settlement Contractors, would increase slightly. CVP Settlement Contractors would see reductions of less than 5% in their total deliveries in both average water years as well as dry and critical water years. As discussed in Section H.2.2, CalSim II model output includes minor fluctuations of up to 5% due to model assumptions; approaches and changes

5% or less are considered "similar" to conditions under the No Action Alternative. The contract type with largest increase on a percentage basis would be CVP agricultural water users in dry and critical water year types with those increases averaging approximately 20%.

Table H.2-1. Alternative 1 - Trinity River, Sacramento River, Clear Creek, Feather River, and American River Contract Deliveries[1] (thousand acre-feet)

	Annual Average	Difference from No Action Alternative	Dry and Critical Water Years	Difference from No Action Alternative
CVP Settlement Contractors	1,599	-10	1,581	-10
CVP Refuge Level 2	162	4	144	1
CVP M&I	223	6	193	4
CVP Ag	255	24	152	26
SWP Feather River Service Area	937	0	874	1
SWP M&I	30	1	21	1

Yellow highlighting indicates a negative change.
[1]Sacramento River DWR Hydrologic Region
Ag - Agricultural
CVP – Central Valley Project
SWP – State Water Project
M&I – Municipal and Industrial

Stanislaus River and San Joaquin River

CVP and SWP deliveries to contractors in Stanislaus River and San Joaquin River watersheds under Alternative 1 are detailed below in Table H.2-2. As is indicated in Table H.2-2, only CVP Refuge Level 2 deliveries would be reduced. These reductions would average less than 5% and are considered similar to conditions under the No Action Alternative. There would be no measurable change in CVP deliveries to Exchange Contractors and CVP and SWP M&I and CVP agricultural deliveries would all improve, with the largest increases identified for CVP agricultural water supply in dry and critical water years with those increases averaging approximately 32%.

Table H.2-2. Alternative 12 – Stanislaus River and San Joaquin River Contract Deliveries[1] (thousand acre-feet)

	Annual Average	Difference from No Action Alternative	Dry and Critical Water Years	Difference from No Action Alternative
CVP Exchange Contractors	852	0	825	0
CVP Refuge Level 2	259	-1	251	0
CVP M&I	17	1	15	1
CVP Ag	387	73	213	52
SWP Ag	4	1	2	0

Yellow highlighting indicates a negative change.
[1] San Joaquin River DWR Hydrologic Region
Ag - Agricultural
CVP – Central Valley Project
SWP – State Water Project
M&I – Municipal and Industrial

Bay-Delta

CVP and SWP contract deliveries in Bay-Delta under Alternative 1 are detailed below in Table H.2-3. As is indicated in Table H.2-3, Alternative 1 would increase water supply deliveries for all contract types. The largest increase on a percentage basis would be for CVP agricultural water users in dry and critical water years with those increases averaging approximately 32%.

Table H.2-3. Alternative 1 - Bay-Delta Contract Deliveries[1] (thousand acre-feet)

	Annual Average	Difference from No Action Alternative	Dry and Critical Water Years	Difference from No Action Alternative
CVP M&I	282	8	292	8
CVP Ag	47	9	26	6
SWP M&I	223	25	132	8

[1] San Francisco DWR Hydrologic Region
Ag - Agricultural
CVP – Central Valley Project
SWP – State Water Project
M&I – Municipal and Industrial

CVP and SWP Service Areas

This section details changes in contract deliveries under Alternative 1 to CVP and SWP Service Areas in central coast, Tulare Lake, South Lahontan and south coast regions. In addition to the modeled estimates of changes to water supply, water transfers could increase water supplies in drier year types (but they are not included in the CalSim II modeling results). Water transfers are the same in the No Action Alternative, Alternative 2, and Alternative 3. Alternative 1 would have a longer time period that transfers could move through the Delta pumping facilities, so it would have the potential to increase water supplies a small amount compared to the other alternatives. The upper limits for transfer amounts would not change, but in many years, transfer quantities are limited by available capacity in the Delta. A longer transfer period would reduce this constraint.

Central Coast Region

SWP contract deliveries in the central coast region under Alternative 1 are detailed below in Table H.2-4. As is indicated in Table H.2-4, SWP M&I deliveries would increase on average approximately 10%.

Table H.2-4. Alternative 1 - Central Coast Region Contract Deliveries[1] (thousand acre-feet)

	Annual Average	Difference from No Action Alternative	Dry and Critical Water Years	Difference from No Action Alternative
SWP M&I	44	4	25	2

[1] Central Coast DWR Hydrologic Region
SWP – State Water Project
M&I – Municipal and Industrial

Tulare Lake Region

CVP and SWP contract deliveries in Tulare Lake region under Alternative 1 are detailed below in Table H.2-5. As is indicated in Table H.2-5, only CVP Refuge Level 2 deliveries would be reduced. These reductions would average less than 5% and are considered similar to conditions under the No Action

Alternative. Deliveries to CVP and SWP agricultural water users and SWP M&I water users would all improve with largest increases forecast for CVP agricultural water users in dry and critical water years (approximately 32%).

Table H.2-5. Alternative 1 - Tulare Lake[1] Region Contract Deliveries[2] (thousand acre-feet)

	Annual Average	Difference from No Action Alternative	Dry and Critical Water Years	Difference from No Action Alternative
CVP Refuge Level 2	12	0	11	0
CVP Ag	783	139	446	108
SWP M&I	85	9	48	5
SWP Ag	669	97	356	36

Yellow highlighting indicates a negative change.
[1] Does not include Friant-Kern Canal or Madera Canal water users
[2] Tulare Lake DWR Hydrologic Region
Ag - Agricultural
CVP – Central Valley Project
SWP – State Water Project
M&I – Municipal and Industrial

South Lahontan Region

SWP contract deliveries in south Lahontan region under Alternative 1 are detailed below in Table H.2-6. As is indicated in Table H.2-6 SWP M&I deliveries would increase on average approximately 14%.

Table H.2-6. Alternative 1 - South Lahontan Region Contract Deliveries[1] (thousand acre-feet)

	Annual Average	Difference from No Action Alternative	Dry and Critical Water Years	Difference from No Action Alternative
SWP M&I	280	34	163	14

[1] South Lahontan DWR Hydrologic Region
SWP – State Water Project
M&I – Municipal and Industrial

South Coast Region

SWP contract deliveries in south coast region under Alternative 1 are detailed below in Table H.2-7. As is indicated in Table H.2-7, SWP M&I deliveries would increase on average approximately 16%. SWP agricultural deliveries would increase approximately 9%.

Table H.2-7. Alternative 1 - South Coast Region Contract Deliveries[1] (thousand acre-feet)

	Annual Average	Difference from No Action Alternative	Dry and Critical Water Years	Difference from No Action Alternative
SWP M&I	1,405	192	817	70
SWP Ag	8	1	5	0

[1] South Coast DWR Hydrologic Region
Ag - Agricultural
SWP – State Water Project
M&I – Municipal and Industrial

H.2.4.2 *Program-Level Effects*

Alternative 1 includes habitat restoration and improvement projects, fish passage improvements, fish hatchery operation programs, and studies to identify further opportunities for habitat improvement. All these actions are evaluated in this EIS as programmatic activities. Given their collective implementation to improve habitat conditions and survival rates for biological resources across the study area, it is assumed that they could improve conditions relative to those resources future survival and population health. Specific to water supply, implementation of these programmatic actions would be expected to help improve conditions for species that limit operation of CVP and SWP and potentially reduce restrictions on CVP and SWP operations in the future.

H.2.5 Alternative 2

H.2.5.1 *Project-Level Effects*

H.2.5.1.1 *Potential changes in water supply deliveries*

Trinity River, Sacramento River, Clear Creek, Feather River, and American River

CVP and SWP deliveries to contractors in Trinity River, Sacramento River, Clear Creek, Feather River, and American River watersheds under Alternative 2 are detailed below in Table H.2-8. As is indicated in Table H.2-8, all contract delivery types with exception of deliveries to CVP Settlement Contractors and SWP Feather River Service Area, would increase slightly. CVP Settlement Contractors and SWP Feather River Service Area would see reductions of less than 5% in their total deliveries in both average water years as well as dry and critical water years. These deliveries are considered similar to conditions anticipated under the No Action Alternative. The contract type with the largest increase on a percentage basis would be CVP agricultural water users in dry and critical water year types with those increases averaging approximately 20%.

Table H.2-8. Alternative 2 - Trinity River, Sacramento River, Clear Creek, Feather River and American River Contract Deliveries[1] (thousand acre-feet)

	Annual Average	Difference from No Action Alternative	Dry and Critical Water Years	Difference from No Action Alternative
CVP Settlement Contractors	1,608	-1	1,589	-1
CVP Refuge Level 2	163	5	149	6
CVP M&I	220	2	187	-2
CVP Ag	254	24	142	16
SWP Feather River Service Area	937	0	873	-1
SWP M&I	31	2	24	4

Yellow highlighting indicates a negative change.
[1] Sacramento River DWR Hydrologic Region
Ag - Agricultural
CVP – Central Valley Project
SWP – State Water Project
M&I – Municipal and Industrial

Stanislaus River and San Joaquin River

CVP and SWP deliveries to contractors in Stanislaus River and San Joaquin River watersheds under Alternative 2 are detailed below in Table H.2-9. As is indicated in Table H.2-9, only CVP Refuge Level 2 deliveries would be reduced. These reductions would average less than 5% and are considered similar to conditions under the No Action Alternative. There would be no measurable change in CVP deliveries to Exchange Contractors and CVP and SWP M&I and CVP agricultural deliveries would all improve, with largest increases identified for CVP agricultural water supply in dry and critical water years with those increases averaging approximately 49%.

Table H.2-9. Alternative 2 - Stanislaus River and San Joaquin River Contract Deliveries[1] (thousand acre-feet)

	Annual Average	Difference from No Action Alternative	Dry and Critical Water Years	Difference from No Action Alternative
CVP Exchange Contractors	852	0	824	0
CVP Refuge Level 2	260	0	249	-1
CVP M&I	18	2	15	1
CVP Ag	437	122	241	79
SWP Ag	4	1	3	1

Yellow highlighting indicates a negative change.
[1] San Joaquin River DWR Hydrologic Region
Ag - Agricultural
CVP – Central Valley Project
SWP – State Water Project
M&I – Municipal and Industrial

Bay-Delta

CVP and SWP contract deliveries in Bay-Delta under Alternative 2 are detailed below in Table H.2-10. As is indicated in Table H.2-10, Alternative 2 would increase water supply deliveries for all contract types. The largest increase on a percentage basis would be for CVP agricultural water users in dry and critical water years with those increases averaging approximately 49%.

Table H.2-10. Alternative 2 - Bay-Delta Contract Deliveries[1] (thousand acre-feet)

	Annual Average	Difference from No Action Alternative	Dry and Critical Water Years	Difference from No Action Alternative
CVP M&I	286	12	295	10
CVP Ag	53	15	30	10
SWP M&I	243	44	154	29

[1] San Francisco DWR Hydrologic Region
Ag - Agricultural
CVP – Central Valley Project
SWP – State Water Project
M&I – Municipal and Industrial

CVP and SWP Service Areas

This section details changes in contract deliveries under Alternative 2 to CVP Service Areas in central coast, Tulare Lake, South Lahontan and the south coast regions.

Central Coast Region

SWP contract deliveries in central coast region under Alternative 2 are detailed below in Table H.2-11. As is indicated in Table H.2-11, SWP M&I deliveries would increase on average approximately 39% in dry and critical water years.

Table H.2-11. Alternative 2 - Central Coast Region Contract Deliveries[1] (thousand acre-feet)

	Annual Average	Difference from No Action Alternative	Dry and Critical Water Years	Difference from No Action Alternative
SWP M&I	52	12	32	9

[1] Central Coast DWR Hydrologic Region
SWP – State Water Project
M&I – Municipal and Industrial

Tulare Lake Region

CVP and SWP contract deliveries in Tulare Lake region under Alternative 2 are detailed below in Table H.2-12. As is indicated in Table H.2-12, only CVP Refuge Level 2 deliveries would be reduced. These reductions would average less than 5% and are considered similar to conditions under the No Action Alternative. Deliveries to CVP and SWP agricultural water users and SWP M&I water users would all improve with largest increases forecast for SWP agricultural water users in dry and critical water years (approximately 58%).

Table H.2-12. Alternative 2 - Tulare Lake[1] Region Contract Deliveries[2] (thousand acre-feet)

	Annual Average	Difference from No Action Alternative	Dry and Critical Water Years	Difference from No Action Alternative
CVP Refuge Level 2	12	0	11	0
CVP Ag	892	248	503	164
SWP M&I	99	23	60	17
SWP Ag	863	291	507	187

Yellow highlighting indicates a negative change.
[1] Does not include Friant-Kern Canal or Madera Canal water users
[2] Tulare Lake DWR Hydrologic Region
Ag - Agricultural
CVP – Central Valley Project
SWP – State Water Project
M&I – Municipal and Industrial
South Lahontan Region

SWP contract deliveries in south Lahontan region under Alternative 2 are detailed below in Table H.2-13. As is indicated in Table H.2-13, SWP M&I deliveries would increase on average approximately 25% and by approximately 37% in dry and critical water years.

Table H.2-13. Alternative 2 - South Lahontan Region Contract Deliveries[1] (thousand acre-feet)

	Annual Average	Difference from No Action Alternative	Dry and Critical Water Years	Difference from No Action Alternative
SWP M&I	308	61	204	55

[1] South Lahontan DWR Hydrologic Region
SWP – State Water Project
M&I – Municipal and Industrial

<u>South Coast Region</u>

SWP contract deliveries in south coast region under Alternative 2 are detailed below in Table H.2-14. As is indicated in Table H.2-14, SWP M&I deliveries would increase on average approximately 34%, and by approximately 41% in dry and critical water years. SWP agricultural deliveries would increase approximately 48%, and by approximately 58% in dry and critical water years.

Table H.2-14. Alternative 2 - South Coast Region Contract Deliveries[1] (thousand acre-feet)

	Annual Average	Difference from No Action Alternative	Dry and Critical Water Years	Difference from No Action Alternative
SWP M&I	1,621	408	1,055	308
SWP Ag	11	3	6	2

[1] South Coast DWR Hydrologic Region
Ag - Agricultural
SWP – State Water Project
M&I – Municipal and Industrial

H.2.6 Alternative 3

H.2.6.1 *Project-Level Effects*

H.2.6.1.1 <u>*Potential changes in water supply deliveries*</u>

Trinity River, Sacramento River, Clear Creek, Feather River, and American River

CVP and SWP deliveries to contractors in Trinity, Sacramento, Clear Creek, Feather and American Rivers watersheds under Alternative 3 are detailed below in Table H.2-15. As is indicated in Table H.2-15, all contract delivery types with exception of deliveries to CVP Settlement Contractors across all water years and to CVP M&I contractors in dry and critical water year types, would increase slightly. CVP Settlement Contractors would observe reductions of less than 5% in their total deliveries in both average water years as well as dry and critical water years. These deliveries are considered similar to conditions anticipated under the No Action Alternative. CVP M&I contractors would observe similar reductions of approximately 5% in dry and critical water year types. As discussed in Section H.2.2, CalSim II model output includes minor fluctuations of up to 5% due to model assumptions and approaches and changes 5% or less are considered "similar" to conditions under the No Action Alternative. The contract type with largest increase on a percentage basis would be SWP M&I water users in dry and critical water year types with those increases averaging approximately 21%.

Table H.2-15. Alternative 3 - Trinity River, Sacramento River, Clear Creek, Feather River, and American River Contract Deliveries[1] (thousand acre-feet)

	Annual Average	Difference from No Action Alternative	Dry and Critical Water Years	Difference from No Action Alternative
CVP Settlement Contractors	1,608	-1	1,589	-2
CVP Refuge Level 2	163	5	149	6
CVP M&I	219	2	186	-2
CVP Ag	252	22	140	13
SWP Feather River Service Area	937	0	874	0
SWP M&I	31	2	24	4

Yellow highlighting indicates a negative change.
[1]Sacramento River DWR Hydrologic Region
Ag - Agricultural
CVP – Central Valley Project
SWP – State Water Project
M&I – Municipal and Industrial

Stanislaus River and San Joaquin River

CVP and SWP deliveries to contractors in Stanislaus River and San Joaquin River watersheds under Alternative 3 are detailed below in Table H.2-16. As is indicated in Table H.2-16, both CVP deliveries to Exchange Contractors and CVP Refuge Level 2 deliveries would be reduced. These reductions would average less than 5% and are considered similar to conditions under the No Action Alternative. CVP and SWP M&I and CVP agricultural deliveries would all improve, with largest increases identified for CVP agricultural water supply in dry and critical water years with those increases averaging approximately 38%.

Table H.2-16. Alternative 3 - Stanislaus River and San Joaquin River Contract Deliveries[1] (thousand acre-feet)

	Annual Average	Difference from No Action Alternative	Dry and Critical Water Years	Difference from No Action Alternative
CVP Exchange Contractors	852	0	823	-1
CVP Refuge Level 2	260	0	249	-1
CVP M&I	18	2	15	1
CVP Ag	432	118	236	74
SWP Ag	4	1	2	1

Yellow highlighting indicates a negative change.
[1] San Joaquin River DWR Hydrologic Region
Ag - Agricultural
CVP – Central Valley Project
SWP – State Water Project
M&I – Municipal and Industrial

Bay-Delta

CVP and SWP contract deliveries in Bay-Delta under Alternative 3 are detailed below in Table H.2-17. As is indicated in Table H.2-17 Alternative 3 would increase water supply deliveries for all contract types. The largest increase on a percentage basis would be for CVP agricultural water users in dry and critical water years with those increases averaging approximately 45%.

Table H.2-17. Alternative 3 - Bay-Delta Contract Deliveries[1] (thousand acre-feet)

	Annual Average	Difference from No Action Alternative	Dry and Critical Water Years	Difference from No Action Alternative
CVP M&I	285	10	292	7
CVP Ag	52	14	29	9
SWP M&I	242	43	154	29

[1] San Francisco DWR Hydrologic Region
Ag - Agricultural
CVP – Central Valley Project
SWP – State Water Project
M&I – Municipal and Industrial

CVP and SWP Service Areas

This section details changes in contract deliveries under Alternative 3 to CVP Service Areas in central coast, Tulare Lake, South Lahontan and south coast regions.

Central Coast Region

SWP contract deliveries in central coast region under Alternative 3 are detailed below in Table H.2-18. As is indicated in Table H.2-18, SWP M&I deliveries would increase on average approximately 37% in dry and critical water years.

Table H.2-18. Alternative 3 - Central Coast Region Contract Deliveries[1] (thousand acre-feet)

	Annual Average	Difference from No Action Alternative	Dry and Critical Water Years	Difference from No Action Alternative
SWP M&I	51	12	31	8

[1] Central Coast DWR Hydrologic Region
SWP – State Water Project
M&I – Municipal and Industrial

Tulare Lake Region

CVP and SWP contract deliveries in Tulare Lake region under Alternative 3 are detailed below in Table H.2-19. As is indicated in Table H.2-19, only CVP Refuge Level 2 deliveries would be reduced. These reductions would average less than 5% and are considered similar to conditions under the No Action Alternative. Deliveries to CVP and SWP agricultural water users and SWP M&I water users would all improve with largest increases forecast for SWP agricultural water users in dry and critical water years (approximately 58%).

Table H.2-19. Alternative 3 - Tulare Lake[1] Region Contract Deliveries[2] (thousand acre-feet)

	Annual Average	Difference from No Action Alternative	Dry and Critical Water Years	Difference from No Action Alternative
CVP Refuge Level 2	12	0	11	0
CVP Ag	886	242	492	154
SWP M&I	98	23	60	16
SWP Ag	855	283	506	186

Yellow highlighting indicates a negative change.
[1] Does not include Friant-Kern Canal or Madera Canal water users
[2] Tulare Lake DWR Hydrologic Region
Ag - Agricultural
CVP – Central Valley Project
SWP – State Water Project
M&I – Municipal and Industrial

South Lahontan Region

SWP contract deliveries in south Lahontan region under Alternative 3 are detailed below in Table H.2-20. As is indicated in Table H.2-20, SWP M&I deliveries would increase on average approximately 26% and by approximately 36% in dry and critical water years.

Table H.2-20. Alternative 3 - South Lahontan Region Contract Deliveries[1] (thousand acre-feet)

	Annual Average	Difference from No Action Alternative	Dry and Critical Water Years	Difference from No Action Alternative
SWP M&I	312	65	203	53

[1]South Lahontan DWR Hydrologic Region
SWP – State Water Project
M&I – Municipal and Industrial

South Coast Region

SWP contract deliveries in south coast region under Alternative 3 are detailed below in Table H.2-21. As is indicated in Table H.2-21, SWP M&I deliveries would increase on average approximately 32%, and by approximately 39% in dry and critical water years. SWP agricultural deliveries would increase approximately 46%, and by approximately 55% in dry and critical water years.

Table H.2-21. Alternative 3 - South Coast Region Contract Deliveries[1] (thousand acre-feet)

	Annual Average	Difference from No Action Alternative	Dry and Critical Water Years	Difference from No Action Alternative
SWP M&I	1,600	388	1,039	292
SWP Ag	11	3	6	2

[1]South Coast DWR Hydrologic Region
Ag - Agricultural
SWP – State Water Project
M&I – Municipal and Industrial

H.2.6.2 *Program-Level Effects*

Alternative 3 includes habitat restoration and improvement projects, fish passage improvements, fish hatchery operation programs, and studies to identify further opportunities for habitat improvement. All of these actions are evaluated in this EIS as programmatic activities. Given their collective implementation to improve habitat conditions and survival rates for biological resources across the study area, it is assumed that they could improve conditions relative to those resources future survival and population health. Specific to water supply, implementation of these programmatic actions would be expected to help improve conditions for species that limit operation of CVP and SWP and potentially reduce restrictions on CVP and SWP operations in the future.

H.2.7 Alternative 4

H.2.7.1 *Project-Level Effects*

H.2.7.1.1 Potential changes in water supply deliveries

Trinity River, Sacramento River, Clear Creek, Feather River, and American River

CVP and SWP deliveries to contractors in Trinity, Sacramento, Clear Creek, Feather, and American Rivers watersheds under Alternative 4 are detailed below in Table H.2-22. As is indicated in Table H.2-22, across all year types, average annual deliveries to all contract delivery types with the exception of CVP Refuge Level 2 deliveries and deliveries to the SWP Feather River Service Area would decrease. These reductions in average annual deliveries would be less than 5% and are considered similar to conditions under the No Action Alternative. As discussed in Section H.2.2, CalSim II model output includes minor fluctuations of up to 5% due to model assumptions and approaches and changes 5% or less are considered “similar” to conditions under the No Action Alternative. In dry and critical water year types, some reductions in average deliveries would exceed this 5% level with CVP M&I deliveries reduced by 6%, CVP agricultural deliveries reduced by 16%, and SWP M&I deliveries reduced by 10%.

Table H.2-22. Alternative 4 - Trinity River, Sacramento River, Clear Creek, Feather River, and American River Contract Deliveries[1] (thousand acre-feet)

	Annual Average	Difference from No Action Alternative	Dry and Critical Water Years	Difference from No Action Alternative
CVP Settlement Contractors	1,601	-9	1,584	-6
CVP Refuge Level 2	158	1	140	-2
CVP M&I	210	-7	176	-12
CVP Ag	226	-4	107	-20
SWP Feather River Service Area	937	0	873	0
SWP M&I	28	-1	18	-2

Yellow highlighting indicates a negative change.
[1]Sacramento River DWR Hydrologic Region
Ag - Agricultural
CVP – Central Valley Project
SWP – State Water Project
M&I – Municipal and Industrial

Stanislaus River and San Joaquin River

CVP and SWP deliveries to contractors in Stanislaus and San Joaquin River watersheds under Alternative 4 are detailed below in Table H.2-16. As is indicated in Table H.2-23, across all year types, average annual CVP M&I, CVP agricultural and SWP agricultural deliveries would be reduced. These reductions in average annual deliveries would be less than 5% and are considered similar to conditions under the No Action Alternative. In dry and critical water year types, some reductions in average deliveries would exceed this 5% level with CVP agricultural deliveries reduced by 19% and SWP agricultural deliveries reduced by 17%.

Table H.2-23. Alternative 4 - Stanislaus River and San Joaquin River Contract Deliveries[1] (thousand acre-feet)

	Annual Average	Difference from No Action Alternative	Dry and Critical Water Years	Difference from No Action Alternative
CVP Exchange Contractors	852	0	825	0
CVP Refuge Level 2	260	0	252	2
CVP M&I	16	0	13	-1
CVP Ag	307	-8	131	-31
SWP Ag	3	0	1	0

Yellow highlighting indicates a negative change.
[1] San Joaquin River DWR Hydrologic Region
Ag - Agricultural
CVP – Central Valley Project
SWP – State Water Project
M&I – Municipal and Industrial

Bay-Delta

CVP and SWP contract deliveries in Bay-Delta under Alternative 4 are detailed below in Table H.2-17. As is indicated in Table H.2-24, across all year types, average annual deliveries to all contract delivery types would be reduced. These reductions in annual average deliveries would be less than 5% and are considered similar to conditions under the No Action Alternative. In dry and critical water year types, the reductions in average deliveries would exceed this 5% level, with CVP M&I deliveries reduced by 6%, CVP agricultural deliveries reduced by 19%, and SWP M&I deliveries reduced by 9%.

Table H.2-24. Alternative 4 - Bay-Delta Contract Deliveries[1] (thousand acre-feet)

	Annual Average	Difference from No Action Alternative	Dry and Critical Water Years	Difference from No Action Alternative
CVP M&I	266	-9	268	-17
CVP Ag	37	-2	16	-4
SWP M&I	190	-8	113	-12

Yellow highlighting indicates a negative change.
[1] San Francisco DWR Hydrologic Region
Ag - Agricultural
CVP – Central Valley Project
SWP – State Water Project
M&I – Municipal and Industrial

CVP and SWP Service Areas

This section details changes in contract deliveries under Alternative 4 to CVP and SWP Service Areas in central coast, Tulare Lake, South Lahontan and south coast regions.

Central Coast Region

SWP contract deliveries in the central coast region under Alternative 4 are detailed below in Table H.2-25. As is indicated in Table H.2-25, across all year types, average annual deliveries to SWP M&I would be reduced by approximately 7% and by approximately 18% in dry and critical water years.

Table H.2-25. Alternative 4 - Central Coast Region Contract Deliveries[1] (thousand acre-feet)

	Annual Average	Difference from No Action Alternative	Dry and Critical Water Years	Difference from No Action Alternative
SWP M&I	37	-3	19	-4

Yellow highlighting indicates a negative change.
[1] Central Coast DWR Hydrologic Region
SWP – State Water Project
M&I – Municipal and Industrial

Tulare Lake Region

CVP and SWP contract deliveries in Tulare Lake region under Alternative 4 are detailed below in Table H.2-26. As is indicated in Table H.2-26, across all year types, average annual CVP Refuge Level 2 deliveries and deliveries in dry and critical water year types would not change. Average annual deliveries would be reduced to all other contract types. The reductions in average annual deliveries would, with the exception of SWP M&I deliveries, average less than 5% and are considered similar to conditions under the No Action Alternative. The reductions in annual SWP M&I deliveries would average 7% when compared to the No Action Alternative. In dry and critical water year types, CVP agricultural deliveries would be reduced by 19%, SWP M&I deliveries would be reduced by 17%, and SWP agricultural deliveries that would be reduced by 11%.

Table H.2-26. Alternative 4 - Tulare Lake[1] Region Contract Deliveries[2] (thousand acre-feet)

	Annual Average	Difference from No Action Alternative	Dry and Critical Water Years	Difference from No Action Alternative
CVP Refuge Level 2	12	0	12	0
CVP Ag	616	-28	275	-64
SWP M&I	70	-5	36	-7
SWP Ag	551	-20	285	-35

Yellow highlighting indicates a negative change.
[1] Does not include Friant-Kern Canal or Madera Canal water users
[2] Tulare Lake DWR Hydrologic Region
Ag - Agricultural
CVP – Central Valley Project
SWP – State Water Project
M&I – Municipal and Industrial

South Lahontan Region

SWP contract deliveries in south Lahontan region under Alternative 4 are detailed below in Table H.2-20. As is indicated in Table H.2-27, across all year types, average annual deliveries to SWP M&I would be reduced by approximately 6% and by approximately 15% in dry and critical water years.

Table H.2-27. Alternative 4 - South Lahontan Region Contract Deliveries[1] (thousand acre-feet)

	Annual Average	Difference from No Action Alternative	Dry and Critical Water Years	Difference from No Action Alternative
SWP M&I	233	-14	128	-22

Yellow highlighting indicates a negative change.
[1]South Lahontan DWR Hydrologic Region
SWP – State Water Project
M&I – Municipal and Industrial

South Coast Region

SWP contract deliveries in south coast region under Alternative 4 are detailed below in Table H.2-28. As is indicated in Table H.2-28, across all year types, average annual deliveries to SWP M&I and to SWP agricultural water users would be reduced by less than 5% and are considered similar to conditions under the No Action Alternative. In dry and critical water year types, SWP M&I deliveries would be reduced by approximately 15% and SWP agricultural deliveries would be reduced by approximately 12%.

Table H.2-28. Alternative 4 - South Coast Region Contract Deliveries[1] (thousand acre-feet)

	Annual Average	Difference from No Action Alternative	Dry and Critical Water Years	Difference from No Action Alternative
SWP M&I	1,155	-57	632	-115
SWP Ag	7	0	4	0

Yellow highlighting indicates a negative change.
[1]South Coast DWR Hydrologic Region
Ag - Agricultural
SWP – State Water Project
M&I – Municipal and Industrial

H.2.7.2 *Program-Level Effects*

Alternative 4 includes actions to improve water use efficiency for M&I and agricultural water users. All of these actions are evaluated in this EIS as programmatic activities. Given their collective implementation to reduce demands for M&I and agricultural water supplies, implementation of these programmatic actions would offset some of the reductions in CVP and SWP water supply deliveries forecast under Alternative 4. Water use efficiency actions, however, would not be able to completely offset the reduced water supply deliveries under Alternative 4.

H.2.8 Mitigation Measures

No mitigation measures are identified for the water supply effects reported in this EIS. Of the reductions in average annual water supply deliveries identified for Alternatives 1, 2, and 3 evaluated above, all adverse changes were 5% or less of total supply delivered. As was noted in Section H.2.2, changes forecast in water supply deliveries are considered “similar” to conditions anticipated under the No Action Alternative given the evaluation approaches and assumptions relied on in the CalSim II model to estimate changes across CVP and SWP. Alternative 4 would generate reductions in average annual deliveries to some contractor types that would exceed 5% and would represent a measurable reduction in water supply when compared to the No Action Alternative. These reductions in water supply deliveries would not be able to be replaced reliably from other sources, such as water transfers or groundwater pumping. The water use efficiency actions included in Alternative 4 at a programmatic level could, as is noted in Section H.2.7.2, reduce the severity of these reductions in water supply deliveries but would not fully replace that water supply. Water transfers are included in the No Action Alternative and would not be available further offset the reduced water supply deliveries generated by Alternative 4. Reliance on groundwater pumping to offset these reductions would not be feasible given the potential for numerous environmental effects generated by additional groundwater pumping in an area with declining groundwater levels and the limits on the availability of groundwater supplies with the implementation of the Sustainable Groundwater Management Act (see Appendix I for more information). Given the environmental and technological limits on the implementation other potential options to offset this impact, no feasible mitigation has been identified to reduce the severity of these reductions.

H.2.9 Summary of Impacts

Table H.2-29 includes a summary of impacts, magnitude and direction of those impacts, and potential mitigation measures for consideration.

Table H.2-29. Impact Summary

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
Potential changes in water supply deliveries	No Action	No impact	--
	1	**Trinity River, Sacramento River, Clear Creek, Feather River, and American River Watersheds –** <5% reductions in water supply deliveries to CVP Settlement Contractors Improvements in water deliveries for all other contractor types **Stanislaus River and San Joaquin River Watersheds –** <5% reductions in water supply CVP Level 2 Refuge deliveries No measurable change in CVP Exchange Contractor deliveries Improvements in water deliveries for all other contractor types **Bay-Delta–** Improvements in water deliveries for all contractor types **CVP Service Areas** ***Tulare Lake*[1] –** <5% reductions in CVP Level 2 Refuge deliveries Improvements in water deliveries for all other contractor types ***Central Coast, South Lahontan Region, South Coast –*** Improvements in water deliveries for all contractor types	--

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
	2	**Trinity River, Sacramento River, Clear Creek, Feather River, and American River Watersheds –** <5% reductions in water supply deliveries to CVP Settlement Contractors and SWP Feather River Service Area water users Improvements in water deliveries for all other contractor types **Stanislaus River and San Joaquin River Watersheds –** <5% reductions in water supply CVP Level 2 Refuge deliveries No measurable change in CVP Exchange Contractor deliveries Improvements in water deliveries for all other contractor types **Bay-Delta–** Improvements in water deliveries for all contractor types **CVP Service Areas** ***Tulare Lake[1] –*** <5% reductions in CVP Level 2 Refuge deliveries Improvements in water deliveries for all other contractor types ***Central Coast, South Lahontan, South Coast–*** Improvements in water deliveries for all contractor types	--

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
	3	**Trinity River, Sacramento River, Clear Creek, Feather River, and American River Watersheds –** <5% reductions in water supply deliveries to CVP Settlement Contractors and CVP M&I water users Improvements in water deliveries for all other contractor types **Stanislaus River and San Joaquin River Watersheds –** <5% reductions in CVP Exchange Contractor and Level 2 Refuge deliveries Improvements in water deliveries for all other contractor types **Bay-Delta–** Improvements in water deliveries for all contractor types **CVP Service Areas** ***Tulare Lake[1]–*** <5% reductions in CVP Level 2 Refuge deliveries Improvements in water deliveries for all other contractor types ***Central Coast, South Lahontan, South Coast–*** Improvements in water deliveries for all contractor types	--

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
	4	**Trinity River, Sacramento River, Clear Creek, Feather River, and American River Watersheds –** <5% reductions in average water supply deliveries to all contractor types with the exception of with the exception of CVP Refuge Level 2 deliveries and deliveries to the SWP Feather River Service Area. **Stanislaus River and San Joaquin River Watersheds –** <5% reductions in average CVP agricultural deliveries No change in average deliveries for all other contractor types **Bay-Delta–** <5% reductions in average deliveries for all contractor types **CVP & SWP Service Areas** ***Central Coast*** 7% reduction in average deliveries to SWP M&I ***Tulare Lake[1]–*** No change in CVP Level 2 Refuge deliveries <5% reductions in average deliveries for CVP agricultural and SWP agricultural deliveries 7% reduction in average deliveries to SWP M&I ***South Lahontan*** 6% reduction in average deliveries to SWP M&I ***South Coast–*** <5% reductions in average deliveries for CVP agricultural and SWP agricultural deliveries	

[1] Does not include Friant-Kern Canal or Madera Canal water users
Ag - Agricultural
CVP – Central Valley Project
SWP – State Water Project
M&I – Municipal and Industrial

H.2.10 Cumulative Effects

H.2.10.1 *Potential changes in water supply deliveries*

The No Action Alternative would generate no changes to water operations and there would be no improvement in existing limits on water supply availability that impact CVP and SWP water users. Thus, No Action Alternative would have no contribution to cumulative water supply condition.

Alternative 1 would improve water supply deliveries to some CVP and SWP contractors and for other water users result in reductions below 5% which, as was detailed in Section H.2.2, would be "similar" to conditions anticipated under the No Action Alternative given evaluation approaches and assumptions relied on in CalSim II model to estimate changes across CVP and SWP. Alternatives 2 and 3 would have similar impacts to Alternative 1 and would not generate substantial contributions to cumulative water supply conditions. Alternative 4 would be similar to Alternatives 1, 2 and 3, resulting in reductions in average water supply deliveries to some CVP and SWP contractors. The reductions in surface water deliveries under Alternative 4 would for many water users be larger than the reductions anticipated under the other alternatives. As is detailed above in Section H.2.7, these reductions in average deliveries in dry and critical water year types could for some contractor delivery types approach 20% when compared to the No Action Alternative.

The past, present, and reasonably foreseeable projects, described in Appendix Y, *Cumulative Methodology,* may have effects on water supply. These cumulative projects include actions across California to develop new water storage capacity, new water conveyance infrastructure, new water recycling capacity, and reoperation of existing water supply infrastructure - including surface water reservoirs and conveyance infrastructure. Cumulative projects also include ecosystem improvement and habitat restoration actions to improve conditions for special status species whose, in many cases, special status constrains water supply delivery operations. Collectively these cumulative projects would be anticipated to generate, directly or as an ancillary benefit, improvements in either local or broader regional water supply conditions. These cumulative projects could, however, generate potential short-term impacts to water supply during construction, or in the case of local water supply projects generate reductions in water supply deliveries to neighboring water users through improved efficiency of local water use at the expense of regional surplus water availability.

Alternative 1, 2, and 3's contribution to these conditions would not be substantial. In the case of cumulative projects anticipated to potentially generate temporary reductions in water supply deliveries or reduce surplus water supply availability to neighboring water users, Alternative 1, 2, and 3's improvement to water supply deliveries for many water users would help to reduce the severity of any potential cumulative effect. In the case of water users to whom Alternatives 1 through 3 are not forecasted to improve deliveries, potential changes in water supply deliveries would not contribute to any cumulative water supply impacts given, as was noted above, these alternatives' similarity to the No Action Alternative.

Given Alternative 4's larger reductions in CVP and SWP deliveries, its contribution to the potential cumulative conditions described above could be substantial in the event of a dry or critical water year type occurrence during a period when a cumulative project was generating temporary reductions in water supply deliveries or reduce surplus water supply availability to neighboring water users. Alternative 4 could in that situation, amplify an adverse effect on water users impacted by that cumulative project.

H.3 References

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Appendix I Groundwater Technical Appendix

This appendix documents the groundwater technical analysis to support the impact analysis in the environmental impact statement (EIS).

I.1 Background Information

Groundwater occurs throughout the study area. However, the groundwater resources that could be directly or indirectly affected through implementation of the alternatives analyzed in the EIS are related to groundwater basins, which include users of Central Valley Project (CVP) and State Water Project (SWP) water supplies that also use groundwater, and areas along the rivers downstream of CVP or SWP reservoirs that use groundwater supplies. Therefore, the following descriptions are limited to these areas and do not include groundwater basins or subbasins that area not directly or indirectly affected by changes in CVP and SWP operations. Changes in groundwater resources because of changes in CVP and SWP operations may occur in the Trinity River, Sacramento Valley (Sacramento River, Feather River, and American River), Clear Creek, San Joaquin Valley (Stanislaus River, San Joaquin River), and Sacramento-San Joaquin Delta (Delta) areas. The additional areas where CVP and SWP deliveries are exported (Central Coast and Southern California regions) are also included.

I.1.1 Overview

Groundwater is a vital resource in California and supplied about 37% of the state's average agricultural, municipal, and industrial water needs between 1998 and 2010, and 40% or more during dry and critical water years in that period (California Department of Water Resources [DWR] 2013a). About 20% of the nation's groundwater demand is supplied from the Central Valley aquifers, making it the second-most-pumped aquifer system in the United States (U.S. Geological Survey [USGS] 2009). The three Central Valley hydrologic regions (Tulare Lake, San Joaquin River, and Sacramento River) account for about 75% of the state's average annual groundwater use (DWR 2013a).

DWR has delineated distinct groundwater systems throughout the state, as described in Bulletin 118-03 (DWR 2003a), that are the most important groundwater basins. These basins and subbasins have various degrees of supply reliability considering yield, storage capacity, and water quality and are typically alluvial, or nonconsolidated (nonfractured rock) aquifers. Through the Sustainable Groundwater Management Act (SGMA), DWR accepted applications to modify the delineation of groundwater basins if enough newer information was available. DWR released final basin boundary modifications on February 11, 2019 (DWR 2019a). The groundwater basin descriptions provided in this appendix are primarily based on the information provided in DWR Bulletin 118.

The importance of groundwater as a resource varies regionally. The Central Coast has the most reliance on groundwater to meet its local uses, with more than 80% of the agricultural, municipal, and industrial water supplies by groundwater in an average year. The Sacramento Valley and northern portion of the San Joaquin Valley Groundwater Basin use groundwater to meet approximately 30 and 40% of the agricultural, municipal, and industrial water demand, respectively. On an annual average basis in the coastal areas of Southern California, groundwater use varies from less than 10% in western San Diego

County to between 35 and 50% of the agricultural, municipal, and industrial water supplies in counties along the coast in western Ventura, Los Angeles, and Riverside Counties and in Orange County. In the inland areas of Southern California, groundwater use varies from approximately 45 to over 90% of the agricultural, municipal, and industrial water supplies (DWR 2013b).

DWR developed a priority ranking for the groundwater basins and subbasins as part of the 2009 Comprehensive Water package. The priority rankings were released in 2014 as part of the California Statewide Groundwater Elevation Monitoring (CASGEM) Program. The SGMA legislation that went into effect in 2015 required DWR to reassess the basin prioritization. Basins were prioritized based on 8 factors: population, population growth, public supply wells in the basin, total wells in the basin, acres of irrigated agriculture, reliance on groundwater as a primarily supply source, documented impacts to groundwater (overdraft, subsidence, saline intrusion, water quality issues) and "other" factors (such as habitat and streamflow). DWR developed four prioritization categories by weighting these factors: high, medium, low, and very low priority. Of the 517 groundwater basins evaluated statewide, DWR identified 109 as high- and medium-priority basins. These basins account for approximately 98% of the groundwater use in California.

I.1.2 Trinity River

The Trinity River Region includes the area along the Trinity River from Trinity Lake to the confluence with the Klamath River and along the Klamath River from the confluence with the Trinity River to the Pacific Ocean.

Most usable groundwater in the Trinity River Region occurs in widely scattered alluvium-filled valleys, such as those immediately adjacent to the Trinity River. These valleys contain only small quantities of recoverable groundwater and therefore are not considered a major source. A number of shallow wells adjacent to the river provide water for domestic purposes (United States Department of the Interior, Bureau of Reclamation [Reclamation] et al. 2006; North Coast Regional Water Quality Control Board [RWQCB] et al. 2009). Groundwater present in these alluvial valleys is in close hydraulic connection with the Trinity River and its tributaries. Both groundwater discharge to surface streams and leakage of steam flow to underlying aquifers are expected to occur at various locations.

Bulletin 118-03 (DWR 2003a, 2004a, 2004b) identified only two groundwater basins underlying the Trinity River Region in the action area, Hoopa Valley, and Lower Klamath River Valley Groundwater Basins. These groundwater basins are small, isolated, valley-fill aquifers that provide a limited quantity of groundwater to satisfy local domestic, municipal, and agricultural needs. Groundwater pumped from these aquifer systems is used strictly for local supply.

Several communities use infiltration galleries along the Trinity River and the tributaries to convey surface water to groundwater wells, including the Lewiston Community Services District, Lewiston Valley Water Company, and Lewiston Park Mutual Water Company (North Coast RWQCB et al. 2009).

Groundwater within the Hoopa Valley Indian Reservation occurs along alluvial terraces (Hoopa Valley Tribe 2008). The aquifers are approximately 10 to 80 feet deep. Some of the shallow wells are productive only during winter and early spring months.

The Lower Klamath River Valley Groundwater Basin extends over 7,030 acres in Del Norte and Humboldt Counties, including areas along the Lower Klamath River (Reclamation 2010). Groundwater along the Lower Klamath River occurs in alluvial fans near the confluences of major tributaries and along terrace and floodplain deposits adjacent to the river (Yurok Tribe 2012). The aquifers range in depth from 10 to 80 feet and are used by some members of the community.

Both the Hoopa Valley and Lower Klamath River Valley Groundwater Basins were designated by DWR as very low priority under SGMA.

Groundwater quality is suitable for many beneficial uses in the region. In other locations, groundwater can include naturally occurring metals, including manganese, cadmium, zinc, and barium (Hoopa Valley Tribe 2008). Other groundwater quality issues include nitrate contamination (DWR 2013a). Groundwater and surface water contamination is suspected at several former and existing mill sites that historically used wood treatment chemicals. Discharges of pentachlorophenol, polychlorodibenzodioxins, and polychlorodibenzofurans have likely occurred because of poor containment practices typically used in historical wood treatment applications. Additional investigation, sampling and monitoring, and enforcement actions have been limited by the insufficient resources that exist to address this historical toxic chemical problem (North Coast RWQCB 2005).

I.1.3 Sacramento River Valley

The Sacramento Valley includes the Redding Area Groundwater Basin and the Sacramento Valley Groundwater Basin. The Sacramento Valley Groundwater Basin is one of the largest groundwater basins in the state and extends from Redding in the north to the Delta in the south (USGS 2009).

Approximately one-third of the Sacramento Valley's urban and agricultural water needs are met by groundwater (DWR 2003a). The portion of the water diverted for irrigation but not actually consumed by crops or other vegetation, or evaporation directly, becomes recharge to the groundwater aquifer or flows back to surface waterways.

Overall, the Sacramento Valley Groundwater Basin is approximately balanced with respect to annual recharge and pumping demand. However, there are several locations showing early signs of persistent drawdown, suggesting limitations because of increased groundwater use in dry years. Locations of persistent drawdown include Glenn County, areas near Chico in Butte County, northern Sacramento County, and portions of Yolo County.

The water quality of groundwater in the Sacramento Valley is generally good. Several areas have localized aquifers with high nitrate, total dissolved solids (TDS), or boron concentrations. High nitrate concentrations frequently occur because of residuals from agricultural operations or septic systems. High TDS, a measure of salinity, concentration can be an indicator of brackish or connate water when it occurs in high concentrations. High boron concentration usually is associated with naturally occurring deposits but can also be a marker for effects of wastewater discharge.

The groundwater conditions in areas surrounding the major rivers in the Sacramento Valley, including the Sacramento, Feather, and American Rivers, are described in the subsequent sections. The descriptions of these areas are combined in this section as they all cover the Sacramento Valley Groundwater Basin.

I.1.3.1 *Overview of Groundwater Basins in the Sacramento Valley*

The Sacramento Valley Groundwater Basin has been divided into 17 subbasins by DWR. However, from a hydrologic standpoint, these individual groundwater subbasins have a high degree of hydraulic connection because the rivers do not always act as barriers to groundwater flow. Therefore, the Sacramento Valley Groundwater Basin functions primarily as a single laterally extensive alluvial aquifer rather than numerous discrete, smaller groundwater subbasins. The Redding Area Groundwater Basin is situated in the extreme northern end of the valley and is a separate, isolated groundwater basin but is discussed as part of the overall Sacramento Valley because of similarities in geology and stratigraphy.

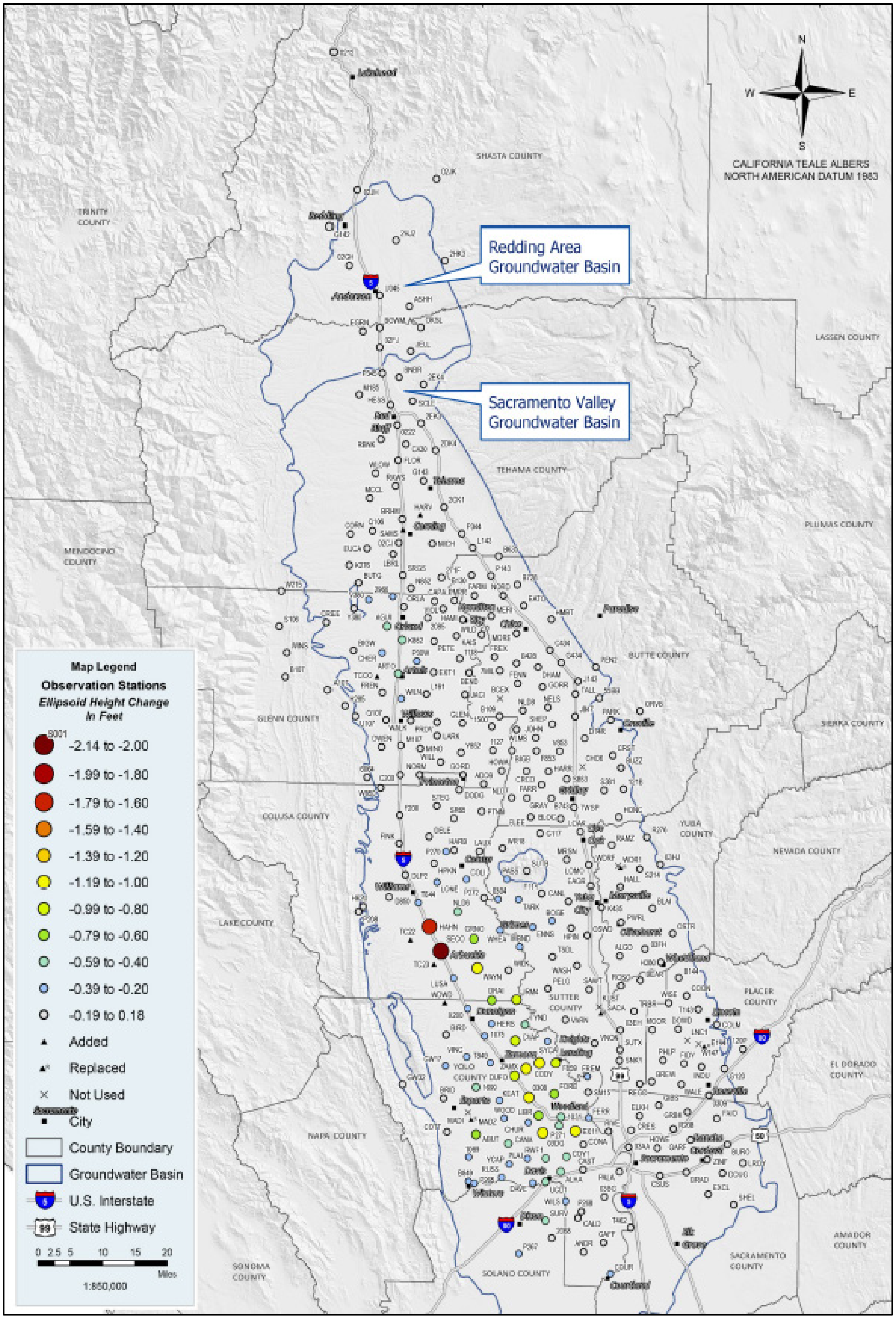
This basin is subdivided into six subbasins by DWR. The basin is bordered by the Coast Ranges on the west and by the Cascade Range and Sierra Nevada mountains on the east.

For discussion purposes and because of their common characteristics, the Sacramento Valley is further subdivided into the Upper Sacramento Valley, the Lower Sacramento Valley west of the Sacramento River, and the Lower Sacramento Valley east of the Sacramento River.

Fresh water in the Sacramento Valley Groundwater Basin generally occurs within continental deposits. Hydrogeologic units containing fresh water along the eastern portion of the basin primarily occur in the Tuscan and Mehrten formations and are derived from the Sierra Nevada. Toward the southeastern portion of the Sacramento Valley, the Mehrten formation is overlain by sediments of the Laguna, Riverbank, and Modesto formations, which also originated in the Sierra Nevada. The primary hydrogeologic unit in the western portion of the Sacramento Valley is the Tehama formation, which was derived from the Coast Ranges. In most of the Sacramento Valley, these deeper units are overlain by younger alluvial and floodplain deposits. Generally, groundwater flows inward from the edges of the basin toward the Sacramento River, then in a southerly direction parallel to the river. Depth to groundwater throughout most of the Sacramento Valley averages about 30 feet below the ground surface, with shallower depths along the Sacramento River and greater depths along the basin margins. Wells developed in the sediments of the valley provide excellent supply to irrigation, municipal, and domestic uses. The deepest elevation of the base of fresh water in the Sacramento Valley ranges between 400 and 3,350 feet below mean sea level (Berkstresser 1973). The location where the base of fresh water is the deepest occurs in the Delta near Rio Vista. Near the valley margins and the Sutter Buttes, the base of fresh water is relatively shallow, suggesting that the base of fresh water may coincide with bedrock or connate water trapped in shallower deposits close to the basin margins (Berkstresser 1973).

Groundwater levels are generally in balance across the Sacramento Valley, with pumping matched by recharge from the various sources annually. Some locales show early signs of persistent drawdown, especially in areas where water demands are met primarily—and in some locales exclusively—by groundwater. These areas include portions of the far west side of the Sacramento Valley in Glenn County, portions of Butte County near Chico, portions of Yolo County, and in the northern Sacramento County area. The persistent areas of drawdown could be early signs that the limits of sustainable groundwater use have been reached in these areas. As a result of the 2011 through 2016 drought, surface water supplies declined, and new wells have been installed. Between January and October 2014, over 100 water supply wells were drilled in both Shasta and Butte Counties (DWR 2014a). In general, periods of drought cause an increased reliance on groundwater.

Land subsidence in the Sacramento Valley has resulted from inelastic deformation (nonrecoverable changes) of fine-grained sediments related to groundwater withdrawal. Areas of subsidence from groundwater level declines have been measured in the Sacramento Valley at several locations. Subsidence monitoring was established following several studies in the 1990s that indicated more than 4 feet of subsidence since 1954 in some areas, such as in Yolo County (Ikehara 1994). Initial data from the Yolo County extensometers indicated subsidence in the Zamora area, which has subsequently been confirmed with a countywide global positioning system network installed in 1999 and monitored in 2002 and 2005. Subsidence up to 0.4 foot occurred between 1999 and 2005 in the Zamora area (Frame Surveying and Mapping 2006). The Zamora area does not currently use CVP or SWP water supplies. However, this area was designated as part of the CVP Sacramento Valley Irrigation Canals service area in the Reclamation Act of 1950 and as amended in the Reclamation Act of 1980 and Central Valley Project Improvement Act. Figure I.1-1, Measured Subsidence, 2008 to 2017, shows the measured subsidence in the Sacramento Valley from 2008 to 2017 (DWR 2018). There are areas on the west side of the valley near Arbuckle and Zamora/Woodland that have seen subsidence of 1 foot or more since 2008.



Source: DWR 2018.

Figure I.1-1. Measured Subsidence, 2008 to 2017

I.1.3.2 *Upper Sacramento Valley*

The Upper Sacramento Valley includes the Redding Area Groundwater Basin and upper portions of the Sacramento Valley Groundwater Basin (DWR 2003a). The Redding Area Groundwater Basin extends from approximately Redding in Shasta County through the northern portions of Tehama County. The portions of the Sacramento Valley Groundwater Basin in the Upper Sacramento Valley are located primarily in Tehama County, with small portions extending into Glenn County near Orland and Butte County near Chico in the south. The geology of this area is dominated by the Tuscan and Tehama formations. The hydrology of this area is dominated by numerous smaller drainages that originate in the Sierra Nevada, Cascade, and Coast Ranges and drain to the Sacramento River (DWR 2003a).

I.1.3.2.1 Hydrogeology and Groundwater Conditions

The Redding Area Groundwater Basin comprises the northernmost part of the Sacramento Valley and is bordered by the Klamath Mountains to the north, the Coast Ranges to the west, the Cascade Mountains to the east, and the Red Bluff Arch to the south. This basin consists of a sediment-filled, symmetrical, southward-dipping trough formed by folding of the marine sedimentary basement rock. These deposits are overlain by a thick sequence of interbedded, continentally derived, sedimentary and volcanic deposits of Late Tertiary and Quaternary age. The primary fresh water-bearing deposits in the basin are the Pliocene age volcanic deposits of the Tuscan formation and the Pliocene age continental deposits of the Tehama formation (DWR 2003a, 2003b, 2004c, 2004d, 2004e, 2004f, 2004g, 2004h).

The Tehama formation consists of unconsolidated to moderately consolidated coarse and fine-grained sediments derived from the Coast Ranges to the west. The Tehama formation is up to 4,000 feet thick and varies in depth from a few feet to several hundred feet below the land surface, with depth generally increasing to the east toward the Sacramento River (DWR 2003a, 2004c, 2004d, 2004e, 2004f, 2004g, 2004h). The Tuscan formation is derived from the Cascade Range to the east and primarily composed of volcaniclastic sediments.

The Redding Area Groundwater Basin includes six subbasins: Anderson, Rosewood, Bowman, Enterprise, Millville, and South Battle Creek (DWR 2003a, 2004c, 2004d, 2004e, 2004f, 2004g, 2004h). The Anderson subbasin is one of the main groundwater units in the Redding Basin. Groundwater levels in the unconfined and confined portions of the aquifer system fluctuate annually by 2 to 4 feet during normal precipitation years and up to 10 to 16 feet during drought years (DWR 2003b). Information indicates that groundwater levels declined at multiple wells by up to 10 feet between spring 2013 and spring 2018 in the Redding Area Groundwater Basin. Many wells experienced changes over this period of ± 2.5 feet (DWR 2019b). The groundwater levels in some areas declined up to 10 feet between fall 2012 and fall 2017, with many wells recording changes of ± 2.5 feet, and several showing increases of up to 10 feet (DWR 2019).

Tehama County overlies three subbasins within the Redding Area Groundwater Basin and seven subbasins in the Sacramento Valley Groundwater Basin. The Rosewood, South Battle Creek, and Bowman subbasins in the Redding Area Groundwater Basin are located in Tehama County. The Red Bluff, Corning, Bend, Antelope, Dye Creek, Los Molinos, and Vina subbasins in the Sacramento Valley Groundwater Basin are located in Tehama County (DWR 2004d, 2004e, 2004h, 2004i, 2004j, 2004k, 2004l, 2004m, 2004n, 2006a). The Corning subbasin extends into northern Glenn County near Orland. The Vina subbasin extends into northern Butte County near Chico. Groundwater levels in these subbasins show a substantial seasonal variation because of high groundwater use for irrigation during the summer months. Groundwater levels showed substantial declines in some wells associated with the 1976 to 1977 and 1987 to 1992 drought periods. Groundwater levels appeared to recover quickly during subsequent wet years. Groundwater levels in the Corning area of Tehama County showed a general decline before 1965 because of increased groundwater pumping for agricultural uses. Following construction by the CVP of the Tehama Colusa Canal and the Corning Canal, surface water was delivered to these areas and there was a subsequent upward trend in groundwater levels following initial operations (Tehama County Flood Control and Water Conservation District 1996). Information indicates that groundwater levels in the upper portion of the Sacramento Valley Groundwater Basin declined at multiple wells approximately 2.5 to 10 feet, with some decreases of over 10 feet, between spring 2013 and spring 2018 (DWR 2019b). Similar changes were also observed from fall 2012 to fall 2017 (DWR 2019b).

Groundwater quality in the Redding Area Groundwater Basin is generally good to excellent for most uses. Some areas of poor quality because of high salinity from marine sedimentary rock exist at the margins of the basin. Portions of the basin are characterized by high boron, iron, manganese, and nitrates in localized areas (DWR 2004c, 2004d, 2004e, 2004f, 2004g, 2004h). In general, groundwater in the Sacramento Valley Groundwater Basin within Tehama County is of excellent quality, with some localized areas with groundwater quality concerns related to boron, calcium, chloride, magnesium, nitrate, phosphorous, and TDS (DWR 2004i, 2004j, 2004k, 2004l, 2004m, 2004n, 2006a). In the vicinity of Antelope, east of Red Bluff, historical high nitrates in groundwater occur. Higher boron levels have been detected in wells located in the eastern portion of Tehama County. High salinity occurs near Salt Creek, which most likely originates from Tuscan Springs, which is a source of high boron and sulfates.

The CASGEM Program prioritized the subbasins in this area as medium priority except for the Bowman, Millville, and South Battle Creek subbasins, which were prioritized as very low. SGMA designated the Antelope subbasin as high priority and the Anderson, Enterprise, and Red Bluff subbasins as medium priority. The other subbasins in the area have final SGMA designations that are pending (DWR 2019b).

I.1.3.2.2 Groundwater Use and Management

Tehama County uses groundwater to meet approximately 65% of its total water needs (Tehama County Flood Control and Water Conservation District 2008). Groundwater in the county provides water supply for agricultural, domestic, environmental, and industrial uses.

One of the main users of groundwater in this area is the Anderson-Cottonwood Irrigation District. Approximately 5% of the irrigated acres rely upon groundwater (DWR 2003b). Groundwater also is the primary water supply for residences and small-scale agricultural operations.

I.1.3.3 *Lower Sacramento Valley (West of Sacramento River)*

The Lower Sacramento Valley area west of the Sacramento River includes three main groundwater subbasins: Colusa, Yolo, and Solano (DWR 2003a, 2004o, 2004p, 2006b).

I.1.3.3.1 Hydrogeology and Groundwater Conditions

Colusa Subbasin

The Colusa subbasin is bordered by the Coast Ranges to the west, Stony Creek to the north, Sacramento River to the east, and Cache Creek to the south. The Colusa subbasin extends primarily in western Glenn and Colusa Counties. This subbasin is composed of continental deposits of late Tertiary age, including the Tehama and the Tuscan formations, to Quaternary age, including alluvial and floodplain deposits and Modesto and Riverbank formations. The Tehama formation represents the main water-bearing formation for the Colusa subbasin (DWR 2003b, 2006b). Groundwater levels are fairly stable in this subbasin except during droughts, such as in 1976 and 1977 and 1987 to 1992 (DWR 2013a). Groundwater levels in the Colusa subbasin declined in the 2008 drought and increased during the wetter periods of 2010 and

2011 to the pre-drought 2008 levels (DWR 2014a, 2014b). Historically, groundwater levels fluctuate by approximately 5 feet seasonally during normal and dry years (DWR 2006b, 2013a). Measurements indicate that groundwater levels declined at multiple wells in the Colusa subbasin over 10 feet from spring 2013 to spring 2018, especially in the northern and southern portions of the subbasin (DWR 2019b). Similar results were measured between fall 2012 and fall 2017.

Groundwater quality for the Colusa subbasin is characterized by moderate to high TDS, with localized areas of high nitrate and manganese concentrations near the town of Colusa (DWR 2006b, 2013a). High TDS and boron concentrations have been observed near Knights Landing. High nitrate levels have been observed near Arbuckle, Knights Landing, and Willows.

The Colusa subbasin is prioritized as a medium priority basin by CASGEM. The final SGMA priority designation is pending.

Yolo Subbasin

The Yolo subbasin lies to the south of the Colusa subbasin, primarily within Yolo County. The primary water-bearing formations for the Yolo subbasin are the same as those for the Colusa subbasin. Younger alluvium from flood basin deposits and stream channel deposits lie above the saturated zone and tend to provide substantial well yields. In general, groundwater levels are stable in this subbasin, except during periods of drought, and in certain localized pumping depressions in the vicinity of Davis, Woodland, and Dunnigan and Zamora (DWR 2004o, 2013b). However, information indicates that groundwater levels in the Yolo subbasin declined at multiple wells at least 10 feet between spring 2013 and spring 2018 (DWR 2019). There are also multiple wells that showed groundwater level increases over 10 feet. Similar results were measured between fall 2012 and fall 2017.

Groundwater quality is generally good for beneficial uses except for localized impairments, including elevated concentrations of boron in groundwater along Cache Creek and in the Cache Creek Settling Basin area, elevated levels of selenium present in the groundwater supplies for the City of Davis, and localized areas of nitrate contamination (DWR 2004o, 2013b). The Cities of Davis and Woodland, which rely heavily on groundwater supply, lost nine municipal wells since 2011 due to high nitrate concentrations (Yolo County Flood Control and Water Conservation District [YCFCWCD] 2012). Sources of high nitrate concentrations near these cities have been determined to be primarily from agricultural and wastewater operations. High salinity levels have also been reported in some areas that may be related to groundwater use for irrigation, which tends to increase salt concentrations in groundwater.

In Yolo County, as much as 4 feet of groundwater withdrawal-related subsidence has occurred since the 1950s. Groundwater withdrawal-related subsidence has damaged or reduced the integrity of highways, levees, irrigation canals, and wells in Yolo County, particularly in the vicinities of Zamora, Knights Landing, and Woodland (Water Resources Association of Yolo County 2007).

The CASGEM prioritization of the Yolo subbasin is a combination of high, medium, and low prioritizations because of recent subbasin modifications. The Yolo subbasin final SGMA priority designation is pending.

Solano Subbasin

The Solano subbasin includes most of Solano County, southeastern Yolo County, and southwestern Sacramento County. In the Solano subbasin, general groundwater flow directions are from the northwest to the southeast (DWR 2004p, 2013b). Increasing agricultural and urban development in the 1940s in the

Solano subbasin has caused substantial groundwater level declines. Groundwater levels are relatively stable but show substantial declines during drought cycles. However, information indicates that groundwater levels in the Solano subbasin declined at multiple wells at least 10 feet between spring 2013 and spring 2018 (DWR 2019b). There are also multiple wells that showed groundwater level increases over 10 feet. Similar results were measured between fall 2012 and fall 2017.

Groundwater quality in the Solano subbasin is generally good and is deemed appropriate for domestic and agricultural use (DWR 2004p, 2013b). However, TDS concentrations are moderately high in the central and southern areas of the basin, with localized areas of high calcium and magnesium.

The CASGEM prioritization of the Solano subbasin was set to be a medium priority. The Solano subbasin final SGMA priority designation is pending.

I.1.3.3.2 Groundwater Use and Management

Many irrigators on the west side of the Sacramento Valley relied primarily on groundwater prior to completion of the CVP Tehama Colusa Canal facilities, which conveyed surface water to portions of Colusa County.

In the Colusa subbasin, although surface water is the primary source of water to meet water supply needs, groundwater is also used to assist in meeting agricultural, domestic, municipal, and industrial water needs, primarily in areas outside of established water districts. The Tehama Colusa Canal Authority service area is also an area of groundwater use in the Colusa subbasin. Although the Tehama Colusa Canal Authority delivers surface water to agricultural users when the CVP water supplies are restricted due to hydrologic conditions, water users rely upon groundwater to supplement limited surface water supplies.

Groundwater is the source of water for municipal and domestic uses in Yolo County except for the City of West Sacramento. In normal years, approximately 40% of the irrigation users in Yolo County rely on groundwater (Yolo County 2009). In the eastern portion of the Yolo subbasin, a 2006 study estimated that groundwater supplies about 80 to 85% of the total annual water demand in the county (YCFCWCD 2012).

Within Yolo and Sacramento Counties' portions of the Solano subbasin, groundwater is used primarily for domestic and irrigation uses. Within Solano County, groundwater is used exclusively by most rural residential landowners and the Cities of Rio Vista and Dixon (Solano County 2008). The City of Vacaville uses groundwater to provide approximately 30% of the water supply. Other communities rely upon surface water. Irrigation users within the Solano Irrigation District rely upon surface water. All other irrigation users rely upon groundwater.

I.1.3.4 *Lower Sacramento Valley (East of Sacramento River)*

The Lower Sacramento Valley area is east of the Sacramento River and includes seven groundwater subbasins: Butte, Wyandotte Creek, North Yuba, South Yuba, Sutter, North American, and South American (DWR 2003a, 2004q, 2004r, 2004s, 2006c, 2006d, 2006e, 2006f).

I.1.3.4.1 Hydrogeology and Groundwater Conditions

The aquifer system throughout the Lower Sacramento Valley east of the Sacramento River is composed of Tertiary to late Quaternary age deposits. The confined portion of the aquifer system includes the Tertiary age Tuscan and Laguna formations. The Tuscan formation consists of volcanic mudflows, tuff breccia, tuffaceous sandstone, and volcanic ash deposits. The Laguna formation consists of moderately consolidated and poorly to well cemented interbedded alluvial sand, gravel, and silt with an overall low permeability. The Quaternary portion of the aquifer system, typically unconfined, is largely composed of unconsolidated gravel, sand, silt, and clay stream channel and alluvial fan deposits. South and east of the Sutter Buttes, the deposits contain Pleistocene alluvium, which is composed of loosely compacted silts, sands, and gravels that are moderately permeable; however, nearly impermeable hardpans and claypans also exist in this deposit, which restrict the vertical movement of groundwater (DWR 2003a, 2004q, 2004r, 2004s, 2006c, 2006d, 2006e, 2006f).

Butte and Wyandotte Creek Subbasins

The Butte subbasin is in Butte, Colusa, Glenn, and Sutter Counties. In the West Butte subbasin, groundwater levels declined during the 1976 to 1977 and 1987 to 1992 droughts, followed by a recovery in groundwater levels to pre-drought conditions of the early 1980s and 1990s (DWR 2004q, 2013b). A comparison of spring-to-spring groundwater levels from the 1950s and 1960s to levels in the early 2000s indicates about a 10-foot decline in groundwater levels in portions of this subbasin. Several groundwater depressions exist in the Chico area due to year-round groundwater extraction for municipal uses. Between spring 2012 and spring 2018, groundwater measurements indicate that groundwater levels were relatively stable, within 2.5 feet over the period, at many wells. There were a few wells with water level declines of 2.5 to 4 feet during this period (DWR 2019b). The results were similar for the period from fall 2012 to fall 2017, with more wells showing decreases. (DWR 2019b).

The Wyandotte Creek subbasin is in Butte County. In the northern portion of the Wyandotte Creek subbasin, annual groundwater fluctuations in the confined and semiconfined aquifer system range from 15 to 30 feet during normal years (DWR 2004r, 2013b). In the southern part of Butte County, groundwater fluctuations for wells constructed in the confined and semiconfined aquifer system average 4 feet during normal years and up to 5 feet during drought years. Between spring 2013 and spring 2018, several wells showed changes of ± 2.5 feet. At least one well showed a decline of 7.5 feet while at least two wells showed groundwater level increases of over 10 feet. From fall 2012 to fall 2017, a similar combination of decreased, increased, and stable water levels, though at smaller changes, were measured (DWR 2019b).

High nitrates occur near the Chico area in the West Butte subbasin. There are localized areas in the subbasin with high boron, calcium, electrical conductivity, and TDS concentrations (DWR 2004q, 2013b). There are several groundwater areas near Chico that historically had high perchloroethylene concentrations from industrial sites. Following implementation of groundwater treatment, the chemicals have not been detected (Butte County 2010).

There are localized high concentrations of calcium, salinity, iron, manganese, magnesium, and TDS throughout the East Butte subbasin (DWR 2004r, 2013b).

Both the Butte and Wyandotte Creek subbasins were designated by the CASGEM program as medium priority. The SGMA designations for these subbasins are still pending.

North and South Yuba Subbasins

The North Yuba subbasin is in Butte and Yuba Counties. The South Yuba subbasin is in Yuba County. In the North Yuba and South Yuba subbasins areas along the Feather River, the groundwater levels have been generally stable since at least 1960, with some seasonal fluctuations between spring and summer conditions. Groundwater levels in the central parts of the two subbasins declined until about 1980 when surface water deliveries were extended to these areas and groundwater levels started to rise. Hydrographs in the central portions of the North and South Yuba subbasins also show the effect of groundwater substitution transfers (during 1991, 1994, 2001, 2002, 2008, and 2009) in the form of reduced groundwater levels followed by recovery to pre-transfer levels (Yuba County Water Agency [YCWA] 2010). Between spring 2013 and spring 2018, most wells showed a stable (±2.5 feet of change) or an increased water level in the North Yuba subbasin. The South Yuba subbasin showed more wells with a decrease on the order of 3 feet combined with wells with an increased water level (DWR 2019b).

Historical water quality data show that in most areas of the North and South Yuba subbasins, trends of increasing concentrations of calcium, bicarbonate, chloride, alkalinity, and TDS occur. In general, groundwater salinity increases with distance from the Yuba River. No groundwater quality impairments were documented at the DWR monitoring wells in the North Yuba subbasin (DWR 2006c). High salinity occurred in the Wheatland area of the South Yuba subbasin within the South Yuba Water District and Brophy Irrigation District (DWR 2006d; YCWA 2010).

The North Yuba and South Yuba subbasins were designated by the CASGEM program as medium priority. The SGMA designations for these subbasins are still pending.

Sutter Subbasin

The Sutter subbasin is in Sutter County. In the Sutter subbasin, groundwater levels have remained relatively constant. The water table is very shallow and most groundwater levels in the subbasin tend to be within about 10 feet of ground surface (DWR 2006e, 2013b). Information indicates that groundwater levels in the Sutter subbasin changed less than 2.5 feet between spring 2013 and spring 2018 (DWR 2019b). At least one well had a decrease of approximately 7 feet while another had an increase of more than 9 feet. The changes from fall 2012 to fall 2017 were similar.

Groundwater quality in the western portion of the Sutter subbasin includes areas with high concentrations of arsenic, boron, calcium magnesium bicarbonate, chloride, fluoride, iron, manganese, sodium, and TDS. In the southern portion of the subbasin, groundwater in the upper aquifer system tends to be high in salinity (DWR 2003b, 2006e).

The CASGEM program designated the Sutter subbasin as medium priority. The SGMA designation for this subbasin is still pending.

North American Subbasin

The North American subbasin underlies portions of Sutter, Placer, and Sacramento Counties, including several dense urban areas. Since at least the 1950s, concentrated groundwater extraction occurred east of downtown Sacramento, which resulted in a regionally extensive cone of depression. Drawdown in the wells in this area has been more than 70 feet over the past 60 years (Sacramento Groundwater Authority [SGA] 2014). Water purveyors have constructed facilities to import surface water to allow groundwater levels to recover from the historical drawdown levels. In general, since around the mid-1990s to the late 2000s, water levels remained stable in the southern portion of the subbasin, and in some cases, groundwater levels are continuing to increase slightly in response to increases in conjunctive use and reductions in pumping near McClellan Air Force Base (SGA 2014). Groundwater levels in Sutter and northern Placer Counties generally have remained stable; however, some wells in southern Sutter County have experienced declines (DWR 2006f, 2013b). Overall, groundwater levels are higher along the eastern portion of the North American subbasin and decline toward the western portion (Roseville et al. 2007). There is a groundwater depression in the southern Placer and Sutter Counties near the border with Sacramento County. Between spring 2013 and spring 2018, many wells in the southern portion of the subbasin showed a change of less than 2.5 feet. Several wells in the northern portion of the subbasin showed a decrease of over 15 feet. However, some wells in the same area showed increases of over 10 feet (DWR 2019b). The groundwater level changes between fall 2012 and fall 2017 are similar.

The area along the Sacramento River extending from Sacramento International Airport northward to the Bear River contains high levels of arsenic, bicarbonate, chloride, manganese, sodium, and TDS (DWR 2006f, 2013b). In an area between Reclamation District 1001 and the Sutter Bypass, high TDS concentrations occur. There have been three sites within the subbasin with substantial groundwater contamination issues: the former McClellan Air Force Base (North Highlands), the Union Pacific Railroad Rail Yard (Roseville), and the Aerojet Superfund Site (Rancho Cordova). Mitigation operations have been initiated for all of these sites. In the deeper portions of the aquifer, the groundwater geochemistry indicates the occurrence of connate water from the marine sediments underlying the freshwater aquifer, which mixes with the fresh water. Water quality concerns because of this type of geology include elevated levels of arsenic, bicarbonate, boron, chloride, fluoride, iron, manganese, nitrate, sodium, and TDS (DWR 2003b).

The CASGEM program designated the North American subbasin as high priority. The SGMA designation for this subbasin is still pending.

South American Subbasin

The South American subbasin is in Sacramento County. Groundwater levels in the South American subbasin have fluctuated over the past 40 years, with the lowest levels occurring during periods of drought. From 1987 to 1995, water levels declined by about 10 to 15 feet and then recovered to levels close to the mid-1980s by 2000. Over the past 60 years, a general lowering of groundwater levels was caused by intensive use of groundwater in the region. Areas affected by municipal pumping show a lower groundwater level recovery than other areas (DWR 2004s, 2013b). Between fall 2012 and fall 2017, groundwater levels varied from an increase of 40 feet to a decrease of 13 feet. Generally, the water levels increased in the western portion and decreased in the eastern portion of the subbasin (DWR 2019b). Less data exists for the spring 2013 to spring 2018 period. The data show a range from an increase of 14 feet to a decrease of 14 feet.

The groundwater quality is characterized by low to moderate TDS concentrations (DWR 2004s, 2013b). Seven sites historically had substantial groundwater contamination, including three Superfund sites near the Sacramento metropolitan area. These sites are in various stages of cleanup.

The CASGEM program designated the South American subbasin as high priority. The SGMA designation for this subbasin is still pending.

I.1.3.4.2 Groundwater Use and Management

In this area, groundwater is used for agricultural, domestic, municipal, and industrial purposes. Most of the groundwater extraction occurs via privately owned domestic and agricultural wells.

Butte and Wyandotte Creek Subbasins

The primary water source in Butte County is surface water (approximately 70% by volume), and groundwater use accounts for about 30% of total county water use. In Butte County, most of the irrigation users rely upon surface water, and approximately 75% of the residential water users rely upon groundwater (Butte County 2004, 2010). The Cities of Chico and Hamilton City are served by groundwater provided by California Water Service Company (California Water Service Company 2011a).

North and South Yuba Subbasins

The Yuba County Water Agency actively manages surface water and groundwater conjunctively to prevent groundwater overdraft in the North and South Yuba subbasins. The majority of water demand in these subbasins is crop water use for irrigated agriculture (YCWA 2010).

Sutter Subbasin

Agricultural water use in Sutter County is composed, on average, of approximately 60% surface water, 20% groundwater, and 20% of land irrigated by both surface water and groundwater. Permanent crops are predominantly irrigated with groundwater. Groundwater is also used for small communities and rural domestic uses (Sutter County 2012).

North American Subbasin

Several agencies manage water resources in the North American subbasin: South Sutter Water District, Placer County Water Agency, Natomas Central Mutual Water Company, and several urban water purveyors that are part of SGA, a joint powers authority (SGA 2014). The northern portion of this subbasin is rural and agricultural, whereas the southern portion is urbanized, including the Sacramento Metropolitan area. Many of the urban agencies in Placer County rely upon surface water for normal operations and have developed or are planning on developing groundwater for emergency situations (Roseville et al. 2007). In the urban area encompassed by SGA, some agencies rely entirely on groundwater for their water supply (SGA 2014).

Local planning efforts have been implemented in a local groundwater planning area known as the American River Basin region. This area encompasses Sacramento County and the lower watershed portions of Placer and El Dorado Counties and overlies the productive North American and South American subbasins. Groundwater is a regionally substantial source of water supply and used as a primary source for many agencies in the region. However, in recent years, regional, conjunctive-use programs have allowed for the optimization of water supplies, and a decrease in groundwater use has been observed in the past 5 years (Regional Water Authority 2013).

Since 2000, groundwater extraction decreased in the northeastern portion of the North American subbasin as additional surface water supplies were made available under conjunctive-use operations implemented following the Water Forum Agreement in 2000. In 2007, groundwater extraction increased because additional surface water was not available due to dry surface water supply conditions (SGA 2013, 2014).

South American Subbasin

The South American subbasin lies entirely within Sacramento County and is overlain by a majority of urban and densely populated areas. Many of the water users in this subbasin use surface water.

The main water purveyors that use South American subbasin groundwater include the Elk Grove Water District, California American Water Company, Golden State Water Company, and the Sacramento County Water Agency. The entities serve the communities of Antelope, Arden, Lincoln Oaks, Parkway, Rosemont, and portions of the City of Rancho Cordova (California American Water Company 2011; Elk Grove Water District 2011; Golden State Water Company 2011a; Sacramento County Water Agency 2011). The majority of groundwater pumping is for agricultural uses (Sacramento Central Groundwater Authority 2010). The South American subbasin also includes portions of the area known as the American River Basin as described above under the North American subbasin section.

I.1.4 Clear Creek

Clear Creek is a major tributary to the Sacramento River that lies just below Shasta Dam. Clear Creek originates in the mountains east of Clair Engle Reservoir and flows approximately 35 miles to its confluence with the Sacramento River, just south of the town of Redding in Shasta County. Clear Creek drains approximately 249 square miles and receives the majority of its inflow from rainfall and snowmelt.

Given that Clear Creek flows primarily through the mountain valleys, there is little in the way of substantial groundwater basins underlying this area. Any groundwater present in these valleys is likely in close hydraulic connection with Clear Creek. Both groundwater discharge to surface streams and leakage of steam flow to underlying aquifers are expected to occur at various locations.

I.1.5 San Joaquin Valley

Extending south into the Central Valley from the Delta to the southern extent marked by the San Joaquin River, DWR has delineated nine subbasins within the northern portion of the San Joaquin Valley Groundwater Basin based on groundwater divides, barriers, surface water features, and political boundaries (DWR 2003a). The Cosumnes, Eastern San Joaquin, and Tracy subbasins partially underlie the Delta. The Delta-Mendota, Modesto, Turlock, Merced, Chowchilla, and Madera subbasins are located between the Delta and the San Joaquin River.

The northern portion of the San Joaquin Valley Groundwater Basin is marked by laterally extensive deposits of thick, fine-grained materials deposited in lacustrine and marsh depositional systems. These units, which can be tens to hundreds of feet thick, create vertically differentiated aquifer systems within the subbasins. The Corcoran Clay (or E-Clay), occurs in the Tulare formation and separates the alluvial water-bearing formations into confined and unconfined aquifers. The direction of groundwater flow generally coincides with the primary direction of surface water flows in the area, which is to the northwest toward the Delta (DWR 2003a, 2004t, 2004u, 2004v, 2004w, 2006g, 2006h, 2006i). Groundwater levels fluctuate seasonally, and a strong correlation exists between depressed groundwater levels and periods of drought when more groundwater is pumped in the area to support agricultural operations.

Water users in the northern portion of the San Joaquin Valley Groundwater Basin rely on groundwater, which is used conjunctively with surface water for agricultural, industrial, and municipal supplies (DWR 2003a). Groundwater is estimated to account for about 38% of the overall water supply in the northern portion of the San Joaquin Valley Groundwater Basin (DWR 2013a). Annual groundwater pumping in the northern portion of the San Joaquin Valley Groundwater Basin accounts for about 19% of all groundwater pumped in the state of California. Groundwater use in the northern portion of the San Joaquin Valley Groundwater Basin is estimated to average 3.2 million acre-feet per year (AFY) between 2005 and 2010.

According to the *California Water Plan Update 2013* (DWR 2013a), three planning areas within the northern portion of the San Joaquin Valley Groundwater Basin rely heavily on groundwater pumping: the Eastern Valley Floor Planning Area, the Lower Valley Eastside Planning Area, and the Valley West Side Planning Area. Each of these areas has limited local surface water supplies and uses extensive groundwater pumping for their agricultural water supply (DWR 2013a).

The northern portion of the San Joaquin Valley Groundwater Basin is divided into two subregions: West of the San Joaquin River and East of the San Joaquin River. These are described below.

I.1.5.1 *West of the San Joaquin River*

The Tracy and Delta-Mendota subbasins are located on the west side of the San Joaquin River.

I.1.5.1.1 Hydrogeology and Groundwater Conditions

Along the western portion of the San Joaquin Valley, the Tulare formation comprises the primary freshwater aquifer. The Tulare formation originated as reworked sediments from the Coast Ranges redeposited in the San Joaquin Valley as alluvial fan, flood plain, deltaic (pertaining to a delta) or lacustrine, and marsh deposits (USGS 1986).

Tracy Subbasin

The Tracy subbasin underlies eastern Contra Costa County and western San Joaquin County. A large portion of the subbasin is in the Delta. In the Tracy subbasin, groundwater generally flows from south to north and discharges into the San Joaquin River. According to DWR and the San Joaquin County Flood Control and Water Conservation District, groundwater levels in the Tracy subbasin have been relatively stable over the past 10 years, apart from seasonal variations resulting from recharge and pumping (DWR 2006g, 2013a). Measurement data indicate that between spring 2013 and spring 2018, groundwater levels declined at some wells in the Tracy subbasin by up to 12 feet (DWR 2019b). Groundwater levels in some areas declined up to 14 feet between fall 2012 and fall 2017. In both the spring and fall measurements, many of the wells had decreased between 0 and 3 feet.

In the Tracy subbasin, areas of poor water quality exist throughout the area. Elevated chloride concentrations are found along the western side of the subbasin near the City of Tracy and along the San Joaquin River. Overall, Delta groundwater wells in the Tracy subbasin are characterized by high levels of chloride, TDS, arsenic, and boron (DWR 2006g, 2013c; USGS 2006). The Central Valley RWQCB recently adopted general waste discharge requirements to protect groundwater and surface water within the San Joaquin County and Delta areas, including the Tracy subbasin (Central Valley RWQCB 2014). Supporting information recognizes the potential for groundwater impairment due to the water quality of applied water to crops if the applied water quality contains high concentrations of constituents of concern.

The CASGEM program designated the Tracy subbasin as medium priority. The SGMA designation for this subbasin is still pending.

Delta-Mendota Subbasin

The Delta-Mendota subbasin underlies portions of Stanislaus, Merced, Madera, and Fresno Counties. The geologic units present in the Delta-Mendota subbasin consist of the Tulare formation, terrace deposits, alluvium, and flood-basin deposits. Groundwater occurs in three water-bearing zones: the lower zone that contains confined fresh water in the lower section of the Tulare formation; the upper zone that contains confined, semiconfined, and unconfined water in the upper section of the Tulare formation; and a shallow zone that contains unconfined water (DWR 2006h, 2013c). The groundwater is characterized by moderate to extremely high salinity, with localized areas of high iron, fluoride, nitrate, and boron (DWR 2006h, 2013c).

In the Delta-Mendota subbasin, groundwater levels generally declined between 1958 and 2006 by as much as 20 feet in the northern portion of the basin near Patterson. Surface water imports in the early 1970s resulted in decreased pumping and a steady recovery of groundwater levels. However, the lack of imported surface water availability during the drought periods of 1976 to 1977, 1986 to 1992, and 2007 to 2009 resulted in increases in groundwater pumping and associated declines in groundwater levels to near-historic lows (USGS 2012). Between measurements in spring 2012 and spring 2018, groundwater levels generally declined. Many wells have decreased between 20 and 50 feet (DWR 2019b). There are two wells with reported decreases over 150 feet. Even given the few well measurements available, many wells showed a decrease of at least 10 feet between fall 2012 and fall 2017 (DWR 2019b).

In areas adjacent to the Delta-Mendota Canal in this subbasin, extensive groundwater withdrawal has caused land subsidence of up to 10 feet in some areas. Land subsidence can cause structural damage to the Delta-Mendota Canal, which has caused operational issues for CVP water delivery. Historical widespread soil compaction and land subsidence between 1926 and 1970 caused reduced freeboard and flow capacity of the Delta-Mendota Canal, the California Aqueduct, other canals, and roadways in the area. To better understand subsidence issues near the Delta-Mendota Canal and improve groundwater management in the area, USGS evaluated and provided information on groundwater conditions and the potential for additional land subsidence in the San Joaquin Valley (USGS 2013b). Results show that a subsidence rate of up to 0.75 foot per year between 2011 and 2018 has been measured near the San Joaquin River and the Eastside Bypass, affecting the southern part of the Delta-Mendota Canal by about 0.8 inch of subsidence during the same period. It was estimated that subsidence rates doubled in 2008 in some areas. The subsidence measured was primarily inelastic (or permanent, not reversible) due to the compaction of fine-grained material. The area of maximum active subsidence is shown to be located southwest of Mendota and extends into the Merced subbasin to the south of El Nido. Land subsidence in this area is expected to continue to occur due to uncertainties and limitations (especially climate-related changes) in surface water supplies to meet irrigation demand and the continuous need to supplement water supply with groundwater pumping.

I.1.5.1.2 Groundwater Use and Management

In this area, groundwater is used for agricultural, domestic, municipal, and industrial purposes.

Tracy Subbasin

The primary water source in Contra Costa County is surface water. Groundwater is used by individual homes and businesses and the communities of Brentwood, Bethel Island, Knightsen, Byron, and Discovery Bay (Contra Costa County 2005).

The Diablo Water District groundwater-blending facility provides water to users in the City of Oakley by blending groundwater and treated water from Contra Costa Water District (CCWD) (Diablo Water District 2011).

CCWD has an agreement with the East Contra Costa Irrigation District to purchase surplus irrigation water for municipal and industrial purposes in East Contra Costa Irrigation District's service area (CCWD 2011). The agreement includes an option to implement an exchange of surface water for groundwater that can be used in the CCWD service area when the CVP allocations are less than full contract amounts. This groundwater exchange water was implemented during the 2007 to 2009 drought.

Groundwater and surface water are used within western San Joaquin County for agricultural operations and for the Cities of Stockton, Lathrop, and Tracy (San Joaquin County 2009). In the 1980s, about 30% of the water supplies in San Joaquin County were based on groundwater (including the Tracy, Cosumnes, and Eastern San Joaquin subbasins). By 2007, groundwater was used to supply over 60% of water demand in the county.

Delta-Mendota Subbasin

Groundwater is used for agricultural and domestic water supplies in the Delta-Mendota subbasin (Reclamation and DWR 2012). Groundwater is primarily used for domestic and industrial water supplies in Stanislaus County, including for the City of Patterson (Stanislaus County 2010; Patterson 2014). In the Delta-Mendota subbasin within Merced County, approximately 3% of groundwater withdrawals are used for municipal and industrial purposes (including uses in the Cities of Gustine and Los Banos, and Santa Nella), and 97% of the groundwater withdrawals are used for agricultural purposes (Merced County 2012). Most of the portions of Madera County within the Delta-Mendota subbasin use groundwater for domestic and agricultural uses (Madera County 2002, 2008). In portions of western Fresno County within the Delta-Mendota subbasin, domestic water users rely upon groundwater (including the Cities of Mendota and Firebaugh), and agricultural water users rely upon surface water and/or groundwater (Mendota 2009; Firebaugh 2015; Fresno County 2000).

I.1.5.2 *East of the San Joaquin River*

The east side of the San Joaquin River is underlain by seven groundwater subbasins: the Cosumnes, Eastern San Joaquin, Modesto, Turlock, Merced, Chowchilla, and Madera subbasins. The Chowchilla, Eastern San Joaquin, and Madera subbasins are in a critical state of overdraft (DWR 2013a).

I.1.5.2.1 Hydrogeology and Groundwater Conditions

Several of the hydrogeologic units present in the southern Sacramento Valley extend south into the San Joaquin Valley. Along the eastern boundary of the Central Valley, the Ione, Mehrten, Riverbank, and Modesto formations are primarily composed of sediments originating from the Sierra Nevada.

Historically, surface water and groundwater were hydraulically connected in most areas of the San Joaquin River and its tributaries. This connection resulted in a substantial quantity of groundwater actively discharging into streams in most of this watershed. However, this condition changed as increased groundwater pumping in the area lowered groundwater levels and reversed the hydraulic gradient between the surface water and groundwater systems, resulting in surface water recharging the underlying aquifer system through streambed seepage. Long-term groundwater production throughout this basin has exceeded natural recharge rates and thereby lowered groundwater levels. Areas where this overdraft has occurred include eastern San Joaquin County, Merced County, and western Madera County. Substantial surface water infiltrates from the river to the groundwater system occurs along the San Joaquin River where the riverbed is highly permeable and river water readily seeps into the underlying aquifer. As such, groundwater overdraft reduces both groundwater and surface water outflows to the Delta, lowers the water table, and may increase the potential for land subsidence (U.S. Fish and Wildlife Service [USFWS] 2012).

Generally, the groundwater in the San Joaquin River subbasins east of the San Joaquin River is of suitable quality for most urban and agricultural uses with only local impairments. There are localized areas with high concentrations of boron, chloride, iron, nitrate, TDS, and organic compounds (DWR 2003a, 2004t, 2004u, 2004v, 2004w, 2006i, 2006j, 2006k). The use of groundwater for agricultural supply is impaired in western Stanislaus and Merced Counties due to elevated boron concentrations. Groundwater use for drinking water supply is also impaired in the Tracy, Modesto-Turlock, Merced, and Madera areas due to elevated nitrate concentrations (USFWS 2012).

Dibromochloropropane (DBCP), a soil fumigant that was extensively used on grapes and cotton before it was banned, is prevalent in groundwater near Merced and Stockton and in the Merced, Modesto, Turlock, Cosumnes, and Eastern San Joaquin subbasins (Central Valley RWQCB 2011; DWR 2004t; USFWS

2012). Many areas with high concentrations of DBCP have undergone groundwater remediation, and DBCP concentrations are declining.

Declining groundwater levels in the subbasins east of the San Joaquin River have resulted in an area approximately 16 miles long with high salinity due to saltwater intrusion from the Delta (USFWS 2012).

Cosumnes Subbasin

The Cosumnes subbasin underlies western Amador County, northwestern Calaveras County, southeastern Sacramento County, and northeastern San Joaquin County. Groundwater levels in the Cosumnes subbasin have fluctuated substantially over the past 40 years, with the lowest levels occurring during periods of drought. From 1987 to 1995, water levels declined by about 10 to 15 feet and then recovered by that same amount through 2000. Areas affected by municipal pumping show a lower magnitude of groundwater level recovery during this period than in other areas of the subbasin (DWR 2006j, 2013c). Within the portion of Sacramento County in the Cosumnes subbasin, it is estimated that the recent average annual decline in groundwater levels has been approximately 1 foot, with a lower rate of decline in more recent years (South Area Water Council 2011). Between measurements in spring 2013 and spring 2018, groundwater levels declined between 4 and 7 feet. There were also increases up to 40 feet (DWR 2019b). Between fall 2012 and fall 2017, measurements at many wells showed water levels declined by 5 to 16 feet.

The Cosumnes subbasin contains groundwater of very good quality, with localized high concentrations of calcium bicarbonate and pesticides (DWR 2006j, 2013c).

The CASGEM program designated the Cosumnes subbasin as medium priority. The SGMA designation for this subbasin is still pending.

Eastern San Joaquin Subbasin

The Eastern San Joaquin subbasin underlies western Calaveras County, a large portion of San Joaquin County, and a portion of Stanislaus County. Groundwater levels in the Eastern San Joaquin subbasin have continuously declined in the past 40 years due to groundwater overdraft. Cones of depression are present near major pumping centers such as the City of Stockton and the City of Lodi (DWR 2006k, 2013c). Groundwater level declines of up to 100 feet have been observed in some wells. In the 1990s, groundwater levels were so low that many wells were inoperable, and many groundwater users were obligated to construct new deeper wells (Northeastern San Joaquin County Groundwater Banking Authority [NSJCGBA] 2004). Between spring 2014 and spring 2018, many wells, especially in the central and southern portion of the subbasin, showed water level decreases greater than 10 feet (DWR 2019b). Groundwater level increases were seen in wells in the northern portion of the subbasin. Similar trends were also seen in the data for measurements between fall 2012 and fall 2017.

In the Eastern San Joaquin subbasin, the groundwater is characterized with low to high salinity levels and localized areas of high calcium or magnesium bicarbonate, salinity, nitrates, pesticides, and organic constituents (DWR 2006k, 2013c). The high groundwater salinity is attributed to poor quality groundwater intrusion from the Delta caused by the pumping-induced decline in groundwater levels, especially in the groundwater underlying the Stockton area since the 1970s (San Joaquin County Flood Control and Water Conservation District 2008). High chloride concentrations have also been observed in the Eastern San Joaquin subbasin. Ongoing studies are evaluating the sources of chloride in groundwater along a line extending from Manteca to north of Stockton. Initial concern was that long-term overdraft conditions in the eastern portion of the subbasin were enabling more saline water from the Delta to migrate inland. Other possible sources include upward movement of deeper saline formation water and agricultural practices (USGS 2006). In addition, large areas of groundwater with elevated nitrate concentrations have been observed in several portions of the subbasin, such as areas southeast of Lodi and south of Stockton and east of Manteca, and in areas extending toward the San Joaquin-Stanislaus County line (USFWS 2012).

The CASGEM program designated the Eastern San Joaquin subbasin as high priority. The SGMA designation for this subbasin is still pending.

Modesto Subbasin

The Modesto subbasin underlies northern Stanislaus County. In the Modesto subbasin, water levels declined nearly 15 feet on average between 1970 and 2000 (DWR 2004t, 2013c), with the major declines occurring in the eastern portion of the subbasin. Groundwater level data indicate that many wells showed groundwater levels decreased by more than 15 to 20 feet between spring 2013 and spring 2018 and also between fall 2012 and fall 2017 (DWR 2019b).

The groundwater is characterized by low to high TDS concentrations, with localized areas of boron, chlorides, DBCP, iron, manganese, and nitrate concentrations (DWR 2004t, 2013c; Stanislaus County 2010).

The CASGEM program designated the Modesto subbasin as high priority. The final SGMA designation for this subbasin is high priority.

Turlock Subbasin

The Turlock subbasin underlies portions of Stanislaus and Merced counties. In the Turlock subbasin, water levels declined nearly 7 feet on average from 1970 through 2000 (DWR 2006j, 2013c). Comparison of groundwater contours from 1958 and 2006 shows that historically, groundwater flows occurred from east to west, toward the San Joaquin River. Groundwater pumping centers to the east of the City of Turlock have drawn the groundwater toward these cones of depression, allowing less water to flow toward the San Joaquin River and diminishing the discharge of groundwater to the river. Groundwater level data indicate that many wells showed groundwater levels decreased by more than 15 to 20 feet between spring 2013 and spring 2018 and also between fall 2012 and fall 2017 (DWR 2019b). The storage capacity of the Turlock subbasin is estimated at about 15,800,000 acre-feet (AF) (DWR 2006j, 2013c).

The groundwater quality is characterized with low to high concentrations of TDS and localized high concentrations of boron, chlorides, DBCP, nitrates, and TDS (DWR 2013c).

The CASGEM program designated the Turlock subbasin as high priority. The final SGMA designation for this subbasin is high priority.

Merced Subbasin

The Merced subbasin underlies most of Merced County. In the Merced subbasin, water levels have declined nearly 30 feet on average from 1970 through 2000. Water level declines have been more severe in the eastern portion of the subbasin (DWR 2004u, 2013c). The estimated specific yield of the groundwater subbasin is 9%. From spring 2013 to spring 2018, several wells, especially in the northwest and southeast portions of this subbasin, showed groundwater level declines over 10 feet, approaching 50 feet (DWR 2019b). There are also several wells with water level declines between fall 2012 and fall 2017; however, there are also wells with water level increases over 10 feet in this period.

The groundwater quality is characterized by low to high TDS concentrations and localized areas with high concentrations of chloride, DBCP, iron, and nitrate (DWR 2004u, 2013c; USFWS 2012).

The CASGEM program designated the Merced subbasin as high priority.

Chowchilla Subbasin

The Chowchilla subbasin underlies southwestern Merced County and northwestern Madera County. In the Chowchilla subbasin, water levels declined nearly 40 feet on average from 1970 to 2000. Water level declines were more severe in the eastern portion of the subbasin from 1980 to present, but the western portion of the subbasin showed the strongest declines before 1980 (DWR 2004v, 2013c). Groundwater recharge in this subbasin is primarily from irrigation water percolation. Groundwater level data show that between spring 2013 and spring 2018, groundwater levels declined at some wells over 25 feet (DWR 2019b).

There are localized areas with high concentrations of chloride, iron, nitrate, and hardness (DWR 2004v, 2013c). Organic chemicals were detected in some wells in the Chowchilla subbasin between 1983 and 2003 (Central Valley RWQCB 2011).

The CASGEM program designated the Chowchilla subbasin as high priority. The SGMA prioritization for this subbasin is still pending.

Madera Subbasin

The Madera subbasin underlies most of Madera County. In the Madera subbasin, water levels have declined nearly 40 feet on average from 1970 through 2000. Water level declines have been more severe in the eastern portion of the subbasin from 1980 to the present, but the western subbasin showed the strongest declines before this period (DWR 2004w, 2013c). At the single well with water levels collected in spring 2013 and spring 2018, a water level decline of over 50 feet was recorded (DWR 2019b).

Groundwater in the Madera subbasin is characterized by low to high TDS and localized areas with high concentrations of chlorides, iron, nitrates, and hardness (DWR 2004w, 2013c). Occurrences of organic chemicals, including DBCP and pesticides, have been observed (Central Valley RWQCB 2011; DWR 2004w, 2013c).

The CASGEM program designated the Madera subbasin as high priority. The SGMA prioritization for this subbasin is still pending.

I.1.5.2.2 Groundwater Use and Management

In this area, groundwater is used for agricultural, domestic, municipal, and industrial purposes.

Cosumnes Subbasin

Currently, urban and agricultural water users on the valley floor are reliant on groundwater for water supply. Water demands in the Cosumnes subbasin area are supported by nearly 95% groundwater (South Area Water Council 2011). Groundwater and surface water are used for agricultural and domestic water supplies in the Cosumnes subbasin (Central Valley RWQCB 2011). Groundwater is used by many agricultural water users and the community of Galt (Central Valley RWQCB 2011; South Area Water Council 2011).

Central Valley RWQCB recently adopted general waste discharge requirements to protect groundwater and surface water within the San Joaquin County and Delta areas, including the Cosumnes subbasin. The new requirements do not address protection of groundwater related to use of recycled water on crops because those operations would require separate discharge permits from Central Valley RWQCB and are not anticipated to be widely used in this area because of limited availability of recycled water near farms. However, the supporting information recognizes the potential for groundwater impairment due to the water quality of applied water (Central Valley RWQCB 2014).

Eastern San Joaquin Subbasin

Groundwater and surface water are used for agricultural and domestic water supplies in the Eastern San Joaquin subbasin (Central Valley RWQCB 2011). Groundwater is the major source of water supply for agricultural areas in eastern San Joaquin County (NSJCGBA 2007). Groundwater is used by many agricultural water users and the communities of Escalon, Lodi, Manteca, Ripon, and Stockton (Eastern San Joaquin County Groundwater Basin Authority [ESJCGBA] 2004, 2007). The Cities of Manteca and Stockton use both groundwater and surface water, whereas Lodi, Escalon, and Ripon primarily use groundwater for their municipal needs.

The City of Stockton uses both surface water and groundwater for its municipal and industrial water needs. Due to overdraft of the aquifer beneath Stockton, the city has limited annual groundwater extraction. Demands on the finite groundwater resources available in the basin historically have resulted in annual groundwater withdrawals in excess of the natural recharge volume in the East San Joaquin subbasin (DWR 2003a, 2006k). This extensive use of groundwater to meet local demand results in localized overdraft conditions within the subbasin.

The NSJCGBA, now called the ESJCGBA, is a joint-powers authority that develops local projects to strengthen water supply reliability in Eastern San Joaquin County. ESJCGBA facilitated the development and adoption of the *Eastern San Joaquin Groundwater Basin Groundwater Management Plan* (NSJCGBA 2004) and completed an integrated regional water management plan (IRWMP). This plan outlines the requirements for an integrated conjunctive use program that takes into account the various surface water and groundwater facilities in eastern San Joaquin County and promotes better groundwater management to meet future basin demands (NSJCGBA 2004). Conjunctive use refers to the use and management of the groundwater resource in coordination with surface water supplies by users overlying the basin. Potential projects that could be implemented to improve groundwater conditions in the area include urban and agricultural water use efficiency projects, recycled municipal water projects, groundwater banking operations, new surface water storage opportunities, improved conveyance facilities, and utilizing new sources of surface water (NSJCGBA 2007). Pursuant to the IRWMP, a program-level environmental impact report identified potential changes to the environmental and mitigation measures to reduce identified substantial adverse effects (NSJCGBA 2011).

The Farmington Groundwater Recharge Program led by Stockton East Water District, in conjunction with the U.S. Army Corp of Engineers and other local water agencies, was developed to utilize flood-season and excess irrigation water supplies in the Eastern San Joaquin groundwater subbasin to recharge the groundwater aquifer. This program supports replenishment of a critically overdrafted groundwater basin by recharging an average of 35,000 AF of water annually into the Eastern San Joaquin subbasin. The program includes recharge of surface water on 800 to 1,200 acres of land using direct field flooding. In addition, the program increases surface water deliveries in-lieu of groundwater pumping to reduce overdraft (Farmington Program 2012).

A joint conjunctive use and groundwater banking project was evaluated by the East San Joaquin Parties Water Authority and East Bay Municipal Utility District (EBMUD), named the Mokelumne Aquifer

Recharge and Storage Project (NSJCGBA 2004). The goal of this project was to store surface water underground in wet years, and in dry years, EBMUD would extract and export the recovered water supply (NSJCGBA 2004, 2009). Several studies have concluded that the test area is suitable for recharge and recovery of groundwater; however, more testing needs to be done to further evaluate the feasibility of this project.

Central Valley RWQCB recently adopted general waste discharge requirements to protect groundwater and surface water within the San Joaquin County and Delta areas. The new requirements do not address protection of groundwater related to the use of recycled water on crops because those operations would require separate discharge permits from Central Valley RWQCB and are not anticipated to be widely used in this area because of the availability of recycled water near farms. However, the supporting information recognizes the potential for groundwater impairment due to the water quality of applied water to crops (Central Valley RWQCB 2014).

Modesto Subbasin

Groundwater is used for agricultural and domestic water supplies in the Modesto subbasin (Reclamation and DWR 2012). Groundwater is used by many agricultural water users and the community of Modesto (DWR 2004t; Stanislaus County 2010).

Turlock Subbasin

Groundwater is used for agricultural and domestic water supplies in the Turlock subbasin (Reclamation and DWR 2012). Groundwater is used by many agricultural water users and the community of Turlock in Stanislaus County and the communities of Delhi and Hilmar in Merced County (DWR 2006i; Stanislaus County 2010; Merced County 2012).

Merced Subbasin

Groundwater is used for agricultural and domestic water supplies in the Merced subbasin (Reclamation and DWR 2012). Groundwater is used by many agricultural water users and the communities of Atwater, El Nido, Le Grand, Livingston, Merced, Planada, and Winton (DWR 2004u; Merced County 2012).

Chowchilla Subbasin

Groundwater is used for agricultural and domestic water supplies in the Chowchilla subbasin (Reclamation and DWR 2012). Groundwater is used by many agricultural water users and the community of Chowchilla (DWR 2006i; Madera County 2002).

Madera Subbasin

Groundwater is used for agricultural and domestic water supplies in the Madera subbasin (Reclamation and DWR 2012). Groundwater is used by many agricultural water users and the community of Madera (DWR 2006i; Madera County 2002, 2008).

I.1.6 Bay-Delta

The Delta overlies the western portion of the area where the Sacramento River and San Joaquin River Groundwater Basins converge. The Delta includes the Solano subbasin and the South American subbasin in the Sacramento Valley Groundwater Basin (as described previously); the Tracy subbasin, the Eastern

San Joaquin subbasin, and the Cosumnes subbasin in the San Joaquin Valley Groundwater Basin (as described previously); and the Suisun-Fairfield Valley Basin (as described subsequently).

I.1.6.1 *Hydrogeology and Groundwater Conditions*

Each groundwater basin in the San Francisco Bay Hydrologic Region contains unique hydrogeologic characteristics. However, generally, water-bearing materials consist of alluvial, unconsolidated sand, sand and gravel, and clay (DWR 2004x, 2004y, 2004z, 2004aa, 2004ab, 2004ac, 2004ad, 2004ae, 2006l, 2006m, 2013d). Aquifers in these basins are hydrologically connected to surface water bodies, such as the San Joaquin River, Suisun Bay, local streams, and San Francisco Bay.

The movement of groundwater is locally influenced by features such as faults and structural depressions and operating production wells; however, groundwater generally flows toward the nearby bays. Groundwater levels in the area exhibit seasonal variation and have been historically depressed from substantial groundwater use. However, as groundwater use decreased over the last few decades following implementation of surface water projects, groundwater levels have risen substantially. Over the entire period of record, groundwater levels have shown only a slight decline and are stable in more recent years.

I.1.6.1.1 Pittsburg Plain, Clayton Valley, Ygnacio Valley, and Arroyo Del Hambre Valley Groundwater Basins

The Pittsburg Plain, Clayton Valley, Ygnacio Valley, and Arroyo Del Hambre Valley Groundwater Basins represent the majority of groundwater storage in northern Contra Costa County. Except for portions of the Pittsburg Plain, most of these groundwater basins are not located within the Delta.

These basins extend inland from Suisun Bay toward Mt. Diablo. The Pittsburg Plain Groundwater Basin is composed of Pleistocene deposits of consolidated and unconsolidated clay sediments overlain by alluvial soft water-saturated muds, peat, and loose sands (DWR 2004x, 2013d). The Clayton Valley and Ygnacio Valley Groundwater Basins are composed of unconsolidated alluvium and semiconsolidated alluvium interbedded with clay, sand, and gravel lenses. Along Suisun Bay, the water-bearing formations are composed of alluvial soft water-saturated muds, peat, and loose sands (DWR 2004y, 2004z, 2004aa, 2013d).

Groundwater levels are relatively stable because the groundwater is recharged from streams (DWR 2004x, 2004y, 2004z, 2004aa, 2013d). The streams include Kirker and Willow Creeks in the Pittsburg Plain Groundwater Basin, Marsh Creek in the Clayton Valley Groundwater Basin, Walnut and Grayson Creeks in the Ygnacio Valley Groundwater Basin, and Alhambra Creek in the Arroyo Del Hambre Valley Groundwater Basin. There are no recent data for these basins related to groundwater levels or storage capacities.

The groundwater in this area is characterized by moderate to high TDS (DWR 2004x, 2004y, 2004z, 2004aa, 2013d). High nitrate concentrations occur in some rural areas of these basins (Contra Costa County 2005).

The CASGEM program designated the Pittsburg Plain, Clayton Valley, Ygnacio Valley, and Arroyo Del Hambre Valley Groundwater Basins as very low priority. These subbasins are also prioritized as very low in the final SGMA rankings.

I.1.6.1.2 San Ramon Valley Groundwater Basin

The San Ramon Valley Groundwater Basin is in southern Contra Costa County and extends from the Alamo area southward under the Town of Danville and City of San Ramon to the county boundary.

The basin is a closed basin characterized by alluvial fan deposits of sand, gravel, silt, and clay sediments (DWR 2004ab, 2013d). Multiple faults within the basin affect groundwater movement.

There are no recent data for this basin related to groundwater levels, storage capacities, or quality (DWR 2004ab, 2013d).

The CASGEM program and SGMA designated the San Ramon Valley Groundwater Basin as very low priority.

I.1.6.1.3 Livermore Valley Groundwater Basin

The Livermore Valley Groundwater Basin extends under northeastern Alameda County and southern Contra Costa County. The Livermore Valley Groundwater Basin contains groundwater-bearing materials originating from continental deposits from alluvial fans, outwash plains, and lakes (DWR 2006l, 2013d).

The Main Basin is the aquifer that includes the highest yielding aquifers and highest quality groundwater (Zone 7 Water Agency [Zone 7] 2018). The Main Basin generally is divided into the Upper Aquifer Zone and Lower Aquifer Zone, which are separated by a relatively continuous silty clay lens. Water from the Upper Aquifer Zone moves into the Lower Aquifer Zone when groundwater levels in the upper zone are high.

Well yields are mostly adequate and, in some areas, can produce large quantities of groundwater for all types of wells (DWR 2006l, 2013d). The movement of groundwater is locally impeded by structural features such as faults that act as barriers to groundwater flow, resulting in varying water levels in the basin. Groundwater follows a westerly flow pattern, similar to the surface water streams, along the structural central axis of the valley toward municipal pumping centers (Zone 7 2005).

Groundwater levels in the main portion of the Livermore Valley Groundwater Basin started declining in the early 1900s when groundwater pumping removed large quantities of groundwater (Zone 7 2005, 2010, 2013). This trend continued until the late 1960s when Zone 7 began importing SWP water. Subsequently, Zone 7 developed surface water projects to capture local runoff. Local runoff and SWP water are stored in Lake Del Valle and used to recharge groundwater within the Livermore Valley. The importation of additional surface water alleviated the pressure on the aquifer, and groundwater levels started to rise in the 1970s. Between spring 2013 and spring 2018, groundwater levels at the majority of wells in the subbasin showed an increase in groundwater level, some approaching 20 or more feet of increase. Differences between fall 2012 and fall 2017 showed similar results.

The Livermore Valley Groundwater Basin is characterized by localized areas of high boron, nitrate, and TDS (DWR 2006l, 2013d; Zone 7 2018). High boron levels can be attributed to marine sediments adjacent to the basin.

Nitrate concentrations generally are within potable water criteria; however, high nitrate concentrations occur in some locations of the upper aquifer (Zone 7 2018). The source of nitrates appears to be related to agricultural activities, wastewater disposal, and natural sources from decaying vegetation.

Salinity of the aquifer depends upon the quality of the water used for recharge operations. Salinity has increased over the past 30 years (Zone 7 2018), especially in the western portion of the Main Basin. Aquifers in the central and eastern portions of the Livermore Valley Groundwater Basin are generally recharged through streambeds and characterized by lower salinity due to the high recharge rate.

The CASGEM program and SGMA designated the Livermore Valley Groundwater Basin as medium priority.

I.1.6.1.4 Castro Valley Groundwater Basin

The Castro Valley Groundwater Basin is in the Castro Valley area of Alameda County between San Lorenzo Creek on the east and the Hayward Fault on the west (Castro Valley 2012).

The basin is composed of alluvial deposits of sand, gravel, silt, and clay sediments (DWR 2004ac, 2013d). Previous studies indicated that the maximum yield was about 140,000 gallons per day (Castro Valley 2012).

The groundwater is characterized by bicarbonates with calcium and sodium. Localized contamination has occurred in this shallow aquifer related to agricultural activities and underground storage tanks (Castro Valley 2012).

The CASGEM program and SGMA designated the Castro Valley Groundwater Basin as very low priority.

I.1.6.1.5 Santa Clara Valley Groundwater Basin

The Santa Clara Valley Groundwater Basin includes three subbasins in areas that are within the CVP and/or SWP service areas. The three subbasins include the East Bay Plain subbasin in Contra Costa and Alameda Counties, Niles Cone subbasin in Alameda County, and Santa Clara subbasin in Santa Clara County.

East Bay Plain Subbasin

The East Bay Plain subbasin is an alluvial plain that extends from San Pablo Bay southward to the Niles Cone subbasin and extends under San Francisco Bay (DWR 2004ad, 2013d; EBMUD 2013). The alluvium consists of unconsolidated sediments of mud, silts, sands, and clays. Multiple faults within the subbasin affect groundwater movement. Groundwater levels declined to approximately 250 feet below the ground surface until the mid-1960s when groundwater levels began to increase. By 2000, groundwater levels were close to the ground surface. The groundwater quality is characterized as calcium and sodium bicarbonate with moderate to high TDS. Higher TDS concentrations occur near San Francisco Bay where localized seawater intrusion has occurred. High nitrate concentrations occur in localized areas due to historic agricultural activities.

The CASGEM program and SGMA designated the East Bay Plain subbasin as medium priority.

Niles Cone Subbasin

The Niles Cone subbasin is mainly comprised of the alluvial fan along Alameda Creek. The Hayward Fault crosses the Niles Cone subbasin and further separates the subbasin into the Below Hayward Fault (west of the Hayward Fault) and Above Hayward Fault (east of the Hayward Fault) subbasins (Alameda County Water District [ACWD] 2012; DWR 2006m, 2013d).

The Niles Cone subbasin was in overdraft condition through the early 1960s. After 1962, groundwater levels increased as SWP water was delivered to the area and used to recharge the groundwater subbasin (DWR 2006m, 2013d).

The main groundwater quality impairment in the Niles Cone subbasin is saltwater intrusion caused by groundwater pumping (ACWD 2012; DWR 2006m, 2013d). In the 1950s, the migration of saline water extended into the Above Hayward Fault subbasin and migrated into deeper aquifers. ACWD has developed aquifer reclamation programs to help control the movement of saline water and restore the quality of groundwater in the affected aquifers as described below.

The CASGEM program and SGMA designated the Niles Cone subbasin as medium priority.

Santa Clara Subbasin

The Santa Clara subbasin is in Santa Clara County along a structural trough that parallels the Coast Ranges and extends from the Diablo Range and Santa Cruz Mountains. Water-bearing formations of the Santa Clara subbasin include unconsolidated to semiconsolidated gravel, sand, silt and clay (DWR 2004ac, 2013d). The upper alluvial fan in the northern portion of the subbasin is characterized by coarse-grained sediments (Santa Clara Valley Water District [SCVWD] 2010). Toward the central portion of the subbasin, thick silty clay lenses are inter-bedded with thin sand and gravel lenses. The northern and central portions of the subbasin are locally referred to as the Santa Clara Plain (SCVWD 2011). The southern portion of the subbasin consists of extensive alluvial deposits of unconsolidated and semiconsolidated sediments and is referred to as the Coyote Valley (SCVWD 2010). The central portions and areas along the edges of the Santa Clara Plain subbasin consist of unconfined aquifers that provide recharge to the basin (SCVWD 2010, 2011). The Shallow Aquifer consists of water-bearing sediments that are less than 150 feet deep. The Principal Aquifer provides most of the groundwater supply for the Santa Clara Valley and is separated from the Shallow Aquifer by a confining lens in some areas of the Santa Clara Plain. The groundwater recharge primarily occurs due to percolation of water on the soil from precipitation or artificial recharge operations (as described below), seepage from streambeds, and subsurface inflow from surrounding hills.

In the Coyote Valley, the groundwater aquifer is primarily unconfined with areas of perched groundwater above discontinuous clay deposits (SCVWD 2010, 2011). Groundwater recharge occurs along the streambeds. When the groundwater levels are high in the Coyote Valley, groundwater seeps into the streams.

The movement of groundwater in the Santa Clara subbasin is locally influenced by groundwater recharge activities, proximity to streams, and operating production wells (SCVWD 2010). Regionally, groundwater in the Santa Clara subbasin generally flows northwest toward the San Francisco Bay.

The Santa Clara subbasin has historically experienced decreasing groundwater level trends; between 1900 and 1970, water level declines of more than 200 feet from groundwater pumping caused unrecoverable land subsidence of nearly 13 feet in San Jose (SCVWD 2011). Importation of surface water using CVP, SWP, and San Francisco Public Utilities District water supplies and the development of an artificial recharge program have resulted in rising groundwater levels and sustainable conditions since the late 1960s. The groundwater levels in some portions of this subbasin increased up to 15 feet between spring 2013 and spring 2018, whereas a few wells decreased approximately 3 feet (DWR 2019b). Similar results are seen between fall 2012 and fall 2017 readings.

The groundwater quality in the Santa Clara subbasin is good to excellent and suitable for most beneficial uses. The groundwater meets all drinking water standards and can be used without additional treatment

(SCVWD 2001, 2010). Some areas affected by historical saltwater intrusion exist in the northern portion of the Santa Clara subbasin in the Shallow Aquifer. Recent groundwater monitoring has indicated that seawater intrusion appears to be stabilizing (SCVWD 2012). High nitrate concentrations occur in portions of the Coyote Valley.

The Santa Clara subbasin was designated by the CASGEM program as medium priority and as high priority in the final SGMA rankings.

I.1.6.2 *Groundwater Use and Management*

Use of groundwater in the San Francisco Bay Hydrologic Region varies extensively. In the basins within Contra Costa County (Pittsburg Plain, Clayton Valley, Ygnacio Valley, Arroyo Del Hambre Valley, and San Ramon Valley), local wells are used for small agricultural activities and landscape irrigation by individual landowners. In the Livermore Valley Groundwater Basin, groundwater is used for a major portion of the water supply.

I.1.6.2.1 Pittsburg Plain, Clayton Valley, Ygnacio Valley, and Arroyo Del Hambre Valley Groundwater Basins

Groundwater use is limited within northern Contra Costa County within the Pittsburg Plain, Clayton Valley, Ygnacio Valley, and Arroyo Del Hambre Valley Groundwater Basins. This area is in the CCWD or EBMUD service areas. These districts provide surface water to most water users in this area.

Within the CCWD service area, groundwater use is limited (CCWD 2011). The use of existing CCWD wells at the Mallard wellfields is limited because of the threat of contamination from adjacent industrial areas.

The City of Pittsburg operates two municipal wells from the Pittsburg Plain Groundwater Basin (Pittsburg 2011).

The City of Martinez operates up to two wells in the Arroyo Del Hambre Valley Groundwater Basin to provide irrigation water to a municipal park (Martinez 2011).

I.1.6.2.2 San Ramon Valley Groundwater Basin

Groundwater use is limited within the San Ramon Valley Groundwater Basin located in southern Contra Costa County. Local wells are used for small agricultural activities and landscape irrigation by individual landowners. This area is in the EBMUD service area. The district provides surface water to most water users in this area.

I.1.6.2.3 Livermore Valley Groundwater Basin

In the Livermore Valley Groundwater Basin, Zone 7 administers oversight of the groundwater basins used for water supply and provides water to California Water Service Company, Dublin San Ramon Services District (DSRSD), City of Livermore, and City of Pleasanton. Zone 7 only withdraws groundwater that has been recharged using surface water supplies (Zone 7 2010). The California Water Service Company, DSRSD, and City of Pleasanton also withdraw groundwater (California Water Service Company 2011b; DSRSD 2011; City of Livermore 2011; City of Pleasanton 2011).

Zone 7 manages the groundwater levels and quality in the Livermore Valley Groundwater Basin to maintain groundwater levels that would avoid subsidence and provide emergency reserves for the worst credible drought (DWR 2006l, 2013d).

Zone 7 artificially recharges the Livermore Valley Groundwater Basin with local surface water supplies and SWP water by releasing the surface waters into the Arroyo Mocho and Arroyo Valle (Zone 7 2005, 2010). The infiltrated water is then pumped from the groundwater basin for various uses, mostly during the summer and during drought periods when local surface water supplies are diminished and the available SWP water supplies are less than the entitlement value Zone 7, City of Livermore, City of Pleasanton, DSRSD, and California Water Service Company are permitted to withdraw from this subbasin.

In 2009, Zone 7 began operation of the Mocho Groundwater Demineralization Plant (Zone 7 2010). This plant is a wellhead treatment plant that produces potable water using reverse osmosis to remove TDS and hardness from the Main Basin.

I.1.6.2.4 Castro Valley Groundwater Basin

Groundwater use is limited within the Castro Valley Groundwater Basin. Local wells are used for small agricultural activities and landscape irrigation by individual landowners (Castro Valley 2012). This area is in the EBMUD service area. The district provides surface water to most water users in this area.

I.1.6.2.5 Santa Clara Valley Groundwater Basin

The Santa Clara Valley Groundwater Basin includes the East Bay Plain, Niles Cone, and Santa Clara subbasins.

East Bay Plain Subbasin

Groundwater use is limited within the East Bay Plains subbasin. Local wells are used for small agricultural activities and landscape irrigation by individual landowners (DWR 2004ad, 2013d; EBMUD 2013). Well fields that served the communities were initially constructed in the late 1800s and early 1900s and were closed by 1930. This area is in the EBMUD service area. The district provides surface water to most water users in this area. EBMUD initiated the Bayside Groundwater Project in 2009 to store surface water in wet years for use during droughts.

Niles Cone Subbasin

ACWD is the primary water agency that relies upon the Niles Cone subbasin. ACWD uses fresh groundwater from the Niles Cone subbasin and desalinated brackish groundwater in addition to local and imported surface water supplies. The Niles Cone subbasin is primarily recharged in the Alameda Creek watershed by percolation of local runoff and SWP water (ACWD 2011, 2012). In wetter years, when local water supplies are abundant, ACWD diverts some of the SWP allocation to the Semitropic Water Storage District in Kern County through a water banking agreement (as described for the Kern County subbasin). This agreement allows ACWD to subsequently recover this water during drier years through an exchange agreement with Semitropic Water Storage District (ACWD 2012).

ACWD provides retail water supplies to the Cities of Fremont, Newark, and Union City. The district has implemented treatment of brackish groundwater to allow previously unused groundwater to be used as a potable water source (ACWD 2011, 2012). In 2003, the ACWD Newark Desalination Facility began to remove salts and other constituents from the Niles Cone subbasin groundwater that is subject to seawater intrusion using a reverse osmosis process. The aquifer reclamation program also includes withdrawing water to prevent a plume of brackish water in the Centerville-Fremont Aquifer from further migrating toward the Alameda County Water District Mowry wellfield. Future groundwater desalination facilities are being evaluated by the district.

Santa Clara Subbasin

Local water agencies and individual landowners use groundwater in the Santa Clara subbasin. The Santa Clara subbasin is primarily recharged from percolation of local runoff and water supplied by the CVP and/or SWP that is discharged to recharge facilities including streambeds and percolation ponds (SCVWD 2016).

Treated water is provided by the SCVWD to retail water agencies to promote conjunctive use of groundwater. The water entities in the Santa Clara subbasin that use treated surface water include the Cities of Milpitas, Mountain View, San Jose, Santa Clara, and Sunnyvale; California Water Service (Los Altos District); and San Jose Water Company. Several of these entities also use surface water from San Francisco Public Utilities Commission as part of their overall water supply.

In the Santa Clara subbasin, groundwater is withdrawn by local water suppliers and private well owners to meet municipal, domestic, agricultural, and industrial water needs (SCVWD 2011). Groundwater provides approximately 40 to 50% of total water supply in Santa Clara County in average water year conditions (SCVWD 2010). Within the Santa Clara subbasin, the users of the most groundwater include San Jose Water Company, City of Santa Clara, Great Oaks Water Company, California Water Service, and individual landowners primarily in the southern portion of the subbasin (SCVWD 2012).

SCVWD is responsible for groundwater management in the Santa Clara subbasin and operates a robust and flexible conjunctive use program that uses a variety of surface water sources—local supplies, imported SWP and CVP supplies, and imported transfer options. Surface water is also supplied to some water users by the San Francisco Public Utilities Commission (SCVWD 2001, 2010). The district operates an extensive system of in-stream and off-stream artificial recharge facilities to replenish the groundwater basin and provide more flexibility to manage water supplies. Five major recharge systems allow local reservoir water and imported water to be released into in-stream recharge and percolation pond facilities for artificial recharge in the Santa Clara subbasin.. Recharge in this subbasin occurs along streambeds and off-stream managed basins.

I.1.7 Central Valley Project and State Water Project Service Areas

I.1.7.1 *Central Coast Region*

The Central Coast Region includes portions of San Luis Obispo and Santa Barbara Counties served by the SWP. The Central Coast Region encompasses the southern planning area of the Central Coast Hydrologic Region (DWR 2013a).

SWP water is provided to the Central Coast Region by the Central Coast Water Authority (Central Coast Water Authority 2013). The facilities divert water from the SWP California Aqueduct at Devil's Den and convey the water to the 43 million gallon per day water treatment plant at Polonto Pass. The treated water is conveyed to municipal water users in San Luis Obispo and Santa Barbara Counties to reduce groundwater overdraft in these areas.

Portions of the Central Coast Region that use CVP and SWP water are included in the Central Coast Hydrologic Region, which includes 50 delineated groundwater basins as defined by DWR (DWR 2003a). The basins vary from large extensive alluvial aquifers to small inland valleys and coastal terraces. Groundwater in the large alluvial aquifers exists in thick unconfined and confined basins.

Groundwater is generally used for urban and agricultural use in the Central Coast Region.

I.1.7.1.1 Hydrogeology and Groundwater Conditions

The areas within the CVP and SWP service areas in the Central Coast Region include the Gilroy-Hollister Valley Groundwater Basin in Santa Clara County; Morro Valley and Chorro Valley Groundwater Basins in San Luis Obispo County; Santa Maria River Valley Groundwater Basin in San Luis Obispo and Santa Barbara Counties; and San Antonio Creek Valley, Santa Ynez River Valley, Goleta, Foothill, Santa Barbara, Montecito, and Carpinteria Groundwater Basins in Santa Barbara County.

Gilroy-Hollister Valley Groundwater Basin

Llagas Subbasin

The Llagas subbasin is part of the larger Gilroy-Hollister Valley Groundwater Basin, which extends into San Benito County to the south (SCVWD 2016). Similar to the Santa Clara subbasin, the Llagas subbasin consists of unconsolidated alluvial sediments. SCVWD is responsible for groundwater management in the Llagas subbasin and operates a robust and flexible program that uses a variety of surface water sources—local supplies, imported SWP and CVP supplies—for recharge water.

In the Llagas subbasin, groundwater is used by municipal and private well owners to meet domestic, agricultural, and industrial water needs (SCVWD 2016). Groundwater provides over 95 percent of the total water supply in Llagas Subbasin. Almost half of the pumping in Llagas subbasin is for agricultural use. The major water users in Llagas subbasin include the cities of Morgan Hill and Gilroy, unincorporated San Martin, private well users, private water companies, and golf courses.

The Llagas subbasin generally produces groundwater of good quality that does not need treatment beyond disinfection at public water supply wells. However, the presence of elevated nitrate is an ongoing groundwater protection challenge, particularly in domestic wells (SCVWD 2016). Most wells tested show stable or decreasing trends over time. SCVWD continues to coordinate with land use and regulatory agencies to influence policies, regulations, and decisions related to nitrate management. More directly, SCVWD's managed recharge program helps dilute nitrate, and water quality testing and nitrate treatment system rebates help reduce well owner exposure (SCVWD 2018).

The Llagas subbasin was designated by the CASGEM program and SGMA as a high priority basin.

Morro Valley and Chorro Valley Groundwater Basins

In the portions of San Luis Obispo County within the SWP service area near Morro Bay, groundwater is provided by Morro Valley and Chorro Valley Groundwater Basins. Water-bearing formations are alluvium that consists of clays, silts, sands, and gravel that extend into the Pacific Ocean (DWR 2004af, 2004ag, 2013e). The alluvium is recharged by seepage from streambeds and precipitation and irrigation water applied to the soils.

The groundwater has moderate TDS (DWR 2004af, 2004ag, 2013e). Localized areas have high nitrate concentrations (Morro Bay 2011). Localized areas with organic contamination are also present; however, actions have been implemented to reduce the concentrations. Seawater intrusion occurs in localized areas near the Pacific Ocean.

The CASGEM program designated Morro Valley and Chorro Valley Groundwater Basins as high priority.

Santa Maria River Valley Groundwater Basin

The Santa Maria River Valley Groundwater Basin is in San Luis Obispo and Santa Barbara Counties. The water-bearing formation is primarily unconfined alluvium, with localized confined areas near the coast (DWR 2004ah, 2013e; Santa Maria Valley Management Area [SMVMA] 2012). Recharge occurs along the streambeds. Groundwater levels in the basin have fluctuated over the past 100 years, with declining groundwater levels until the mid-1970s, recovery through the mid-1980s, and declining levels through the mid-1990s. Following importation of SWP water, groundwater levels increased to historic high levels. However, in the last decade, groundwater levels have gradually declined, which could be partially due to reductions in Twitchell Reservoir releases for groundwater recharge since 2000. Groundwater levels have been maintained at levels above 15 feet above mean sea level in shallow and deep aquifers near the coast to avoid seawater intrusion. Groundwater recharge occurs along streambeds. Water released from Twitchell and Lopez Reservoirs increases groundwater recharge rates (SMVMA 2012).

Groundwater quality issues in the Santa Maria Valley Groundwater Basin include hardness, nitrates, salinity, sulfate, and volatile organic compounds (DWR 2004ah, 2013e; San Luis Obispo County 2011; SMVMA 2012). TDS concentrations are moderate to high. There are localized areas in the basin with high sulfate concentrations. Volatile organic compound contamination was a major issue for two wells used by the City of San Luis Obispo in the late 1980s. High nitrate concentrations occur in the shallow aquifer due to historic agricultural practices. Higher salinity levels occur in the shallow aquifer near the coast than within the inland areas or in the deep aquifer.

The CASGEM program designated the Santa Maria River Valley Groundwater Basin as high priority. The final SGMA priority for this subbasin is pending.

San Antonio Creek Valley Groundwater Basins

San Antonio Creek Valley Groundwater Basin is located along the Pacific Ocean within San Luis Obispo and Santa Barbara Counties. The water-bearing formations are characterized by unconsolidated alluvial and terrace deposits of sand, clay, silt, and gravel (DWR 2004b, 2013e). Groundwater flows toward the Pacific Ocean. A groundwater barrier to the east of the Pacific Ocean creates the Barka Slough. Groundwater has declined in some areas of the basin over the past 60 years. Groundwater quality issues include areas with high salinity near the Pacific Ocean.

The CASGEM program and final SGMA rankings designated the San Antonio Creek Valley Groundwater Basin as medium priority.

Santa Ynez River Valley Groundwater Basins

Several groundwater basins in Santa Barbara County are in a state of overdraft, including the Santa Ynez River Valley Groundwater Basin. The Santa Ynez Groundwater Basin is located along the Pacific Ocean in southwestern Santa Barbara County. The water-bearing formations are characterized by unconsolidated alluvial and terrace deposits of gravel, sand, silt, and clay (DWR 2004ai, 2013e). Groundwater flows toward the Santa Ynez River and then toward the Pacific Ocean. Groundwater recharge occurs along the streambeds.

Groundwater quality is generally good for municipal and agricultural uses. There are localized areas with high TDS near the Pacific Ocean due to seawater intrusion (DWR 2004ai, 2013e).

The CASGEM program and SGMA final rankings designated the Santa Ynez River Valley Groundwater Basin as medium priority.

Goleta, Foothill, Santa Barbara, Montecito, and Carpinteria Groundwater Basins

The Goleta, Foothill, Santa Barbara, Montecito, and Carpinteria Groundwater Basins are located in southwestern Santa Barbara County along the Pacific Ocean and near the boundary with Ventura County. The water-bearing formations in the Goleta, Foothill, Santa Barbara, and Montecito Groundwater Basins are unconsolidated alluvium of clay, silt, sand, and/or gravel that overlays the generally confined Santa Barbara formation of marine sand, silt, and clay (DWR 2004ai, 2004aj, 2004ak, 2004al, 2013e).

In the Carpinteria Groundwater Basin, the alluvium extends under the agricultural plain (DWR 2004am, 2013e). A confined aquifer occurs under a thick clay bed in the lower part of the alluvium. This basin includes the Santa Barbara formation; the Carpinteria formation, of unconsolidated to poorly consolidated sand with gravel and cobble; and the Casitas formation, of poorly to moderately consolidated clay, silt, sand, and gravel.

Several faults restrict groundwater flow throughout these basins. Recharge occurs along streambeds and from subsurface inflow into the basin from upland areas. Water released from Lake Cachuma increases groundwater recharge rates.

The groundwater levels in portions of these groundwater basins declined up to 10 feet between spring 2013 and spring 2018 and more than 70 feet in some areas (DWR 2019b).

Groundwater quality is generally good for municipal and agricultural uses. There are localized areas with high TDS near the Pacific Ocean due to seawater intrusion (DWR 2004ai, 2004aj, 2004ak, 2004al, 2004am, 2013e; Goleta Water District [GWD] and La Cumbre Mutual Water Company [GWD and LCMWC] 2010). High concentrations of nitrate, iron, and manganese occur in localized areas in the Goleta Groundwater Basin. Localized areas of high nitrate and sulfate concentrations occur within the Foothill Groundwater Basin. High concentrations of calcium, magnesium, bicarbonate, and sulfate occur in localized areas of the Santa Barbara Groundwater Basin. High concentrations of iron and manganese occur in localized areas of the Montecito Groundwater Basin. Localized areas with high nitrates occur within the Carpinteria Groundwater Basin. Other basins are in equilibrium due to management of the basin through conjunctive use by local water districts (Santa Barbara County 2007). The Goleta Groundwater Basin generally is near or above historical groundwater conditions (GWD and LCMWC 2010), with the northern and western portions of the basin having groundwater levels near the ground surface. High groundwater levels may result in degradation to building foundations and agricultural crops (water levels within the crop root zone).

The CASGEM program designated the Goleta Groundwater Basin as medium priority. Goleta, Foothill, Santa Barbara, Montecito, and Carpinteria Groundwater Basins were designated as very low priority. The final SGMA priority ranking lists the Foothill, Goleta, and Santa Barbara groundwater basins as very low priority. The SGMA priority for the Carpinteria and Montecito groundwater basins is still pending.

I.1.7.1.2 Groundwater Use and Management

Groundwater is an important source of water supply for the population of the Central Coast; it is the region’s primary water source.

Gilroy-Hollister Valley Groundwater Basin

In the Llagas subbasin, groundwater is withdrawn by local water suppliers and private well owners to meet municipal, domestic, agricultural, and industrial water needs (SCVWD 2016). Groundwater provides over 95% of the total water supply in Llagas Subbasin. Almost half of the pumping in Llagas subbasin is for agricultural use. The major pumpers in Llagas subbasin include Cities of Morgan Hill and Gilroy, private well users, private water companies, and golf courses.

SCVWD is responsible for groundwater management in the Llagas subbasin and operates a flexible conjunctive use program that uses a variety of surface water sources—local supplies, imported SWP and CVP supplies, and imported transfer options. SCVWD operates a system of in-stream and off-stream artificial recharge facilities to replenish the groundwater basin and provide more flexibility to manage water supplies. Artificial recharge in this subbasin occurs in two major recharge systems that release water in streambeds and off-stream managed basins. Both local reservoir water and imported water are used in the Upper Llagas recharge system, while the Lower Llagas system uses only local water. The amount of water artificially recharged throughout the entire service area depends upon the availability of local, CVP, and/or SWP surface water supplies. The subbasin is in long-term balance, with sustainable conditions.

Morro Valley and Chorro Valley Groundwater Basins

The City of Morro Bay uses groundwater from Morro Valley and Chorro Valley Groundwater Basins. These basins have been designated by the California State Water Resources Control Board (SWRCB) as riparian underflow basins. The City of Morro Bay and other users of these basins have received water rights permits, which limit the rate and volume of groundwater withdrawals (Morro Bay 2011).

Santa Maria River Valley Groundwater Basin

The Santa Maria River Valley Groundwater Basin is the primary water supply for irrigation in southwestern San Luis Obispo County and northwestern Santa Barbara County. Groundwater also is a major portion of the water supplies for the communities of Pismo Beach, Grover Beach, Arroyo Grande, Oceano, Nipomo, and several smaller communities in San Luis Obispo County and Guadalupe, Santa Maria, and Orcutt in Santa Barbara County (City of Grover Beach 2011). In many cases, groundwater is the total water supply for these communities, including Nipomo Community Services District (NCSD) (NCSD 2011).

The groundwater basin was adjudicated as defined by a settlement agreement, or stipulation, in 2005 that was filed in 2008. The stipulation defined the safe yield of the basin and measures to protect groundwater supplies (Pismo Beach 2011; Arroyo Grande 2012; NCSD 2011; Santa Maria 2011). The stipulation provided for the Northern Cities Management Area, Nipomo Mesa Management Area, and Santa Maria Valley Management Area. The groundwater adjudication considers groundwater recharge from precipitation and applied irrigation water and water released from Reclamation's Twitchell Reservoir and San Luis Obispo Flood Control and Water Conservation District's Lopez Reservoir that recharge the basin from the downstream streambeds.

The Cities of Pismo Beach, Grover Beach, and Arroyo Grande; Oceano Community Services District; San Luis Obispo County; and San Luis Obispo Flood Control and Water Conservation District have formed the Northern Cities Management Area to manage and protect groundwater supplies in accordance with the adjudication stipulation (Pismo Beach 2011; Arroyo Grande 2012; NCSD 2011). Historical monitoring reporting indicates that the groundwater levels have varied from 20 feet above to 20 feet below mean sea level. When groundwater levels are below mean sea level, there is a potential for seawater intrusion. In 2008, groundwater levels in this area were approximately 10 feet below mean sea level. In 2010, groundwater levels had recovered and ranged from 0 to 20 feet above mean sea level. Overdraft conditions occurred more frequently prior to the groundwater adjudication and completion of the Central Coast Water Authority project that provides SWP water supplies to the area. There is a deep aquifer under the City of Arroyo Grande (Pismo formation) that provides groundwater not addressed in the adjudicated Santa Maria Groundwater Basin.

Agricultural water users and the communities of Guadalupe, Orcutt, and Santa Maria use groundwater in the Santa Maria Valley Management Area of the Santa Maria Groundwater Basin (SMVMA 2012). Historically, groundwater was used to provide almost 50% of the water supply to the City of Santa Maria. Recently, groundwater supplies have become 10 to 20% of the total water supply to the city (Santa Maria 2011). Groundwater provides most of the water supplies in Orcutt (Golden State Water Company 2011b).

San Antonio Creek Valley Groundwater Basin

Groundwater is used for agricultural and domestic water supplies in the San Antonio Creek Valley Groundwater Basin, including the Los Alamos area (DWR 2004an, 2013e).

Santa Ynez River Valley Groundwater Basin

Groundwater is used for agricultural and domestic water supplies in the Santa Ynez River Valley Groundwater Basin. Groundwater is used by all agricultural water users and the communities of Buellton, Lompoc, Solvang, Mission Hills, Vandenberg Village, and Santa Ynez (DWR 2004ao, 2013e; Santa Barbara County 2007).

Goleta, Foothill, Santa Barbara, Montecito, and Carpinteria Groundwater Basins

Groundwater is used for agricultural and domestic water supplies in the Goleta, Foothill, Santa Barbara, Montecito, and Carpinteria Groundwater Basins within Santa Barbara County. GWD and LCMWC are the major communities that use groundwater in the Goleta Groundwater Basin (DWR 2004ai; GWD 2011; GWD and LCMWC 2010). This basin is operated under an adjudication settlement in 1989 and a voter-passed groundwater management plan. Historically, GWD provided up to 14% of the water supply by groundwater. GWD has increased use of surface water from Lake Cachuma and the SWP and decreased long-term average use of groundwater to about 5% of the total water supply.

Portions of the LCMWC and City of Santa Barbara use groundwater from the Foothill Groundwater Basin. The City of Santa Barbara also relies upon groundwater from the Santa Barbara Groundwater Basin. The City of Santa Barbara manages groundwater in accordance with the Pueblo water rights (Santa Barbara 2011).

Montecito Water District uses groundwater from the Montecito Groundwater Basin. Carpinteria Valley Water District uses groundwater from the Carpinteria Groundwater Basin (Carpinteria Valley WD 2011). Total groundwater pumping averages approximately 3,700 AFY.

I.1.8 Southern California Region

The Southern California Region includes portions of Ventura, Los Angeles, Orange, San Diego, Riverside, and San Bernardino Counties served by the SWP. The Southern California Region groundwater basins are as varied as the geology that occurs in different geographic portions of the region.

- Ventura County and northwestern Los Angeles County
- Central and southern Los Angeles County and Orange County

- Western San Diego County
- Western and central Riverside County and southern San Bernardino County
- Antelope Valley and Mojave Valley

I.1.8.1 *Western Ventura County and Northwestern Los Angeles County*

The areas within the SWP service area in Ventura County and northwestern Los Angeles County in the Southern California Region include the Acton Valley Groundwater Basin in Los Angeles County; Santa Clara River Valley, Thousand Oaks Area, and Russell Valley Groundwater Basins in Ventura and Los Angeles Counties; and Simi Valley, Las Posas Valley, Pleasant Valley, Arroyo Santa Rosa Valley, Tierre Rejada, and Conejo Valley Groundwater Basins in Ventura County.

I.1.8.1.1 Hydrogeology and Groundwater Conditions

Acton Valley Groundwater Basin

The Acton Valley Groundwater Basin is upgradient of the Santa Clara River Valley Groundwater Basin and drains toward the Santa Clara River. Water-bearing formations include unconsolidated alluvium of sand, gravel, silt, and clay with cobbles and boulders and poorly consolidated terraced deposits (DWR 2004ap, 2013f). Recharge occurs along the streambed, water applied to the soils, and subsurface inflow. Groundwater is characterized by calcium, magnesium, and sulfate bicarbonate, with localized areas of high concentrations of TDS, sulfate, nitrate, and chlorides.

The CASGEM program and SGMA designated the Acton Valley Groundwater Basin as very low priority.

Santa Clara River Valley Groundwater Basin

The Santa Clara River Valley Groundwater Basin is the source of local groundwater along the Santa Clara River watershed from the Santa Clarita Valley in northwestern Los Angeles County to the Pacific Ocean near the City of Oxnard in Ventura County. The Santa Clara River Valley Groundwater Basin includes the Piru, Fillmore, Santa Paula, Mound, and Oxnard subbasins in Ventura county and Santa Clara River Valley East Subbasin in Los Angeles County. Groundwater movement is affected by the occurrence of several fault zones (DWR 2004aq, 2004ar, 2006n, 2006o, 2006p, 2013f). Groundwater recharge occurs along the Santa Clara River and its tributaries and by percolation of precipitation and applied irrigation water.

The Santa Clara River Valley East subbasin is characterized by unconsolidated alluvium of sand, gravel, silt, and clay; poorly consolidated terrace deposits of gravel, sand, and silt; and the Saugus formation of poorly consolidated sandstone, siltstone, and conglomerate (DWR 2006n, 2013f).

The Piru, Fillmore, Santa Paula, Mound, and Oxnard subbasins are characterized by alluvium of silts and clays interbedded with sand and gravel lenses. The San Pedro formation includes fine sands and gravels over the alluvium (DWR 2004aq, 2004ar, 2006o, 2006p, 2006q, 2013f).

Groundwater levels throughout the Santa Clara River Valley Groundwater Basin showed declines of at least 10 feet between spring 2013 and spring 2018 (DWR 2019b). Similar changes were observed between fall 2012 and fall 2017.

Groundwater quality in the Santa Clara River Valley Groundwater Basin is suitable for a variety of beneficial uses. However, some areas have been impaired by elevated TDS, nitrate, and boron concentrations (DWR 2004aq, 2004ar, 2006o, 2006p, 2006q, 2013f; Castaic Lake Water Agency

[CLWA] et al. 2012). Groundwater quality is characterized by fluctuating salinity that increases during dry periods. Localized areas of high nitrates and organic compounds occur due to historic agricultural activities and wastewater disposal.

The CASGEM program designated Piru, Oxnard, and Santa Clara River Valley East subbasins as high priority. The Fillmore, Santa Paula, and Mound subbasins were designated as medium priority. Each of the subbasins in the Santa Clara River Valley Groundwater Basin have their final SGMA priorities pending, with the exception of the Santa Clara River Valley East subbasin, which is listed as a high priority.

Simi Valley Groundwater Basin

The Simi Valley Groundwater Basin is in Ventura County (DWR 2004at, 2013f). Water-bearing formations in this basin are characterized by generally unconfined alluvium of gravel, clays, and sands, with local clay lenses that provide confined aquifers. The Simi Fault confines the basin on the northern boundary. Groundwater recharge occurs along streambeds. Groundwater quality is characterized as calcium sulfate, with localized areas of high TDS and organic contaminants.

The Simi Valley Groundwater Basin was designated by the CASGEM program as low priority and by SGMA as very low priority.

Las Posas Valley and Pleasant Valley Groundwater Basins

The Las Posas Valley and Pleasant Valley Groundwater Basins are located in western Ventura County. Groundwater is found within these basins in thick alluvium that is dominated by sand and gravel in the eastern part of the Las Posas Valley Groundwater Basin and by silts and clays with lenses of sands and gravels in the western part of the Las Posas Valley Groundwater Basin and the Pleasant Valley Groundwater Basin (DWR 2006r, 2006s, 2013f). Underlying the alluvium are the San Pedro and Santa Barbara formations of gravels, sands, silts and clays with a discontinuous aquitard located within the Santa Barbara formation. The movement of groundwater is locally influenced by features such as faults, structural depressions and constrictions, and operating production wells; however, groundwater generally flows west-southwest toward the Oxnard subbasin. Hydrographs from the Las Posas Valley and Pleasant Valley Groundwater Basins have exhibited a variety of groundwater-level histories 2o to 30 years. Most hydrographs in the eastern part of the Las Posas Valley Groundwater Basin indicate relatively unchanged groundwater levels or a slight rise since 1994. Most hydrographs in the western Las Posas Valley and Pleasant Valley Groundwater Basins indicate that groundwater levels have risen to and been maintained at moderate levels since 1992.

Groundwater levels throughout the Las Posas Valley and Pleasant Valley Groundwater Basins showed declines of at least 10 feet between spring 2013 and spring 2018 (DWR 2019b), with decreases approaching 70 feet in some areas. Similar changes were observed between fall 2012 and fall 2017.

Groundwater quality in the Las Posas Valley and Pleasant Valley Groundwater Basins is suitable for a variety of beneficial uses. Moderate to high TDS concentrations occur in the Las Posas Valley Groundwater Basin and the Pleasant Valley Groundwater Basin (DWR 2006r, 2006s, 2013f).

The CASGEM program and SGMA designated Las Posas Valley and Pleasant Valley Groundwater Basins as high priority.

Arroyo Santa Rosa Valley Groundwater Basin

The Arroyo Santa Rosa Valley Groundwater Basin is in Ventura County. The water-bearing formations include alluvium of gravel, sand, and clay and the alluvial San Pedro formation of sand and gravel (DWR 2006t, 2013f). Groundwater recharge occurs along the Santa Clara River and its tributaries and by percolation of precipitation and applied irrigation water. Fault zones affect groundwater movement within the basin. Groundwater quality is adequate for community and agricultural water uses. Localized areas of high sulfate and nitrate concentrations occur within the basin.

The CASGEM program designated the Arroyo Santa Rosa Valley Groundwater Basin as medium priority. The final SGMA priority for this basin is pending.

Tierra Rejada Valley, Conejo Valley, and Thousand Oaks Area Groundwater Basins

The Tierra Rejada Valley, Conejo Valley, and Thousand Oaks Groundwater Basins in southern Ventura County are characterized by shallow alluvium that overlays marine sandstone and shale of the Modelo and Topanga formations (DWR 2004au, 2004av, 2004aw, 2013f). In some portions of the basin, the Topanga formation of volcanic tuff, debris flow, and basaltic flow occurs. Groundwater recharge occurs along the streambeds and by percolation of precipitation and applied irrigation water. Fault zones affect groundwater movement within the basins. Groundwater quality is adequate for community and agricultural water uses. Localized areas of high alkalinity and nitrate concentrations occur within the basins. High iron and TDS occur in the Thousand Oaks Area Groundwater Basin (Thousand Oaks 2011).

The CASGEM program designated the Conejo Valley Groundwater Basin as low priority. The Tierra Rejada Valley and Thousand Oaks Area Groundwater Basins were designated as very low priority. The three groundwater basins have a very low priority in the final SGMA listing.

Russell Valley Groundwater Basin

The Russell Valley Groundwater Basin is located along the boundaries of Ventura and Los Angeles counties (DWR 2004ax, 2013f). This small groundwater basin is characterized by unconsolidated, poorly bedded, sand, gravel, silt, and clay with cobbles and boulders. The groundwater is recharged by precipitation within the basin. Groundwater quality is characterized by sodium bicarbonate and calcium bicarbonate with high sulfates and TDS in some localized areas.

The CASGEM program and SGMA designated the Russell Valley Groundwater Basin as very low priority.

I.1.8.1.2 Groundwater Use and Management

Groundwater is an important water supply throughout the Southern California Region. Many of the basins have been adjudicated, and groundwater management agencies have been established to manage, preserve, and regulate groundwater withdrawals and recharge actions. In Ventura County, the Fox Canyon Groundwater Management Agency was established in 1982 to implement a groundwater plan that identifies withdrawal allocations and groundwater elevation and quality criteria (Metropolitan Water District of Southern California [MWDSC] 2007).

Acton Valley Groundwater Basin

The Acton community primarily uses groundwater supplemented by SWP water treated at the Antelope Valley East Kern Acton Water Treatment Plant (Los Angeles County 2014a).

Santa Clara River Valley Groundwater Basin

Communities and agricultural water users in the Santa Clara River Valley Groundwater Basin use a combination of surface water and groundwater to meet water demands. Agricultural use of groundwater is greater than community use of groundwater in this basin (United Water Conservation District [UWCD] 2012).

Four retail water purveyors provide water service to most residents of the Santa Clara River Valley East Subbasin. These water purveyors include the CLWA; Santa Clarita Water Division, Los Angeles County Waterworks District Number 36; Newhall County Water District; and Valencia Water Company. Groundwater is used by the communities of Santa Clarita, Saugus, Canyon Country, Newhall, Val Verde, Hasley Canyon, Valencia, Castaic, and Stevenson Ranch (CLWA et al. 2012).

Water purveyors in the Piru, Fillmore, Santa Paula, Mound, and Oxnard subbasins include UWCD and Ventura County. UWCD operates surface water facilities to encourage groundwater protection through conjunctive use (UWCD 2012). Groundwater issues within the UWCD service area (which includes all of the basin) include overdraft conditions, seawater intrusion, and high nitrate concentrations.

Simi Valley Groundwater Basin

The Simi Valley area primarily relies upon surface water supplies, including SWP water supplies. Groundwater is used to supplement these supplies and by users that cannot be easily served with surface water. Groundwater is provided by Golden State Water Company and Ventura County Waterworks District No. 8. The Golden State Water Company provides less than 10% of the total water supply to the area (Golden State Water Company 2011c). Ventura County Waterworks District No. 8 provides groundwater to a golf course, nursery, and industrial users in the Simi Valley area (Ventura County Waterworks District No. 8 2011).

Las Posas Valley and Pleasant Valley Groundwater Basins

Communities and agricultural water users in the Las Posas Valley and Pleasant Valley Groundwater Basins use a combination of surface water and groundwater to meet water demands. Agricultural use of groundwater is greater than community use of groundwater in this basin (UWCD 2012). United Water Conservation District and Ventura County manage water service to many residents of the Las Posas Valley and Pleasant Valley Groundwater Basins.

UWCD operates surface water facilities to encourage groundwater protection through conjunctive use (UWCD 2012). Groundwater is used within the UWCD service area, which includes western Las Posas Valley and Pleasant Valley Groundwater Basins. The Oxnard subbasin of the Santa Clara River Valley Groundwater Basin and Las Posas Valley and Pleasant Valley Groundwater Basins are within the groundwater management plan established by the Fox Canyon Groundwater Management Agency (Fox Canyon GMA 2013). Fox Canyon GMA manages and monitors groundwater in areas with groundwater overdraft and seawater intrusion, which includes the communities of Port Hueneme, Oxnard, Camarillo, and Moorpark. The long-term average groundwater use within Fox Canyon GMA includes a portion of the withdrawals reported by UWCD.

The Calleguas Municipal Water District (MWD), in partnership with MWDSC, operates the Las Posas Basin Aquifer Recharge and Recovery project. Calleguas MWD stores SWP surplus water in the Las Posas Valley Groundwater Basin, near the City of Moorpark. The current aquifer recharge and recovery system includes 18 wells (Calleguas MWD 2011).

Arroyo Santa Rosa Valley Groundwater Basin

Communities and agricultural water users in the Arroyo Santa Rosa Valley Groundwater Basin use a combination of surface water and groundwater to meet water demands. Camarosa Water District and Fox Canyon GMA manage groundwater supplies within the basin (Camarosa Water District 2013).

Tierra Rejada Valley, Conejo Valley, and Thousand Oaks Area Groundwater Basins

Groundwater in the Tierra Rejada Valley, Conejo Valley, and Thousand Oaks Area Groundwater Basins is primarily used by agricultural and individual residential water users. Portions of the Tierra Rejada Valley Groundwater Basin is within the Camarosa Water District; however, this area is primarily open space and provides agricultural land uses with individual wells (Camarosa Water District 2013). The City of Thousand Oaks operates two wells; however, the city primarily relies upon SWP water supplies because of the high iron concentrations and salinity in the groundwater (Thousand Oaks 2011).

Russell Valley Groundwater Basin

Most groundwater users in the Russell Valley Groundwater Basin are agricultural and individual residential water users. Portions of the basin are located within the Calleguas MWD. However, the district does not use water from this basin (Calleguas MWD 2011). The Las Virgenes MWD withdraws groundwater from the Russell Basin to augment recycled water supplies (Greater Los Angeles County Integrated Regional Water Management Region [GLCIRWMR] 2014).

I.1.8.2 *Western Los Angeles County and Orange County*

The areas within the SWP service area in Central and Southern Los Angeles County and Orange County in the Southern California Region include the San Fernando Valley, Raymond, San Gabriel Valley, Coastal Plain of Los Angeles, and Malibu Valley Groundwater Basins in Los Angeles County and Coastal Plain of Orange County and San Juan Valley Groundwater Basins in Orange County.

I.1.8.2.1 Hydrogeology and Groundwater Conditions

San Fernando Valley Groundwater Basin

The San Fernando Valley Groundwater Basin extends under the Los Angeles River watershed. Groundwater flows toward the middle of the basin, beneath the Los Angeles River Narrows, to the Central Subbasin of the Coastal Plain of Los Angeles Groundwater Basin. The water-bearing formation is mainly unconfined gravel and sand with clay lenses that provide some confinement in the western part of the basin (DWR 2004ay).

Groundwater movement is affected by the occurrence of several fault zones (DWR 2004ay). Groundwater is recharged naturally from precipitation and stream flow and from imported water and reclaimed wastewater that percolates into the groundwater from stormwater spreading grounds.

In the San Fernando Valley Groundwater Basin, the groundwater is characterized by calcium, magnesium, radioactive material, and sulfate bicarbonate, with localized areas of high TDS, volatile organic compounds, petroleum compounds, chloroform, pesticides, nitrate, and sulfate (DWR 2004ay; Upper Los Angeles River Area Watermaster [ULARAW] 2013). There are several ongoing groundwater remediation programs within the groundwater basin to reduce volatile organic compounds and one program to reduce hexavalent chromium.

The CASGEM program designated the San Fernando Valley Groundwater Basin as medium priority. The SGMA priority for this basin is very low.

Raymond Groundwater Basin

The Raymond Groundwater Basin is located to the north of the San Gabriel Valley Groundwater Basin. Groundwater flow is affected by the occurrence of several fault zones and causes the groundwater to flow into the San Gabriel Valley Groundwater Basin. The water-bearing formations are mainly unconsolidated gravel, sand, and silt, with local areas of confinement (DWR 2004az). Groundwater is recharged naturally from precipitation and stream flow and from water that percolates into the groundwater from spreading grounds and local dams.

In the Raymond Groundwater Basin, the groundwater is characterized by calcium, magnesium, and sulfate bicarbonate, with localized areas of high volatile organic compounds, nitrate, radioactive material, and perchlorate (DWR 2004az). There is an ongoing groundwater remediation program within the groundwater basin to reduce volatile organic compounds and perchlorate.

The CASGEM program designated the Raymond Groundwater Basin as medium priority. The SGMA priority for this basin is very low.

San Gabriel Valley Groundwater Basin

Groundwater in the San Gabriel Valley Groundwater Basin flows from the San Gabriel Mountains toward the west under the San Gabriel Valley to the Whittier Narrows where it discharges into the Coastal Plain of Los Angeles Groundwater Basin (DWR 2004ba). Groundwater in the San Gabriel Valley Groundwater Basin also is interconnected to groundwater in the Chino subbasin of the Upper Santa Ana Valley Groundwater Basin in Riverside County. The northeastern portion of the San Gabriel Valley Groundwater Basin adjacent to the Chino subbasin includes six subbasins and is known as Six Basins. Water-bearing formations include unconsolidated to semiconsolidated alluvium deposits of gravel, sands, and silts.

Groundwater recharge occurs from spreading basins and direct percolation of precipitation and stream flow, including treated wastewater effluent conveyed in the San Gabriel River (DWR 2004ba). In the San Gabriel Valley Groundwater Basin, the groundwater is characterized by calcium bicarbonate, with localized areas of high TDS, carbon tetrachloride nitrate, and volatile organic compounds (DWR 2004ba).

The CASGEM program designated the San Gabriel Valley Groundwater Basin as high priority. The SGMA priority for this basin is very low.

Coastal Plain of Los Angeles Groundwater Basin

The Coastal Plain of Los Angeles Groundwater Basin includes the Hollywood, Santa Monica, Central, and West Coast subbasins.

Hollywood Subbasin

The Hollywood subbasin is located to the north of the Central subbasin. Groundwater flows toward the Pacific Ocean (DWR 2004bb). The water-bearing formations are mainly alluvial gravel. Groundwater is recharged naturally from precipitation and stream flow.

The CASGEM program and SGMA designated the Hollywood subbasin as very low priority.

Santa Monica Subbasin

The Santa Monica subbasin is located to the north of the West Coast subbasin and to the west of the Hollywood subbasin. Groundwater flows toward the west and the Hollywood subbasin (DWR 2004bc). The water-bearing formations are mainly alluvial gravel and sand with semiperched areas over silt and clay deposits. Unconfined shallow aquifers occur in the northern and eastern portions of the subbasin. Confined deeper aquifers occur in the remaining portion of the subbasin. Groundwater is recharged naturally from precipitation and stream flow.

The CASGEM program designated the Santa Monica subbasin as high priority. The SGMA priority is medium.

Central Subbasin

The Central subbasin is located to the east of the West Coast subbasin. The Central subbasin is characterized by shallow sediments and extends from the Los Angeles River Narrows and Whittier Narrows, with groundwater flows from the San Gabriel Valley (DWR 2004bd).

The nonpressurized, or forebay, portions of the subbasin are located in the northern portion of the subbasin in unconfined aquifers underlying the Los Angeles and San Gabriel Rivers (DWR 2004bd). These areas provide the major recharge areas for the subbasin. The pressure areas are confined aquifers composed of permeable sands and gravel separated by less permeable sandy clay and clay and constitute the main water-bearing formations. Several faults and uplifts create some restrictions to groundwater flow in the subbasin while others run parallel to the groundwater flow and do not restrict flow.

In the Central subbasin, the groundwater is characterized by localized areas of high inorganics and volatile organic compounds (DWR 2004bd).

The CASGEM program designated the Central subbasin as high priority. The SGMA priority for this basin is very low.

West Coast Subbasin

The West Coast subbasin is located on the southern coast of Los Angeles County to the west of the Central subbasin. The water-bearing formations are composed of unconfined and semiconfined aquifers composed of sands, silts, clays, and gravels (DWR 2004be). Several fault zones paralleling the coast act as partial barriers to groundwater flow in certain areas. The general regional groundwater flow pattern is southward and westward toward the Pacific Ocean. Recharge occurs through groundwater flow from the Central subbasin and from infiltration along the Los Angeles and San Gabriel Rivers. Seawater intrusion occurs along the Pacific Ocean coast.

In the West Coast subbasin, the most critical issue is high TDS along the Pacific Ocean coast due to seawater intrusion. Several agencies have implemented seawater barrier projects to protect the groundwater quality.

The CASGEM program designated the West Coast subbasin as high priority. The SGMA priority for this basin is very low.

Malibu Valley Groundwater Basin

The Malibu Valley Groundwater Basin is an isolated alluvial basin in northern Los Angeles County along the Pacific Ocean Coast under the Malibu Creek watershed (DWR 2004bf). Groundwater flows toward the Pacific Ocean. The water-bearing formations are mainly gravel, sand, clays, and silt (DWR 2004az). Groundwater is recharged naturally from precipitation and stream flow.

In the Malibu Valley Groundwater Basin, the groundwater is characterized by localized areas of high TDS due to seawater intrusion along the Pacific Ocean coast (DWR 2004bf).

The CASGEM program and SGMA designated the Malibu Valley Groundwater Basin as very low priority.

Coastal Plain of Orange County Groundwater Basin

The Coastal Plain of Orange County Groundwater Basin is under a coastal alluvial plain in northern Orange County (DWR 2004bg). Groundwater is recharged naturally from precipitation and injection wells to reduce seawater intrusion. The water-bearing formations are mainly interbedded marine and continental sand, silt, and clay deposits (DWR 2004bi). The Newport-Inglewood fault zone parallels the coast and generally forms a barrier to groundwater flow. Groundwater recharge occurs along the Santa Ana River. Water levels are characterized by seasonal fluctuations (DWR 2013f; Orange County 2009). Groundwater flowed toward the Pacific Ocean prior to recent development. However, due to extensive groundwater withdrawals, there are groundwater depressions that result in potential seawater intrusion. Groundwater levels have increased since the 1990s, following implementation of several recharge programs.

In the Coastal Plain of Orange County Groundwater Basin, the groundwater is characterized as sodium-calcium bicarbonate, with localized areas of high TDS due to seawater intrusion along the Pacific Ocean coast, nitrate, and volatile organic compounds (DWR 2004bg).

The CASGEM program and SGMA designated the Coastal Plain of Orange County Groundwater Basin as medium priority.

San Juan Valley Groundwater Basin

The San Juan Valley Groundwater Basin is in southern Orange County (DWR 2004bh). Groundwater flows toward the Pacific Ocean. The water-bearing formations are mainly sand, clays, and silt. Groundwater is recharged naturally from precipitation and stream flows from San Juan and Oso Creeks and Arroyo Trabuca.

In the San Juan Valley Groundwater Basin, the groundwater is characterized as calcium bicarbonate, bicarbonate-sulfate, calcium-sodium sulfate, and sulfate-chloride, with localized areas of high TDS due to seawater intrusion along the Pacific Ocean coast and high fluoride near hot springs near Thermal Canyon (DWR 2004bh).

The CASGEM program designated the San Juan Valley Groundwater Basin as low priority. The SGMA priority is very low.

I.1.8.2.2 Groundwater Use and Management

Groundwater is an important water supply throughout the Southern California Region. Many of the groundwater basins in Los Angeles and Orange Counties have been adjudicated, and groundwater management agencies have been established to manage, preserve, and regulate groundwater withdrawals and recharge actions.

San Fernando Valley Groundwater Basin

The communities and agricultural users in the San Fernando Valley Groundwater Basin use a combination of surface water and groundwater to meet water demands (GLCIRWMR 2014; ULARAW 2013). MWDSC provides wholesale surface water supplies to several communities. The Cities of Los Angeles, Glendale, Burbank, San Fernando, Crescenta Valley, Bell Canyon, and Hidden Hills provide retail water supplies, including groundwater, to the communities. The groundwater basin has been adjudicated and is managed by the ULARAW.

Groundwater is recharged in the San Fernando Valley Groundwater Basin through seepage of precipitation within the groundwater basin, including the recharge of stormwater at spreading grounds between 1968 and 2012, and storage of imported water (ULARAW 2013). The spreading basins for stormwater flows are operated by Los Angeles County and the Cities of Los Angeles and Burbank. A portion of the extracted groundwater is exported to areas that overlie other groundwater basins.

The operations of the San Fernando Valley Groundwater Basin are defined by the Upper Los Angeles River Area January 26, 1979 Final Judgment; the Sylmar Basin Stipulations of August 26, 1983; and subsequent agreements. These agreements, as managed by the ULARAW, provide for the right to extract a portion of surface water, including applied recycled water, that enters specified subbasins of the San Fernando Valley Groundwater Basin, with specific calculations to identify maximum withdrawals for the Cities of Burbank, Glendale, Los Angeles, and San Fernando and Crescenta Valley Water District. The agreements also provide the right to store and withdraw water within specified subbasins by the Cities of Burbank, Glendale, Los Angeles, and San Fernando and acknowledgment that the City of Los Angeles has an exclusive Pueblo water right for the native safe yield of the San Fernando subbasin within the larger San Fernando Valley Groundwater Basin.

Raymond Groundwater Basin

The communities in the Raymond Groundwater Basin use a combination of surface water and groundwater to meet water demands (GLCIRWMR 2014). The MWDSC and Foothills Municipal Water District provide wholesale surface water supplies to several communities. The Cities of Alhambra, Arcadia, Pasadena, San Marino, and Sierra Madre; Upper San Gabriel Municipal Water District; and Valley Water Company and several other private water companies provide retail water supplies, including groundwater, to the communities of Altadena, La Crescenta-Montrose, La Cañada Flintridge, Rubio Canyon, and South Pasadena. The City of Alhambra and San Gabriel Valley Municipal Water District can withdraw groundwater from the Raymond Basin but currently are not operating wells within this groundwater basin (City of Alhambra 2011).

The groundwater basin was the first adjudicated groundwater basin in California and is managed by the Raymond Basin Management Board (RBMB) as the watermaster (RBMB 2014). RBMB limits the amount of groundwater withdrawals in different areas of the basin and allows for short- and long-term storage of water in the groundwater basin.

Groundwater is recharged in the Raymond Groundwater Basin through seepage of precipitation within the groundwater basin, injection wells, and spreading basins operated by Los Angeles County and the Cities of Pasadena and Sierra Madre (MWDSC 2007). Water from MWDSC, which is generally a combination of SWP water and Colorado River water, cannot be used for direct recharge if the TDS is greater than 450 milligrams/liter (RBMB 2014). A portion of the extracted groundwater is exported to areas that overlie other groundwater basins.

San Gabriel Valley Groundwater Basin

The communities in the San Gabriel Valley Groundwater Basin use a combination of surface water and groundwater to meet water demands (GLCIRWMR 2014; MWDSC 2007). MWDSC, San Gabriel Valley Municipal Water District, Upper San Gabriel Municipal Water District; Three Valleys Municipal Water District, and Covina Irrigating Company provide wholesale surface water and/or groundwater supplies to several communities. The Cities of Alhambra, Arcadia, Azusa, Covina, El Monte, Glendora, La Verne, Monrovia, Pomona, San Marino, and Upland; San Gabriel County Water District and Valley County Water District; and private water companies such as Golden State Water Company, San Antonio Water Company (SAWC), San Gabriel Valley Water Company, Suburban Water Systems, Valencia Heights Water Company, and others provide retail water supplies, including groundwater, to users within their communities. Additionally, they provide retail water supplies, including groundwater, to the communities of Baldwin Park, Bradbury, Claremont, Duarte, Hacienda Heights, Irwindale, La Puente, Montebello, Monterey Park, Pico Rivera, Rosemead, San Dimas, San Gabriel, Santa Fe Springs, Sierra Madre, South El Monte, South San Gabriel, Temple City, Valinda, and Whittier (City of Alhambra 2011; City of Arcadia 2011; City of La Verne 2011; City of Pomona 2011; City of Upland 2011; Golden State Water Company 2011d; San Gabriel County Water District 2011; San Gabriel Valley Water Company [SGVWC] 2011; Suburban Water Systems 2011; SAWC 2011; Three Valleys Municipal Water District 2011; Upper San Gabriel Valley Municipal Water District 2011).

The San Gabriel Valley Groundwater Basin includes several adjudicated basins. A portion of the groundwater basin is managed by the San Gabriel River Watermaster and the Main San Gabriel Basin Watermaster (MWDSC 2007; SGVWC 2011). The Watermasters coordinate groundwater elevation and water quality monitoring, coordinate imported water supplies, coordinate recharge operations with imported water and recycled water, manage the amount of groundwater withdrawals in different areas of the basin by balancing the amount of groundwater recharge, and allow for short- and long-term storage of water in the groundwater basin. Groundwater is recharged through seepage of precipitation within the groundwater basin, injection wells, and spreading basins operated by Los Angeles County and a private water company (MWDSC 2007). Water recharged into the spreading basins is from MWDSC and San Gabriel Valley Municipal Water District.

The Six Basins portion of the groundwater basin also is adjudicated and managed by the Six Basins Watermaster Board (MWDSC 2007). The Watermaster manages withdrawals and requires replenishment obligation of equal amounts for withdrawals over the operating safe yield of the basin. The Pomona Valley Protective Agency conveys flows from San Antonio Creek and SWP water to the San Antonio Spreading Grounds and from local waters to the Thompson Creek Spreading Grounds. The City of Pomona conveys flows from local surface waters to the Pomona Spreading Grounds. Los Angeles County Department of Public Works conveys flows from local surface water and SWP water to the Live Oak Spreading Grounds.

The Cities of Alhambra, Arcadia, La Verne, Monterey Park, San Gabriel Valley Water Company, and other water entities operate groundwater treatment facilities to remove dichloroethane, chloroform, other volatile organic compounds, and/or nitrates (City of Alhambra 2011; City of Arcadia 2011; City of Monterey Park 2012; MWDSC 2007; SGVWC 2011).

Coastal Plain of Los Angeles Groundwater Basin

The Coastal Plain of Los Angeles Groundwater Basin includes four subbasins: Hollywood, Santa Monica, Central, and West Coast.

Hollywood Subbasin

The primary user of groundwater in the Hollywood subbasin is the City of Beverly Hills (MWDSC 2007). The basin is not adjudicated. The city manages the groundwater subbasin through limits on withdrawals and discharges to the groundwater. Groundwater is recharged through seepage of precipitation within the groundwater subbasin (City of Beverly Hills 2011). All groundwater withdrawn by the city is treated to reduce salinity.

Santa Monica Subbasin

The primary user of groundwater in the Santa Monica subbasin is the City of Santa Monica (MWDSC 2007). The basin is not adjudicated. Groundwater is recharged through seepage of precipitation within the groundwater subbasin (City of Santa Monica 2011; MWDSC 2007). Groundwater treatment is provided to a portion of the subbasin withdrawals to reduce volatile organic compounds and methyl tertiary butyl ether (MTBE).

Central Subbasin

The communities in the Central subbasin use a combination of surface water and groundwater to meet water demands (GLCIRWMR 2014; MWDSC 2007). MWDSC and Central Basin Municipal Water District provide wholesale surface water supplies to several communities. The Cities of Bell, Bell Gardens, Cerritos, Compton, Cudahy, Downey, Huntington Park, Lakewood, Long Beach, Los Angeles, Lynwood, Monterey Park, Norwalk, Paramount, Pico Rivera, Santa Fe Springs, Signal Hill, South Gate, Vernon, and Whittier; Los Angeles County Water District, La Habra Heights County Water District, Orchard Dale Water District, and Paramount Water District; and private water companies such as Golden State Water Company, Suburban Water Systems, Bellflower-Somerset Mutual Water Company, Montebello Land & Water Company, Park Water Company, Dominguez Water Corp, California Water Service Company, San Gabriel Valley Water Company, Walnut Park Mutual Water Company, and others provide retail water supplies, including groundwater, to users within their communities. Additionally, they provide retail water supplies, including groundwater, to the communities of Artesia, Commerce, Dominguez, East La Mirada, East Los Angeles, East Rancho, Florence-Graham, Hawaiian Gardens, La Mirada, Los Nieto, Maywood, Montebello, South Whittier, Walnut Park, Westmount, West Whittier, and Willow Brook (Central Basin Municipal Water District [CBMWD] 2011; Bellflower-Somerset Mutual Water Company 2011; City of Compton 2011; City of Downey 2012; City of Huntington Park 2011; City of Lakewood 2011; City of Long Beach 2011; City of Los Angeles 2011; City of Monterey Park 2012; City of Norwalk 2011; City of Paramount 2011; City of Pico Rivera 2011; City of Santa Fe Springs 2011; City of South Gate; City of Vernon 2011; City of Whittier 2011; La Habra Heights County Water District 2012; Golden State Water Company 2011e, 2011f, 2011g, 2011h; Suburban Water Systems 2011).

The Central subbasin was adjudicated and is managed by DWR. The adjudication specifies a total amount of allowed annual withdrawals (or Allowable Pumping Allocation) in the Central subbasin (MWDSC 2007; Water Replenishment District of Southern California [WRD] 2013a). Approximately 25% of the water users of groundwater from the Central subbasin are not located on the land that overlies the subbasin (CBMWD 2011). Groundwater from the San Gabriel Valley Groundwater Basin also is used by water users that overlie the Central subbasin.

WRD of Southern California has the statutory authority to replenish the groundwater in the Central and West Coast subbasins of the Coastal Plain of Los Angeles Groundwater Basin. WRD of Southern California purchases water for water replenishment facilities operated by Los Angeles County Department of Public Works at the Montebello Forebay near the Rio Hondo and San Gabriel Rivers near the boundaries of the Central and West Coast subbasins (CBMWD 2011; Los Angeles County 2015; WRD 2013a). The Montebello Forebay includes the Rio Hondo Coastal Basin Spreading Grounds along the Rio Hondo Channel, the San Gabriel River Coastal Basin Spreading Grounds, and the unlined reach of the lower San Gabriel River from Whittier Narrows Dam to Florence Avenue (WRD 2013a).

The replenishment water is purchased water from two sources: recycled water from various regional treatment facilities and imported water (WRD 2013a). The recycled water is used for groundwater recharge at the spreading grounds and at the seawater barrier wells. WRD of Southern California must blend recycled water with other water sources to meet the groundwater recharge water quality and volumetric requirements established by the SWRCB. This blended water is either imported water from the SWP and/or the Colorado River or untreated surface water flows from the San Gabriel River, Rio Hondo River, and waterways in the San Gabriel Valley (CBMWD 2011). Up to 35% of the replenishment water can be provided from recycled water supplies. Several recent projects have been implemented to store stormwater flows for increased replenishment water volumes.

In the Central subbasin, WRD of Southern California also purchases imported and recycled water for injection by the Los Angeles County Department of Public Works into the portion of the Alamitos Barrier Project located in Los Angeles County to reduce seawater intrusion (MWDSC 2007; WRD 2007). Initially, imported SWP water was used to prevent seawater intrusion. However, over the past 20 years, recycled water has been used for a substantial amount of the groundwater injection program. WRD of Southern California is planning to fully use recycled water at the Alamitos Gap Barrier Project by 2014 (WRD 2013b).

The Cities of Long Beach, Monterey Park, South Gate, and Whittier operate groundwater treatment facilities in the Central subbasin (City of Long Beach 2012; City of Monterey Park 2012; City of South Gate; City of Whittier 2011).

<u>West Coast Subbasin</u>

The communities in the West Coast subbasin use a combination of surface water and groundwater to meet water demands (GLCIRWMR 2014; MWDSC 2007). MWDSC and West Basin Municipal Water District (WBMWD) provide wholesale surface water supplies to several communities. The Cities of Inglewood, Lomita, Manhattan Beach, and Torrance and private water companies such as Golden State Water Company, California Water Service Company, and others provide retail water supplies, including groundwater, to users within their communities and to the communities of Athens, Carson, Compton, Del Aire, Gardena, Hawthorne, Hermosa Beach, Inglewood, Lawndale, Lennox, Redondo Beach, and Torrance (WBMWD 2011; City of Inglewood 2011; City of Lomita 2011; City of Manhattan Beach 2011; City of Torrance 2011; Golden State Water 2011i; California Water Service Company 2011c, 2011d, 2011e, 2011f). The communities of El Segundo, Long Beach, and Los Angeles overlie the West Coast subbasin; however, no groundwater from this subbasin is used in these communities due to water quality issues and facilities locations. Groundwater use is primarily for emergency uses, including firefighting, in the communities of Hawthorne, Lomita, and Torrance because of high concentrations of minerals (e.g., iron and manganese), sulfides, and/or volatile organic compounds.

The West Coast subbasin was adjudicated and is managed by DWR. The adjudication specifies a total amount of allowed annual withdrawals (or Allowable Pumping Allocation) in the West Coast subbasin

(MWDSC 2007; WBMWD 2011; WRD 2013a). Groundwater from the Central subbasin is used by some water users that overlie the West Coast subbasin.

WRD of Southern California has the statutory authority to replenish the groundwater in the Central and West Coast subbasins of the Coastal Plain of Los Angeles Groundwater Basin. In the West Coast subbasin, WRD of Southern California purchases imported and recycled water for injection by the Los Angeles County Department of Public Works into the West Coast Barrier Project and the Dominguez Barrier Project (MWDSC 2007; WRD 2007; WRD 2013b). Water is purchased WRD of Southern California for injection at the barrier projects (WRD 2013b). Initially, imported SWP water was used to prevent seawater intrusion. However, over the past 20 years, recycled water has been used for a substantial amount of the groundwater injection program. WRD of Southern California is planning to fully use recycled water at the West Coast Barrier Project and the Dominguez Barrier Project by 2014 and 2017, respectively (WRD 2013b).

California Water Service Company operates groundwater treatment facilities within the community of Hawthorne (California Water Service Company 2011c). WRD of Southern California operates the Robert W. Goldsworthy Desalter near Torrance to reduce salinity for up to 18,000 AFY of groundwater located inland of the West Coast Basin Barrier (WRD 2013a).

The WBMWD treats brackish groundwater at the C. Marvin Brewer Desalter Facility for two wells near Torrance that are affected by a saltwater plume in the West Coast subbasin (WBMWD 2011).

Malibu Valley Groundwater Basin

No groundwater is used by the communities in this groundwater basin, including the Malibu area (Los Angeles County 2011; MWDSC 2007).

Coastal Plain of Orange County Groundwater Basin

The communities in the Coastal Plain of Orange County Groundwater Basin use a combination of surface water and groundwater to meet water demands (MWDSC 2007). The Municipal Water District of Orange County, Orange County Water District (OCWD), and East Orange County Water District provide wholesale surface water supplies to several communities. The Cities of Anaheim, Buena Park, Fountain Valley, Fullerton, Garden Grove, Huntington Beach, La Habra, La Palma, Newport Beach, Orange, Santa Ana, Seal Beach, Tustin, and Westminster; East Orange County Water District, Irvine Ranch Water District, Mesa Consolidated Water District, Rowland Water District, Serrano Water District, Walnut Valley Water District, and Yorba Linda Water District; and private water companies such as Golden State Water Company, California Water Service Company, California Domestic Water Company, and others provide retail water supplies, including groundwater, to users within their communities and to the communities of Brea, Costa Mesa, Cypress, Diamond Bar, Garden Grove, Hacienda Heights, Industry, Irvine, La Palma, La Puente, Los Alamitos, Midway City, Newport Beach, Orange, Panorama Heights, Placentia, Pomona, Rowland Heights, Rossmoor, Seal Beach, Stanton, Villa Park, Walnut, West Covina, West Orange, and Yorba Linda (City of Anaheim 2011; City of Brea 2011; City of Buena Park 2011; City of Fountain Valley 2011; City of Fullerton 2011; City of Garden Grove 2011; City of Huntington Beach 2011; City of La Habra 2011; City of La Palma 2011; City of Newport Beach 2011; City of Orange 2011; City of Santa Ana 2011; City of Seal Beach 2011; City of Tustin 2011; City of Westminster 2011; Irvine Ranch Water District 2011; Mesa Consolidated Water District 2011; Rowland Water District 2011; Serrano Water District 2011; Walnut Valley Water District 2011; Yorba Linda Water District 2011; Golden State Water Company 2011i, 2011j). Groundwater use is primarily for nonpotable water uses in West Covina and for supplemental supplies for users of recycled water in Rowland Heights.

The Coastal Plain of Orange County Groundwater Basin is managed by OCWD in accordance with special State legislation to increase supply and provide uniform costs for groundwater (MWDSC 2007). The basin is managed to maintain a water balance over several years using two-step pricing levels to incentivize users to obtain alternative water supplies after withdrawing a basin production target. The groundwater basin is managed to provide approximately a 3-year drought supply.

OCWD manages an extensive groundwater recharge program in the Coastal Plain of Orange County Basin (OCWD 2014). OCWD manages spreading basins along the Santa Ana River and Santiago Creek for groundwater recharge (MWDSC 2007). Water is supplied to these basins with flows diverted from the Santa Ana River into the recharge basins at inflatable rubber dams, SWP water, and recycled water from the OCWD/Orange County Sanitation District Groundwater Replenishment System Advanced Water Purification Facility (OCWD n.d.).

OCWD also injects water into the Talbert Barrier and the portion of the Alamitos Barrier Project within Orange County. Water supplies for the seawater barriers include water from the Groundwater Replenishment System and SWP water (OCWD n.d.; MWDSC 2007).

The Irvine Desalter Project was initiated in 2007 by OCWD, Irvine Ranch Water District, Metropolitan Water District of Orange County, MWDSC, and the U.S. Navy to reduce TDS and salts (Irvine Ranch Water District 2011; MWDSC 2007). Several other treatment facilities remove volatile organic compounds. The city of Tustin operates the Tustin Seventeenth Street Desalter to reduce TDS within the Tustin community (MWDSC 2007). The City of Garden Grove and Mesa County Water District operate treatment facilities to reduce nitrates and compounds that change the color of the water, respectively (City of Garden Grove 2011; Mesa Consolidated Water District 2011).

San Juan Valley Groundwater Basin

The communities in the San Juan Groundwater Basin use a combination of surface water and groundwater to meet water demands (MWDSC 2007). The Municipal Water District of Orange County provides wholesale surface water supplies to several communities. The City of San Juan Capistrano; Moulton Niguel Water District (MNWD), Santa Margarita Water District (SMWD), and South Coast Water District (SCWD) provide retail water supplies to users within their communities and to the communities of Coto de Caza, Dana Point, Laguna Forest, Laguna Woods, Las Flores, Ladera Ranch, Mission Viejo, Rancho Santa Margarita, South Laguna, Talega, (City of San Juan Capistrano 2011; MNWD 2011; SCWD 2011; SMWD 2011). Most of the groundwater use occurs within or near the City of San Juan Capistrano. Groundwater use is small or does not occur within the SMWD, SCWD, and MNWD service areas.

The San Juan Basin Authority manages water resources development in the San Juan Valley Groundwater Basin and in the surrounding San Juan watershed to protect water quality and water resources (MWDSC 2007; San Juan Basin Authority 2013). In addition to community uses, groundwater is used for agricultural and industrial purposes and golf course irrigation. Overall, groundwater provides less than 10% of the total water supply within the groundwater basin.

The City of San Juan Capistrano Groundwater Recovery Plant reduces iron, manganese, and TDS concentrations. This city is modifying the treatment plant to reduce recently observed high concentrations of MTBE (City of San Juan Capistrano 2011; MWDSC 2007). The South Coast Water District operates the Capistrano Beach Groundwater Recovery Facility in Dana Point to reduce iron and manganese concentrations (SCWD 2011; MWDSC 2007).

I.1.8.3 *Western San Diego County*

The areas within the SWP service area in western San Diego County in the Southern California Region include the San Mateo Valley Groundwater Basin in Orange and San Diego Counties and the San Onofre Valley, Santa Margarita Valley, San Luis Rey Valley, Escondido Valley, San Marcos Area, Batiquitos Lagoon Valley, San Elijo Valley, San Dieguito Creek, Poway Valley, San Diego River Valley, El Cajon Valley, Mission Valley, Sweetwater Valley, Otay Valley, Tijuana Basin Groundwater Basins in San Diego County.

I.1.8.3.1 Hydrogeology and Groundwater Conditions

In San Diego County, several smaller groundwater basins exist, in the western portion of the county. The most productive groundwater basins are characterized by narrow river valleys filled with shallow sand and gravel deposits. Groundwater occurs farther inland in fractured bedrock and semiconsolidated sedimentary deposits with limited yield and storage (San Diego County Water Authority [SDCWA] et al. 2013).

San Mateo Valley, San Onofre Valley, and Santa Margarita Valley Groundwater Basins

The San Mateo Valley Groundwater Basin is in southern Orange County and northern San Diego County (DWR 2004bi). The San Onofre Valley and Santa Margarita Valley Groundwater Basins are located in northwestern San Diego County (DWR 2004bj, 2004bk). Groundwater flows toward the Pacific Ocean. The water-bearing formations are mainly gravel, sand, clays, and silt. Groundwater is recharged naturally from precipitation and stream flows. In the San Mateo Valley and San Onofre Valley Groundwater Basins, treated wastewater effluent discharged from the Marine Corps Base Camp Pendleton wastewater treatment plants into local streams also recharges the groundwater. In the San Mateo Valley and Santa Margarita Valley Groundwater Basins, the groundwater is characterized as calcium-sulfate-chloride. In the San Onofre Valley Groundwater Basin, the groundwater is characterized as calcium-sodium bicarbonate-sulfate. Localized areas with high boron, chloride, magnesium, nitrate, sulfate, and TDS occur in the Santa Margarita Valley Groundwater Basin.

The CASGEM program designated the Santa Margarita Valley Groundwater Basin as medium priority. San Mateo Valley and San Onofre Valley Groundwater Basins were designated as very low priority. All three basins are listed as low priority by SGMA.

San Luis Rey Valley Groundwater Basin

The San Luis Rey Valley Groundwater Basin is in northwestern San Diego County (DWR 2004bl). Groundwater flows toward the Pacific Ocean. The water-bearing formations are mainly gravel and sand. Under some portions of the alluvial aquifer, partially consolidated marine terrace deposits of partly consolidated sandstone, mudstone, siltstone, and shale occur. Groundwater is recharged naturally from precipitation and stream flows and from runoff that flows into the streams from lands irrigated with SWP water. The groundwater is characterized as calcium-sodium bicarbonate-sulfate, with localized areas of high magnesium, nitrate, and TDS (MWDSC 2007).

The CASGEM program designated the San Luis Rey Valley Groundwater Basin as medium priority. The SGMA priority for this basis in pending.

San Marcos Valley, Escondido Valley, San Pasqual Valley, Pamo Valley, Santa Maria Valley, and Poway Valley Groundwater Basins

The San Marcos Valley, Escondido Valley, San Pasqual Valley, Pamo Valley, Santa Maria Valley, and Poway Valley Groundwater Basins are located in the foothills within central, western San Diego County. The water-bearing formations are mainly alluvium of sand, gravel, clay, and silt; consolidated sandstone; or weathered crystalline basement rock (DWR 2004bm, 2004bn, 2004bo, 2004bp, 2004bq, 2004br). The basins area is bounded by semipermeable marine and nonmarine deposits and impermeable granitic and metamorphic rocks. Groundwater is recharged naturally from precipitation and stream flows and from runoff that flows into the streams from irrigated lands. The groundwater is characterized with moderate to high concentrations of salinity. There are localized areas with high sulfate and nitrate concentrations in the Santa Maria Valley Groundwater Basin.

The CASGEM program designated the San Pasqual Valley Groundwater Basin as medium priority. San Marcos Valley, Escondido Valley, Pamo Valley, Santa Maria, and Poway Valley Groundwater Basins were designated as very low priority.

Batiquitos Lagoon Valley, San Elijo Valley, and San Dieguito Valley Groundwater Basins

The Batiquitos Lagoon Valley, San Elijo Valley, and San Dieguito Valley Groundwater Basins are located along the central San Diego County coast of the Pacific Ocean. The water-bearing formations are mainly alluvium of sand, gravel, clay, and silt with areas of consolidated sandstone (DWR 2004bs, 2004bt, 2004bu). Some areas of the Batiquitos Lagoon Valley Groundwater Basin are bounded by impermeable crystalline rock. Groundwater is recharged naturally from precipitation and stream flows, and from runoff that flows into the streams from irrigated lands. The groundwater is characterized with moderate to high concentrations of salinity.

The CASGEM program and SGMA designated Batiquitos Valley, San Elijo Valley, and San Dieguito Valley Groundwater Basins as very low priority.

San Diego River Valley, El Cajon, Mission Valley, Sweetwater Valley, Otay Valley, and Tijuana Groundwater Basins

The San Diego River Valley, El Cajon, Mission Valley, Sweetwater Valley, Otay Valley, and Tijuana Groundwater Basins are located in the southwestern portion of San Diego County. The water-bearing formations are mainly alluvium of sand, gravel, cobble, clay, and silt or siltstone and sandstone (DWR 2004bv, 2004bw, 2004bx, 2004by, 2004bz, 2004ca). Groundwater is recharged naturally from precipitation and stream flows and from runoff that flows into the streams from irrigated lands. The groundwater is characterized with moderate to high levels of salinity. A recent USGS study evaluated the sources and movement of saline groundwater in these groundwater basins (USGS 2013a). The chloride concentrations ranged from 57 to 39,400 milligrams per liter. The sources of salinity were natural geologic sources and seawater intrusion. There are localized areas with high sulfate and magnesium concentrations.

SGMA designated the San Diego River Valley Groundwater Basin as medium priority. El Cajon, Mission Valley, Sweetwater Valley, Otay Valley, and Tijuana Groundwater Basins were designated as very low priority.

I.1.8.3.2 Groundwater Use and Management

Groundwater production and use in the San Diego region is currently limited due to a lack of aquifer storage capacity, available recharge, and degraded water quality because of high salinity. Groundwater currently represents about 3% of the water supply portfolio within the areas of San Diego County that could be served by SWP water (SDCWA et al. 2013).

San Mateo Valley, San Onofre Valley, and Santa Margarita Valley Groundwater Basins

The primary user of groundwater in the San Mateo Valley, San Onofre Valley, and Santa Margarita Valley Groundwater Basins is the Marine Corps Base Camp Pendleton (Fallbrook Public Utility District [FPUD] 2011; MWDSC 2007; SCWD 2011; SDCWA et al. 2013). The Marine Corps Base Camp Pendleton withdraws approximately 8,500 AFY from the three groundwater basins and operates spreading basins to recharge the groundwater in the Santa Margarita Valley Groundwater Basin. Portions of the SCWD overlie the northern portions of the San Mateo Valley Groundwater Basin; however, the district does not withdraw water from that basin. FPUD overlies northern portions of the Santa Margarita Valley Groundwater Basin; however, the district currently uses a small amount of groundwater to meet their water demand (FPUD 2011).

The Santa Margarita Valley Groundwater Basin is within an adjudicated watershed (Santa Margarita River Watershed Watermaster 2011). The Santa Margarita River Watermaster manages both surface water and groundwater that contributes direct or indirect flows into the Santa Margarita River in accordance with the Modified Final Judgment and Decrees of 1966 by the U.S. District Court in the *United States v. Fallbrook Public Utility et al*. The watershed includes the Santa Margarita Valley Groundwater Basin near the Pacific Ocean and the Temecula Valley Groundwater Basins in the upper Santa Margarita River Watershed within Riverside County as discussed in the following subsection. Within San Diego County, the only groundwater user in the Santa Margarita Valley Groundwater Basin is the Marine Corps Base Camp Pendleton.

San Luis Rey Valley Groundwater Basin

The communities in the San Luis Rey Valley Groundwater Basin use a combination of surface water and groundwater to meet water demands (City of Oceanside 2011; MWDSC 2007; Rainbow Municipal Water District (RMWD) 2011; Valley Center Municipal Water District [VCMWD] 2011; Yuima Municipal Water District 2014a, 2014b). SDCWA provides wholesale surface water supplies to several communities. The City of Oceanside; RMWD, VCMWD, and Yuima Municipal Water District; and Rancho Pauma Mutual Water Company and other private water companies provide retail water supplies to users within their communities. Groundwater use is small or does not occur within the RMWD or VCMWD. Groundwater also is used on agricultural lands, especially for orchards in the Pauma area (San Diego County 2010). The Tribal lands also depend upon groundwater, including lands within the La Jolla Reservation, Los Coyotes Reservation, Pala Reservation, Pauma and Yuima Reservation, Rincon Reservation, and Santa Ysabel Reservation (SDCWA et al. 2013).

There are three municipal water districts that overlie the San Luis Rey Valley Groundwater Basin that manage water rights protection efforts. Groundwater is the only water supply within the Pauma Municipal Water District and the primary water supplies within the Mootamai Municipal Water District and the San Luis Rey Municipal Water District (San Diego Local Agency Formation Commission 2011; SDCWA et al. 2013). The districts protect groundwater, surface water rights, and water storage and coordinate planning studies and legal activities within the San Luis Rey River watershed. Vista Irrigation District withdraws and stores groundwater in Lake Henshaw and withdraws groundwater in a subbasin located upgradient the San Luis Rey Valley Groundwater Basin.

San Marcos, Escondido Valley, San Pasqual Valley, Pamo Valley, Santa Maria Valley, and Poway Valley Groundwater Basins

The communities in the San Marcos, Escondido Valley, San Pasqual Valley, Pamo Valley, Santa Maria Valley, and Poway Valley Groundwater Basins use a combination of surface water and groundwater to meet water demands (City of Escondido 2011; City of Poway 2011; Ramona Municipal Water District 2011; Rincon del Diablo Municipal Water District [RDDMWD] 2011; Vallecitos Water District 2011). SDCWA provides wholesale surface water supplies to several communities. The Cities of Escondido and Poway; Ramona Municipal Water District, RDDMWD, Vallecitos Water District, and Vista Irrigation District; and private water companies provide retail water supplies to users within their communities. Groundwater use is small or does not occur within the Cities of Escondido and Poway, Ramona Municipal Water District, RDDMWD, and Vallecitos Water District. Ramona WMD used to use groundwater until high nitrate concentrations required the district to abandon the wells.

Batiquitos Lagoon Valley, San Elijo Valley, and San Dieguito Valley Groundwater Basins

The communities in the Batiquitos Lagoon Valley, San Elijo Valley, and San Dieguito Valley Groundwater Basins primarily use surface water to meet water demands (Carlsbad Municipal Water District [CMWD] 2011; Olivenhain Municipal Water District 2011; San Diego Local Agency Formation Commission 2011; San Dieguito Water District 2011; Santa Fe Irrigation District 2011). SDCWA provides wholesale surface water supplies to several communities. Groundwater use is limited to private wells within the CMWD, including the City of Carlsbad; Olivenhain Municipal Water District, including the Cities of Encinitas, Carlsbad, San Diego, Solano Beach, and San Marcos and the communities of Olivenhain, Leucadia, Elfin Forest, Rancho Santa Fe, Fairbanks Ranch, Santa Fe Valley, and 4S Ranch; San Dieguito Water District, including the communities of Encinitas, Cardiff-by-the-Sea, New Encinitas, and Old Encinitas; and Santa Fe Irrigation District, including the City of Solana Beach and the communities of Rancho Santa Fe and Fairbanks Ranch. Groundwater was used within the CMWD area until high salinity caused the area to abandon the wells. Questhaven Municipal Water District manages groundwater for a recreation community located to the west of Escondido.

San Diego River Valley, El Cajon, Mission Valley, Sweetwater Valley, Otay Valley, and Tijuana Groundwater Basins

The communities in the San Diego River Valley, El Cajon, Mission Valley, Sweetwater Valley, Otay Valley, and Tijuana Groundwater Basins use a combination of surface water and groundwater to meet water demands (California American Water Company 2012; City of San Diego 2011; Helix Water District 2011; Otay Water District 2011; Padre Dam Municipal Water District 2011; SDCWA et al. 2013; Sweetwater Authority 2011). SDCWA provides wholesale surface water supplies to several communities. The City of San Diego, Helix Water District, and Sweetwater Authority provide retail surface water and/or groundwater supplies to users within the Cities of La Mesa, Lemon Grove, National City, and San Diego; portions of Chula Vista and El Cajon; and all or portions of the communities of Bonita, Lakeside, and Spring Valley. The County of San Diego-Campo Water and Sewer Maintenance District, Cuyamaca Water District, Decanso Community Services District, Julian Community Services District, Majestic Pines Community Services District, Wynola Water District, Lake Morena Oak Shores Mutual Water Company, Pine Hills Mutual Water Company, and Pine Valley Mutual Water Company rely upon groundwater to meet their water demands. Groundwater is not used for water supplies within Padre Dam Municipal Water District, which serves the City of Santee and portions of the City of El Cajon; Otay Water District, which serves portions of the Cities of Chula Vista, El Cajon, and La Mesa, and several unincorporated communities; and California American Water, which serves the City of Imperial Beach and portions of the Cities of Chula Vista, Coronado, and San Diego. Sweetwater Authority operates the Desalination Facility to treat brackish groundwater (Sweetwater Authority 2016).

I.1.8.4 *Western Riverside County and Southwestern San Bernardino County*

The areas within the SWP service area in western and central Riverside County and southern San Bernardino County in the Southern California Region include the Upper Santa Ana Valley Groundwater Basin in Riverside and San Bernardino Counties; the Elsinore Valley and San Jacinto Groundwater Basins in Riverside County; and the Temecula Valley Groundwater Basin in Riverside and San Diego Counties.

I.1.8.4.1 Hydrogeology and Groundwater Conditions

Upper Santa Ana Valley Groundwater Basin

The Upper Santa Ana Valley Groundwater Basin consists of the Cucamonga, Chino, Riverside-Arlington, Temescal, Rialto-Colton, Cajon, Bunker Hill, Yucaipa, and San Timoteo groundwater subbasins.

Cucamonga Subbasin

The Cucamonga subbasin is in San Bernardino County in the upper Santa Ana River watershed (DWR 2004cb; MWDSC 2007). Groundwater is contained within the subbasin by the Red Hill fault. The water-bearing formations are mainly alluvium of gravel, sand, and silt with beds of compacted clay. Groundwater is recharged naturally from precipitation and stream flows, water discharged to spreading basins, and runoff that flows into the streams from irrigated lands, including lands irrigated with SWP water. The groundwater is characterized as calcium-sodium bicarbonate with moderate to high TDS and nitrates and localized areas with high volatile organic compounds, perchlorate, and DBCP (MWDSC 2007).

The CASGEM program designated the Cucamonga subbasin as medium priority, and it was designated very low priority by SGMA.

Chino Subbasin

The Chino subbasin is in San Bernardino County. The Chino subbasin is composed of alluvial material. The Rialto-Colton, San Jose, and the Cucamonga Faults act as groundwater flow barriers (DWR 2006u). Along the southern boundary of the subbasin, groundwater can rise to the elevation of the Santa Ana River and be discharged into the stream. Groundwater is recharged naturally from precipitation and stream flows along the Santa Ana River and its tributaries, water discharged to spreading basins, and runoff that flows into the streams from irrigated lands, including lands irrigated with SWP water.

The Chino subbasin is characterized with high TDS and nitrate concentrations and localized areas of high volatile organic compounds, and perchlorate (MWDSC 2007).

The CASGEM program designated the Chino subbasin as high priority, and it was designated very low priority by SGMA.

Riverside-Arlington Subbasin

The Riverside-Arlington subbasin is in the Santa Ana River Valley in southwestern San Bernardino County and northwestern Riverside County (DWR 2004cc). Water-bearing formations include alluvial deposits of sand, gravel, silt, and clay. The Rialto-Colton Fault separates this subbasin from the Rialto-Colton subbasin. The Riverside and Arlington portions of the subbasin are also separated. Groundwater flows to the northwest and to the Arlington Gap in the southwest area of the subbasin and continues into the Temescal subbasin. Groundwater is recharged naturally from precipitation and stream flows in the Santa Ana River and flow from adjacent subbasins. The groundwater is characterized as calcium-sodium bicarbonate with moderate to high TDS and nitrates and localized areas with high volatile organic compounds, perchlorate, and DBCP (MWDSC 2007).

The CASGEM program designated the Riverside-Arlington subbasin as high priority, and it was designated very low priority by SGMA.

Temescal Subbasin

The Temescal subbasin is in the Santa Ana River Valley in Riverside County. Water-bearing formations consist of alluvium bounded by the Elsinore fault zone on the west and the Chino fault zone on the northwest (DWR 2006v). Groundwater is recharged naturally from precipitation and stream flows in the tributaries of the Santa Ana River. The groundwater is characterized as calcium-sodium bicarbonate with moderate to high TDS and nitrates and localized areas with high volatile organic compounds, perchlorate, iron, and manganese (MWDSC 2007).

The CASGEM program and SGMA designated the Temescal subbasin as medium priority.

Cajon Subbasin

The Cajon subbasin is in the upper Santa Ana River Valley in San Bernardino County. Water-bearing formations consist of alluvium bounded by the San Andreas Fault zone on the south and impermeable rock formations on the east and west (DWR 2004cd). Groundwater is recharged naturally from precipitation, stream flows in the tributaries of the Santa Ana River, and runoff that flows into the streams from irrigated lands, including lands irrigated with SWP water. The groundwater quality is good for the beneficial uses.

The CASGEM program and SGMA designated the Cajon subbasin as very low priority.

Rialto-Colton Subbasin

The Rialto-Colton subbasin is in the upper Santa Ana River Valley in southwestern San Bernardino County and northwestern Riverside County. Water-bearing formations consist of alluvium bounded by the Rialto-Colton and San Jacinto fault zones (DWR 2004ce). Groundwater is recharged naturally from precipitation and stream flows. The groundwater quality is good for the beneficial uses, with localized areas of high volatile organic compounds.

The CASGEM program designated the Rialto-Colton subbasin as medium priority, and SGMA designated it as very low.

Bunker Hill Subbasin

The Bunker Hill subbasin is in San Bernardino County. The water-bearing formations include alluvium of sand, gravel, and boulders with deposits of silt and clay bounded by the Rialto-Colton and San Jacinto Fault zones (DWR 2004cf). Groundwater is recharged naturally from precipitation, stream flows in the Santa Ana River and its tributaries, water discharged to spreading basins, and runoff that flows into the streams from irrigated lands, including lands irrigated with SWP water. The groundwater quality is good for the beneficial uses. The groundwater is characterized as calcium bicarbonate, with localized areas of high volatile organic compounds and perchlorate within several contamination plumes (*Lockheed Martin Corporation v. United States, Civil Action No. 2008-1160*).

The CASGEM program designated the Bunker Hill subbasin as high priority, and SGMA designated it as very low.

Yucaipa Subbasin

The Yucaipa subbasin is in the upper Santa Ana River Valley in San Bernardino County. Water-bearing formations include alluvial deposits of sand, gravel, boulders, silt, and clay (DWR 2004cg). Several fault zones restrict groundwater movement. The San Timoteo formation along the western boundary of the basin causes the water to rise to the elevation of the San Timoteo Wash, a tributary of the Santa Ana River. Groundwater is recharged naturally from precipitation and stream flows, and water discharged to recharge basins. The groundwater is characterized as calcium-sodium bicarbonate with moderate TDS and high nitrate concentrations and localized areas with high volatile organic compounds.

The CASGEM program designated the Yucaipa subbasin as medium priority, and SGMA designated it as high priority.

San Timoteo Subbasin

The San Timoteo subbasin is in the upper Santa Ana River Valley in Riverside County. Water-bearing formations include alluvial deposits of gravel, silt, and clay (DWR 2004ch). Several fault zones restrict groundwater movement. Groundwater is recharged naturally from precipitation and stream flows and water discharged to recharge basins. The groundwater is characterized as calcium-sodium bicarbonate and good quality for the beneficial uses.

The CASGEM program designated the San Timoteo as medium priority. The SGMA priority for this subbasin is pending.

San Jacinto Groundwater Basin

The San Jacinto Groundwater Basin is in the upper Santa Ana River Valley in Riverside County and underlies the San Jacinto, Perris, Moreno and Menifee Valleys and Lake Perris. The water-bearing formations are alluvium over crystalline basement rock (DWR 2006w). Several fault zones restrict groundwater movement. Groundwater is recharged naturally from precipitation and stream flows along the San Jacinto River and its tributaries, percolation from Lake Perris, and water discharged to recharge basins. The groundwater is characterized as calcium-sodium bicarbonate with high TDS and nitrate concentrations and localized areas with high iron, manganese, sulfides, volatile organic compounds, and perchlorate (DWR 2006x; MWDSC 2007).

The CASGEM program designated the San Jacinto Groundwater Basin as high priority. The SGMA priority for this subbasin is pending.

Elsinore Valley Groundwater Basin

The Elsinore Valley Groundwater Basin is in upper Santa Ana River Valley in Riverside County. The water-bearing formations are alluvial fan, floodplain, and lacustrine deposits underlain by alluvium of gravel, sand, silt, and clay (DWR 2006x). Several fault zones restrict groundwater movement. Groundwater is recharged naturally from precipitation and stream flows along the San Jacinto River and water discharged to recharge basins. The groundwater is characterized as calcium-sodium bicarbonate with moderate salinity and localized areas with high fluoride, arsenic, nitrate, iron, manganese, volatile organic compounds, and perchlorate (DWR 2006x; MWDSC 2007).

The CASGEM program designated the Elsinore Valley Groundwater Basin as high priority. The SGMA priority for this subbasin is medium.

Temecula Valley Groundwater Basin

The Temecula Valley Groundwater Basin is in the upper Santa Margarita River watershed within Riverside and San Diego Counties. The water-bearing formations are alluvium of sand, tuff, and silt underlain by fractured bedrock (DWR 2004ci). Several fault zones restrict groundwater movement. Groundwater is recharged naturally from precipitation and stream flows. The groundwater is characterized as calcium-sodium bicarbonate with high TDS, fluoride, nitrate, volatile organic compounds, and perchlorate (DWR 2006x; MWDSC 2007).

The CASGEM program designated the Temecula Valley Groundwater Basin as high priority. The SGMA priority for this basin is very low.

I.1.8.4.2 Groundwater Use and Management

Upper Santa Ana Valley Groundwater Basin

The Upper Santa Ana Valley Groundwater Basin consists of the Cucamonga, Chino, Riverside-Arlington, Temescal, Rialto-Colton, Cajon, Bunker Hill, Yucaipa, and San Timoteo groundwater subbasins.

Cucamonga and Chino Subbasins

The communities in the Cucamonga and Chino subbasins use a combination of surface water and groundwater to meet water demands (City of Chino 2011; City of Ontario 2011; City of Pomona 2011; City of Upland 2011; Cucamonga Valley Water District 2011; Fontana Water Company 2011; Jurupa Community Services District [JCSD] 2011; MWDSC 2007; Monte Vista Water District 2011; SAWC 2011; Western Municipal Water District [WMWD] 2011). The Cities of Chino, Ontario, Pomona, and Upland; Cucamonga Valley Water District, JCSD, Monte Vista Water District, and Western Municipal Water District; and SAWC, Fontana Water Company, Santa Ana River Water Company, and Marygold Mutual Water Company, and Golden State Water Company provide wholesale and/or retail water supplies, including groundwater, to users within their communities and to portions of the City of Rialto, Montclair, Rancho Cucamonga, and San Antonio Heights.

The Cucamonga subbasin was adjudicated in 1958 to allocate groundwater rights in the basin and surface water rights to Cucamonga Creek (City of Chino 2011; Cucamonga Valley Water District 2011; MWDSC 2007). The water supplies are allocated to the Cucamonga Valley Water District, SAWC, and the West End Consolidated Water Company. The City of Upland has agreements with SAWC and the West End Consolidated Water Company to divert from the subbasin.

The Chino subbasin was adjudicated in 1978 through the Chino Basin Judgment, which established the Chino Basin Watermaster to manage the subbasin and enforce the provisions of the judgment (City of Chino 2011; Cucamonga Valley Water District 2011; MWDSC 2007). The judgment and subsequent agreements allocated the available safe yield to three categories, or pools: Overlying Agricultural Pool, including dairies, farms, and the State of California; Overlying Non-Agricultural Pool for industrial users; and the Appropriative Pool Committee, including local cities, public water agencies, and private water companies. The judgment and subsequent agreements included provisions for reallocation of water rights, groundwater replenishment if the subbasin is operated in a controlled overdraft condition, and development of a groundwater management plan. *Peace Agreements* adopted in 2000 and amended in 2004 included provisions to allow members of the Overlying Non-Agricultural Pool to transfer their water within their pool or to the Watermaster, appropriators to provide water service to overlying lands, and the Watermaster to allocate unallocated safe yield. The Peace Agreement also addressed use of local storage facilities and management of the subbasin under the Dry Year Yield program when imported water, including SWP water, is not fully available. Groundwater replenishment is allowed through spreading basins, percolation, groundwater injection, and in-lieu use of other water supplies, including SWP water. The Chino Basin Watermaster also was required to develop an optimum basin management plan, adopted in 1998, to address approaches that would enhance basin water supplies, protect and enhance water quality, enhance management of the basin, and equitably finance implementation of programs identified in the plan. The Peace II Agreement, adopted in 2007, addressed procedures related to basin reoperation under controlled overdraft conditions, using the Chino Desalters to meet the replenishment obligation and maintain hydraulic control in the subbasin, and transfers. The groundwater recharge master plan update was prepared by the Watermaster in 2010.

The Santa Ana Regional Water Quality Control Board adopted a water quality control plan in 2004 for the entire Santa Ana River Basin, which included a maximum benefit basin plan, recommended by the Chino Basin Watermaster and the Inland Empire Utilities Agency (IEUA). The plan established water quality objectives in groundwater for TDS and total inorganic nitrogen and wasteload allocations to allow use of recycled water for groundwater recharge. The maximum benefit basin plan includes commitments for surface water and groundwater monitoring programs; implementation of up to 40 million gallons/day of treated groundwater at desalters; implementation of recharge facilities, conjunctive use programs, and recycled water quality management programs; and groundwater management to provide hydraulic controls to protect the Santa Ana River water quality.

Operations of the Chino Basin portion of the upper Santa Ana River are also affected by surface water rights judgments administered by the Santa Ana River Watermaster.

A large portion of the natural runoff in the upper Santa Ana River watershed is captured and used to recharge the groundwater aquifers. Flood control channels and percolation basins are operated by San Bernardino County Flood Control District to allow for flood control and groundwater recharge (MWDSC 2007). Groundwater recharge also occurs in spreading basins operated by the City of Upland and SAWC. The Chino Basin Water Conservation District operates percolation ponds and spreading basins to facilitate groundwater recharge (IEUA 2011).

IEUA manages production and treatment of recycled water supplies that are used in groundwater recharge operations and as part of conjunctive use programs in the Cities of Chino, Chino Hills, Ontario, and Upland and in the service areas of the Cucamonga Valley Water District, Monte Vista Water District, Fontana Water Company, and SAWC (IEUA 2011). The district is a member of the Chino Basin Watermaster Board of Directors. IEUA operates several recharge facilities in the Chino subbasin. Recharge water comes from three sources: recycled water, stormwater, and imported SWP water. IEUA operates the Chino Desalter Authority's Chino I and Chino II Desalters that treat water from 22 wells. The Chino Desalter Authority is a joint powers authority that includes the Cities of Chino, Chino Hills, Norco, and Ontario and the JCSD, Santa Ana River Water Company, WMWD, and IEUA. The treated water from the desalters is used for potable water supplies, groundwater recharge with water with reduced salts and nitrates, and improved water quality of the Santa Ana River.

Riverside-Arlington and Temescal Subbasins

The communities in the Riverside-Arlington and Temescal subbasins use a combination of surface water and groundwater to meet water demands (City of Corona 2011; City of Norco 2014; City of Rialto 2011; City of Riverside 2011; JCSD 2011; MWDSC 2007; Rancho California Water District [RCWD] 2011; San Bernardino Valley Municipal Water District [SBVMWD] 2011; WMWD 2011). The SBVMWD and

WMWD provide wholesale and retail water supplies, including groundwater, in the areas that overlay the Riverside-Arlington and Temescal subbasins. The Cities of Colton, Corona, Norco, Rialto, and Riverside; Elsinore Valley Municipal Water District (EVMWD), JCSD, Lee Lake Water District; Rubidoux Community Services District, SBVMWD, WMWD, and West Valley Water District; and Box Springs Mutual Water Company, Riverside Highland Mutual Water Company, and Terrace Water Company provide retail water supplies, including groundwater, to users within their communities. JCSD uses wells within the Riverside-Arlington subbasin for nonpotable uses (JCSD 2011).

The Riverside portion of the Riverside-Arlington subbasin was adjudicated in 1969 through the stipulated judgment for the *Western Municipal Water District of Riverside County et al. v. East San Bernardino County Water District et al*. The judgment provided average annual extraction volumes and replenishment schedules for the separate sections of the subbasin as defined by the San Bernardino County and Riverside County boundary (Riverside North and Riverside South portions of the subbasin) (City of Riverside 2011; MWDSC 2007). Within the Riverside North portion, the judgment affects only withdrawals that are to be used in Riverside County because withdrawals for use of water in San Bernardino County are not limited. The Western-San Bernardino Watermaster manages the monitoring and reporting of groundwater conditions of the Riverside portion of the subbasin.

The northern portion of the Riverside portion of the subbasin also was part of the 1969 judgment in the *Orange County Water District v. City of Chino et al.* This judgment primarily includes the Bunker Hill subbasin and small portions of the northern Riverside, Rialto-Colton, and Yucaipa subbasins and requires minimum downstream flows into the lower Santa Ana River (SBVMWD 2011). To meet the flow obligations, the SBVMWD is responsible to manage groundwater and surface waters within the San Bernardino Basin Area as defined in the judgment. The district manages the groundwater by allocation of groundwater withdrawal amounts and requiring replenishment when additional groundwater is withdrawn.

The Arlington portion of the Riverside-Arlington subbasin and the Temescal subbasins are not adjudicated (City of Corona 2011; MWDSC 2007). In 2008, an agreement was adopted between EVMWD and the City of Corona for use of water from the southern portion of the Temescal subbasin.

The City of Riverside operates two water treatment plants as part of the North Riverside Water Project to remove volatile organic compounds. The City of Corona operates the Temescal Basin Desalter Treatment Plant/Facility, and WMWD operates the Arlington Desalter (City of Corona 2011; WMWD 2011) to reduce TDS. The City of Norco operates a groundwater treatment plant to reduce iron, manganese, and hydrogen sulfide (City of Norco 2014).

<u>Cajon, Rialto-Colton, Bunker Hill, Yucaipa, and San Timoteo Subbasins</u>

The communities in the Cajon, Rialto-Colton, Bunker Hill, Yucaipa, and San Timoteo subbasins use a combination of surface water and groundwater to meet water demands (City of Rialto 2011; City of Riverside 2011; MWDSC 2007; SBVMWD 2011; Yucaipa Valley Water District [YVWD] 2011; WMWD 2011; West Valley Water District 2014a). The SBVMWD and WMWD provide wholesale and retail water supplies, including groundwater, in the areas that overlay the Cajon, Rialto-Colton, Bunker Hill, Yucaipa, and San Timoteo subbasins. The Cities of Colton, Loma Linda, Redlands, Rialto, Riverside, and San Bernardino; Beaumont-Cherry Valley Water District (BCVWD), East Valley Water District, South Mesa Water District, West Valley Water District, Western Municipal Water District, Walnut Valley Water District, and YVWD t; and several private water companies provide retail water supplies, including groundwater, to users within their communities and to portions of the Cities of Beaumont, Calimesa, and Yucaipa; the communities of Cherry Valley, Mission Grove, Orange Crest, and Woodcrest; and numerous private water companies.

Groundwater adjudication in these subbasins has occurred over the past 90 years. A portion of the Bunker Hill subbasin underlays the Lytle Creek watershed (City of Rialto 2011). The remaining portion of the Lytle Creek watershed overlays the Lytle Creek groundwater basin that is not included in the DWR Bulletin 118. The entire Lytle Creek groundwater basin, including the portion in the Bunker Hill subbasin, is a major groundwater recharge source to the Bunker Hill and Rialto-Colton subbasins and was adjudicated in 1924. The stipulation of the judgment allocated groundwater withdrawal right to the City of Rialto, Citizens Land and Water Company, Lytle Creek Water and Improvement Company, Rancheria Water Company, and Mutual Water Company.

The Rialto-Colton subbasin was adjudicated in 1961 under the *Lytle Creek Water & Improvement Company v. Fontana Ranchos Water Company et al.* (City of Rialto 2011). The adjudication allocated groundwater withdrawals between the Cities of Rialto and Colton, West Valley Water District, and Fontana Union Water Company based upon spring groundwater levels at three index wells between March and May of each water year. The groundwater subbasin is managed by the Rialto Basin Management Association. The stipulation of the judgment allocated groundwater withdrawal right to the City of Rialto, Citizens Land and Water Company, Lytle Creek Water and Improvement Company, and private well users. Use of this aquifer has been limited due to contamination with volatile organic compounds, which are currently being treated. The City of Rialto also has agreements with San Bernardino Municipal Water District to store SWP water in the Rialto subbasin. The city can withdraw the stored water without affecting the water allowed to be withdrawn under the 1961 decree.

As described under the Riverside-Arlington and Temescal Subbasins section, in 1969 there was a stipulated judgment for the *Western Municipal Water District of Riverside County et al. v. East San Bernardino County Water District et al*. to preserve the safe yield of the San Bernardino Basin Area through entitlements to groundwater withdrawals to protect the safe yield and establishment of replenishment schedules when the safe yield is exceeded (City of Rialto 2011; SBVMWD 2011). The San Bernardino Basin Area includes the Bunker Hill subbasin and portions of the Rialto-Colton and Yucaipa subbasins and portions of the Mill Creek, Lytle Creek, and upper Santa Ana River watersheds. The Western-San Bernardino Watermaster, which includes WMWD and San Bernardino Municipal Water District, manages the monitoring and reporting of groundwater conditions. The primary users of the groundwater under this decree include the Cities of Colton, Loma Linda, Redlands, and Rialto; East Valley Water District, San Bernardino Municipal Water District, West Valley Water District, and YVWD; and Riverside-Highland Water Company and 13 private water companies.

In 2002, the City of Beaumont, BCVWD, South Mesa Water Company, and YVWD formed the San Timoteo Watershed Management Authority to enhance water supplies and water quality, manage groundwater in the Beaumont Basin (part of the San Timoteo subbasin), protect riparian habitat in San Timoteo Creek, and allocate benefits and costs of these programs (Beaumont Basin Watermaster 2013; SBVMWD 2011). One of the issues that the authority initiated was negotiations related to groundwater withdrawals by the City of Banning. A Stipulated Agreement was adopted in 2004 in accordance with the judgment for the *San Timoteo Watershed Management Authority v. City of Banning et al.* The judgment established a Watermaster committee of the Cities of Banning and Beaumont, BCVWD, South Mesa Water Company, and YVWD. The judgment allocated groundwater supplies in a manner that allows for storage of groundwater recharge from spreading basins or in-lieu programs.

The Seven Oaks Accord, a settlement agreement, was signed by the City of Redlands; East Valley Water District, SBVMWD, and WMWD; and Bear Valley Mutual Water Company, Lugonia Water Company, North Fork Water Company, and Redlands Water Company to recognize prior rights of water users to a portion of the natural flow of the Santa Ana River (SBVMWD 2011). The Seven Oaks Accord requires that SBVMWD, and WMWD develop a groundwater spreading program, in cooperation with other parties to the accord, to recharge the groundwater to maintain relatively constant groundwater levels.

In 2005, the SBVMWD entered into an agreement with the San Bernardino Valley Water Conservation District to work cooperatively to develop and implement a groundwater management plan, which includes groundwater banking programs (SBVMWD 2011).

The City of Rialto, SBVMWD, West Valley Water District, and Riverside Highland Water District have jointly constructed the Baseline Feeder to convey groundwater from the Bunker Hill subbasin to the Rialto area and West Valley Water District to be used in an in-lieu program that would reduce reliance on SWP water supplies (City of Rialto 2011; West Valley Water District 2014b, 2014c).

West Valley Water District implemented a bioremediation wellhead treatment system (West Valley Water District 2014b).

San Jacinto Groundwater Basin

The communities in the San Jacinto Groundwater Basin use a combination of surface water and groundwater to meet water demands (City of Hemet 2011; City of San Jacinto 2011; Eastern Municipal Water District [EMWD] 2011; Lake Hemet Municipal Water District 2011; MWDSC 2007; RCWD 2011). EMWD provides wholesale and retail water supplies, including groundwater, in the areas that overlay the San Jacinto Groundwater Basin. The Cities of Hemet and San Jacinto and EMWD and Rancho California provide retail water supplies, including groundwater, to users within their communities and to portions of the Cities of Menifee, Moreno Valley, Murrieta, and Temecula; Lake Hemet Municipal Water District; Nuevo Water Company and numerous private water companies; and the communities of Edgemont, Homeland, Juniper Flats, Lakeview, Mead Valley, North Perris Water System, Romoland, Sunnymead, Valle Vista, and Winchester. The City of Perris overlays a portion of the San Jacinto Groundwater Basin; however, the city does not use groundwater. A substantial portion of the groundwater supplies within the San Jacinto Groundwater Basin are used by agricultural water users.

The 1954 Fruitvale Judgment allows for EMWD to withdraw water from the San Jacinto Groundwater Basin if the groundwater elevation is greater than a specified elevation (EMWD 2009, 2011, 2014). The judgment includes a maximum withdrawal volume for use outside of the groundwater basin. There are further restrictions within the Canyon Basin subbasin of the San Jacinto Groundwater Basin. DWR worked with the Cities of Hemet and San Jacinto, Lake Hemet Municipal Water District, EMWD, and private groundwater companies to file a stipulated judgment in 2007 to form a Watermaster to develop and implement the Hemet/San Jacinto Water Management Plan, including the Hemet/San Jacinto Integrated Recharge and Recovery Program, Recycled Water In-Lieu Project, and Hemet Filtration Plant. The stipulated judgment also limited groundwater withdrawals to protect the groundwater basin, provide for recharge programs, expand water production, and protect water quality. The program uses SWP water and San Jacinto River runoff to recharge the San Jacinto-Upper Pressure Groundwater Management Zone. In 2013, the judgment was filed with the court to adopt the Hemet/San Jacinto Water Management Plan and create the Watermaster Board.

The stipulated judgment also addressed methods to fulfil the Soboaba Band of Luiseño Indians water rights in accordance with the findings of the Court for the *Soboba Band of Luiseño Indians Water Settlement Agreement* in 2006. In 2008, the Soboba Settlement Act was signed by the President of the United States to provide an annual water supply and provide funds for economic development. The legislation also provides funds to construct recharge facilities and provisions for the Soboba Tribe to participate in restoration efforts.

EMWD adopted the West San Jacinto Groundwater Basin Management Plan in 1995. The management plan includes the Nuevo Water Company, City of Moreno Valley, City of Perris, and McCanna Ranch Water Company (MWDSC 2007).

EMWD operates two desalination plants to treat brackish water within the San Jacinto Groundwater Basin as part of the Groundwater Salinity Management Program (EMWD 2011). Other wells within EMWD also include treatment facilities to reduce hydrogen sulfide, iron, and/or manganese.

Elsinore Groundwater Basin

The communities in the Elsinore Groundwater Basin use a combination of surface water and groundwater to meet water demands (EVMWD 2011; MWDSC 2007). EVMWD provides wholesale and retail water supplies, including groundwater, in the areas that overlay the Elsinore Groundwater Basin. The Cities of Lake Elsinore, Canyon Lake, and Wildomar; EVMWD and Elsinore Water District; and Farm Mutual Water Company provide retail water supplies, including groundwater, to users within their communities and to portions of Cleveland Ranch, Farm, Horsethief Canyon, Lakeland Village, Meadowbrook, Rancho Capistrano – El Cariso Village, and Temescal Canyon.

The Elsinore Groundwater Basin is not adjudicated. EVMWD was responsible for over 90% of the groundwater withdrawals in mid-2000s (EVMWD 2011). The Elsinore Basin Groundwater Management Plan, adopted by EVMWD in 2005, identifies conjunctive use projects, including direct recharge projects. The direct recharge projects use imported water, including SWP water.

Temecula Valley Groundwater Basin

The communities in the Temecula Valley Groundwater Basin use a combination of surface water and groundwater to meet water demands (MWDSC 2007; Rubidoux Community Services District 2011; WMWD 2011). RCWD and WMWD (including Murrieta County Water District) provide wholesale and retail water supplies, including groundwater, in the areas that overlay the Temecula Valley Groundwater Basin, including the Cities of Murrieta and Temecula. The Pechanga Indian Reservation operates groundwater wells within the Temecula Valley Groundwater Basin (MWDSC 2007).

The Temecula Valley Groundwater Basin is in the Santa Margarita River watershed. As described for the San Mateo Valley, San Onofre Valley, and Santa Margarita Valley Groundwater Basins, the groundwater basins that contribute direct or indirect flows into the Santa Margarita River have been adjudicated and are managed by the Santa Margarita River Watermaster in accordance with the 1940 Stipulated Judgment, the 1966 Modified Final Judgment and Decree, and subsequent court orders (MWDSC 2007; RCWD 2011; Santa Margarita River Watershed Watermaster 2011; WMWD 2011). The court-appointed steering committee for the Watermaster includes EMWD, FPUD, MWDSC, Pechanga Band of Luiseno Mission Indians of the Pechanga Reservation, RCWD, WMWD, and Marine Corps Base Camp Pendleton. In accordance with the judgment, the Rancho California Water District prepares the annual groundwater audit and recommended groundwater production report that allocates groundwater withdrawals based upon rainfall, recharge area, and pumping capacity. The subsequent orders adopted following 1966 included the Cooperative Water Resource Management Agreement between RCWD and the Marine Corps Base Camp Pendleton to manage groundwater levels and surface water flows; water rights to Vail Lake on Temecula Creek; and an agreement between the RCWD and the Pechanga Band of Luiseno Mission Indians of the Pechanga Reservation.

RCWD provides imported water, including SWP water, and natural runoff released from Vail Lake to the Valle de Los Caballos Recharge Basins (RCWD 2011). The district also has implemented the Vail Lake Stabilization and Conjunctive Use Project to store imported water in Vail Lake for subsequent groundwater recharge (RCWD et al. 2014).

I.1.8.5 *Central Riverside County*

The areas within the SWP service area that receive Colorado River water in-lieu of SWP water deliveries are located within the Coachella Valley Groundwater Basin. The Coachella Valley Groundwater Basin includes the Desert Hot Springs, Indio, Mission Creek, and San Gorgonio Pass subbasins.

I.1.8.5.1 Hydrogeology and Groundwater Conditions

The Coachella Valley Groundwater Basin underlies the entire floor of the Coachella Valley. Primary water-bearing materials in the Coachella Valley Groundwater Basin are unconsolidated alluvial deposits along the valley floor, which consist of older alluvium and a thick sequence of poorly bedded coarse sand and gravel, terrace deposits under the surrounding foothills in the Mission Creek subbasin, and partly consolidated fine to coarse sandstone in the surrounding mountains in the San Gorgonio Pass subbasin (DWR 2004cj, 2004ck, 2004cl, 2004cm). The movement of groundwater is locally influenced by features such as faults, structural depressions, and constrictions; however, groundwater generally flows to the southeast toward the Salton Sea. Groundwater recharge occurs along streambeds and from groundwater inflows from adjacent subbasins. Within the Indio subbasin, groundwater also is recharged from spreading basins and injection wells.

The groundwater quality is characterized as calcium-sodium bicarbonate. Groundwater quality is adequate for community and agricultural water uses within the San Gorgonio Pass, Mission Creek, and Indio subbasins. There are localized areas with high fluoride near the Banning and San Andreas fault zones. Groundwater quality in the Desert Hot Springs subbasin is poor due to the geothermal activity that results in high sodium sulfate, TDS, and chlorides. The hot springs water is only used by a resort for bathing.

The CASGEM program designated the Desert Hot Springs Groundwater Basin as low priority, SGMA designated it as very low. Indio, Mission Creek, and San Gorgonio Pass Groundwater Basins were designated as medium priority as part of both the CASGEM program and SGMA.

I.1.8.5.2 Groundwater Use and Management

Coachella Valley Groundwater Basin

The Coachella Valley Groundwater Basin includes the San Gorgonio Pass, Mission Creek, Desert Hot Springs, and Indio subbasins.

San Gorgonio Pass Subbasin

The communities in the San Gorgonio Pass subbasin use a combination of surface water and groundwater to meet water demands (BCVWD 2013; City of Banning 2011; San Gorgonio Pass Water Agency 2010). The City of Banning, BCVWD, Cabazon Water District, and High Valley Water District provide retail water supplies, including groundwater, in the areas that overlay the San Gorgonio Pass subbasin, including the City of Banning and the eastern portion of the City of Beaumont; Banning Heights Mutual Water Company; and the community of Cabazon. The Morongo Band of Mission Indians operates groundwater wells within the San Gorgonio Pass subbasin.

The western portion of the San Gorgonio Pass subbasin is in the Beaumont Basin (USGS 1974). The City of Beaumont, BCVWD, South Mesa Water Company, and YVWD formed the San Timoteo Watershed Management Authority to enhance water supplies and water quality, manage groundwater, protect riparian habitat in San Timoteo Creek, and allocate benefits and costs of these programs (Beaumont Basin

Watermaster 2013). One of the issues that the authority initiated was negotiations related to groundwater withdrawals by the City of Banning. A Stipulated Agreement was adopted in 2004 in accordance with the judgment for the *San Timoteo Watershed Management Authority v. City of Banning et al.* The judgment established a Watermaster committee of the Cities of Banning and Beaumont, BCVWD, South Mesa Water Company, and YVWD. The judgment allocated groundwater supplies in a manner that allows for storage of groundwater recharge from spreading basins or in-lieu programs.

Mission Creek, Desert Hot Springs, and Indio Subbasins

The communities in the Mission Creek, Desert Hot Springs, and Indio subbasins use a combination of surface water and groundwater to meet water demands (City of Coachella 2011; Coachella Valley Water District [CVWD] 2011, 2012; Desert Water Agency [DWA] 2011; Indio Water Authority 2010; Mission Springs Water District [MSWD] 2011). The City of Coachella, CVWD, DWA, Indio Water Authority, and MSWD provide retail water supplies, including groundwater, in the areas that overlay the Mission Creek, Desert Hot Springs, and Indio subbasins, including the Cities of Cathedral City, Coachella, Desert Hot Springs, Indian Wells, Indio, La Quinta, Palm Desert, Palm Springs, and Rancho Mirage and the communities of Barton Canyon, Bermuda Dunes, Bombay Beach, Desert Crest, Desert Edge, Indio Hills, Mecca, Mecca Hills, Palm Springs Crest, Salton City, Thermal, and West Palm Springs Village. The Cabazon Band of Mission Indians and the Torres-Martinez Desert Cahuilla Indians operate groundwater wells within the subbasins.

The CVWD, DWA, and MSWD all participate in groundwater management programs within the subbasins (CVWD 2011, 2012; DWA 2011; MSWD 2011). These programs include purchasing imported Colorado River water for groundwater recharge and in-lieu programs, conjunctive use programs, and conservation programs. CVWD and DWA are SWP water contractors. However, because no conveyance facilities exist to deliver the SWP water, these districts have agreements with the MWDSC to exchange SWP water for Colorado River water (CVWD 2012). Since 1973, these agencies have recharged more than 2.6 million AF in the groundwater basin with delivery of Colorado River water to the Whitewater River Recharge Facility. The MWDSC also has an agreement with CVWD and DWA to store water in the Coachella Valley Groundwater Basin. The CVWD also operates the Thomas E. Levy Groundwater Replenishment Facility and the Martinez Canyon Pilot Recharge Facility. CVWD and DWA also provide recycled water for in-lieu programs. CVWD has agreed to operate groundwater recharge facilities to store Colorado River water for Imperial Irrigation District (CVWD 2011).

These groundwater recharge programs and broader groundwater management programs for the Indio subbasin have been developed in accordance with the Whitewater Basin Water Management Plan developed by CVWD and DWA and the Coachella Valley Water Management Plan developed by CVWD (CVWD 2011, 2012; DWA 2011).

The CVWD, DWA, and MSWD jointly manage the Mission Creek subbasin in accordance with the 2004 Mission Creek Settlement Agreement (DWA 2011; MSWD 2011). CVWD and DWA also manage portions of the subbasin in accordance with the 2003 Mission Creek Groundwater Replenishment Agreement. These agreements provide for the allocation of available Colorado River water under the SWP water exchange agreement with MWDSC between the Mission Creek and Indio (also known as the Whitewater) subbasins.

I.1.8.6 *Antelope Valley and Mojave Valley*

The areas within the SWP service area in the Antelope Valley and Mojave Valley include Salt Wells Valley, Cuddeback Valley, Pilot Knob Valley, Grass Valley, Superior Valley, El Mirage Valley, Upper Mojave River Valley, Middle Mojave River Valley, Lower Mojave River Valley, Caves Canyon Valley, Langford Valley, Cronise Valley, Coyote Lake Valley, Kane Wash Area, Iron Ridge Area, Bessemer Valley, Lucerne Valley, Johnson Valley, Means Valley, Deadman Valley, Twentynine Palms Valley, Joshua Tree, Ames Valley, Copper Mountain Valley, Warren Valley, and Morongo Valley Groundwater Basins in San Bernardino County; Harper Valley and Fremont Valley Groundwater Basins in San Bernardino and Kern Counties; Lost Horse Valley in Riverside and San Bernardino Counties; Antelope Valley Groundwater Basin in San Bernardino, Kern, and Los Angeles Counties; and Indian Wells and Searles Valley Groundwater Basins in San Bernardino, Inyo, and Kern Counties.

I.1.8.6.1 Hydrogeology and Groundwater Conditions

Indian Wells Valley Groundwater Basin

Indian Wells Valley Groundwater Basin is in Inyo, Kern, and San Bernardino Counties. Water-bearing formations consist of unconsolidated lakebed, stream, and alluvial fan deposits with upper and lower aquifers (DWR 2004cn). The lower aquifer is more productive and has a saturated thickness of approximately 1,000 feet. The upper aquifer provides low yield and has low quality. The lower aquifer is considered unconfined in most of the valley. There is indication that some faults within the valley could obstruct groundwater flow. Groundwater is recharged from runoff on the southwest to northeast sides of the valley. Groundwater levels have been declining since 1945. Groundwater quality varies throughout the groundwater basin from appropriate for beneficial uses to areas with poor water quality because of wastewater disposal practices. Areas near geothermal activity are characterized by high chloride, boron, and arsenic concentrations.

The CASGEM program designated the Indian Wells Valley Groundwater Basin as medium priority. This basin is prioritized as high by SGMA.

Salt Wells Valley Groundwater Basin

Salt Wells Valley Groundwater Basin is in San Bernardino County. Water-bearing formations consist of unconsolidated to poorly consolidated alluvium (DWR 2004co). Groundwater is recharged from the Indian Wells Groundwater Basin and percolation of rainfall on the valley floor. The regional groundwater flow direction is toward the east into the Searles Valley Groundwater Basin. The groundwater has extremely high salinity, TDS, and boron.

The CASGEM program and SGMA designated the Salt Wells Valley Groundwater Basin as very low priority.

Searles Valley Groundwater Basin

Searles Valley Groundwater Basin is in San Bernardino, Inyo, and Kern Counties. Water-bearing formations consist of alluvium with unconsolidated to semiconsolidated deposits (DWR 2004cm). The Garlock fault may be a barrier to groundwater flow in the southern part of the basin. Groundwater is recharged from percolation of mountain runoff through the alluvial fan deposits and subsurface inflow from Salt Wells Valley and Pilot Knob Valley Groundwater Basins. Groundwater flows toward Searles Lake except in the northern portion of the basin where pumping by industrial water users has altered the groundwater flow. Groundwater levels near Searles Lake are close to the lake bed elevations. Groundwater quality is generally appropriate for beneficial uses, with localized areas with high levels of fluoride and nitrate. In the vicinity of Searles Lake, the groundwater quality is poor, with high levels of fluoride, boron, sodium, chloride, sulfate, and TDS.

The CASGEM program and SGMA designated the Searles Valley Groundwater Basin as very low priority.

Cuddeback Valley, Pilot Knob Valley, Grass Valley, and Superior Valley, Groundwater Basins

Cuddeback Valley, Pilot Knob Valley, Grass Valley, and Superior Valley Groundwater Basins are in northern San Bernardino County. Water-bearing formations consist of unconsolidated to poorly consolidated alluvium (DWR 2004cp, 2004cq, 2004cr, 2004cs). Several fault zones restrict groundwater movement. Groundwater is recharged in the Cuddeback Valley, Pilot Knob Valley, Grass Valley, and Superior Valley Groundwater Basins primarily through groundwater inflow into the basins and percolation of precipitation at the valley margins. Groundwater within Cuddeback Valley, Grass Valley, and Superior Valley Groundwater Basins flows toward the Harper Valley Groundwater Basin. Groundwater in the Cuddeback Valley Groundwater Basin also flows toward Cuddeback Lake. Groundwater in Pilot Knob Valley Groundwater Basin flows toward the Searles Valley and Brown Mountain Valley Groundwater Basins. Groundwater quality is characterized as sodium chloride-bicarbonate with high salinity and TDS in the Cuddeback Valley Groundwater Basin and high concentrations of sodium and fluoride in the Superior Valley Groundwater Basin.

The CASGEM program designated the Cuddeback Valley, Pilot Knob Valley, Grass Valley, and Superior Valley Groundwater Basins as very low priority.

Harper Valley Groundwater Basin

Harper Valley Groundwater Basin is in western San Bernardino County and eastern Kern County. Water-bearing formations consist of lacustrine deposits and unconsolidated to semiconsolidated alluvial deposits (DWR 2004ct). The alluvial deposits at the center of the basin are generally more interbedded with lacustrine silty clay. Faults in the Harper Valley Groundwater Basin cause at least partial barriers to groundwater flow. Groundwater is recharged from percolation of rainfall and runoff through alluvial fan material at the valley edges and underflow from Cuddeback Valley, Grass Valley, Superior Valley, and Middle Mojave River Valley Groundwater Basins. Regional groundwater flows toward the south and Harper Lake. Groundwater quality is characterized as sodium chloride-bicarbonate with high concentrations of boron, fluoride, and sodium.

The CASGEM program designated the Harper Valley Groundwater Basin as low priority, and SGMA designated it as very low.

Fremont Valley Groundwater Basin

The Fremont Valley Groundwater Basin is in eastern Kern County and northwestern San Bernardino County. Water-bearing formations consist of alluvial and lacustrine deposits (DWR 2004cu). The alluvial deposits are generally unconfined, and the lacustrine deposits may exhibit locally confined conditions. Fault zones, including the Garlock and El Paso fault zones, are barriers to groundwater flow. Groundwater is recharged along streambeds in the Sierra Nevada Mountains. Groundwater flow is generally toward the center of the valley and Koehn Lake. Groundwater is characterized as sodium bicarbonate with high concentrations of calcium, chloride, fluoride, and sodium.

The CASGEM program and SGMA designated the Fremont Valley Groundwater Basin as low priority.

Antelope Valley Groundwater Basin

The Antelope Valley Groundwater Basin is in Kern, Los Angeles, and San Bernardino Counties. Water-bearing formations consist of unconsolidated alluvial and lacustrine deposits consisting of compact gravels, sand, silt, and clay (DWR 2004cv). Several fault zones restrict groundwater movement. Groundwater is recharged along streams from the surrounding mountains, including Big Rock Creek and Little Rock Creek. The regional groundwater flow direction historically was toward the dry lakebeds of Rosamond, Rogers, and Buckhorn Lakes. However, extensive groundwater pumping has caused subsidence and reduced the groundwater storage and flow direction. The groundwater is characterized as sodium bicarbonate, with localized areas of high nitrate and boron.

The CASGEM program designated the Antelope Valley Groundwater Basin as high priority. The basin is listed as very low priority in SGMA.

El Mirage Valley Groundwater Basin

The El Mirage Valley Groundwater Basin is in San Bernardino County. Water-bearing formations consist of unconsolidated to semiconsolidated alluvium (DWR 2003c). Several fault zones restrict groundwater movement. Groundwater is recharged in alluvial deposits at the mouth of Sheep Creek. The regional groundwater flow direction is generally north toward El Mirage Lake. The groundwater is characterized as sodium bicarbonate, with localized areas of high levels of fluoride, sulfate, sodium, and TDS.

The CASGEM program designated the El Mirage Valley Groundwater Basin as medium priority. The basin is listed as very low priority in SGMA.

Upper Mojave River Valley, Middle Mojave River Valley, Lower Mojave River Valley, and Caves Canyon Valley Groundwater Basins

The Upper Mojave River Valley, Middle Mojave River Valley, Lower Mojave River Valley, and Caves Canyon Valley Groundwater Basins are located along the Mojave River in southwestern and central San Bernardino County. The water-bearing formations consist of alluvial fan deposits overlain by river channel, floodplain, or lake deposits (DWR 2004cw, 2004cx, 2003d, 2003e). The general groundwater flow direction follows the Mojave River north through the Upper Mojave River Valley Groundwater Basin and east through the Middle Mojave River Valley, Lower Mojave River Valley, and Caves Canyon Valley Groundwater Basins. Several fault zones restrict groundwater movement. Groundwater is recharged from precipitation on the valley floor, underflow from the Mojave River, streamflow, and flow between the basins. Treated wastewater and irrigation return flows also provide a source of groundwater recharge in these basins. Groundwater quality in the Upper Mojave River Valley, Middle Mojave River Valley, Lower Mojave River Valley, and Caves Canyon Valley Groundwater Basins varies throughout the basins due to geological formations and includes areas dominated by calcium bicarbonate, calcium-sodium bicarbonate, calcium-sodium sulfate, sodium-calcium sulfate, and sodium sulfate-chloride. There are localized areas of high nitrate, iron, and manganese in the Upper Mojave River Valley Groundwater Basin and areas with high nitrates, fluoride, and boron in the Middle Mojave River Valley and Lower Mojave River Valley Groundwater Basins. Localized areas with high volatile organic compounds occur in the Upper Mojave River Valley and Lower Mojave River Valley Groundwater Basins.

The CASGEM program designated the Upper Mojave River Valley Groundwater Basin as high priority. The Lower Mojave River Valley Groundwater Basin was designated as medium priority. The Middle Mojave River Valley Groundwater Basin was designated as low priority, and the Caves Canyon Valley Groundwater Basin was designated as very low priority. All four groundwater basins are listed as low priority per SGMA.

Langford Valley Groundwater Basin–Langford Well Lake Subbasin, and Cronise Valley and Coyote Lake Valley Groundwater Basins

The Langford Well Lake subbasin and the Cronise Valley and Coyote Lake Valley Groundwater Basins are located in central San Bernardino County. Water-bearing formations consist of unconsolidated to semiconsolidated alluvium (DWR 2004cy, 2004cz, 2004da). Groundwater is recharged from precipitation, stream flows into alluvial deposits along the mountains at the basin boundaries, and subsurface inflow from other groundwater basins, including the Superior Valley Groundwater Basin. Groundwater quality is poor due to high concentrations of fluoride, boron, and TDS and localized areas with high iron in the Langford Well Lake subbasin.

The CASGEM program and SGMA designated the Langford Well Lake subbasin and the Cronise Valley and Coyote Lake Valley Groundwater Basins as very low priority.

Kane Wash Area Groundwater Basin

The Kane Wash Area Groundwater Basin is in San Bernardino County. Water-bearing formations consist of unconsolidated to semiconsolidated alluvium with undissected coarse gravel to sand in the younger deposits and dissected gravel sand and silt in the older deposits (DWR 2004db). Groundwater is recharged from precipitation and stream flows. The groundwater is characterized as sodium sulfate-bicarbonate with moderate TDS concentrations.

The CASGEM program and SGMA designated the Kane Wash Area Groundwater Basin as very low priority.

Iron Ridge Area Groundwater Basin

The Iron Ridge Area Groundwater Basin is in southern San Bernardino County. Water-bearing formations consist of unconsolidated to semiconsolidated alluvium (DWR 2004dc). Several fault zones restrict groundwater movement. Groundwater is recharged from precipitation and stream flows from the nearby mountains.

The CASGEM program and SGMA designated the Iron Ridge Area Groundwater Basin as very low priority.

Bessemer Valley Groundwater Basin

The Bessemer Valley Groundwater Basin is in eastern San Bernardino County. Water-bearing formations consist of unconsolidated to semiconsolidated alluvial deposits, fanglomerate, and playa lake deposits (DWR 2004dd). More recent deposits consist of unconsolidated, undissected coarse gravel to sand. Older deposits consist of gravel, sand, and silt from dissected alluvial fans. Several fault zones restrict groundwater movement. Groundwater is recharged from precipitation and stream flows at the valley margins.

The CASGEM program and SGMA designated the Bessemer Valley Groundwater Basin as very low priority.

Lucerne Valley Groundwater Basin

The Lucerne Valley Groundwater basin is in San Bernardino County. Water-bearing formations consist of unconsolidated or semiconsolidated alluvial deposits and dune sand deposits composed of gravel, sand, silt, clay, and occasional boulders (DWR 2004de). Several fault zones restrict groundwater movement. Groundwater is recharged from precipitation and stream flows. Groundwater levels have declined throughout the basin and caused subsidence. The groundwater is characterized as calcium-magnesium bicarbonate or magnesium-sodium sulfate with TDS and nitrates.

The CASGEM program designated the Lucerne Valley Groundwater Basin as low priority, and SGMA designated it as very low.

Johnson Valley Groundwater Basin

The Johnson Valley Groundwater Basin is in San Bernardino County and includes the Soggy Lake and Upper Johnson Valley subbasins. Water-bearing formations in both subbasins consist of alluvial deposits with mainly sand and gravel in the Soggy Lake subbasin and silt, clay, sand, and gravel in the Upper Johnson Valley subbasin (DWR 2004df, 2004dg). Springs occur throughout the Soggy Lake subbasin. Groundwater flows from Soggy Lake subbasin into the Upper Johnson Valley subbasin. Several fault zones restrict groundwater movement. The groundwater is characterized with moderate to high TDS and localized areas with high fluoride.

The CASGEM program and SGMA designated the Johnson Valley Groundwater Basin as very low priority.

Means Valley Groundwater Basin

The Means Valley Groundwater Basin is in south central part of San Bernardino County. Water-bearing formations consist of alluvial and lacustrine deposits with unconsolidated fine- to coarse-grained sand, pebbles, and boulders and varying silt and clay deposits throughout the basin (DWR 2004dh). Several fault zones restrict groundwater movement. Groundwater is recharged from precipitation and subsurface inflow from the Johnson Valley Groundwater Basin. The groundwater is characterized as sodium-chloride bicarbonate with high TDS, fluoride, and nitrates.

The CASGEM program and SGMA designated the Means Valley Groundwater Basin as very low priority.

Deadman Valley Groundwater Basin

The Deadman Valley Groundwater Basin is in San Bernardino County. The Deadman Valley Groundwater Basin includes the Deadman Lake and Surprise Spring subbasins. Water-bearing formations consist of unconsolidated to partly consolidated continental deposits, including interbedded gravels, conglomerates, clays, and silts in alluvial fan units (DWR 2004di, 2004dj). Several fault zones restrict groundwater movement. Groundwater is recharged from precipitation and stream flows. Groundwater flows from the Surprise Spring subbasin into the Deadman Lake subbasin and from Deadman Lake subbasin to the dry Mesquite Lake. Groundwater also flows from the Ames Valley Groundwater Basin into the Surprise Spring subbasin. The groundwater is characterized as sodium bicarbonate with moderate to high TDS and localized areas of high fluoride.

The CASGEM program and SGMA designated the Deadman Valley Groundwater Basin as very low priority.

Twentynine Palms Valley, Joshua Tree, Ames Valley, Copper Mountain Valley, and Warren Valley Groundwater Basins

The Twentynine Palms Valley, Ames Valley, and Copper Mountain Valley Groundwater Basins are in southern San Bernardino County. The Joshua Tree and Warren Valley Groundwater Basins are in southern San Bernardino County and northern Riverside County. Water-bearing formations consist of unconfined, unconsolidated to partly consolidated continental deposits with interbedded gravels, conglomerates, lake playa, silts, clays, and sandy-clay deposits (DWR 2004dh, 2004di, 2004dj, 2004dk, 2004dl). Several fault zones restrict groundwater movement. Groundwater is recharged from precipitation, stream flows, and wastewater effluent disposal. Groundwater flows from the Joshua Tree Groundwater Basin into the Copper Mountain Valley Groundwater Basin. Groundwater recharge in the Warren Valley Groundwater Basin also occurs at spreading grounds. The groundwater is characterized as calcium-sodium bicarbonate or sodium sulfate with moderate to high TDS in all of the basins except the Copper Mountain Valley Groundwater Basin and localized areas with high fluoride, nitrate, sulfate, and chloride.

The CASGEM program designated the Warren Valley Groundwater Basin as medium priority. Twentynine Palms Valley was designated as low priority. Joshua Tree, Ames, and Copper Mountain Valley Groundwater Basins were designated as very low priority. Each of these basins is listed as very low priority per SGMA. The SGMA priority for Joshua Tree basin is pending.

Morongo Valley Groundwater Basin

The Morongo Valley Groundwater basin is in southern San Bernardino County. Water-bearing formations consist of alluvial deposits composed of sand, gravel, silt, and clay (DWR 2003f). Several fault zones restrict groundwater movement. Groundwater is recharged from precipitation and stream flows in the Big Morongo and Little Morongo creeks. The groundwater is characterized as calcium-sodium bicarbonate with moderate TDS.

The CASGEM program and SGMA designated the Morongo Valley Groundwater Basin as very low priority.

Lost Horse Valley Groundwater Basin

The Lost Horse Valley Groundwater Basin is located on the border between southeastern San Bernardino County and northeastern Riverside County. Water-bearing formations consist of unconsolidated to semiconsolidated alluvial deposits (DWR 2004dm). Groundwater is recharged from precipitation and stream flows.

The CASGEM program and SGMA designated the Lost Horse Valley Groundwater Basin as very low priority.

I.1.8.6.2 Groundwater Use and Management

Within the Antelope Valley and Mojave Valley, groundwater management is facilitated by the Antelope Valley-East Kern Water Agency (AVEK) and Mojave Water Agency (MWA). These agencies purchase SWP water and other water supplies to be used for groundwater recharge or in-lieu uses to protect groundwater within the Antelope and Mojave Valleys.

Antelope Valley

AVEK provides SWP water to areas that overlay portions of the Antelope Valley, Fremont Valley, and Indian Wells Valley Groundwater Basins. To maintain groundwater aquifers in the area, the AVEK provides treated SWP water to users through the domestic-agricultural water network and untreated SWP water to some agricultural users (AVEK 2011). AVEK participates in groundwater banking programs. Communities within the AVEK service area also use groundwater, including the Cities of California City, Lancaster, and Palmdale; Edwards Air Force Base; County of Los Angeles Waterworks District No. 40; Boron Community Services District, Desert Lake Community Services District, Indian Wells Water District (including the City of Ridgecrest), Mojave Public Utilities District, Palmdale Water District (PWD), Palm Ranch Irrigation District, Quartz Hill Water District, and Rosamond Community Services District; and California Water Service Company (Antelope Valley, Lake Hughes, areas outside of the City of Lancaster, and Leona Valley), Edgemont Crest Municipal Water Company, El Dorado Mutual Water Company, Lake Elizabeth Mutual Water Company, Shadow Acres Mutual Water Company, Sunnyside Farm Mutual Water Company, Westside Park Mutual Water Company, and White Fence Farms Mutual Water Company provide retail groundwater supplies (AVEK 2011; Apple Valley Ranchos Water Company 2011; California Water Service Company 2011g; City of California City 2013; Indian Wells Valley Water District 2011; Los Angeles County et al. 2011; PWD 2011; Rosamond Community Services District 2011).

In 2004, the County of Los Angeles Waterworks District No. 40 and PWD filed for the adjudication of the Antelope Valley Groundwater Basin (DWR 2014c; Los Angeles County et al. 2011; PWD 2011). The request of the filing is to allocate groundwater rights within the basin to these districts, other municipal and industrial water users, and overlying landowners and provide for a program to replace groundwater withdrawals in excess of a specified yield in order to stabilize or reverse groundwater declines.

Mojave Valley

Within the Mojave Water Agency service area, most of the water supply is from groundwater (Apple Valley Ranchos Water Company 2011; City of Adelanto 2011; Golden State Water Company 2011l; Hi-Desert Water District [HDWD] 2011; Hesperia Water District 2011; Joshua Basin Water District 2011; MWA 2011; Phelan Piñon Hills Community Services District 2011; San Bernardino County 2012; Twentynine Palms Water District 2014; Victorville Water District 2011). MWA uses natural surface water flows, recycled water imported from outside of the agency's service area, SWP water, and return flows from water users of groundwater within the service area to recharge groundwater. These water supplies are provided as wholesale water supplies to retail groundwater users to maintain groundwater levels in the area. MWA overlays all or portions of all of the groundwater basins described in this subsection. The City of Adelanto; Hesperia Water District, HDWD, Joshua Water District, Twentynine Palms Water District, Victorville Water District, Apple Foothill County Water District, Apple Heights County Water District, Juniper Riviera County Water District, Thunderbird County Water District, Daggett Community Services District, Helendale Community Services District, Phelan Piñon Hills Community Services District, Yermo Community Services District, Bighorn-Desert View Water Agency, and San Bernardino County Service Areas numbers 64 and 70; and Golden State Water Company, Apple Valley Ranchos Water Company, Jubilee Water Company, and Rancheritos Mutual Water Company provide retail groundwater supplies. These entities provide water to the Cities of Adelanto, Barstow, Hesperia, Twentynine Palms, Victorville; towns of Apple Valley and Yucca; Joshua Tree National Park; Twentynine Palms Marine Corps Base; and the communities of Apple Heights, Apple Valley, Daggett, Flamingo Heights, Helendale, Johnson Valley, Landers, Lucerne Valley, Newberry Springs, Oak Hills, Spring Valley Lake, Yermo, and users between these communities. The Morongo Band of Mission Indians also rely upon groundwater from this area.

MWA has implemented 13 groundwater recharge facilities (MWA 2011). The SWP water is delivered to the recharge facilities throughout the Mojave Water Agency service area.

The area known as the Mojave Basin Area has been adjudicated. This area includes all or portions of Cuddeback Valley, Superior Valley, Harper Valley, Antelope Valley, El Mirage Valley, Upper Mojave River Valley, Middle Mojave River Valley, Lower Mojave River Valley, Caves Canyon Valley, Langford Valley, Cronise Valley, Coyote Lake Valley, Kane Wash Area, Iron Ridge Area, Lucerne Valley, and Johnson Valley Groundwater Basins (Golden State Water Company 2011l; MWA 2011). The Mojave Basin Judgment allocated groundwater withdrawals in the area and required groundwater users that withdraw more than the allocated amount to purchase replenishment SWP water from the Watermaster or from another entity within the judgment. The judgment considers local surface water sources, including groundwater recharge near Hesperia with treated wastewater effluent from Lake Arrowhead Community Services District (Lake Arrowhead Community Services District 2011). The judgment also provides for carryover storage between water years. MWA has been appointed as the Watermaster.

The Warren Valley Groundwater Basin was adjudicated in 1977 (MWA 2011). HDWD was appointed as the Watermaster to manage groundwater withdrawals and groundwater quality; provide SWP water, captured stormwater, and recycled water; and encourage conservation.

In 1991, the Bighorn-Desert Water Agency and HDWD agreed to the court-approved Ames Valley Basin Water Management Agreement. In accordance with this agreement, HDWD implemented the mainstream wells and expansion to conveyance and monitoring approaches.

I.2 Evaluation of Alternatives

This section describes the technical background for the evaluation of environmental consequences associated with the action alternatives and the No Action Alternative.

I.2.1 Methods and Tools

While the changes in CVP and SWP operations under the alternatives compared with the No Action Alternative do not directly result in pumping more or less groundwater, changes to CVP and SWP operations may change the amount of surface water delivered to users along the systems. A change in surface water deliveries may result in users changing the amount of groundwater pumping to account for this change in surface water supply. For example, if less surface water is supplied to an agricultural area, additional groundwater would need to be pumped and supplied to maintain cropping. The surface water supply analysis was conducted using the CalSim II model, as described in Appendix F, *Model Documentation*, to simulate the operational assumptions of each alternative. The CalSim II results were then applied to the Central Valley Hydrologic Model (CVHM) groundwater flow model (see Appendix F) to simulate changes in groundwater conditions, including the changes to pumping, groundwater-surface water interaction, and groundwater elevation. The CVHM modeling was conducted for the basins and subbasins in the Sacramento and San Joaquin Valleys. A qualitative assessment was conducted in the other project areas.

The effects of the 2014 SGMA legislation was not explicitly simulated as part of the action alternatives. SGMA requires that groundwater basins be operated sustainably by a Groundwater Sustainability Agency (GSA) under a Groundwater Sustainability Plan (GSP) by either January 31, 2020 (for medium and high priority basins with overdraft conditions) or January 31, 2022 (for medium and high priority basins without overdraft conditions). Basins designated as low or very-low priority are not subject to SGMA. Adjudicated basins are not required to develop a GSP. Given the fact that GSPs for areas in the Central

Valley have not been fully developed and adopted yet, the exact details of sustainable management under SGMA for each basin and subbasin are not known. However, there are six identified effects caused by groundwater conditions that are to be sustainable managed under a GSP: (1) chronic lowering of groundwater levels, (2) reduction in groundwater storage, (3) seawater intrusion, (4) degraded water quality, (5) land subsidence, and (6) depletion of interconnected surface water. For the development of the GSP, the GSA is required to manage the basin sustainability according to these criteria. Operation of the action alternatives will need to be incorporated in the development of the GSP.

I.2.2 No Action Alternative

Under the No Action Alternative, conditions would be the same as those under existing conditions. Therefore, there would be no changes from existing conditions that would affect groundwater.

I.2.3 Alternative 1

I.2.3.1 *Project-Level Effects*

I.2.3.1.1 <u>Potential Changes in Groundwater Pumping</u>

Trinity River Region

Project level actions in Alternative 1 will likely result in changes to flows of surface water in this region. However, there is expected to be little change to groundwater pumping resulting from these actions because groundwater is not a substantial supply source in this area.

Central Valley Region

Compared with the No Action Alternative, Alternative 1 is expected to result in additional surface water supply to both the Sacramento and San Joaquin Valleys. Refer to Appendix H, *Water Supply Technical Appendix,* for additional information related to changes in deliveries. This increase in supply, especially when made to meet agricultural demands, will result in a decrease in the need for groundwater pumping to meet demands. Most of the change in pumping is expected to be in the San Joaquin Valley because that is the location of the majority of CVP and SWP contractors that will have increases in their surface water supply. Little change in delivery is expected in the Sacramento Valley.

The changes in CVP and SWP deliveries projected by the CalSim II model to the San Joaquin Valley region were input to the CVHM. The CVHM then simulated the amount of groundwater pumping required to meet agricultural needs as the difference between demand and the supply from surface water. With the increase in surface water supply, the amount of groundwater pumping decreased. Table I.2-1, Simulated Central Valley Hydrologic Model Groundwater Pumping, shows the amount of groundwater pumping simulated by CVHM under the No Action Alternative and Alternative 1. Table I.2-2, Change in Central Valley Hydrologic Model Simulated Groundwater Pumping, shows the percent change in simulated groundwater pumping between Alternative 1 and the No Action Alternative.

Tables I.2-1 and I.2-2 also include information related to Alternatives 2, 3, and 4, which will be described in later sections.

Table I.2-1. Simulated Central Valley Hydrologic Model Groundwater Pumping

Year	Sacramento Valley	San Joaquin Valley	Groundwater Pumping				
	Water Year Type[1]	Water Year Type[1]	No Action Alternative (TAF)	Alternative 1 (TAF)	Alternative 2 (TAF)	Alternative 3 (TAF)	Alternative 4 (TAF)
1	BN	BN	8,825	8,396	7,690	7,693	8,975
2	W	AN	6,816	6,572	6,002	5,991	6,849
3	D	C	9,536	9,382	9,131	9,142	9,466
4	W	AN	7,004	6,795	6,420	6,399	7,005
5	BN	D	9,465	8,890	8,533	8,546	9,491
6	W	W	6,452	6,274	6,196	6,145	6,511
7	BN	D	8,483	7,949	7,434	7,431	8,132
8	W	W	4,672	4,663	4,622	4,626	4,624
9	W	AN	6,760	6,264	6,173	6,242	6,759
10	W	BN	7,318	6,970	6,574	6,580	7,514
11	BN	C	9,553	9,476	8,782	8,873	9,606
12	AN	AN	5,834	5,475	5,278	5,274	5,827
13	W	AN	5,663	5,550	5,104	5,103	5,641
14	W	AN	5,781	5,612	5,108	5,104	5,911
15	C	C	8,530	8,352	8,167	8,215	8,551
16	C	C	12,022	11,672	11,700	11,651	11,940
17	AN	W	4,790	4,582	4,521	4,529	4,678
18	BN	AN	6,361	5,910	5,837	5,887	6,324
19	AN	W	4,913	4,707	4,678	4,679	4,935
20	D	D	7,756	7,382	7,004	6,990	8,080
21	W	W	3,918	3,890	3,760	3,757	4,056
22	W	W	3,143	3,126	3,105	3,106	3,143
23	W	W	5,864	5,421	5,369	5,414	5,832
24	D	D	6,689	6,392	6,221	6,187	6,879
25	W	W	5,179	5,073	4,831	4,912	5,254
26	D	C	8,245	7,698	7,585	7,612	7,944
27	C	C	9,722	9,465	9,021	9,000	9,576
28	D	C	9,264	8,837	8,705	8,645	9,223
29	C	C	10,678	10,520	10,508	10,502	10,747
30	C	C	10,771	10,465	10,076	10,113	10,749
31	C	C	10,400	10,031	9,987	9,992	10,289
32	AN	AN	5,480	5,129	4,849	4,857	5,511
33	C	C	8,368	8,369	7,582	7,660	9,031
34	W	W	4,388	4,348	4,198	4,262	4,485
35	W	W	5,693	5,371	5,067	5,135	5,491
36	W	W	5,925	5,396	5,350	5,724	5,746
37	W	W	3,334	3,307	3,261	3,293	3,332

Year	Sacramento Valley	San Joaquin Valley	Groundwater Pumping				
	Water Year Type[1]	Water Year Type[1]	No Action Alternative (TAF)	Alternative 1 (TAF)	Alternative 2 (TAF)	Alternative 3 (TAF)	Alternative 4 (TAF)
38	W	AN	5,726	5,224	5,030	5,070	5,605
39	AN	AN	6,365	6,071	5,389	5,393	6,496
40	D	C	7,641	7,512	7,260	7,252	7,615
41	D	C	8,237	8,136	7,599	7,635	8,690
42	AN	BN	7,101	6,906	6,507	6,485	7,253
Average			**7,111**	**6,847**	**6,577**	**6,598**	**7,137**

[1] Water year types: W – Wet, AN – Above Normal, BN – Below Normal, D – Dry, C – Critically Dry
TAF = thousand acre-feet

Table I.2-2. Change in Central Valley Hydrologic Model Simulated Groundwater Pumping

Year	Sacramento Valley	San Joaquin Valley	Change in Groundwater Pumping							
	Water Year Type[1]	Water Year Type[1]	Alternative 1 versus No Action Alternative (TAF)	Alternative 1 versus No Action Alternative (percent)	Alternative 2 versus No Action Alternative (TAF)	Alternative 2 versus No Action Alternative (percent)	Alternative 3 versus No Action Alternative (TAF)	Alternative 3 versus No Action Alternative (percent)	Alternative 4 versus No Action Alternative (TAF)	Alternative 4 versus No Action Alternative (percent)
1	BN	BN	-430	-4.9%	-1,135	-12.9%	-1,132	-12.8%	149	1.7%
2	W	AN	-244	-3.6%	-814	-11.9%	-825	-12.1%	33	0.5%
3	D	C	-154	-1.6%	-406	-4.3%	-395	-4.1%	-70	-0.7%
4	W	AN	-209	-3.0%	-584	-8.3%	-605	-8.6%	1	0.0%
5	BN	D	-575	-6.1%	-932	-9.9%	-919	-9.7%	25	0.3%
6	W	W	-178	-2.8%	-257	-4.0%	-307	-4.8%	59	0.9%
7	BN	D	-534	-6.3%	-1,049	-12.4%	-1,052	-12.4%	-351	-4.1%
8	W	W	-10	-0.2%	-50	-1.1%	-46	-1.0%	-48	-1.0%
9	W	AN	-496	-7.3%	-586	-8.7%	-518	-7.7%	-1	0.0%
10	W	BN	-349	-4.8%	-744	-10.2%	-739	-10.1%	196	2.7%
11	BN	C	-77	-0.8%	-771	-8.1%	-680	-7.1%	54	0.6%
12	AN	AN	-359	-6.2%	-556	-9.5%	-560	-9.6%	-7	-0.1%
13	W	AN	-113	-2.0%	-558	-9.9%	-560	-9.9%	-22	-0.4%
14	W	AN	-169	-2.9%	-673	-11.6%	-677	-11.7%	130	2.2%
15	C	C	-178	-2.1%	-363	-4.3%	-315	-3.7%	21	0.2%
16	C	C	-350	-2.9%	-322	-2.7%	-371	-3.1%	-82	-0.7%
17	AN	W	-209	-4.4%	-269	-5.6%	-261	-5.4%	-112	-2.3%
18	BN	AN	-451	-7.1%	-524	-8.2%	-474	-7.5%	-37	-0.6%
19	AN	W	-206	-4.2%	-235	-4.8%	-234	-4.8%	22	0.5%
20	D	D	-374	-4.8%	-753	-9.7%	-766	-9.9%	323	4.2%
21	W	W	-28	-0.7%	-159	-4.1%	-161	-4.1%	138	3.5%
22	W	W	-17	-0.6%	-38	-1.2%	-36	-1.2%	0	0.0%
23	W	W	-443	-7.6%	-495	-8.4%	-450	-7.7%	-32	-0.5%

Year	Sacramento Valley	San Joaquin Valley	Change in Groundwater Pumping							
	Water Year Type[1]	Water Year Type[1]	Alternative 1 versus No Action Alternative (TAF)	Alternative 1 versus No Action Alternative (percent)	Alternative 2 versus No Action Alternative (TAF)	Alternative 2 versus No Action Alternative (percent)	Alternative 3 versus No Action Alternative (TAF)	Alternative 3 versus No Action Alternative (percent)	Alternative 4 versus No Action Alternative (TAF)	Alternative 4 versus No Action Alternative (percent)
24	D	D	-297	-4.4%	-468	-7.0%	-502	-7.5%	189	2.8%
25	W	W	-106	-2.0%	-347	-6.7%	-266	-5.1%	75	1.5%
26	D	C	-547	-6.6%	-660	-8.0%	-633	-7.7%	-301	-3.7%
27	C	C	-257	-2.6%	-701	-7.2%	-722	-7.4%	-146	-1.5%
28	D	C	-428	-4.6%	-559	-6.0%	-619	-6.7%	-41	-0.4%
29	C	C	-158	-1.5%	-170	-1.6%	-176	-1.7%	69	0.6%
30	C	C	-306	-2.8%	-694	-6.4%	-658	-6.1%	-22	-0.2%
31	C	C	-369	-3.5%	-413	-4.0%	-408	-3.9%	-111	-1.1%
32	AN	AN	-351	-6.4%	-631	-11.5%	-623	-11.4%	31	0.6%
33	C	C	1	0.0%	-786	-9.4%	-708	-8.5%	663	7.9%
34	W	W	-40	-0.9%	-190	-4.3%	-126	-2.9%	97	2.2%
35	W	W	-323	-5.7%	-626	-11.0%	-558	-9.8%	-202	-3.5%
36	W	W	-529	-8.9%	-575	-9.7%	-201	-3.4%	-179	-3.0%
37	W	W	-27	-0.8%	-73	-2.2%	-41	-1.2%	-2	-0.1%
38	W	AN	-502	-8.8%	-697	-12.2%	-656	-11.5%	-121	-2.1%
39	AN	AN	-293	-4.6%	-976	-15.3%	-972	-15.3%	132	2.1%
40	D	C	-129	-1.7%	-381	-5.0%	-389	-5.1%	-26	-0.3%
41	D	C	-101	-1.2%	-638	-7.7%	-601	-7.3%	453	5.5%
42	AN	BN	-195	-2.8%	-594	-8.4%	-616	-8.7%	152	2.1%
Average			**-264**	**-3.7%**	**-535**	**-7.5%**	**-513**	**-7.1%**	**26**	**0.4%**

[1] Water year types: W – Wet, AN – Above Normal, BN – Below Normal, D – Dry, C – Critically Dry
TAF = thousand acre-feet

The model simulations show that, on average, groundwater pumping is 3.7% lower in Alternative 1 than the No Action Alternative.

Central Valley Project and State Water Project Service Areas

Alternative 1 is expected to increase water supply to the CVP and SWP service areas. With this increase in supply, the reliance on groundwater pumping is expected to stay the same or be reduced compared with the No Action Alternative. Therefore, there is expected to be similar or less groundwater pumping in Alternative 1.

I.2.3.1.2 Potential Changes in Groundwater-Surface Water Interaction

Trinity River Region

Most usable groundwater in the Trinity River Region occurs in widely scattered alluvium-filled valleys, such as those immediately adjacent to the Trinity River. These valleys contain only small quantities of recoverable groundwater and therefore are not considered a major source. Given this hydrogeologic nature of this region, changes in surface water flow will likely result in little change to the groundwater-surface water interaction flow.

Central Valley Region

The amount of groundwater-surface water interaction flow simulated in the CVHM, throughout the Central Valley, is shown in Table I.2-3, Simulated Central Valley Hydrologic Model Groundwater-Surface Water Interaction Flow, for Alternative 1. Table I.2-4, Simulated Change in Central Valley Hydrologic Model Groundwater-Surface Water Interaction, shows the change in groundwater-surface water interaction for Alternative 1 compared with the No Action Alternative. Over the length of the CVHM simulation, the change in groundwater-surface water interaction is 10.3% (reduced flow from groundwater to surface water) in Alternative 1 compared with the No Action Alternative.

Tables I.2-3 and I.2-4 also include information related to Alternatives 2, 3, and 4, which will be described in later sections.

Table I.2-3. Simulated Central Valley Hydrologic Model Groundwater-Surface Water Interaction Flow

Year	Sacramento Valley	San Joaquin Valley	Groundwater Gain (+) or Lost (−) from/to Surface Water				
	Water Year Type[1]	Water Year Type[1]	No Action Alternative (TAF)	Alternative 1 (TAF)	Alternative 2 (TAF)	Alternative 3 (TAF)	Alternative 4 (TAF)
1	BN	BN	2454	2377	2488	2385	2560
2	W	AN	739	717	660	638	697
3	D	C	247	272	340	292	278
4	W	AN	1153	1047	1101	1068	1230
5	BN	D	568	623	566	605	595
6	W	W	1653	1668	1660	1619	1613
7	BN	D	290	236	157	217	319
8	W	W	3636	3468	3484	3401	3638
9	W	AN	262	16	-11	90	379
10	W	BN	-461	-484	-502	-486	-420
11	BN	C	-202	-189	-249	-214	-250
12	AN	AN	313	298	228	231	297
13	W	AN	264	207	172	226	194
14	W	AN	-168	-174	-255	-276	-65
15	C	C	-432	-492	-418	-474	-425
16	C	C	-278	-256	-254	-252	-248
17	AN	W	2561	2043	2277	2314	2368
18	BN	AN	192	228	190	205	198
19	AN	W	1060	1011	1048	1095	1112
20	D	D	44	70	-35	-48	-31
21	W	W	1032	1101	971	991	1058
22	W	W	1886	1893	1863	1806	1992

Year	Sacramento Valley	San Joaquin Valley	Groundwater Gain (+) or Lost (−) from/to Surface Water				
	Water Year Type[1]	Water Year Type[1]	No Action Alternative (TAF)	Alternative 1 (TAF)	Alternative 2 (TAF)	Alternative 3 (TAF)	Alternative 4 (TAF)
23	W	W	-705	-746	-749	-782	-743
24	D	D	-802	-820	-897	-870	-819
25	W	W	721	659	593	635	780
26	D	C	-695	-719	-721	-720	-722
27	C	C	-498	-506	-485	-403	-487
28	D	C	-147	-186	-208	-243	-146
29	C	C	-176	-254	-288	-188	-196
30	C	C	473	253	235	253	290
31	C	C	160	106	136	85	110
32	AN	AN	896	877	808	842	836
33	C	C	-73	-165	-96	-114	-145
34	W	W	3880	3952	4567	3730	3965
35	W	W	-148	-270	-466	-256	-143
36	W	W	875	881	730	842	904
37	W	W	2650	2526	2563	2777	2997
38	W	AN	-1119	-1197	-1340	-1296	-1204
39	AN	AN	-538	-565	-591	-558	-517
40	D	C	-753	-790	-793	-784	-784
41	D	C	-361	-387	-550	-524	-293
42	AN	BN	-215	-170	-360	-333	-248
Average			**482**	**432**	**418**	**417**	**489**

[1] Water year types: W – Wet, AN – Above Normal, BN – Below Normal, D – Dry, C – Critically Dry
TAF = thousand acre-feet

Table I.2-4. Simulated Change in Central Valley Hydrologic Model Groundwater-Surface Water Interaction Flow

Year	Sacramento Valley	San Joaquin Valley	Change in Groundwater Gain (+) or Lost (−) from/to Surface Water							
	Water Year Type[1]	Water Year Type[1]	Alt 1 versus No Action Alternative (TAF)	Alt 1 versus No Action Alternative (percent)	Alt 2 versus No Action Alternative (TAF)	Alt 2 versus No Action Alternative (percent)	Alt 3 versus No Action Alternative (TAF)	Alt 3 versus No Action Alternative (percent)	Alt 4 versus No Action Alternative (TAF)	Alt 4 versus No Action Alternative (percent)
1	BN	BN	-77	-3.1%	34	1.4%	-69	-2.8%	106	4.3%
2	W	AN	-22	-3.0%	-80	-10.8%	-102	-13.8%	-42	-5.7%
3	D	C	25	10.1%	93	37.4%	44	17.9%	31	12.5%
4	W	AN	-107	-9.3%	-52	-4.5%	-85	-7.4%	77	6.7%
5	BN	D	55	9.7%	-2	-0.4%	36	6.4%	26	4.7%
6	W	W	15	0.9%	7	0.5%	-34	-2.1%	-40	-2.4%
7	BN	D	-55	-18.9%	-134	-46.0%	-74	-25.4%	29	9.9%

Year	Sacramento Valley	San Joaquin Valley	Change in Groundwater Gain (+) or Lost (−) from/to Surface Water							
	Water Year Type[1]	Water Year Type[1]	Alt 1 versus No Action Alternative (TAF)	Alt 1 versus No Action Alternative (percent)	Alt 2 versus No Action Alternative (TAF)	Alt 2 versus No Action Alternative (percent)	Alt 3 versus No Action Alternative (TAF)	Alt 3 versus No Action Alternative (percent)	Alt 4 versus No Action Alternative (TAF)	Alt 4 versus No Action Alternative (percent)
8	W	W	-168	-4.6%	-152	-4.2%	-235	-6.5%	2	0.1%
9	W	AN	-247	-94.1%	-273	-104.3%	-172	-65.8%	117	44.7%
10	W	BN	-23	5.0%	-41	9.0%	-25	5.5%	41	-8.9%
11	BN	C	13	-6.5%	-47	23.3%	-11	5.6%	-48	23.6%
12	AN	AN	-14	-4.5%	-85	-27.1%	-81	-26.0%	-16	-5.0%
13	W	AN	-58	-21.8%	-92	-34.9%	-38	-14.3%	-70	-26.4%
14	W	AN	-6	3.6%	-87	51.9%	-108	64.6%	103	-61.4%
15	C	C	-60	13.8%	14	-3.3%	-42	9.6%	7	-1.7%
16	C	C	21	-7.7%	24	-8.6%	26	-9.4%	30	-10.7%
17	AN	W	-518	-20.2%	-284	-11.1%	-247	-9.6%	-193	-7.5%
18	BN	AN	36	18.6%	-2	-1.3%	13	6.8%	6	3.2%
19	AN	W	-49	-4.6%	-12	-1.2%	34	3.2%	51	4.8%
20	D	D	26	59.0%	-79	-180.3%	-92	-209.4%	-75	-171.1%
21	W	W	68	6.6%	-62	-6.0%	-41	-4.0%	26	2.5%
22	W	W	7	0.4%	-23	-1.2%	-80	-4.2%	106	5.6%
23	W	W	-41	5.8%	-44	6.3%	-77	10.9%	-38	5.4%
24	D	D	-17	2.1%	-95	11.8%	-68	8.4%	-17	2.1%
25	W	W	-62	-8.6%	-129	-17.8%	-87	-12.0%	58	8.1%
26	D	C	-24	3.4%	-26	3.8%	-25	3.6%	-27	3.9%
27	C	C	-8	1.5%	13	-2.7%	95	-19.1%	12	-2.3%
28	D	C	-39	26.7%	-62	41.9%	-96	65.5%	1	-0.8%
29	C	C	-78	44.4%	-112	63.9%	-12	6.6%	-20	11.3%
30	C	C	-220	-46.5%	-238	-50.4%	-220	-46.4%	-183	-38.8%
31	C	C	-54	-33.8%	-24	-14.8%	-75	-46.6%	-50	-31.2%
32	AN	AN	-20	-2.2%	-88	-9.9%	-55	-6.1%	-61	-6.8%
33	C	C	-93	127.8%	-24	32.7%	-41	56.5%	-72	99.8%
34	W	W	72	1.9%	687	17.7%	-150	-3.9%	85	2.2%
35	W	W	-122	82.9%	-319	216.0%	-109	73.5%	5	-3.2%
36	W	W	6	0.7%	-145	-16.5%	-33	-3.7%	29	3.3%
37	W	W	-124	-4.7%	-87	-3.3%	127	4.8%	347	13.1%
38	W	AN	-78	7.0%	-222	19.8%	-177	15.9%	-85	7.6%
39	AN	AN	-27	5.0%	-53	9.9%	-21	3.8%	20	-3.8%
40	D	C	-37	4.9%	-40	5.3%	-31	4.1%	-31	4.1%
41	D	C	-26	7.1%	-188	52.1%	-162	44.9%	68	-18.8%
42	AN	BN	46	-21.2%	-145	67.4%	-117	54.5%	-33	15.2%
Average			**-50**	**-10.3%**	**-64**	**-13.2%**	**-65**	**-13.4%**	**7**	**1.4%**

[1] Water year types: W – Wet, AN – Above Normal, BN – Below Normal, D – Dry, C – Critically Dry
TAF = thousand acre-feet

Central Valley Project and State Water Project Service Areas

Alternative 1 increases water supply to the CVP and SWP service areas and, therefore, likely results in little change, or potentially a reduction, in the amount of groundwater pumping. With little change to groundwater pumping, there would be little change in the groundwater system to result in a change in the amount of groundwater-surface water interaction flow. Therefore, Alternative 1, compared with the No Action Alternative, may result in groundwater levels rising, allowing for additional infiltration of groundwater to surface water or reduced infiltration of surface water to groundwater.

I.2.3.1.3 Potential Changes in Groundwater Elevation

Trinity River Region

Given that there is likely to be little change to the volume of groundwater either through pumping or groundwater-surface water interaction flow, there will be little change to groundwater levels in the area are also not expected to change.

Central Valley Region

The CVHM simulations indicate that the amount of groundwater pumping in Alternative 1 will be less than in the No Action Alternative. Simulations also suggest that less water will recharge to the groundwater system in Alternative 1 than in the No Action Alternative. These two factors combine to potentially affect groundwater elevations. Less groundwater pumping would work to increase groundwater levels while less recharge from surface water to groundwater could lower groundwater levels. CVHM was used to estimate change to groundwater levels resulting from the combined effects of project level changes.

CVHM results at 24 locations across the San Joaquin Valley are presented in the following figures. The results, presented in two types of figures, show changes in groundwater levels with time at a specific location (first type of figures) and contours of the simulated change in groundwater level between Alternative 1 and the No Action Alternative (second type of figures). Figure I.2-1, Location of 24 Hydrographs, shows the 24 arbitrary locations selected for presentation. Hydrographs are not shown in the Sacramento Valley because there is relatively little change in simulated groundwater level.

In the first type of graphic, the x-axis of these figures is the over 40 years of the CVHM simulation. The y-axis is either the groundwater elevation at the specified location for a simulation or the difference between groundwater elevations between two different simulations. Figures in this first type are identified below:

- Figures I.2-2 through I.2-25 show the simulated groundwater elevations at the 24 arbitrary locations throughout the San Joaquin Valley. Changes in groundwater pumping were not simulated in the Sacramento Valley; therefore, modeled groundwater elevations in the Sacramento Valley are not shown. Where possible the vertical scale of these figures was set at 200 feet for consistency.
- Figures I.2-26 through I.2-49 show the simulated change in groundwater elevation at these 24 locations. The vertical scales of these figures vary based on location.

Figures of the second type, which show contours of the simulated change in groundwater level between Alternative 1 and the No Action Alternative, are identified below:

- Figures I.2-50 through I.2-54 show the simulated change in groundwater level spatially across the Central Valley under Alternative 1 compared with the No Action Alternative. These figures show the average change in groundwater levels in July during each of the five water year types (Wet, Above Normal, Below Normal, Dry, Critical Dry).

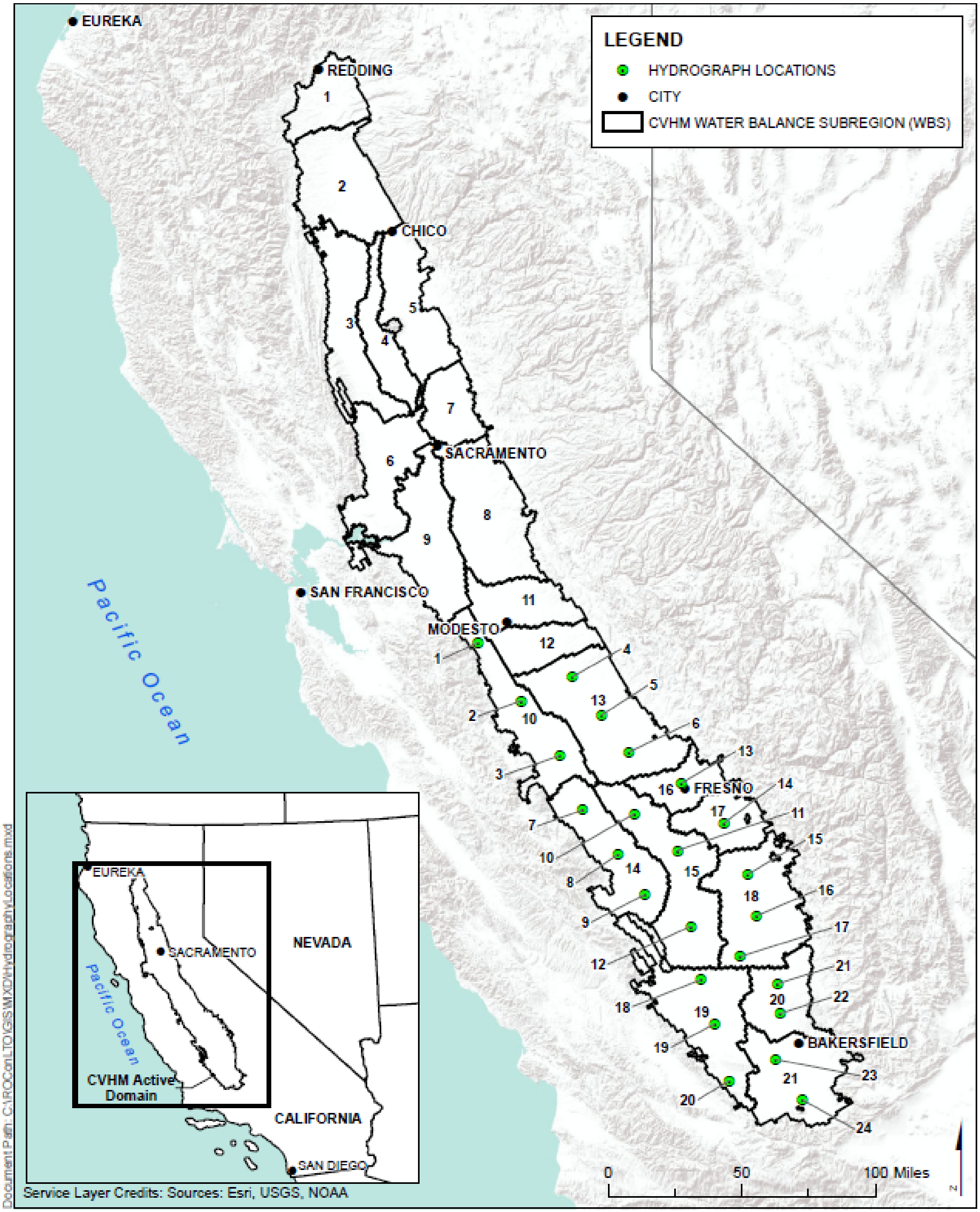


Figure I.2-1. Location of 24 Hydrographs

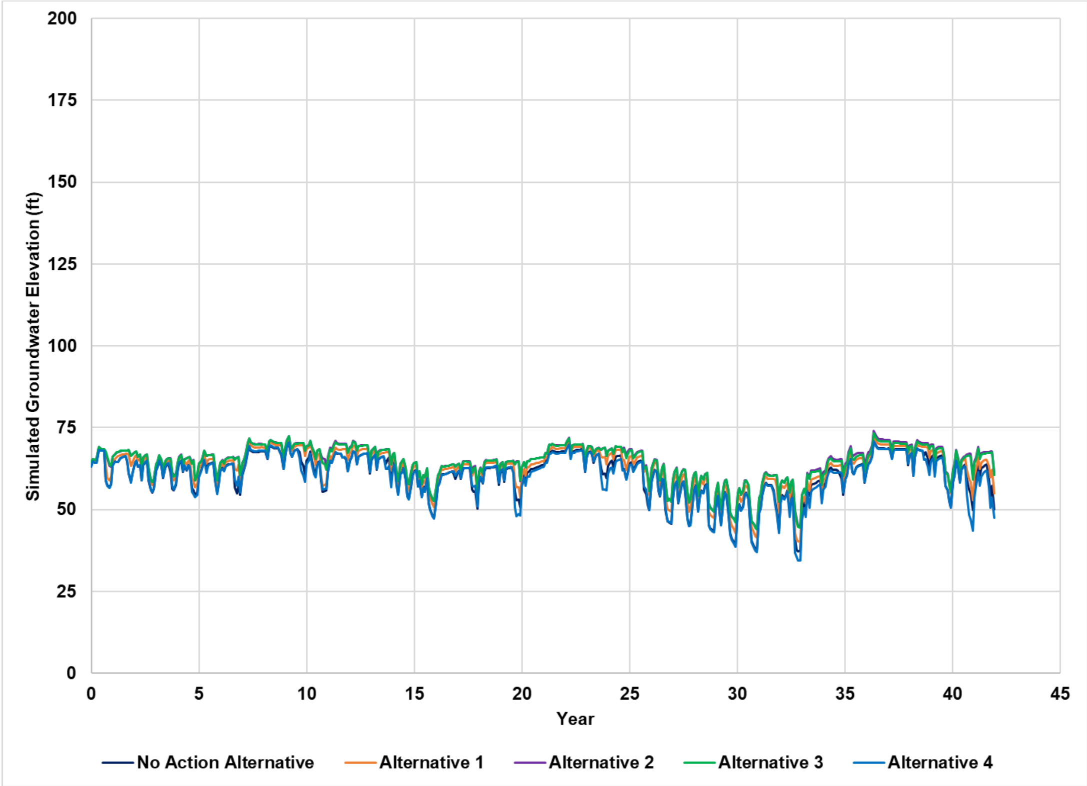


Figure I.2-2. Simulated Groundwater Elevation Location 1

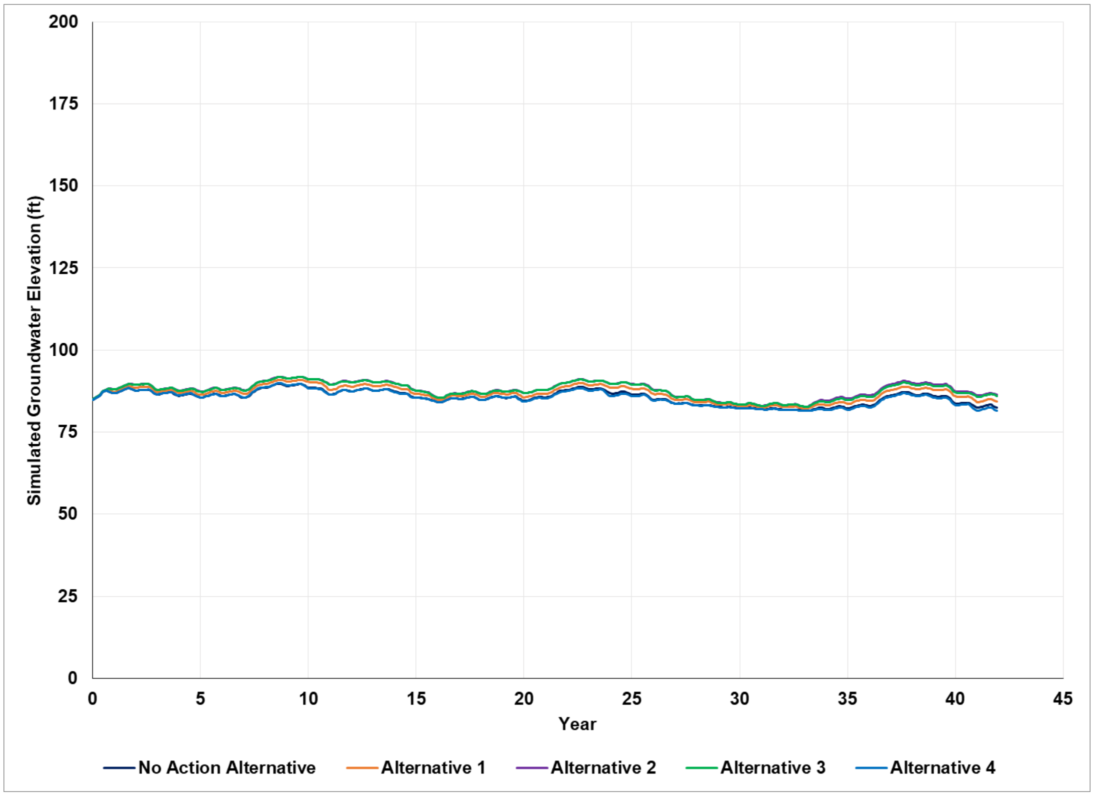


Figure I.2-3. Simulated Groundwater Elevation Location 2

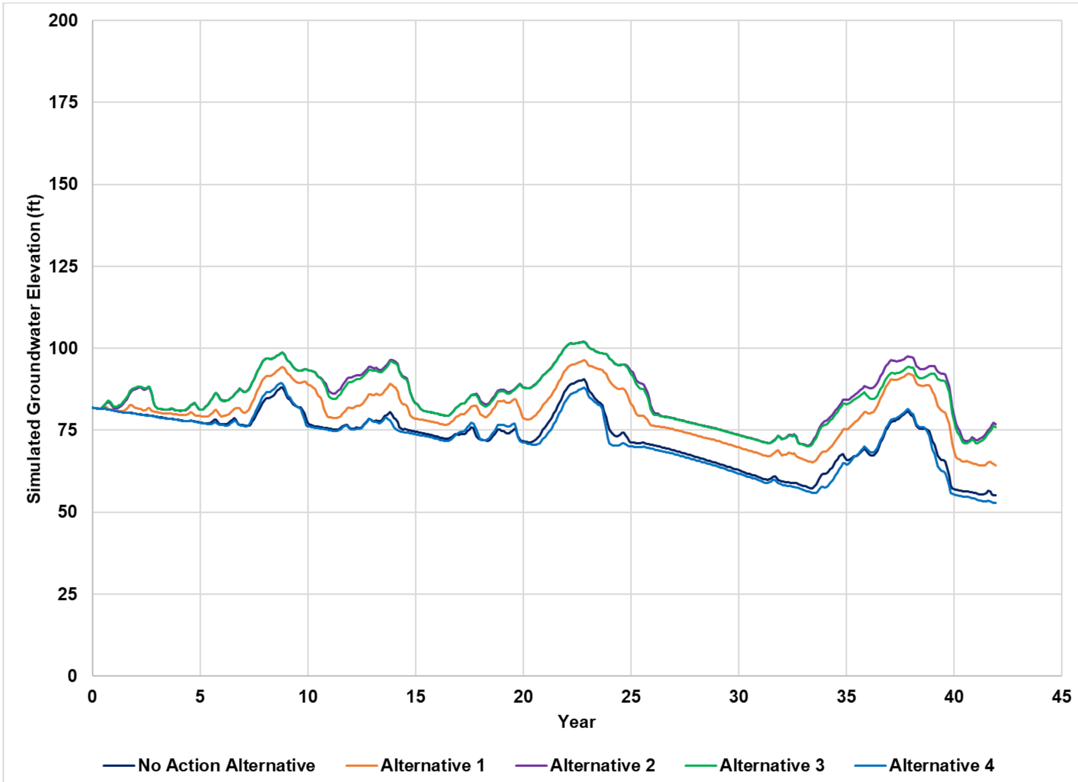


Figure I.2-4. Simulated Groundwater Elevation Location 3

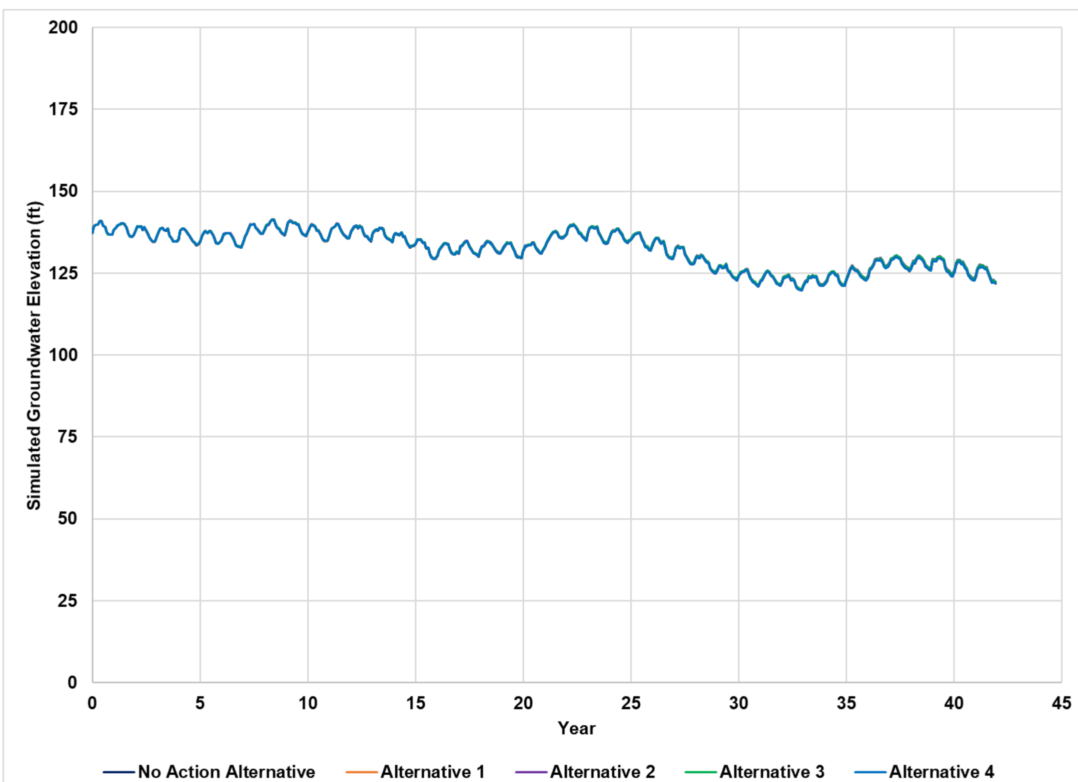


Figure I.2-5. Simulated Groundwater Elevation Location 4

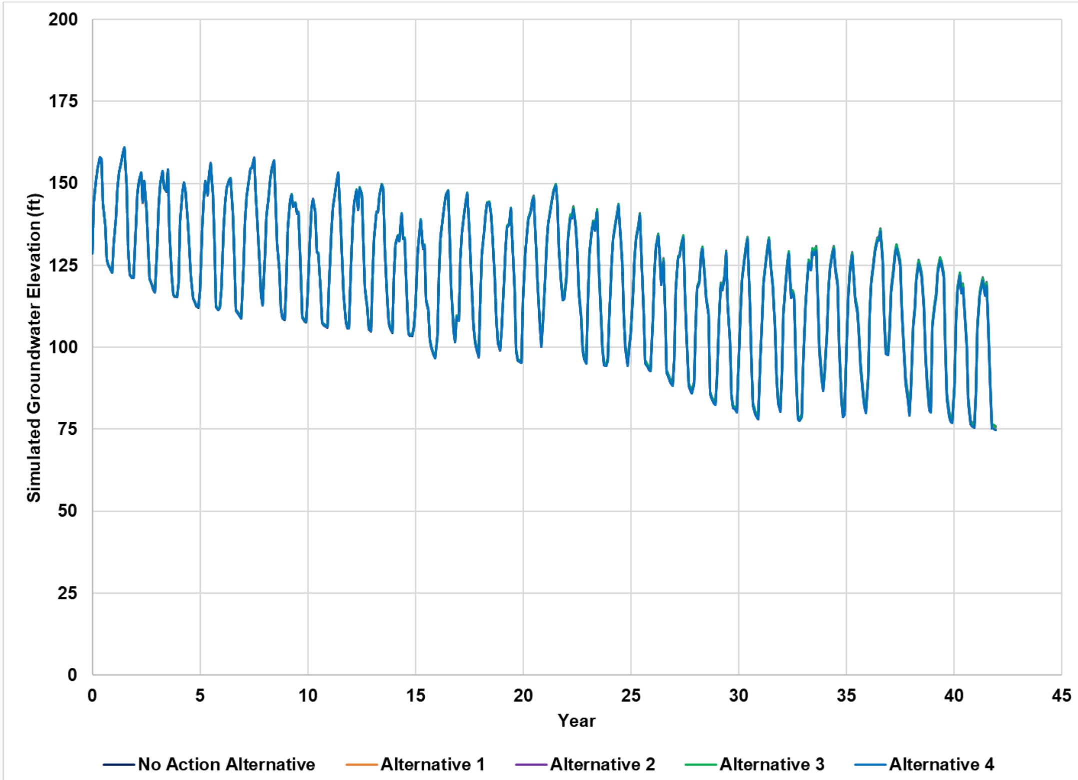


Figure I.2-6. Simulated Groundwater Elevation Location 5

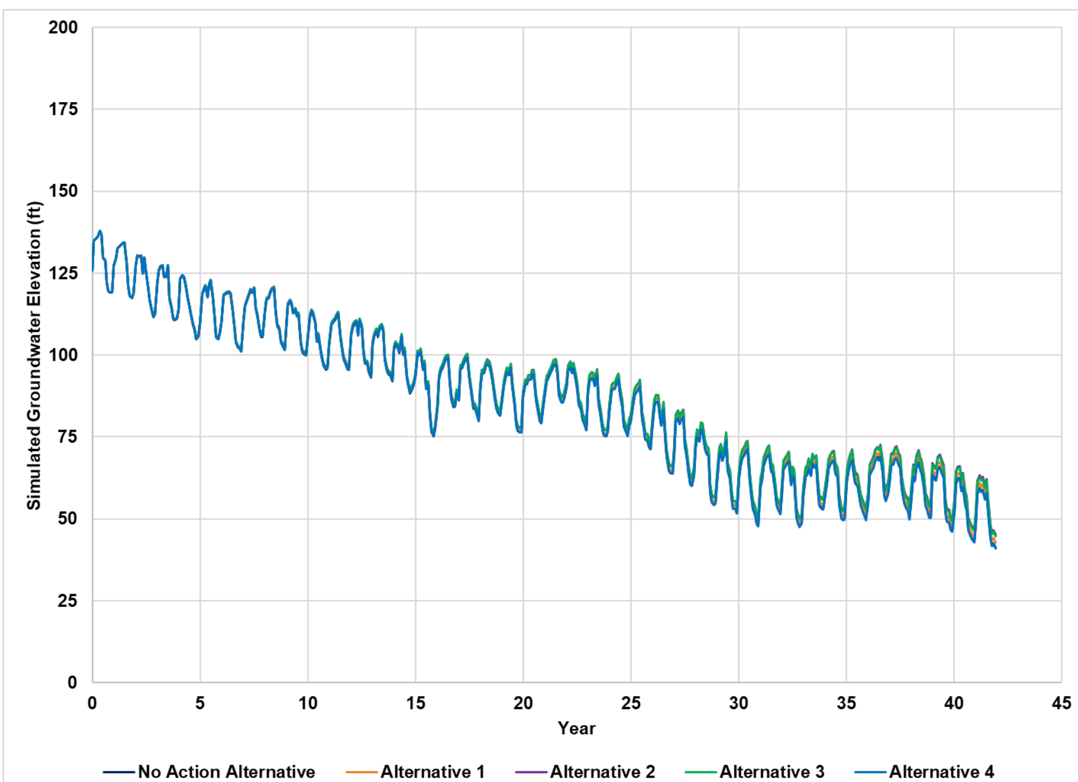


Figure I.2-7. Simulated Groundwater Elevation Location 6

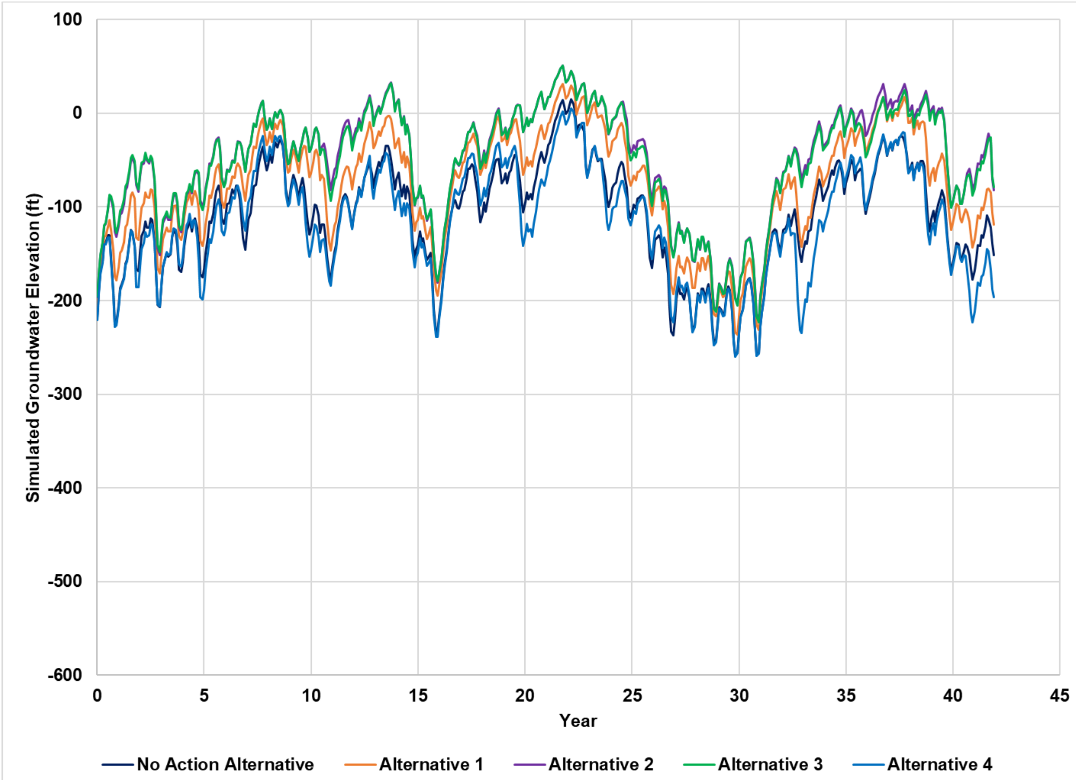


Figure I.2-8. Simulated Groundwater Elevation Location 7

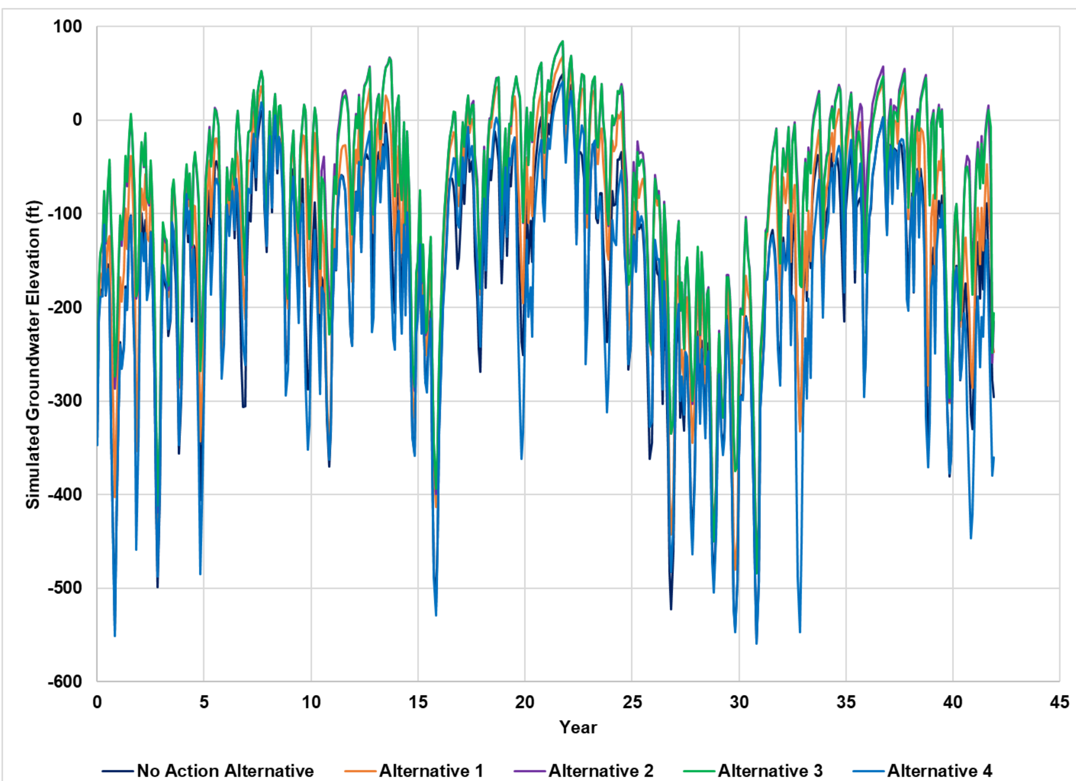
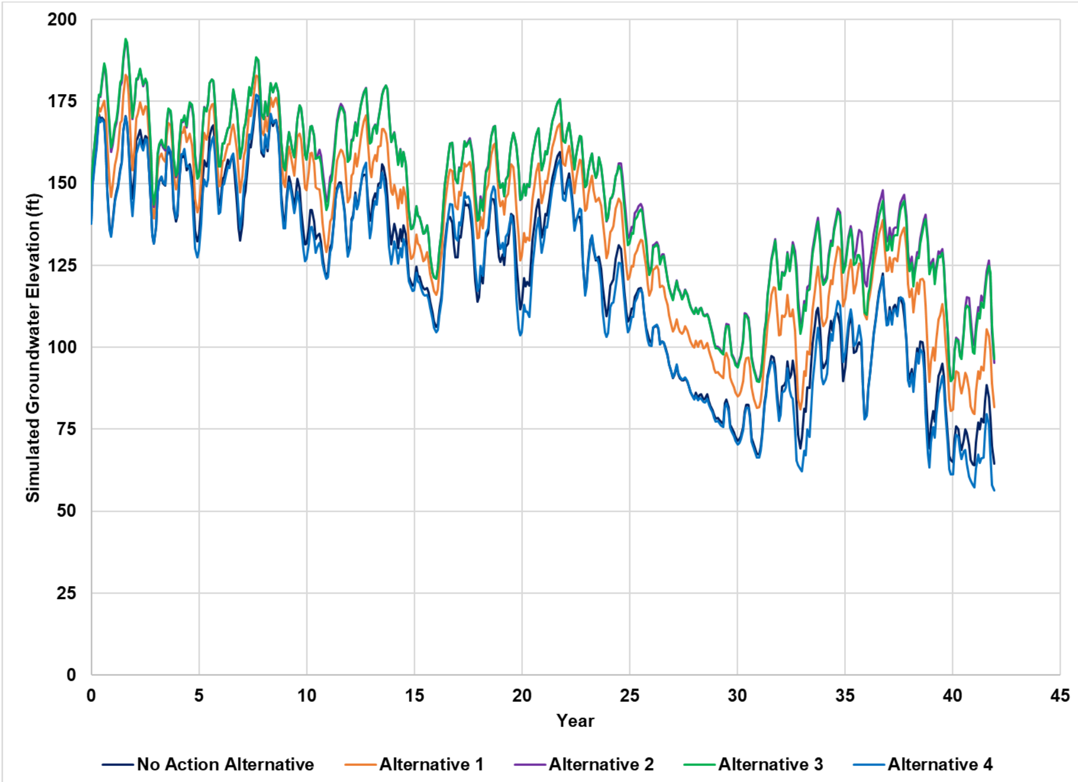


Figure I.2-9. Simulated Groundwater Elevation Location 8



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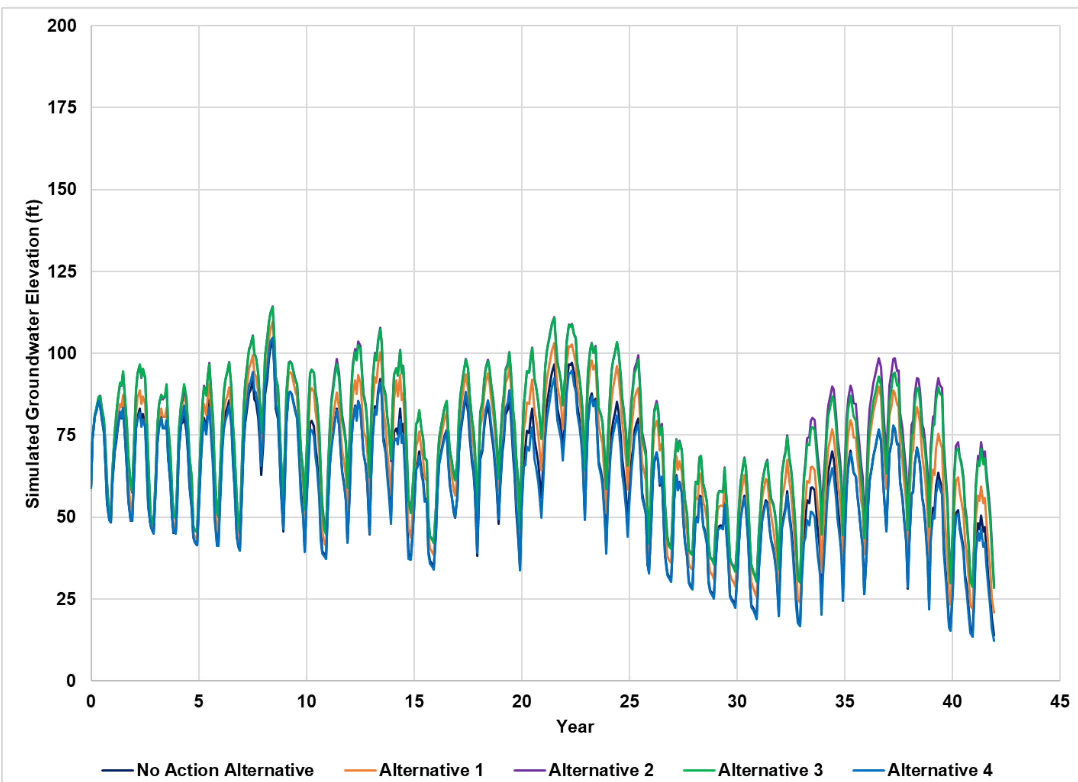

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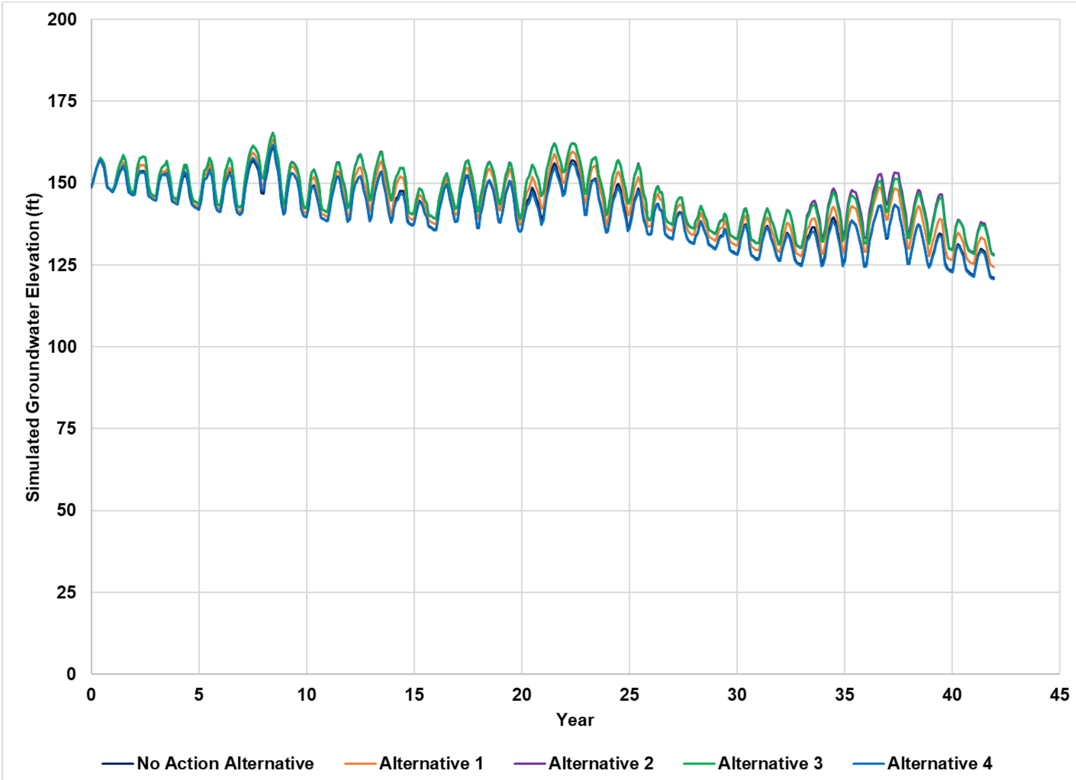

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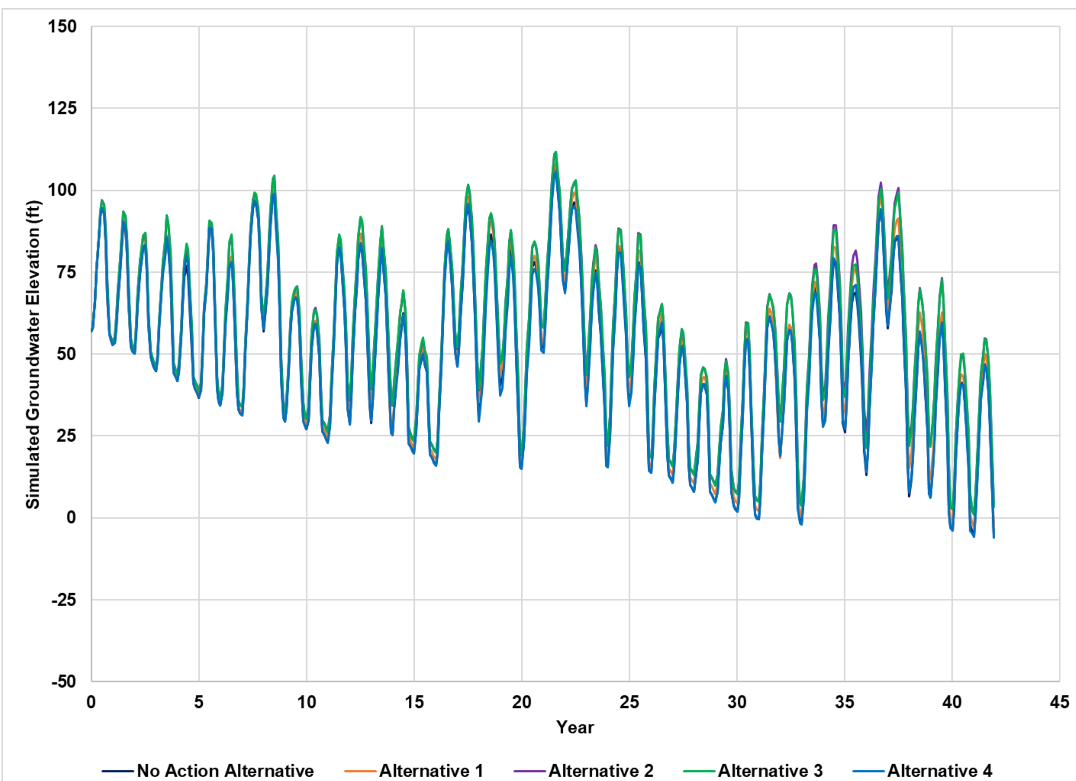
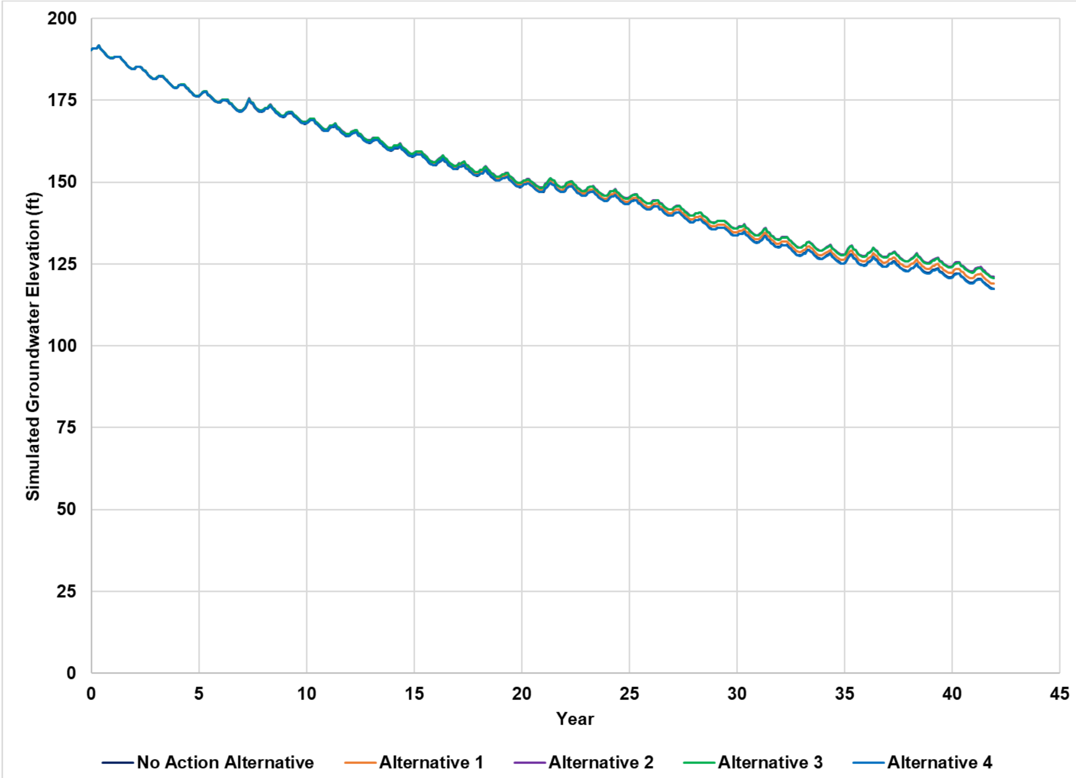


Figure I.2-13. Simulated Groundwater Elevation Location 12



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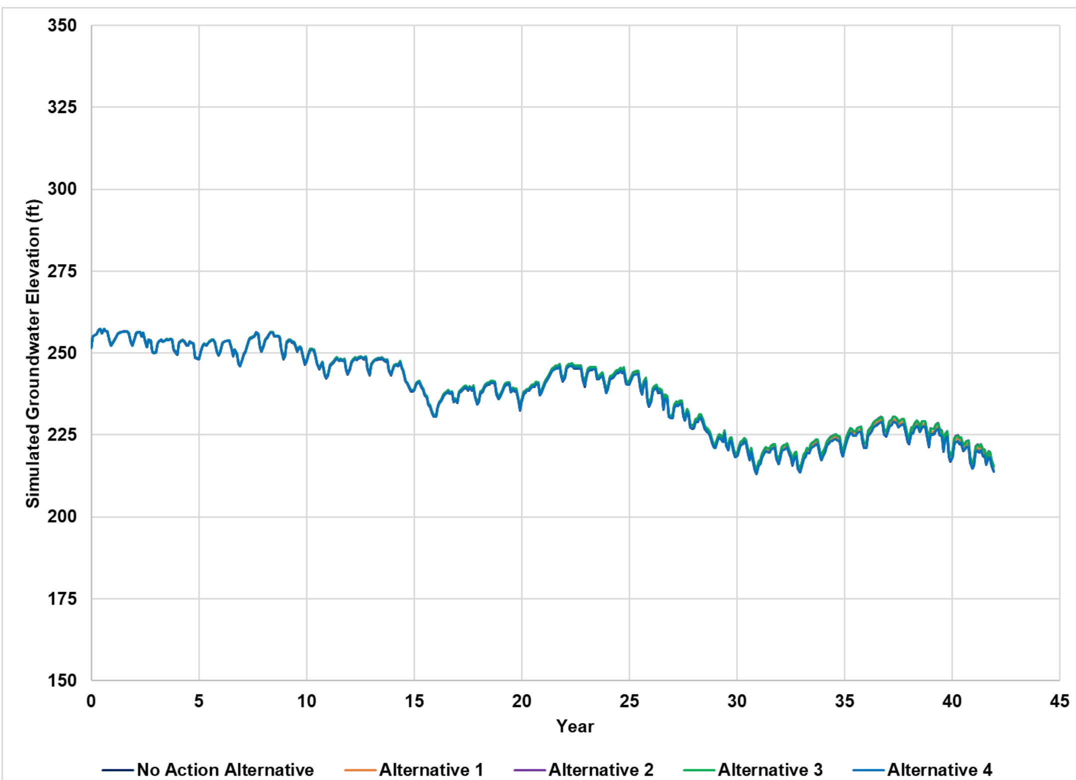

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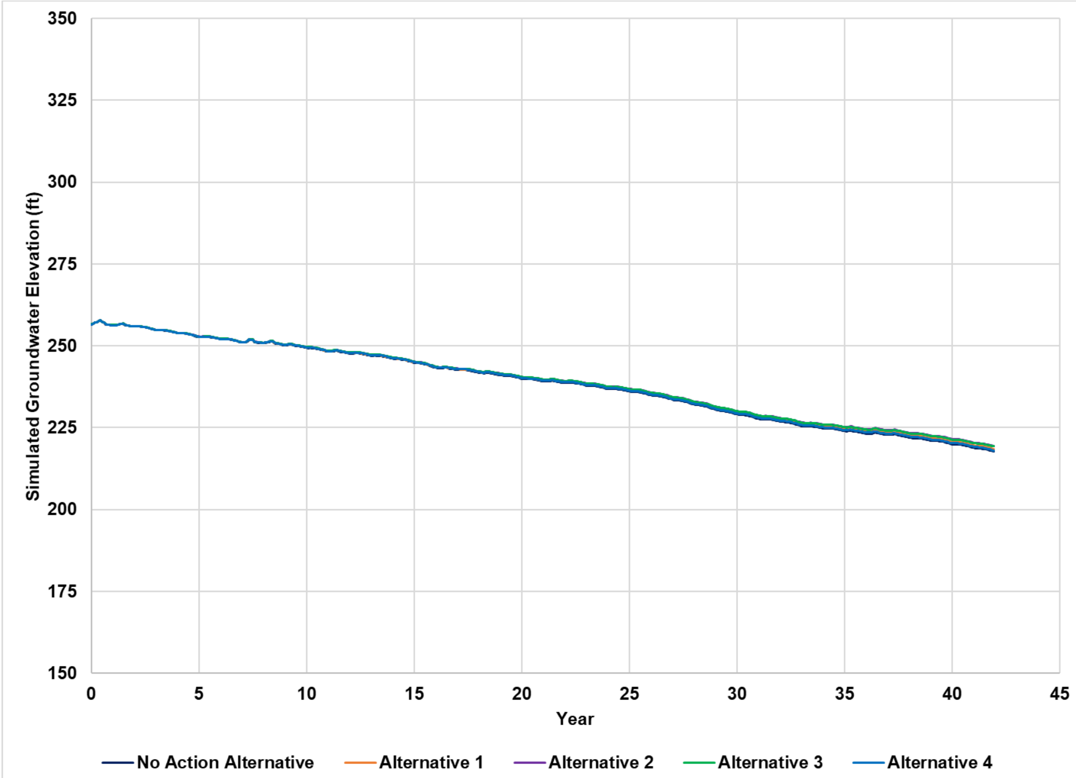

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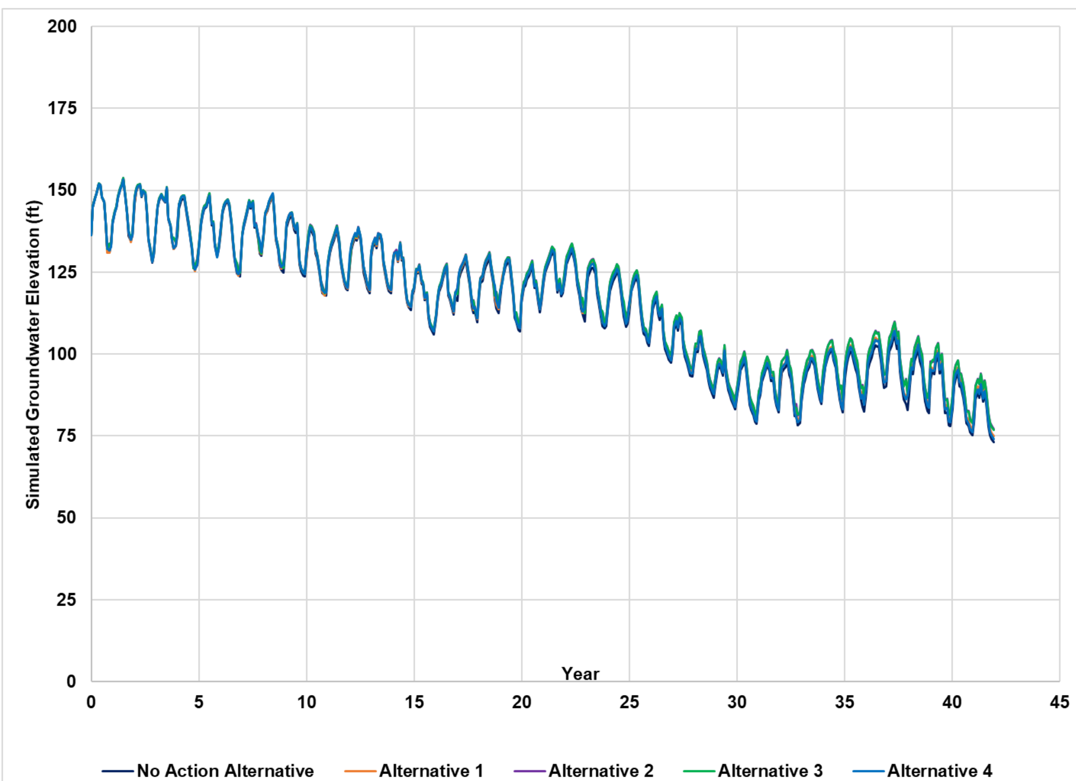

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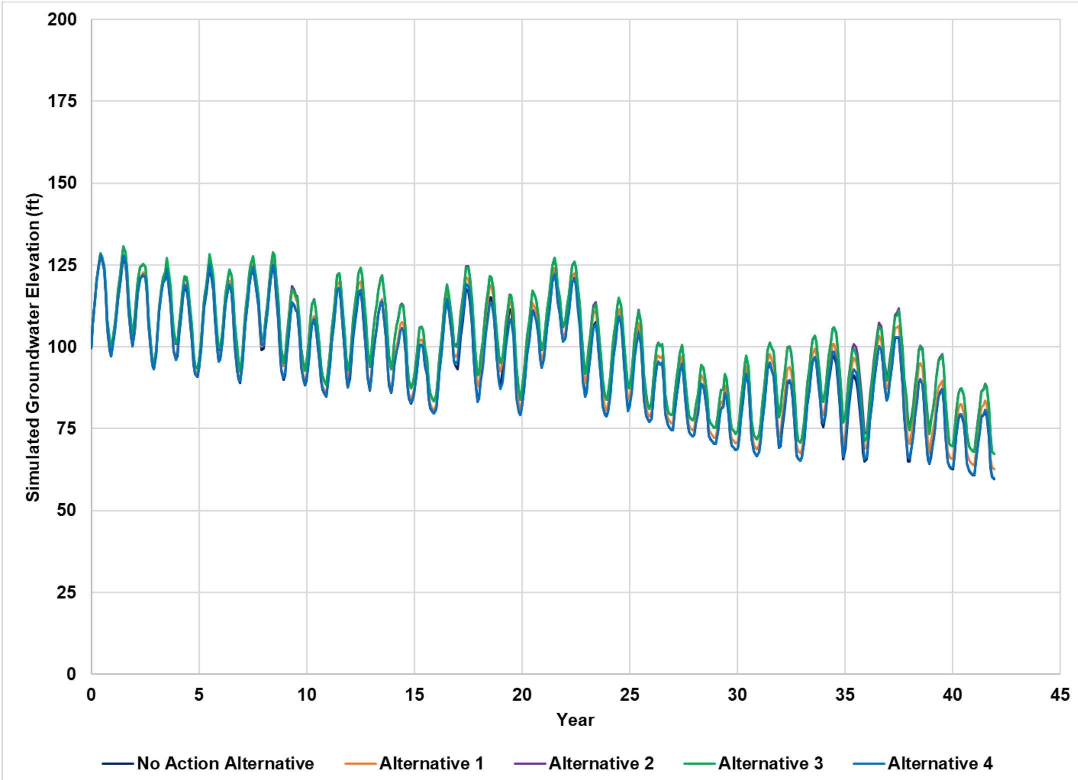

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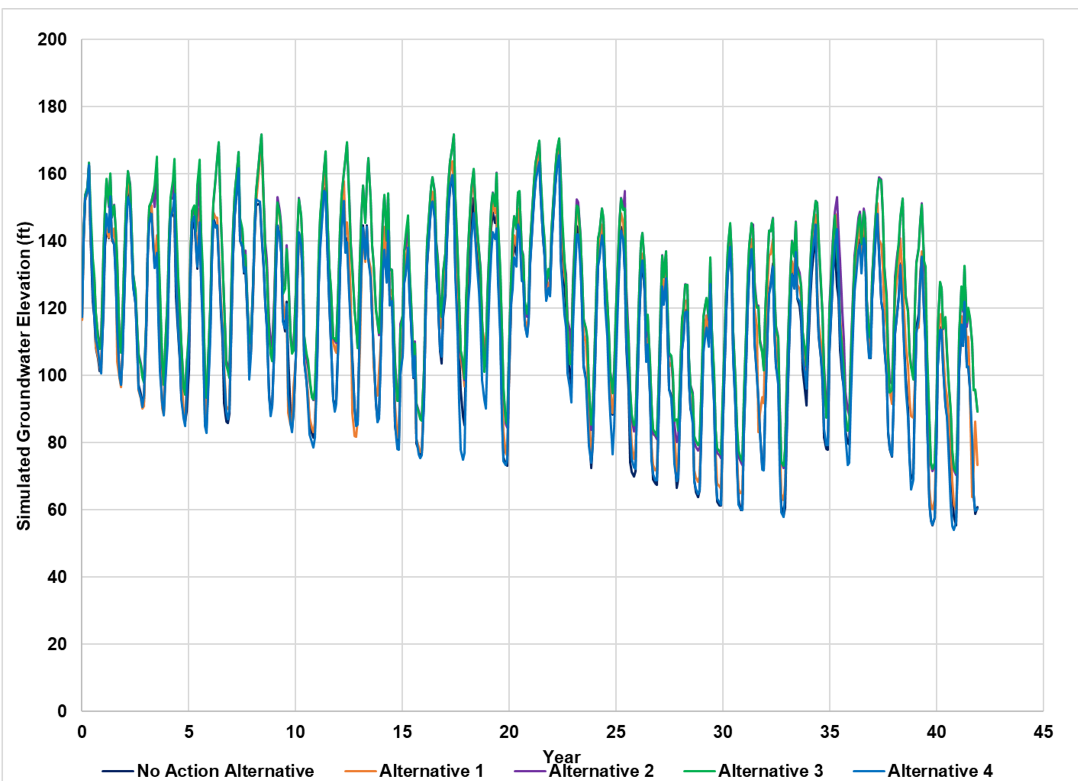
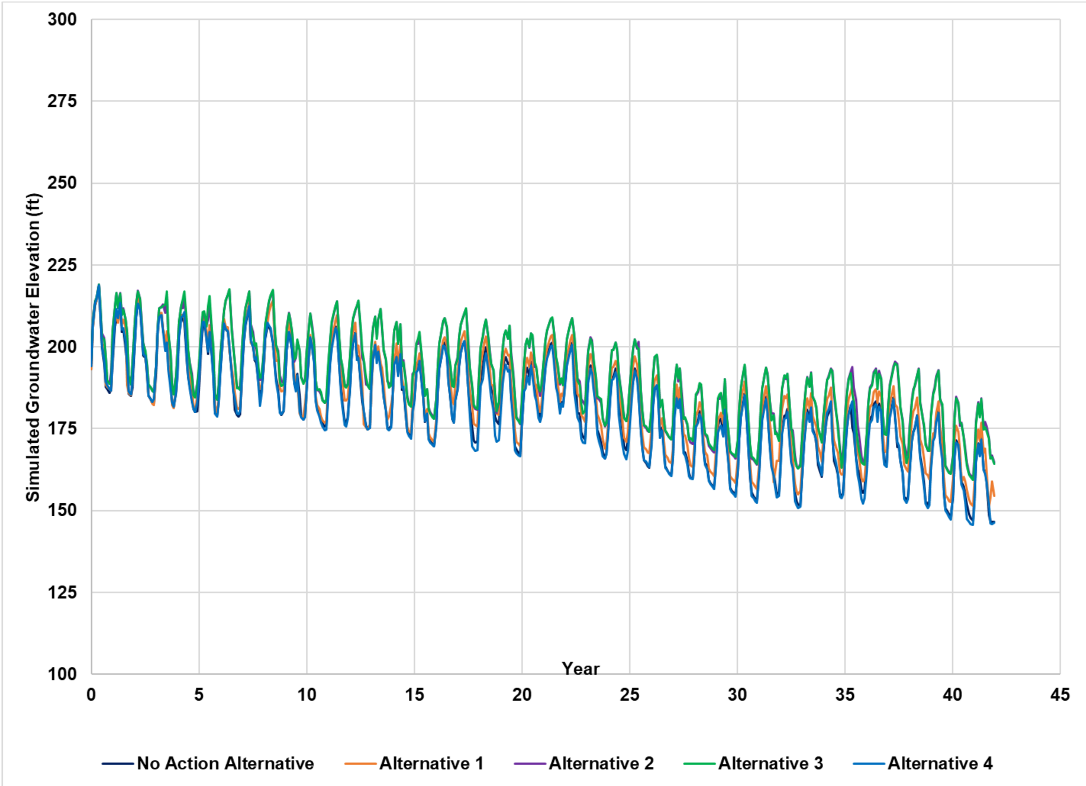


Figure I.2-19. Simulated Groundwater Elevation Location 18



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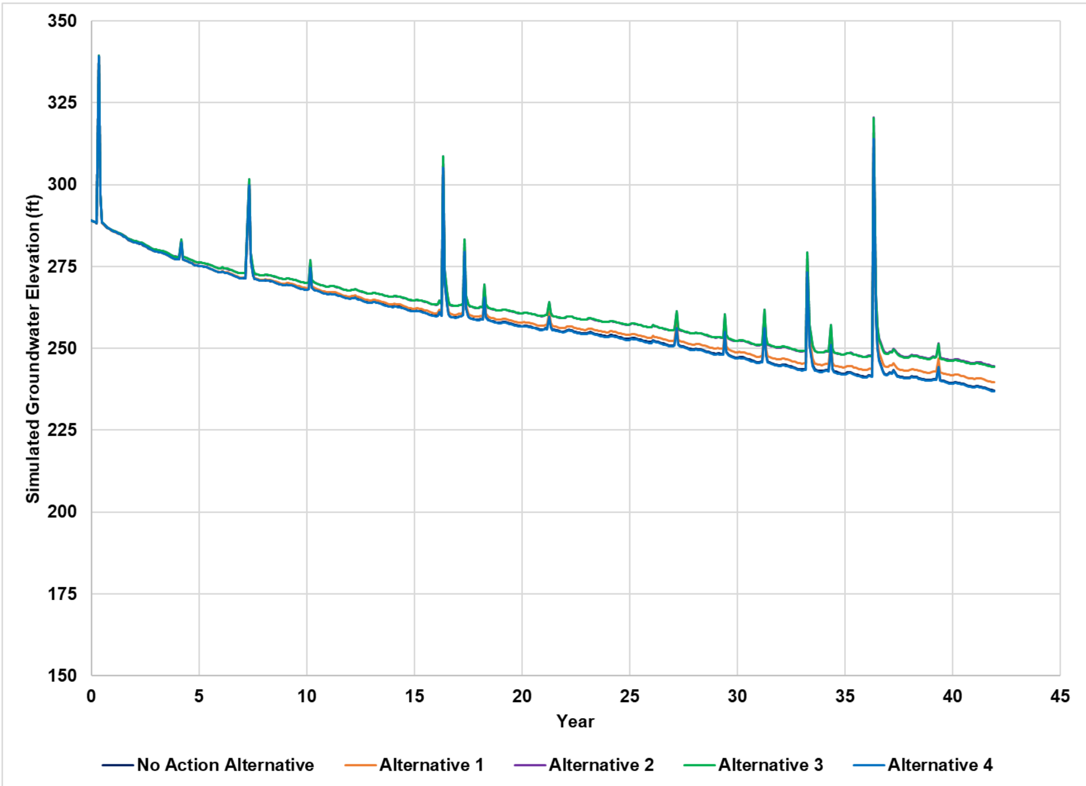


Figure I.2-21. Simulated Groundwater Elevation Location 20

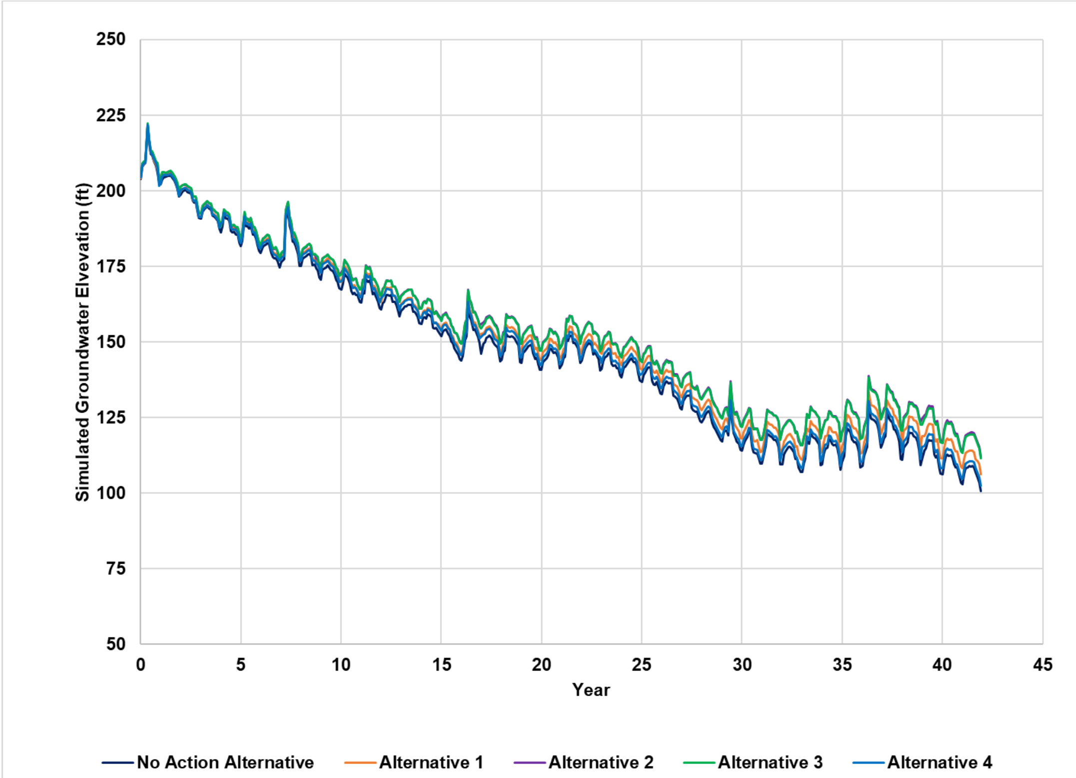


Figure I.2-22. Simulated Groundwater Elevation Location 21

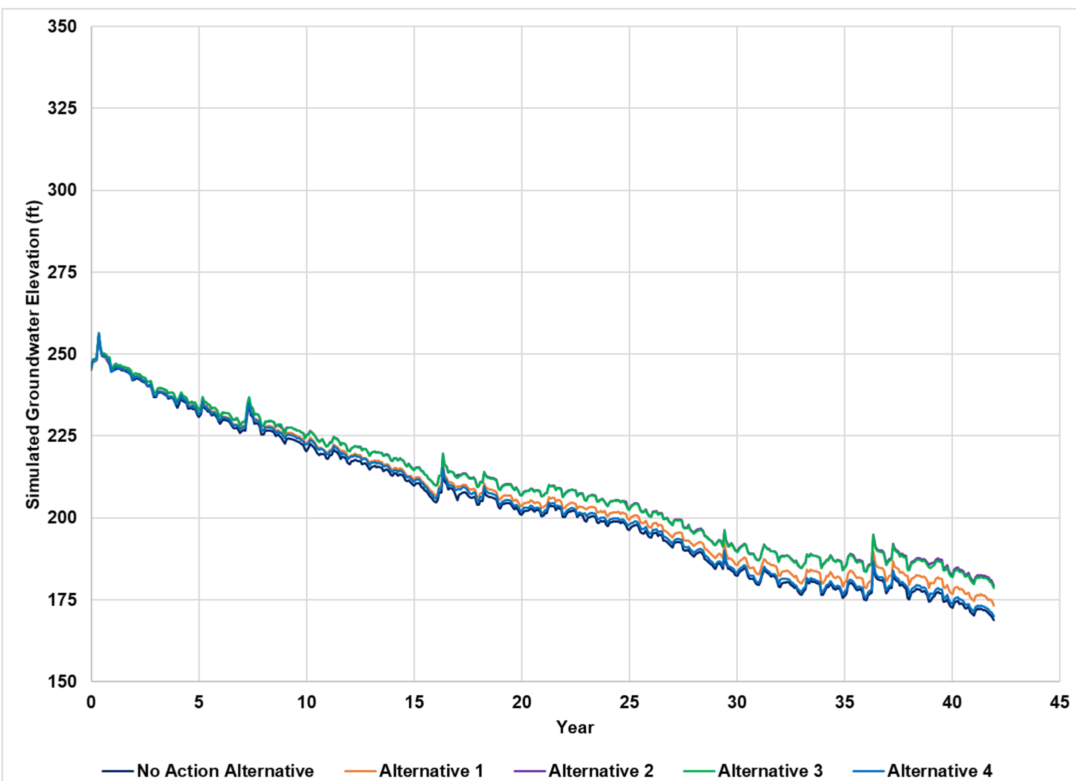


Figure I.2-23. Simulated Groundwater Elevation Location 22

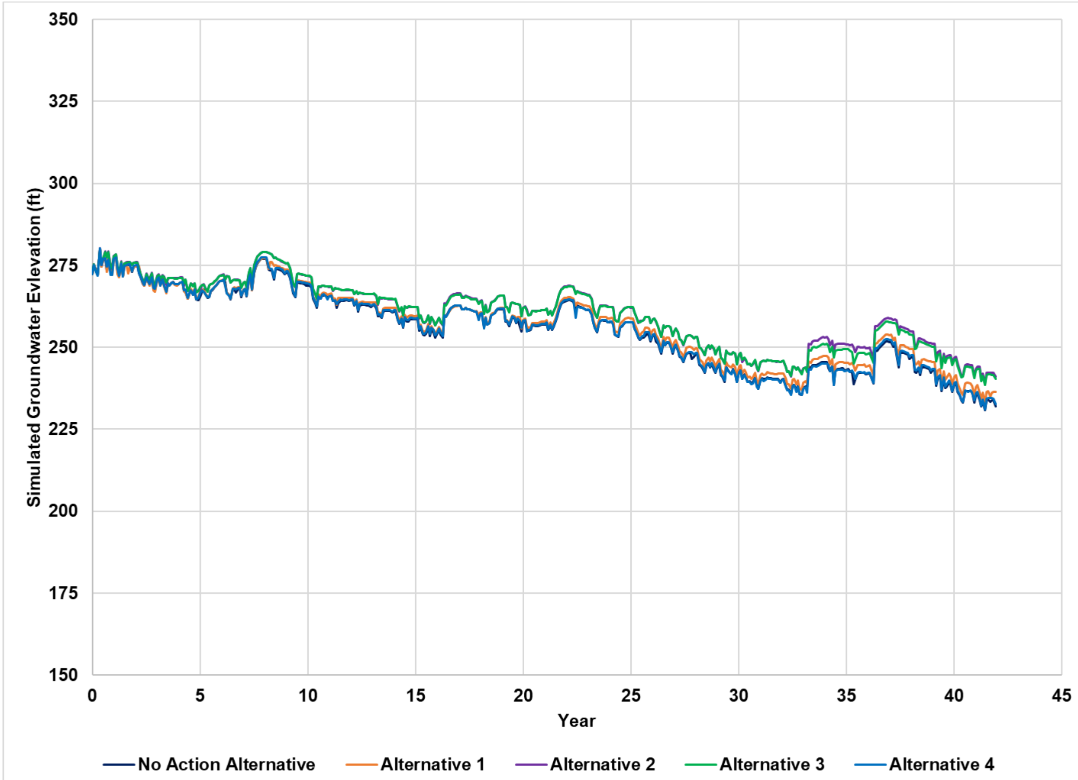


Figure I.2-24. Simulated Groundwater Elevation Location 23

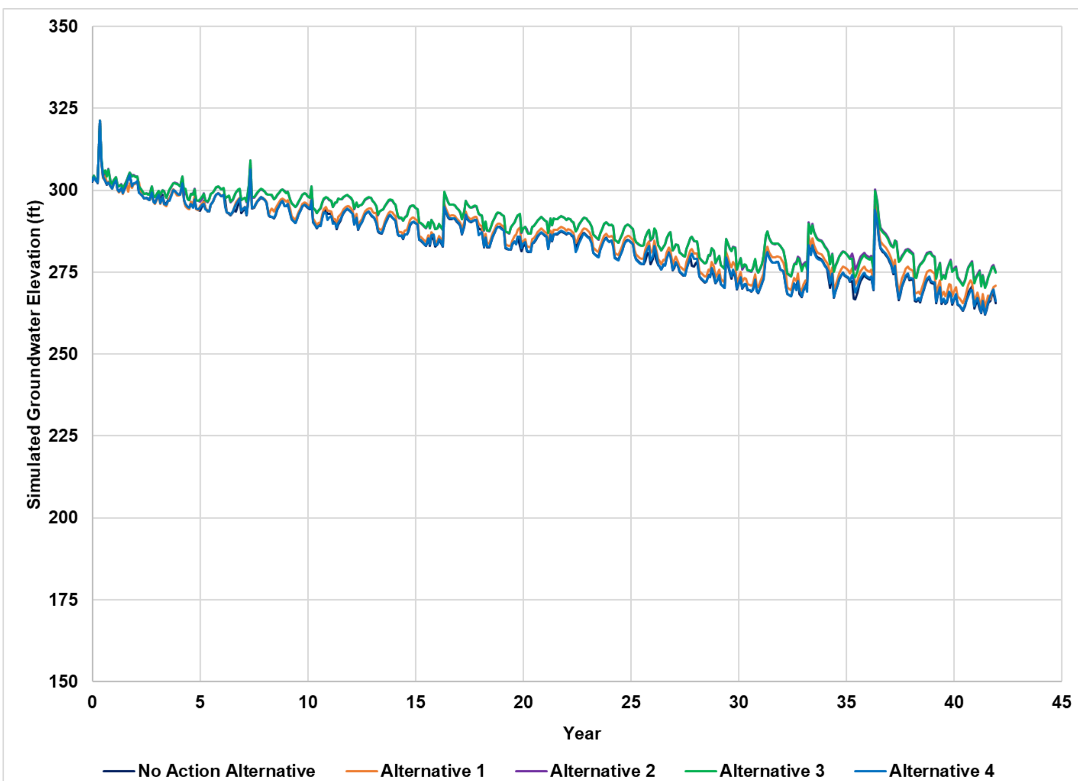


Figure I.2-25. Simulated Groundwater Elevation Location 24

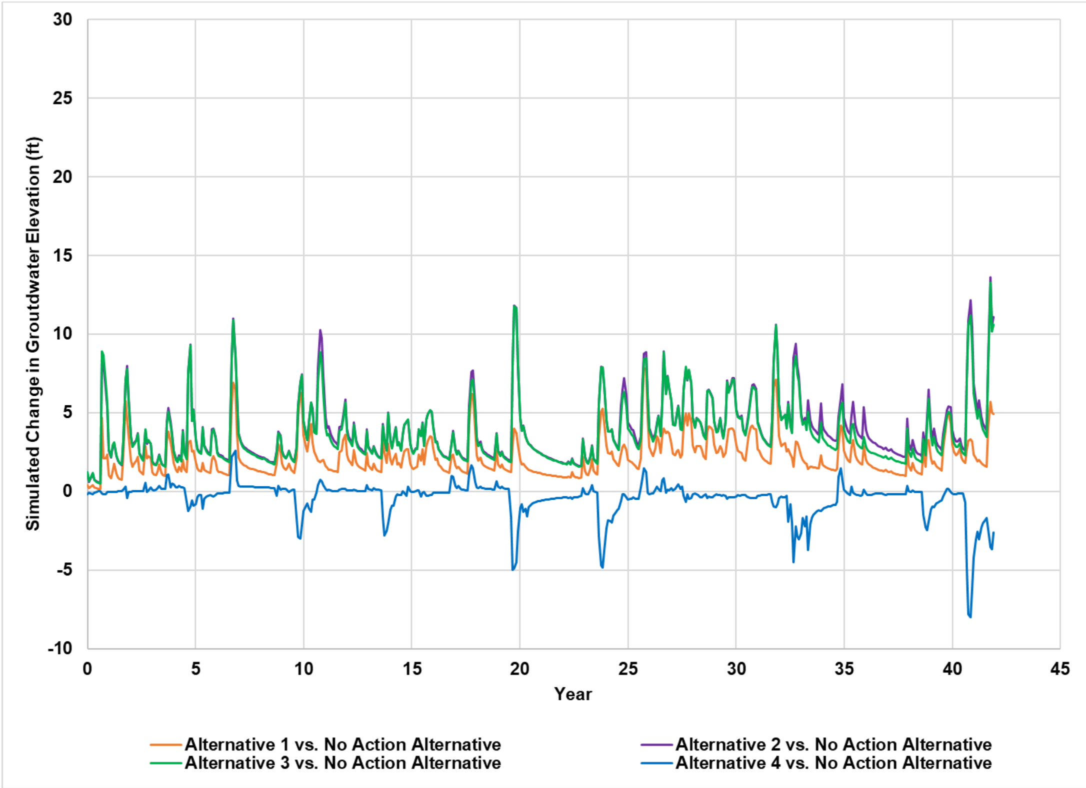


Figure I.2-26. Simulated Change in Groundwater Elevation Location 1

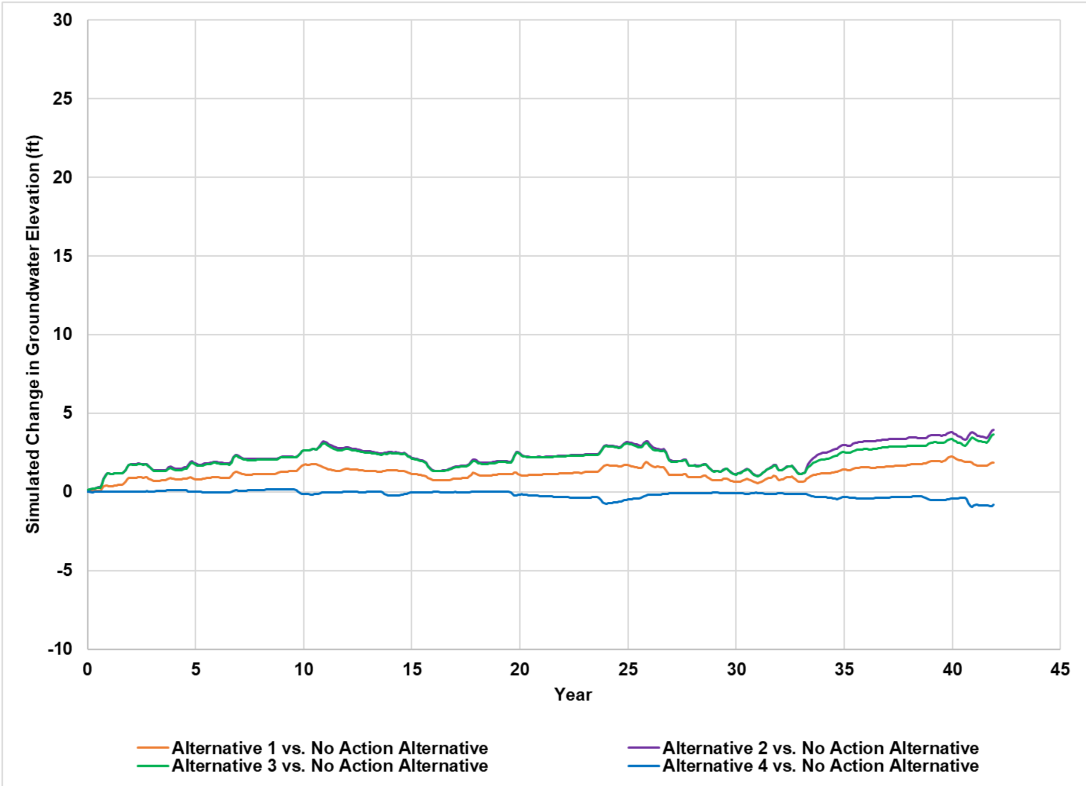


Figure I.2-27. Simulated Change in Groundwater Elevation Location 2

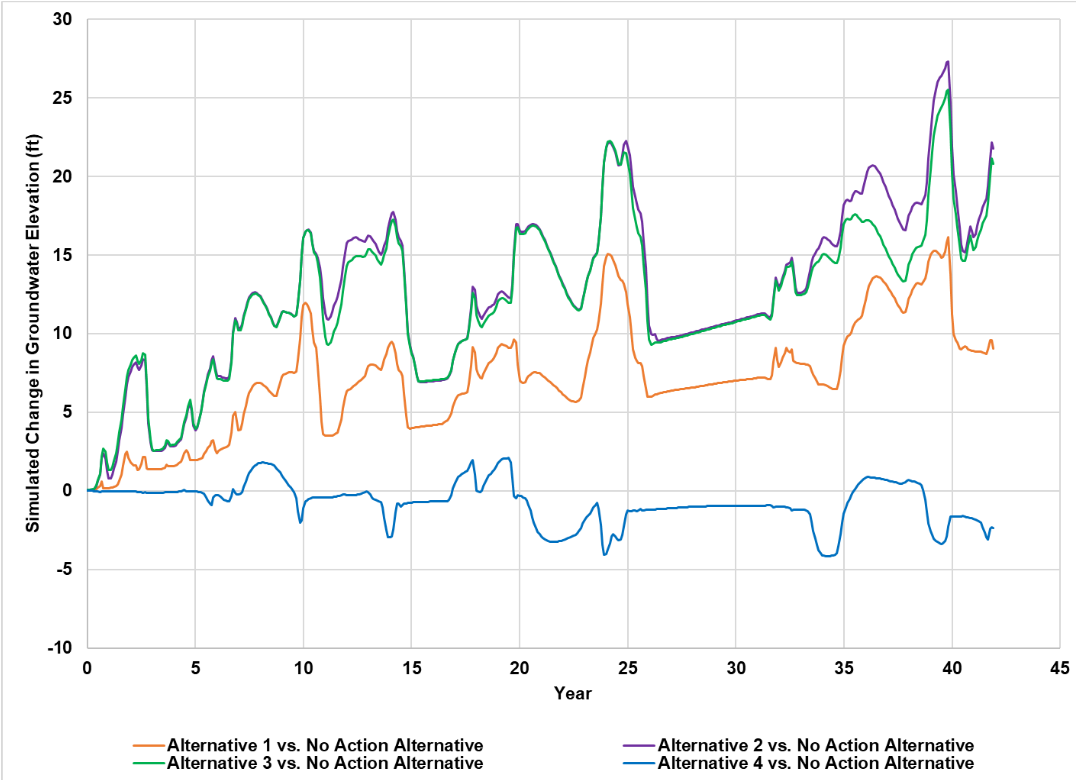


Figure I.2-28. Simulated Change in Groundwater Elevation Location 3

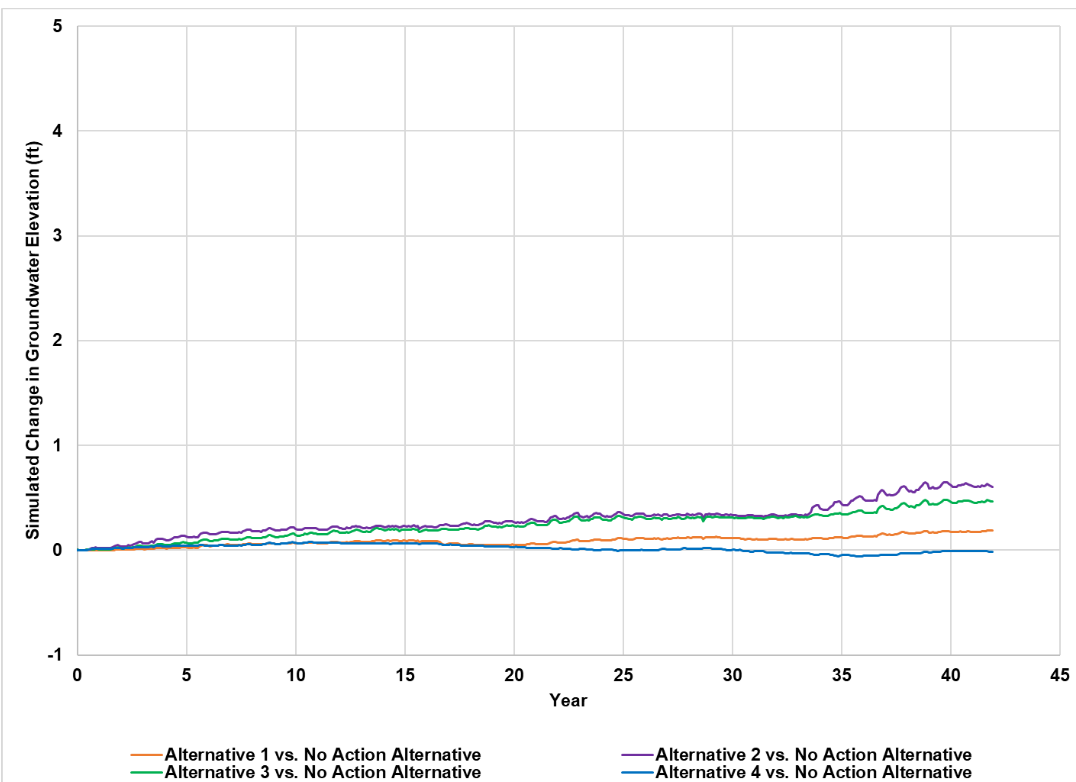


Figure I.2-29. Simulated Change in Groundwater Elevation Location 4

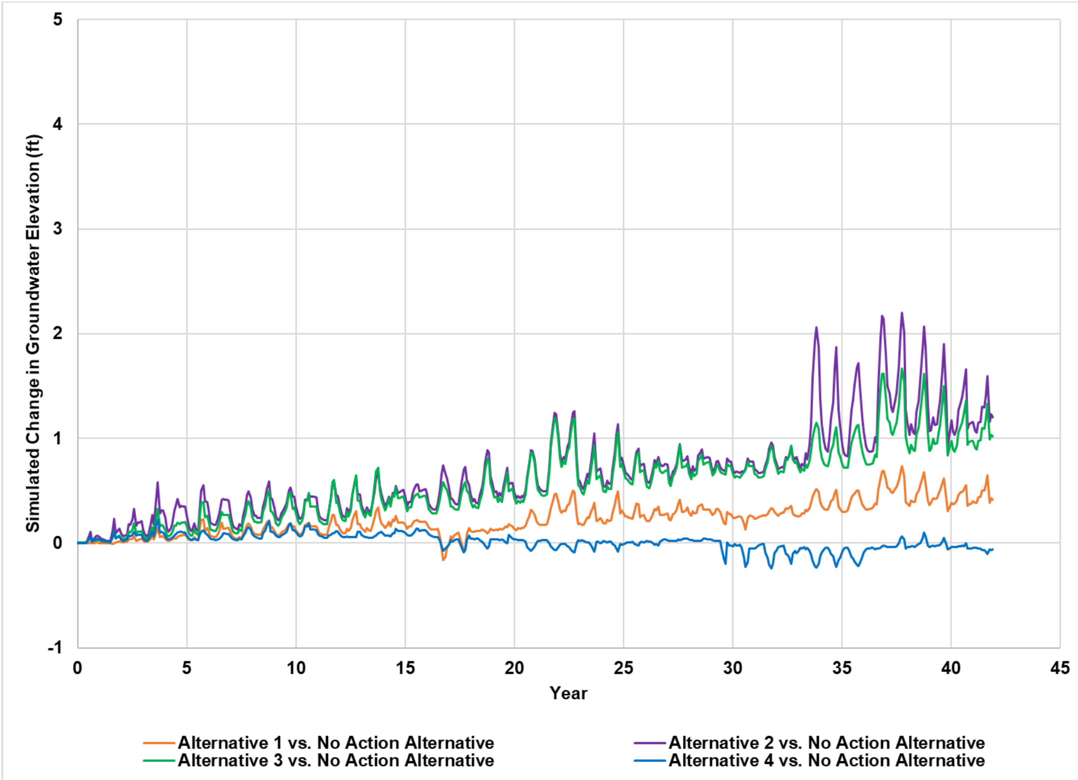


Figure I.2-30. Simulated Change in Groundwater Elevation Location 5

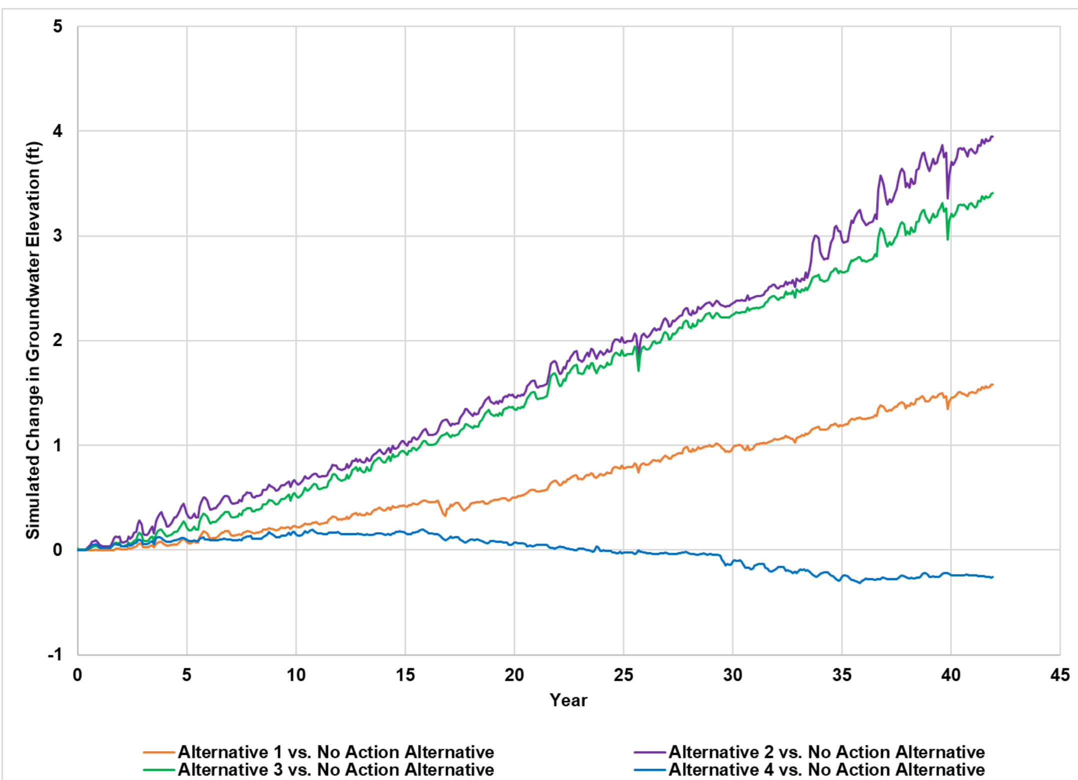


Figure I.2-31. Simulated Change in Groundwater Elevation Location 6

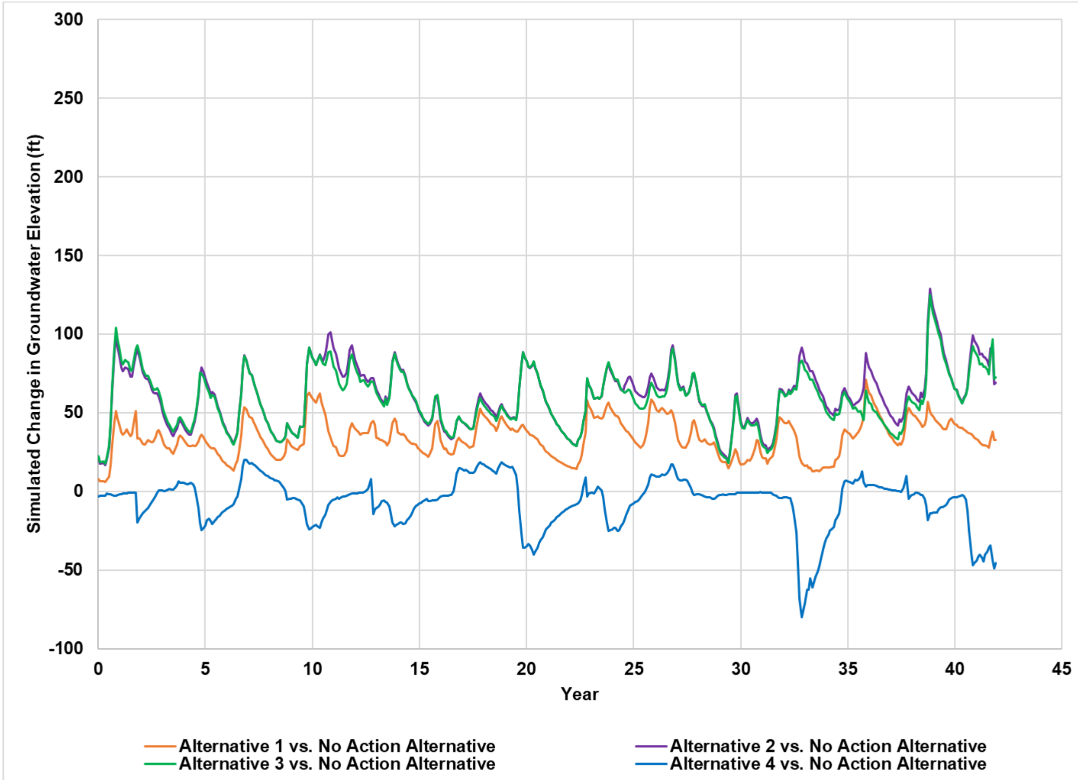


Figure I.2-32. Simulated Change in Groundwater Elevation Location 7

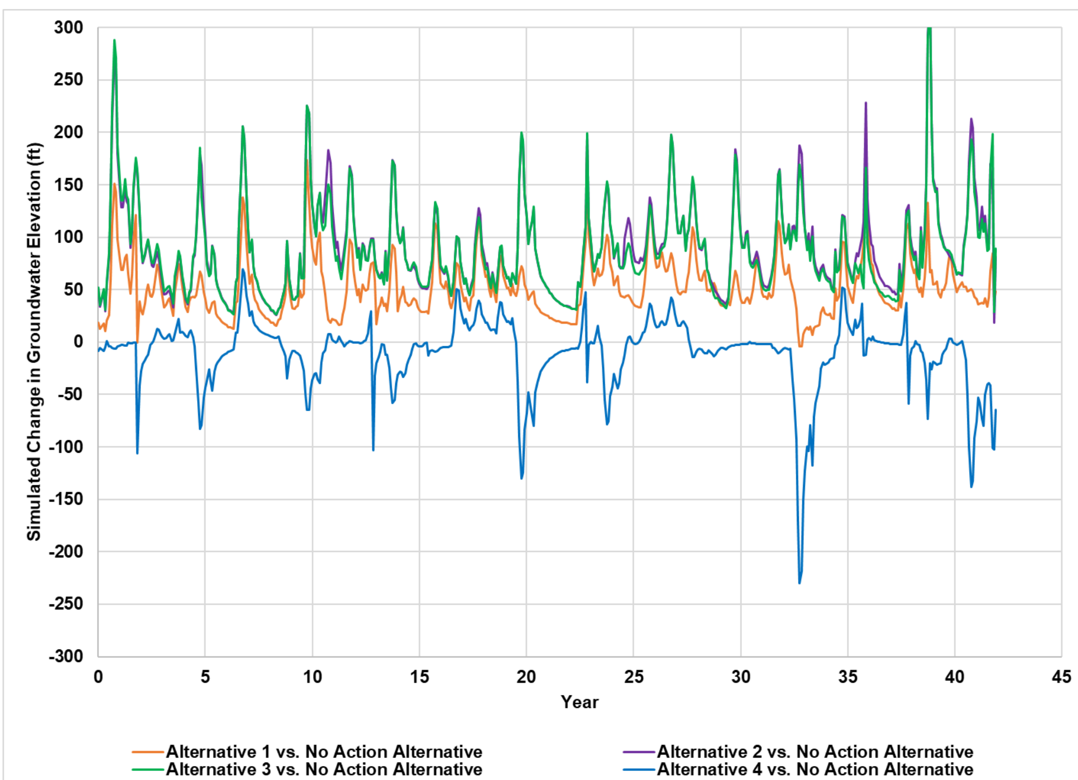


Figure I.2-33. Simulated Change in Groundwater Elevation Location 8

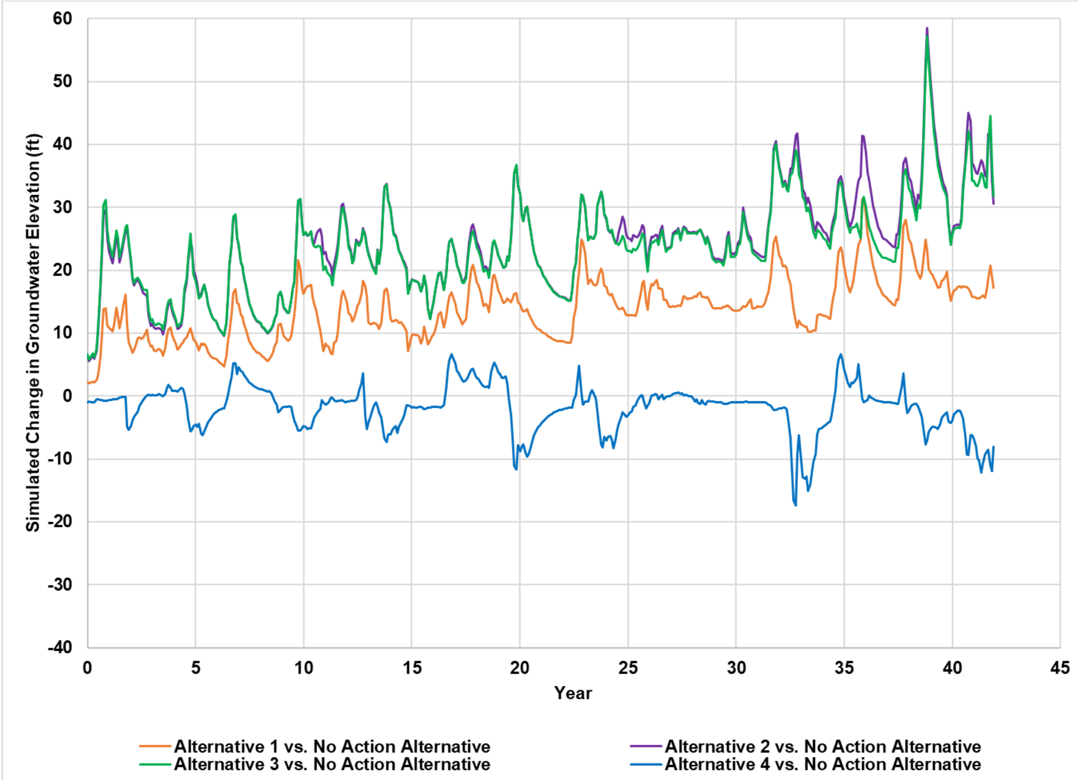


Figure I.2-34. Simulated Change in Groundwater Elevation Location 9

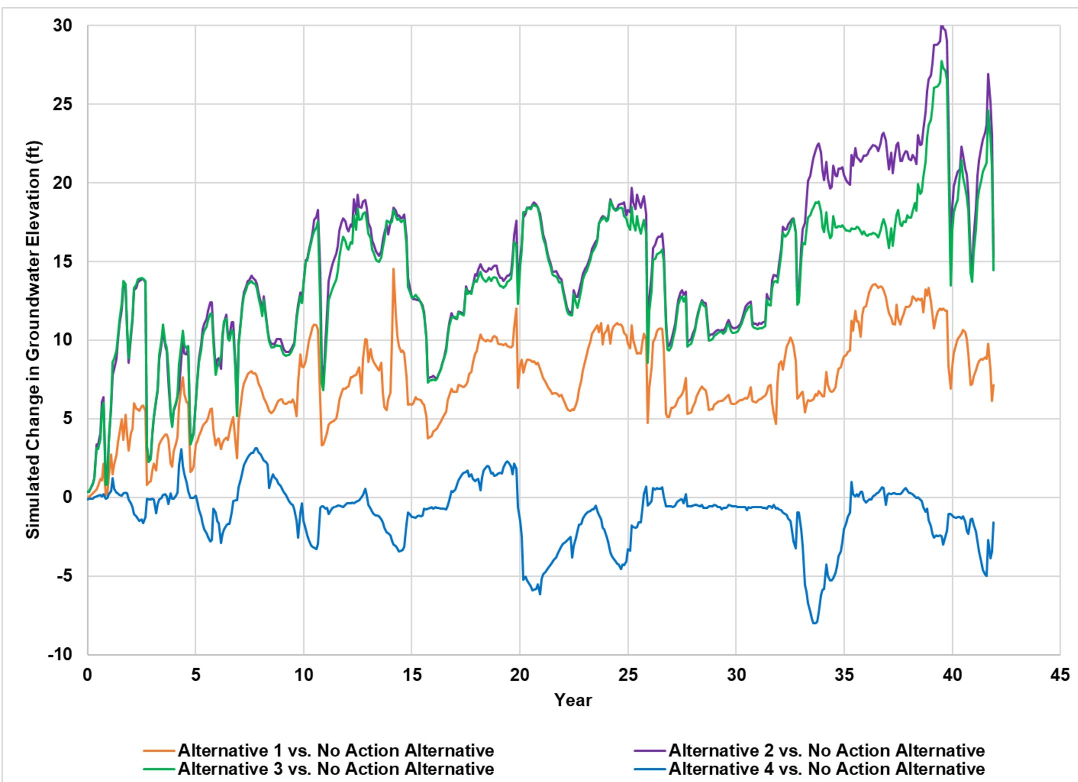


Figure I.2-35. Simulated Change in Groundwater Elevation Location 10

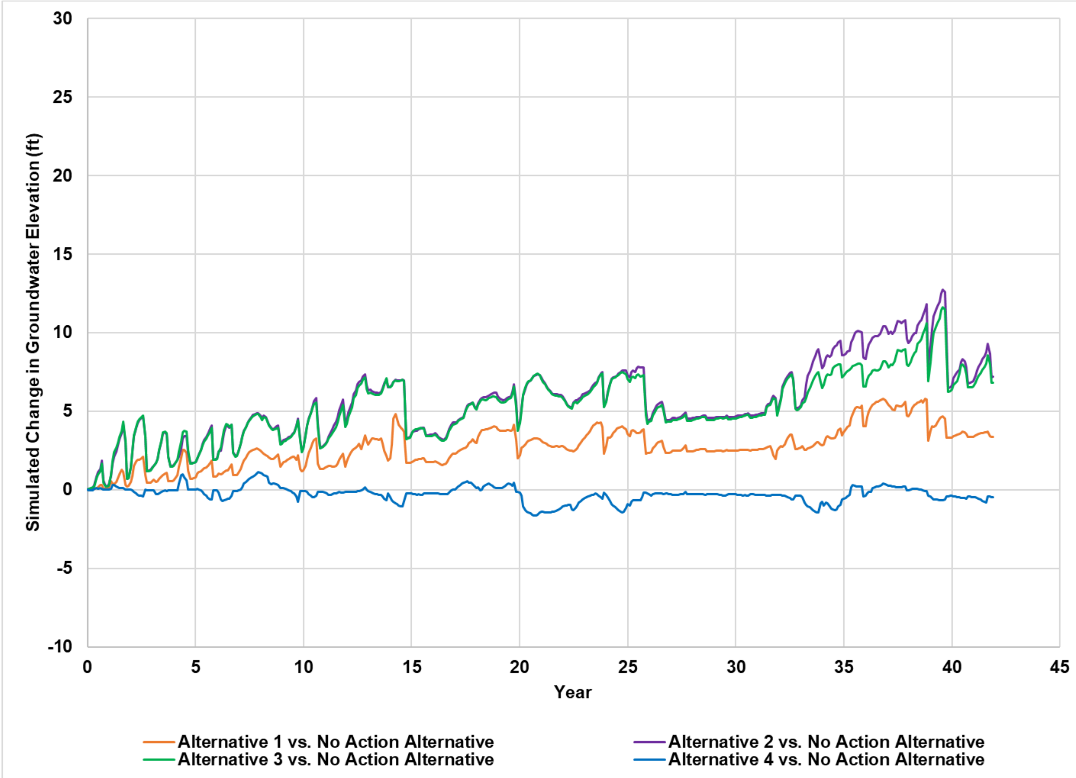


Figure I.2-36. Simulated Change in Groundwater Elevation Location 11

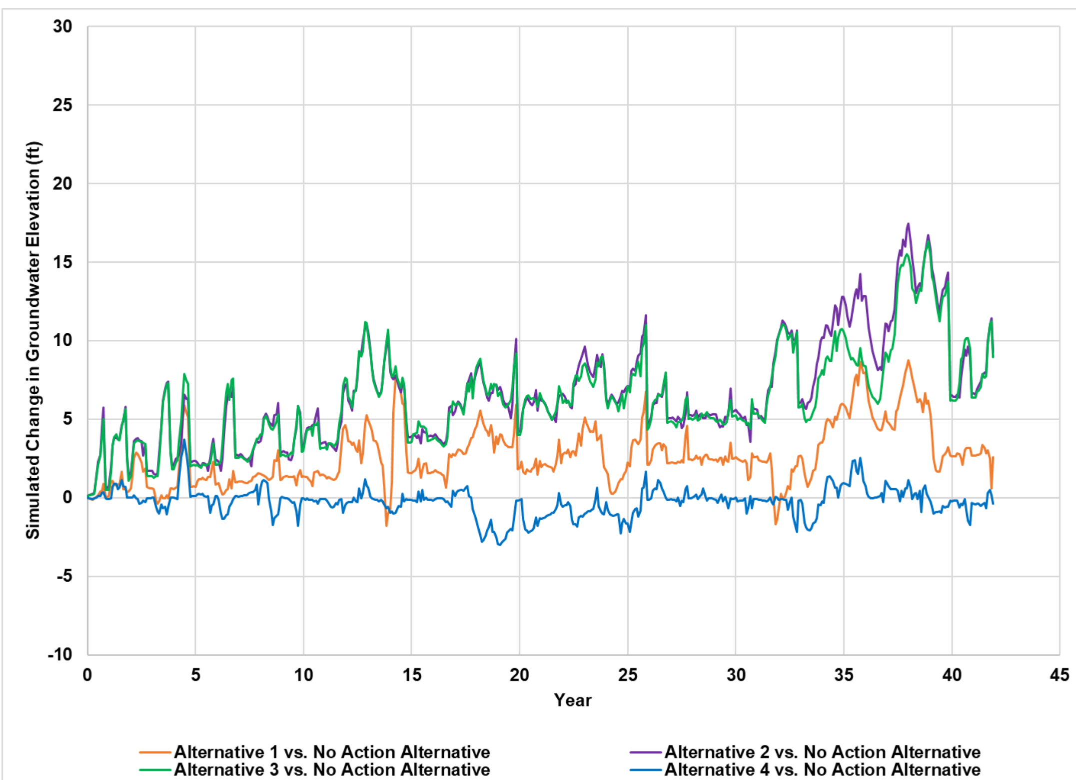


Figure I.2-37. Simulated Change in Groundwater Elevation Location 12

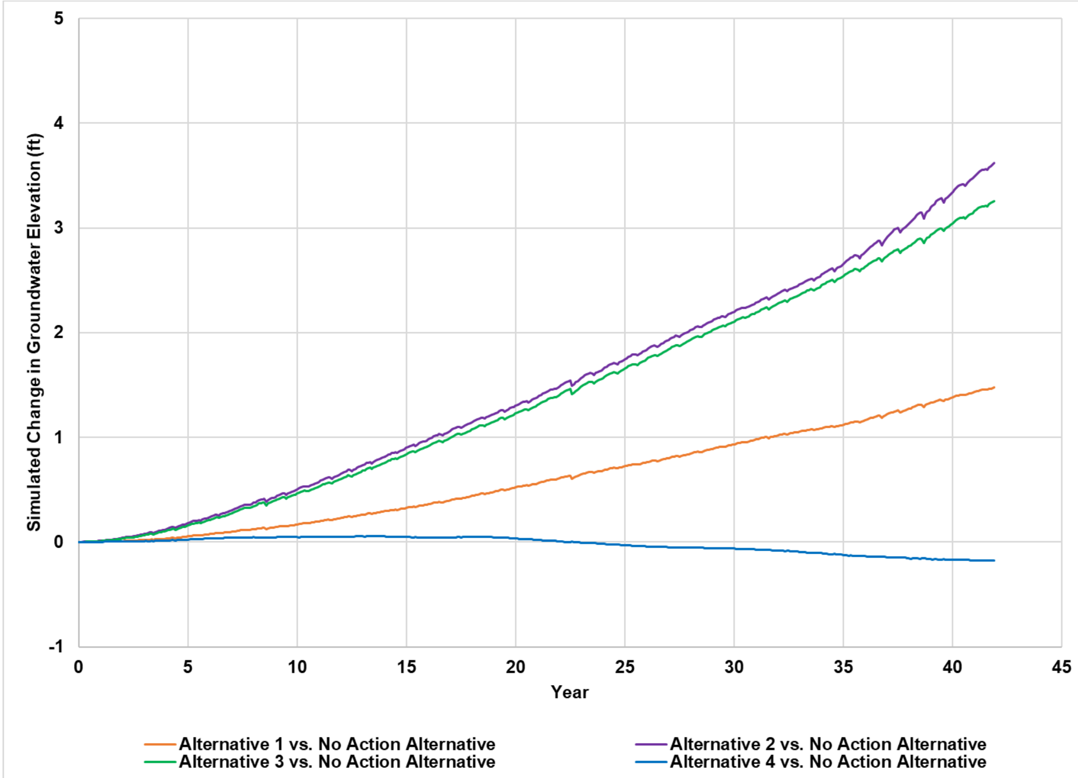


Figure I.2-38. Simulated Change in Groundwater Elevation Location 13

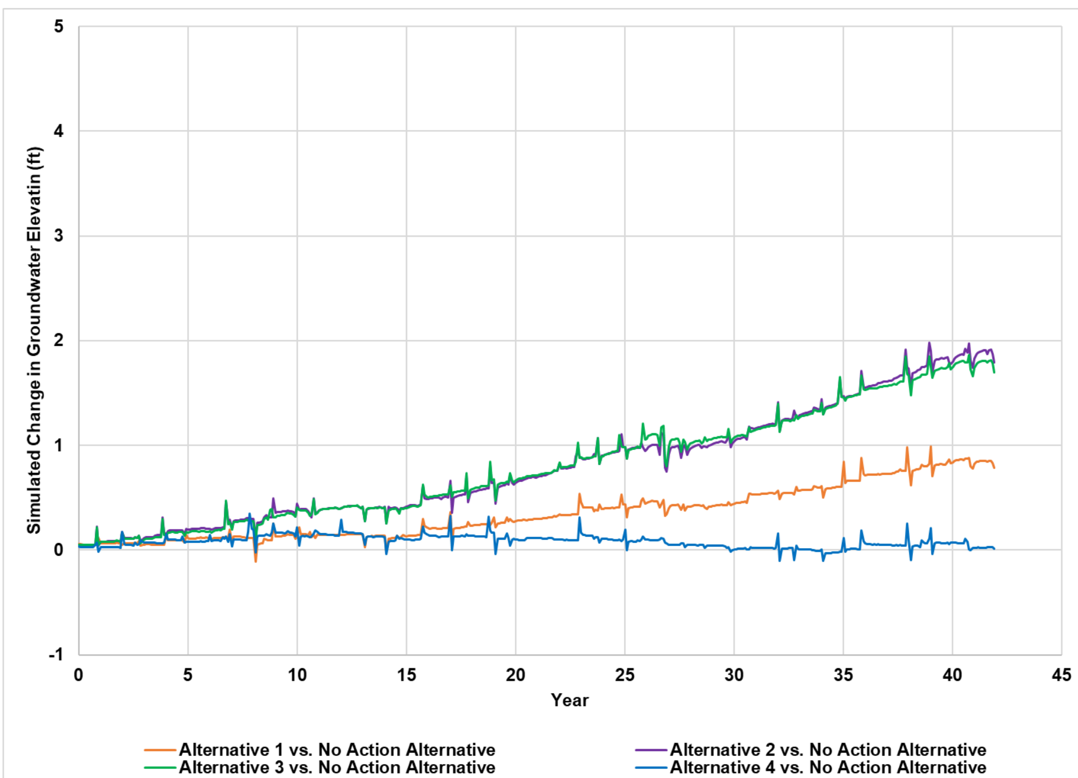


Figure I.2-39. Simulated Change in Groundwater Elevation Location 14

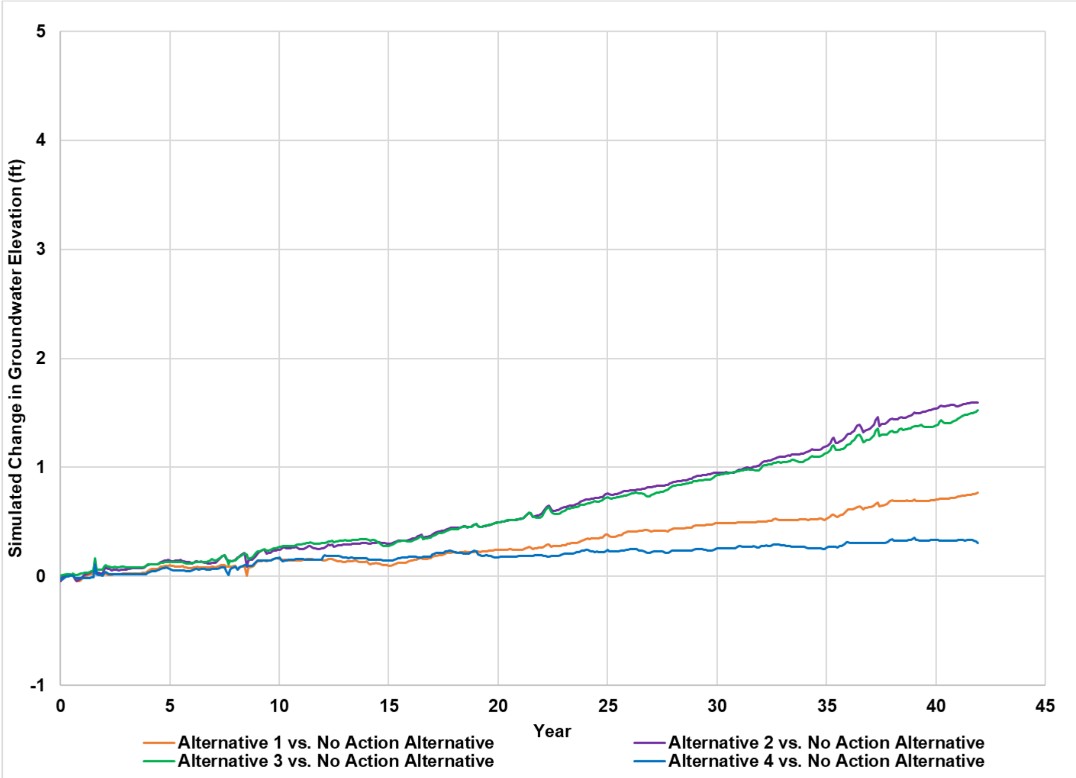


Figure I.2-40. Simulated Change in Groundwater Elevation Location 15

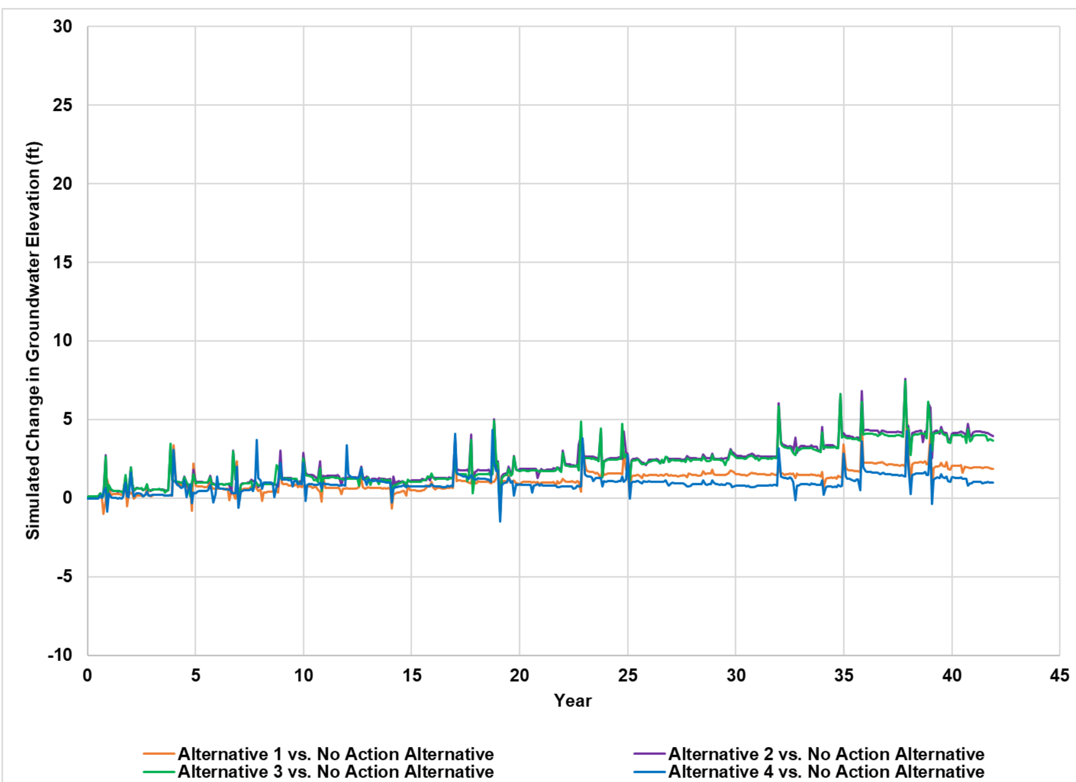
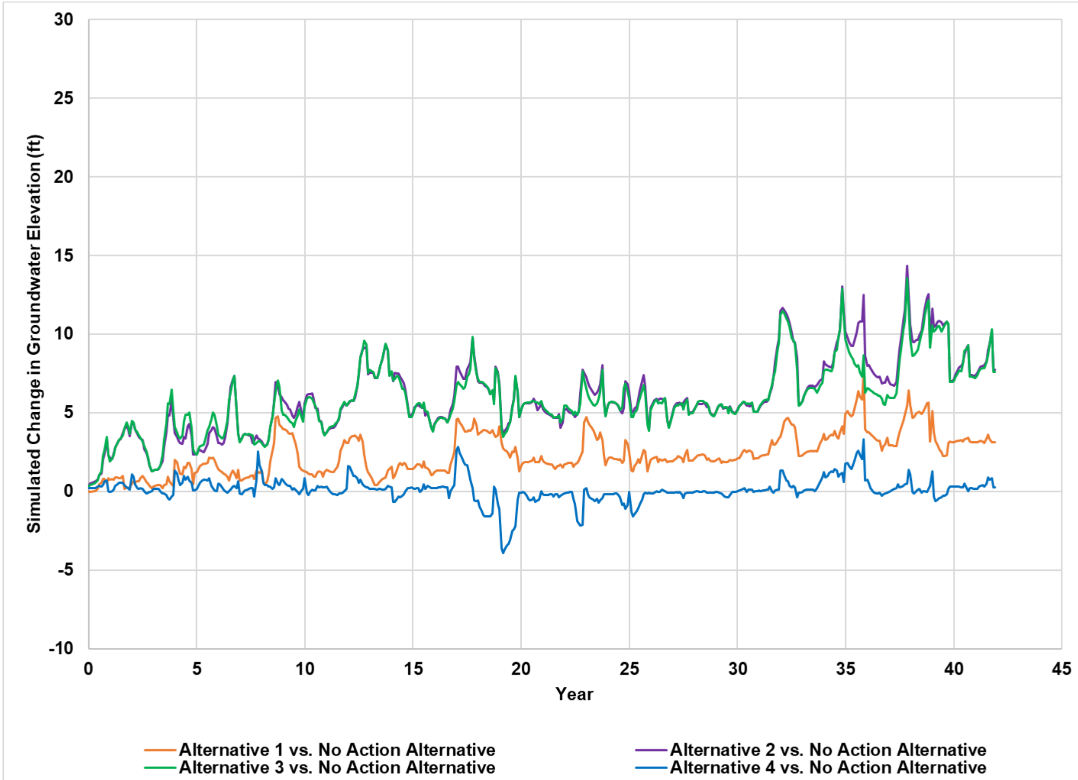


Figure I.2-41. Simulated Change in Groundwater Elevation Location 16



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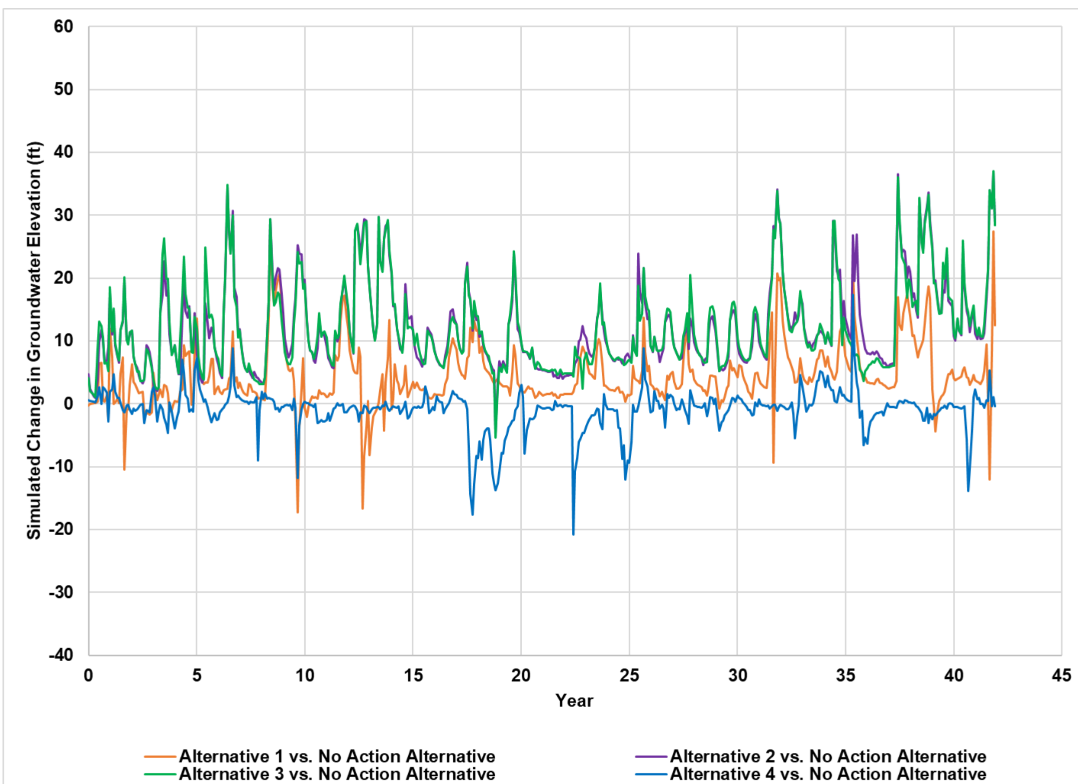

Figure I.2-43. Simulated Change in Groundwater Elevation Location 18

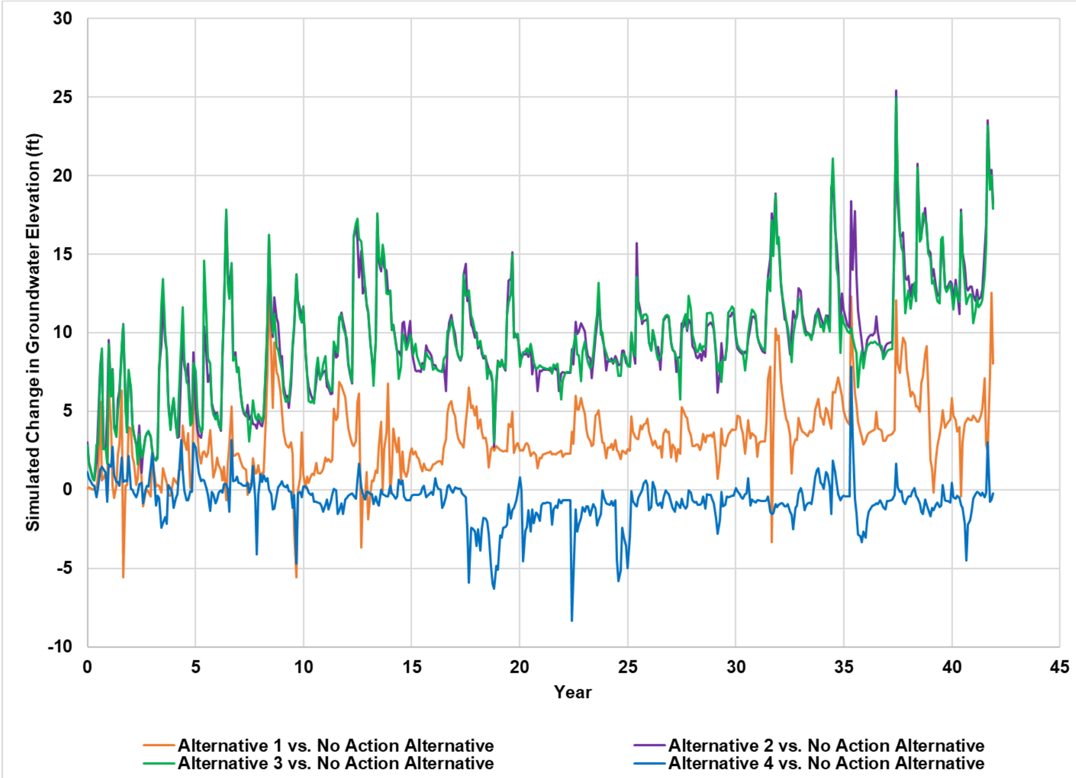

Figure I.2-44. Simulated Change in Groundwater Elevation Location 19

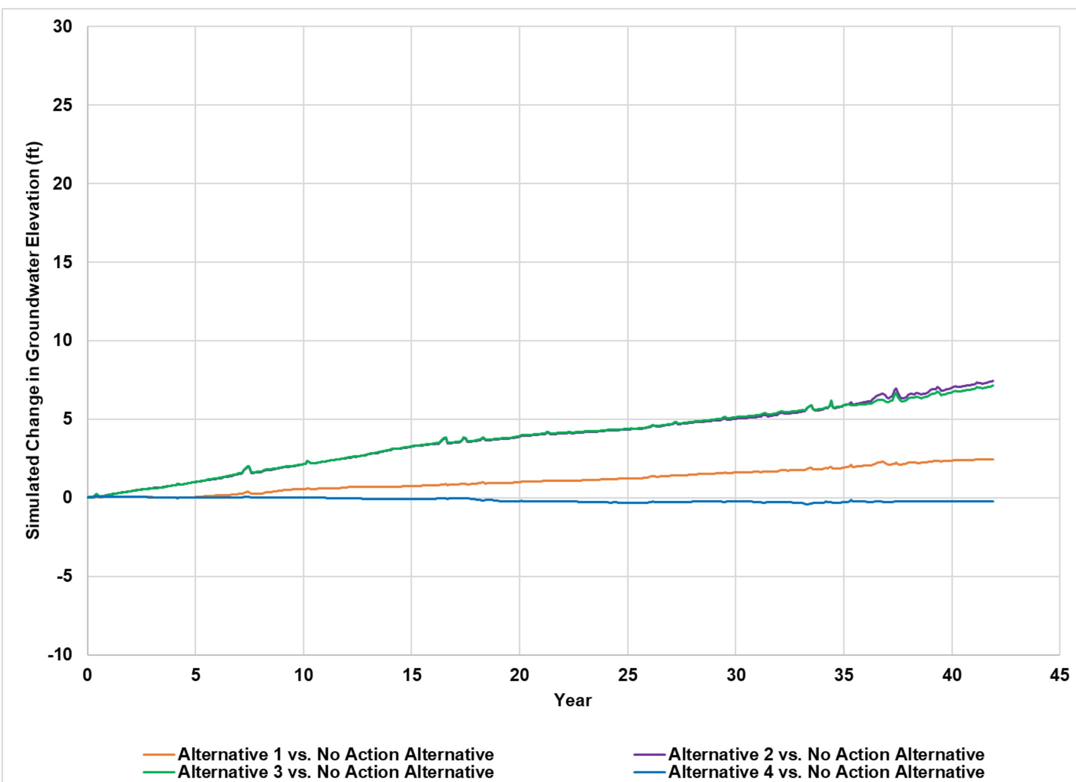

Figure I.2-45. Simulated Change in Groundwater Elevation Location 20

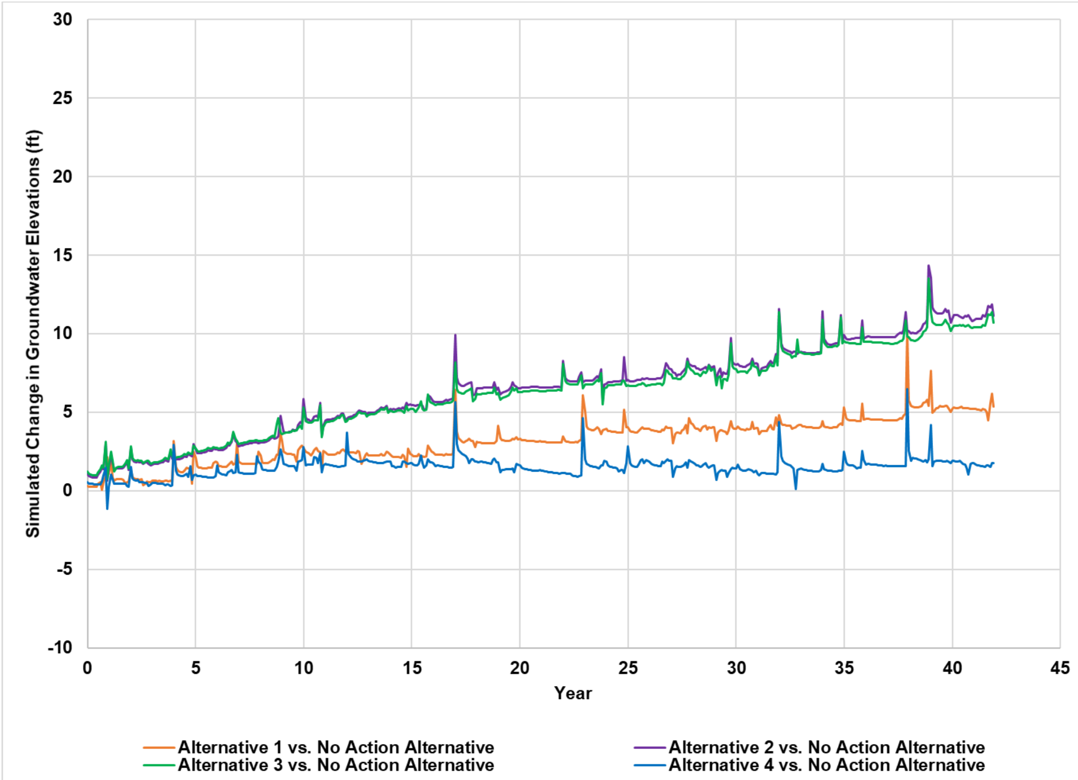

Figure I.2-46. Simulated Change in Groundwater Elevation Location 21

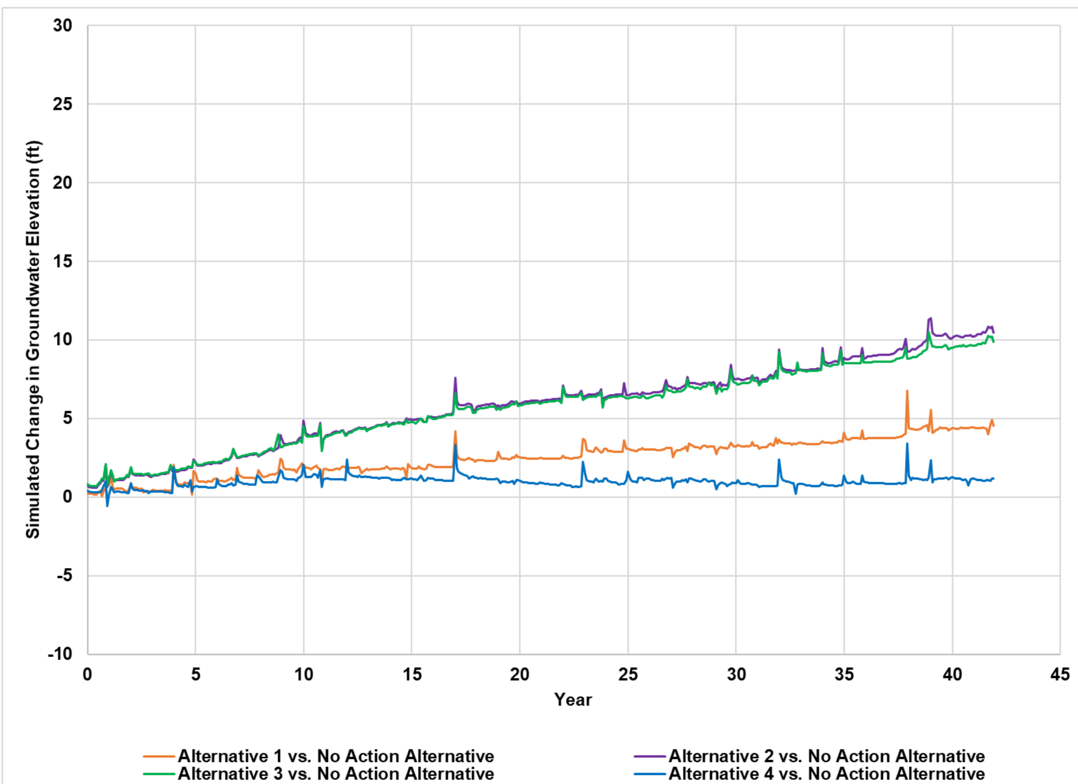

Figure I.2-47. Simulated Change in Groundwater Elevation Location 22

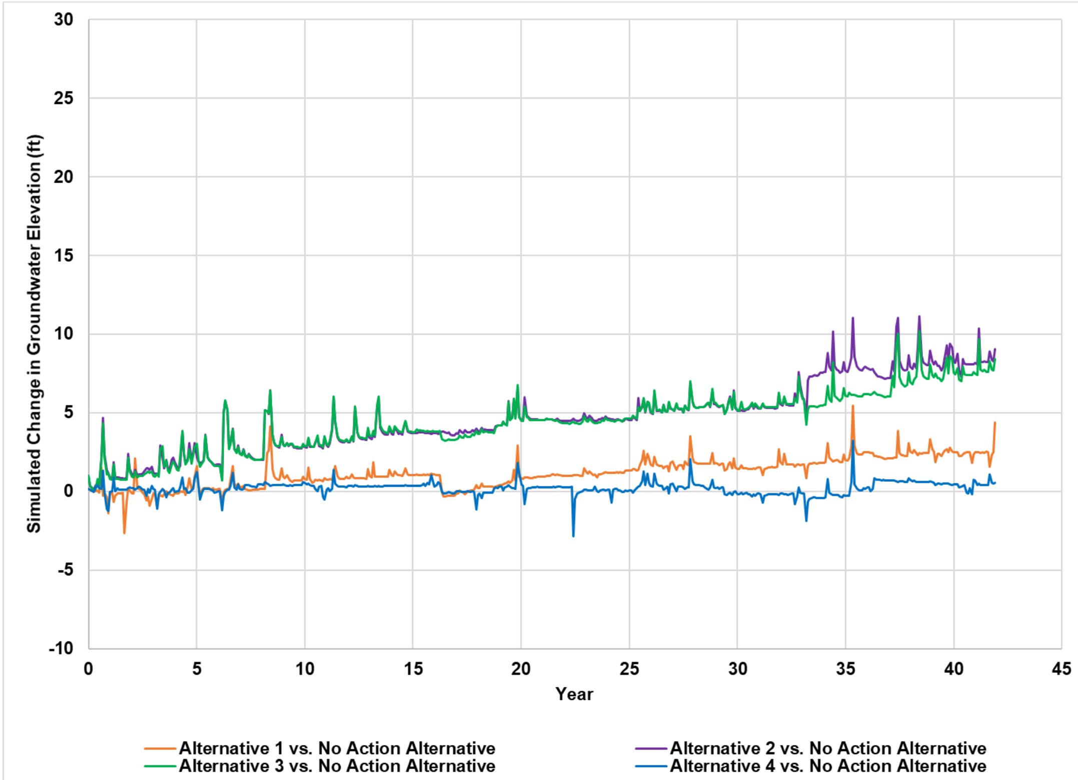

Figure I.2-48. Simulated Change in Groundwater Elevation Location 23

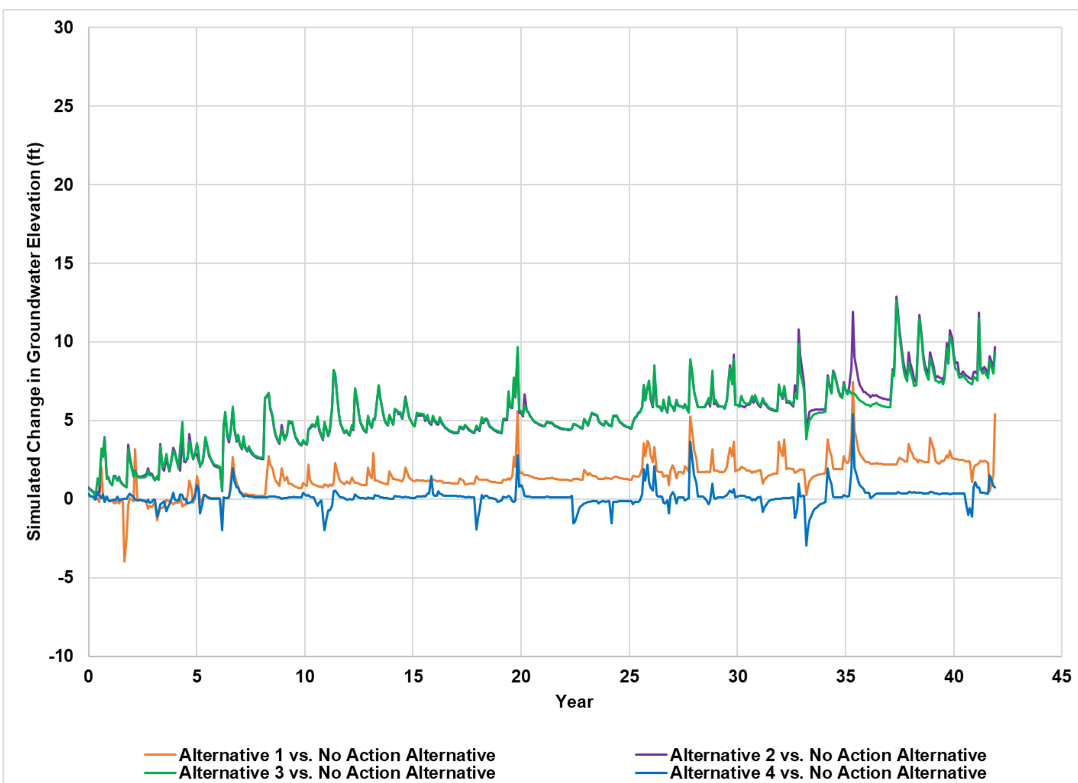

Figure I.2-49. Simulated Change in Groundwater Elevation Location 24

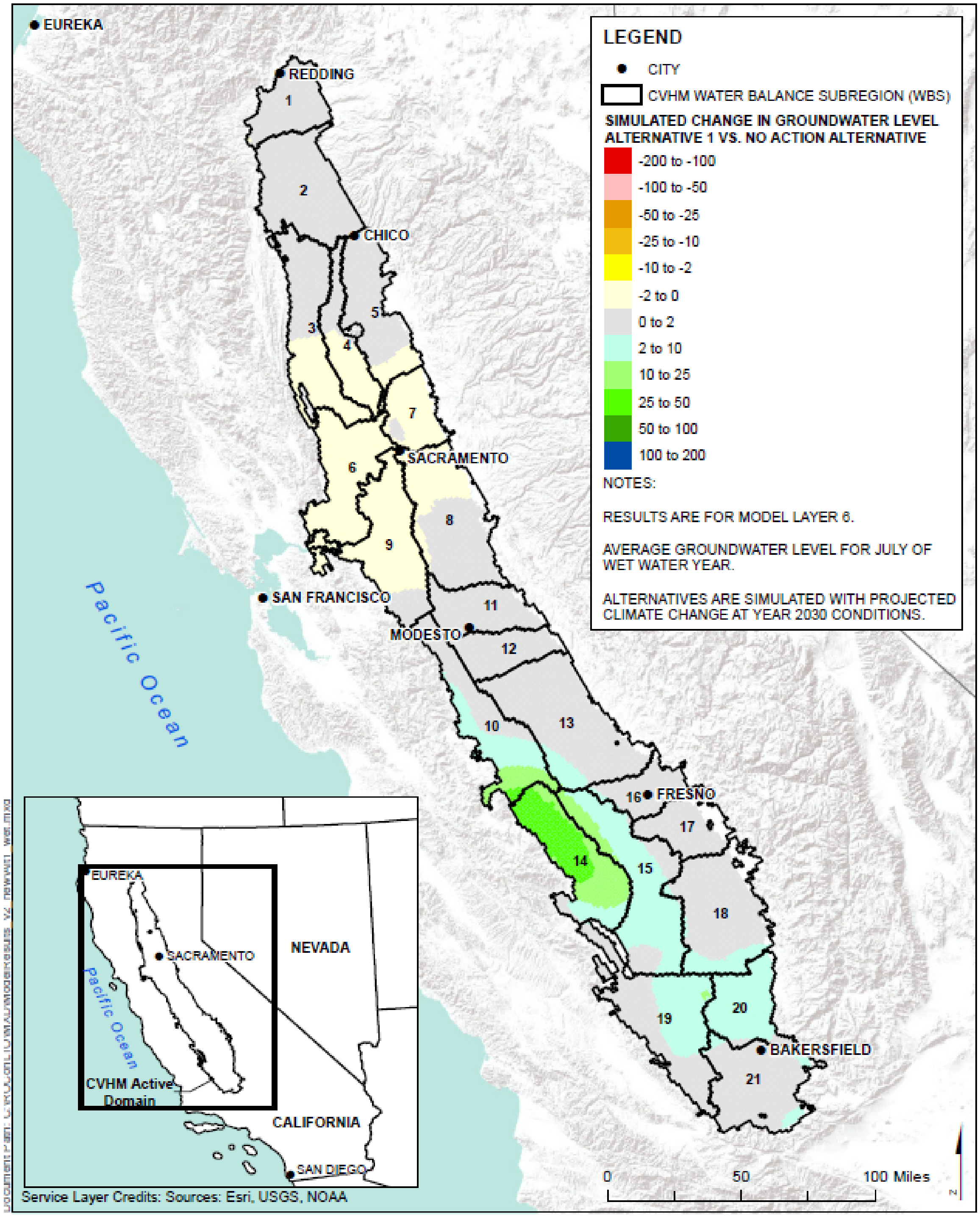

Figure I.2-50. Simulated Change in Groundwater Level, July of Wet Years, Alternative 1 versus No Action Alternative

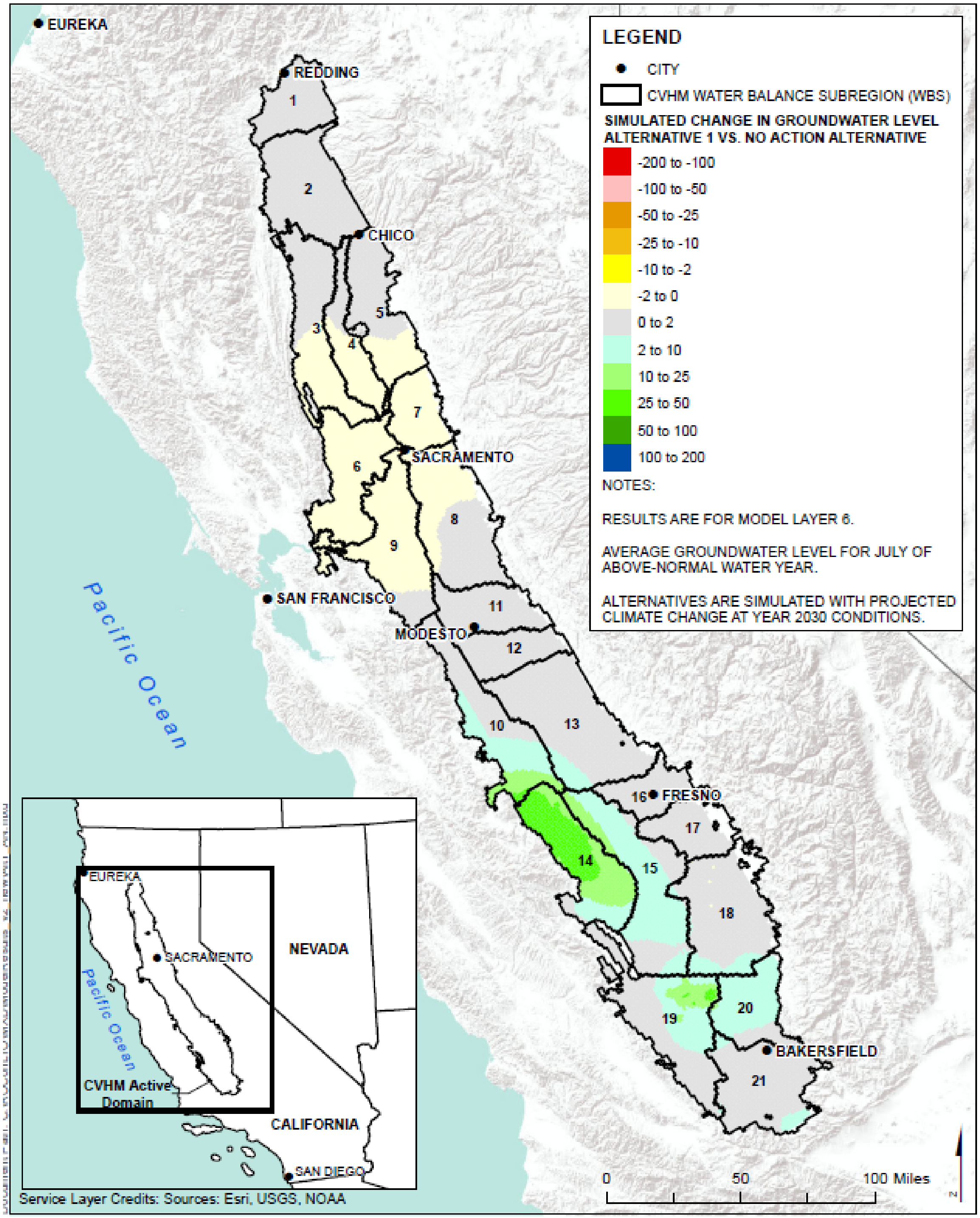

Figure I.2-51. Simulated Change in Groundwater Level, July of Above Normal Years, Alternative 1 versus No Action Alternative

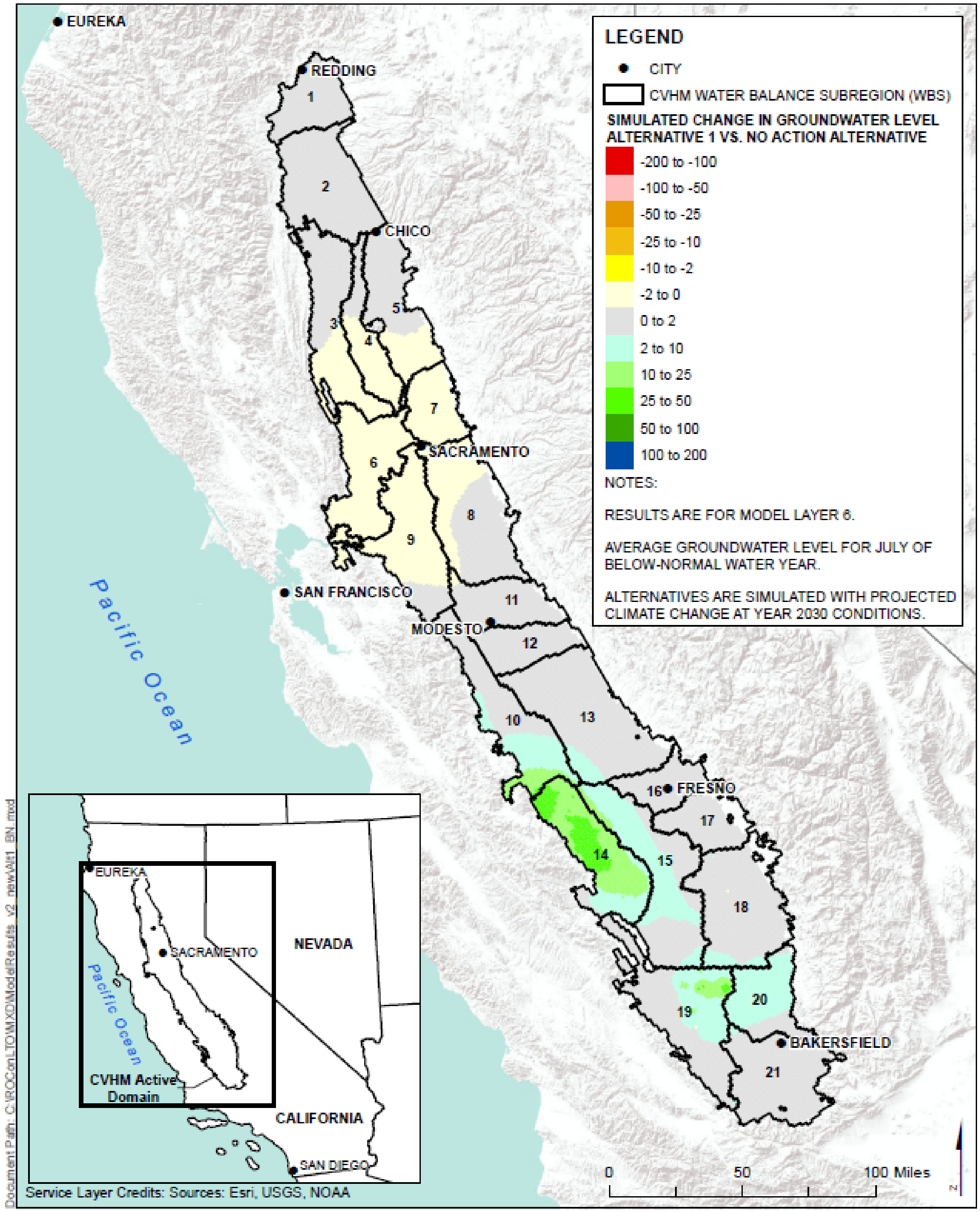

Figure I.2-52. Simulated Change in Groundwater Level, July of Below Normal Years, Alternative 1 versus No Action Alternative

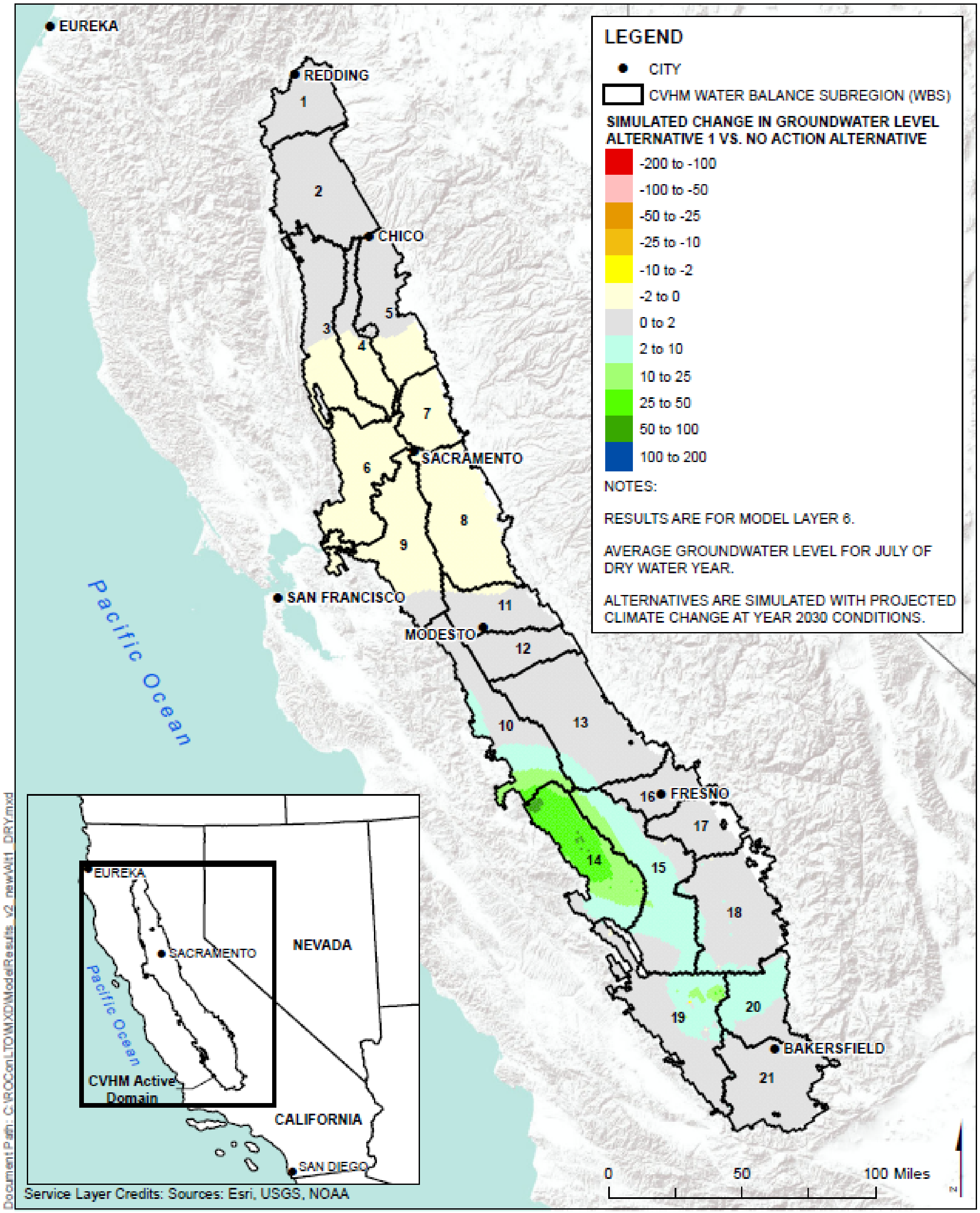

Figure I.2-53. Simulated Change in Groundwater Level, July of Dry Years, Alternative 1 versus No Action Alternative

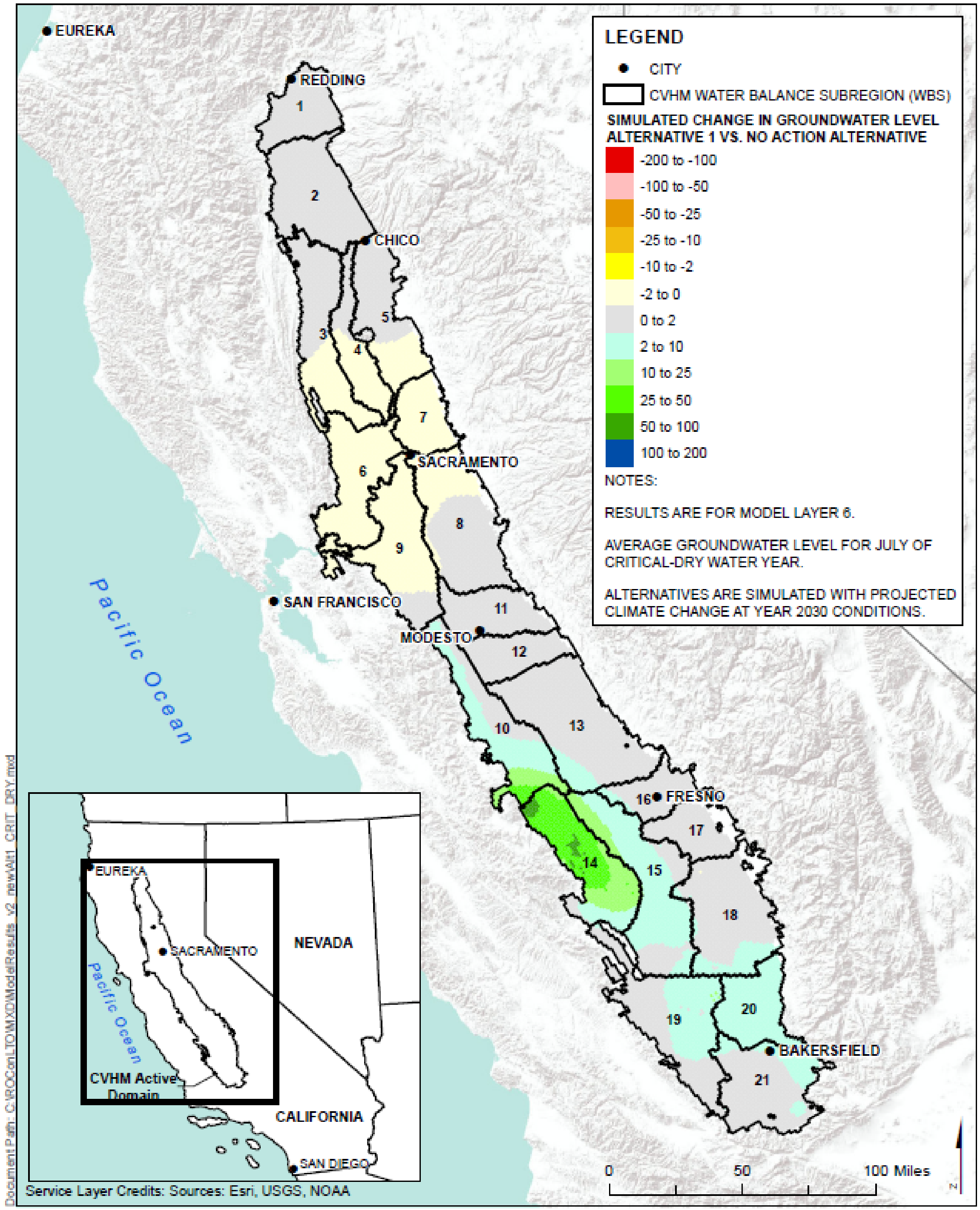

Figure I.2-54. Simulated Change in Groundwater Level, July of Critical Dry Years, Alternative 1 versus No Action Alternative

These figures show that, on average, groundwater levels increase as a result of Alternative 1 compared with the No Action Alternative in the areas south of the Delta. There is a slight decrease in groundwater levels near and north of the Delta.

Central Valley Project and State Water Project Service Areas

There is not expected to be an increase in the amount of groundwater pumping in Alternative 1 compared with the No Action Alternative. If pumping is not increased and groundwater-surface water interaction is not substantially changed, then groundwater levels in this area would be expected to remain similar to the No Action Alternative or potentially increase.

I.2.3.1.4 Potential Changes in Land Subsidence

Trinity River Region

The fact that the area along the Trinity River is not known to be susceptible to subsidence and that groundwater pumping is not expected to increase in this region suggests that subsidence will not be a concern in this area.

Central Valley Region

Land subsidence is caused by the consolidation of certain subsurface soils when the pore pressure in those soils is reduced. In the Sacramento and San Joaquin Valleys, that reduction in pore pressure is usually caused by groundwater pumping that causes groundwater levels to fall below historical low levels. Given that groundwater levels are generally expected to increase or remain unchanged due to Alternative 1, it is unlikely that Alternative 1 would cause additional subsidence compared with the No Action Alternative.

Central Valley Project and State Water Project Service Areas

Land subsidence is caused by the consolidation of certain subsurface soils when the pore pressure in those soils is reduced. That reduction in pore pressure is usually caused by groundwater pumping that causes groundwater levels to fall below historical low levels. Given that groundwater levels are generally not expected to decrease due to Alternative 1, it is unlikely that Alternative 1 would cause additional subsidence compared with the No Action Alternative.

I.2.3.2 *Program-Level Effects*

Alternative 1 includes habitat restoration and improvement projects, fish passage improvements, fish hatchery operation programs, and studies to identify further opportunities for habitat improvement. Given their collective implementation to improve habitat conditions and survival rates for the biological resources across the study area, it is assumed that they could improve conditions relative to those resources' future survival and population health. These actions are focused on surface water conditions and/or activities on the ground surface. The effects to groundwater are likely to be minimal as a result of these actions.

I.2.4 Alternative 2

I.2.4.1 *Project-Level Effects*

I.2.4.1.1 Potential Changes in Groundwater Pumping

Trinity River Region

Project-level actions in Alternative 2 will likely result in changed in flows of surface water in this region. However, there is expected to be little change to groundwater pumping resulting from these actions because groundwater is not a substantial supply source in this region.

Central Valley Region

Compared with the No Action Alternative, Alternative 2 is expected to result in additional surface water supply to both the Sacramento and San Joaquin Valleys. This increase in supply, especially when made to meet agricultural demands, will result in a decrease in the need for groundwater pumping to meet demands. Most of the change in pumping is expected to be in the San Joaquin Valley.

The changes in CVP and SWP deliveries projected by the CalSim II model to the San Joaquin Valley region were input to the CVHM. The CVHM then simulated the amount of groundwater pumping required to meet agricultural needs as the difference between demand and the supply from surface water. With the increase in surface water supply, the amount of groundwater pumping would decrease. Table I.2-1 shows the amount of groundwater pumping simulated by CVHM under the No Action Alternative and Alternative 2. Table I.2-2 shows the percent change in simulated groundwater pumping between Alternative 2 and the No Action Alternative.

The model simulations show that, on average, groundwater pumping is 7.5% lower in Alternative 2 than the No Action Alternative.

Central Valley Project and State Water Project Service Areas

Alternative 2 is expected to increase water supply to the CVP and SWP service areas. With this increase in supply, the reliance on groundwater pumping is expected to stay the same or be reduced compared with the No Action Alternative. Therefore, there is expected to be similar or less groundwater pumping in Alternative 2 compared with the No Action Alternative.

I.2.4.1.2 Potential Changes in Groundwater-Surface Water Interaction

Trinity River Region

Most usable groundwater in the Trinity River Region occurs in widely scattered alluvium-filled valleys, such as those immediately adjacent to the Trinity River. These valleys contain only small quantities of recoverable groundwater and therefore are not considered a major source. Given this hydrogeologic nature of this region, changes in surface water flow will likely result in little change to the groundwater-surface water interaction flow.

Central Valley Region

The amount of groundwater-surface water interaction flow simulated in the CVHM for Alternative 2, throughout the Central Valley, is shown in Table I.2-3. Table I.2-4 shows the change in groundwater-surface water interaction for Alternative 2 compared with the No Action Alternative. Over the length of the CVHM simulation, the change in groundwater-surface water interaction is 13.2% (reduced flow from groundwater to surface water) in Alternative 2 compared with the No Action Alternative.

Central Valley Project and State Water Project Service Areas

Alternative 2 increases water supply to the CVP and SWP service areas and, therefore, likely results in little change, or potentially a reduction, in the amount of groundwater pumping. With little change to groundwater pumping, there would be little change in the groundwater system to result in a change in the amount of groundwater-surface water interaction flow. Therefore, Alternative 2, compared with the No Action Alternative, may result in groundwater levels rising, allowing for additional infiltration of groundwater to surface water features.

I.2.4.1.3 Potential Changes in Groundwater Elevation

Trinity River Region

Given that there is likely to be little change in groundwater pumping and also little change in the groundwater-surface water interaction flow, there will be little change to groundwater levels in the area compared with the No Action Alternative.

Central Valley Region

The CVHM simulations indicate that the amount of groundwater pumping in Alternative 2 will be less than in the No Action Alternative. Simulations also suggest that less water will recharge to the groundwater system in Alternative 2 than in the No Action Alternative. These two factors combine to potentially affect groundwater elevations. Less groundwater pumping would work to increase groundwater levels, whereas less recharge from surface water to groundwater could lower groundwater levels. CVHM was used to estimate change to groundwater levels resulting from the combined effects of project level changes.

Figures I.2-2 through I.2-25 show the simulated groundwater elevations at 24 arbitrary locations throughout the San Joaquin Valley. Changes in groundwater pumping were not simulated in the Sacramento Valley; therefore, modeled groundwater elevations in the Sacramento Valley are not shown. Figures I.2-26 through I.2-49 show the simulated change in groundwater elevation at these 24 locations.

Figures I.2-55 through I.2-59 show the simulated change in groundwater level spatially across the Central Valley under Alternative 2 compared with the No Action Alternative. These figures show the average change in groundwater levels in July during each of the five water year types (Wet, Above Normal, Below Normal, Dry, Critical Dry).

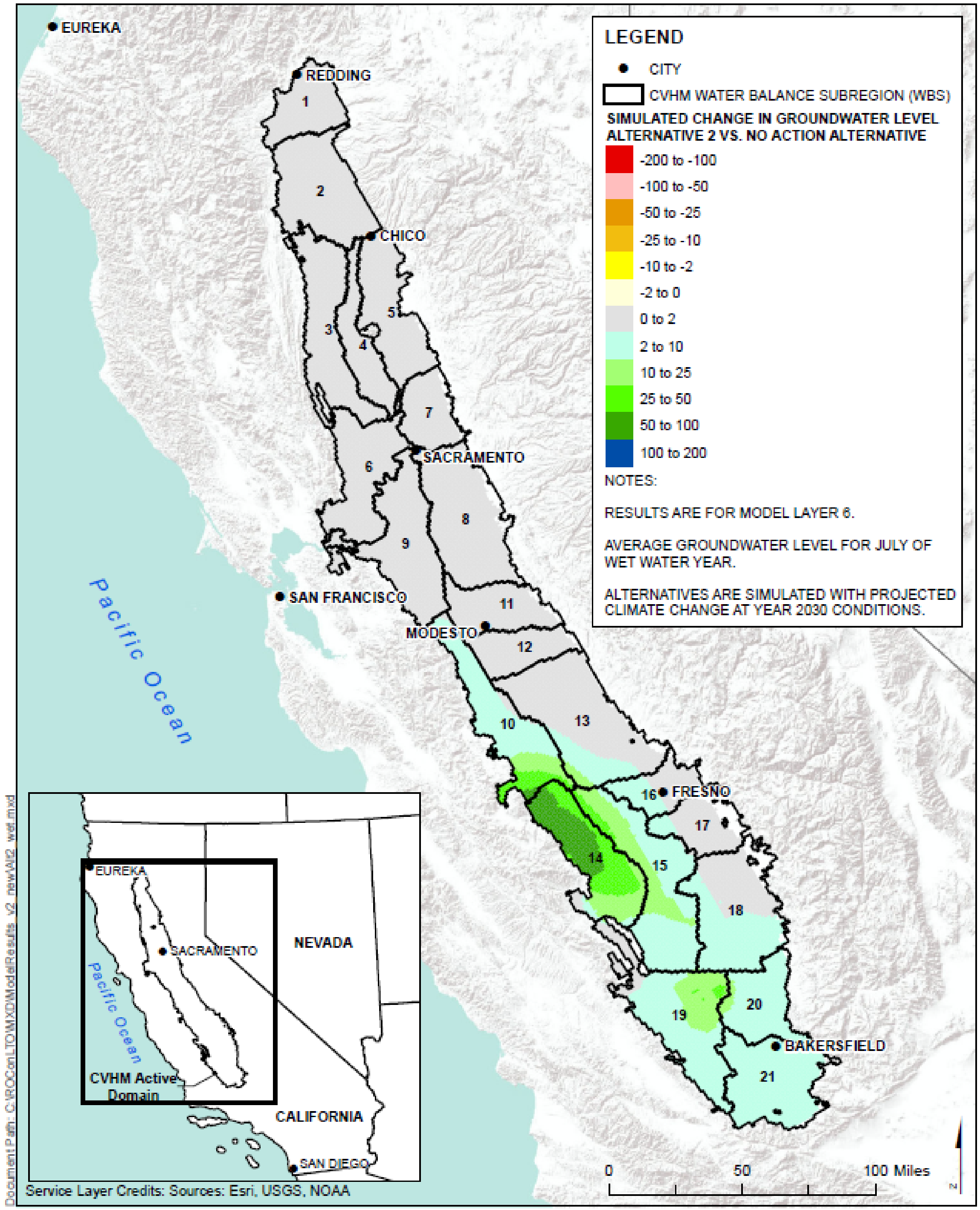

Figure I.2-55. Simulated Change in Groundwater Level, July of Wet Years, Alternative 2 versus No Action Alternative

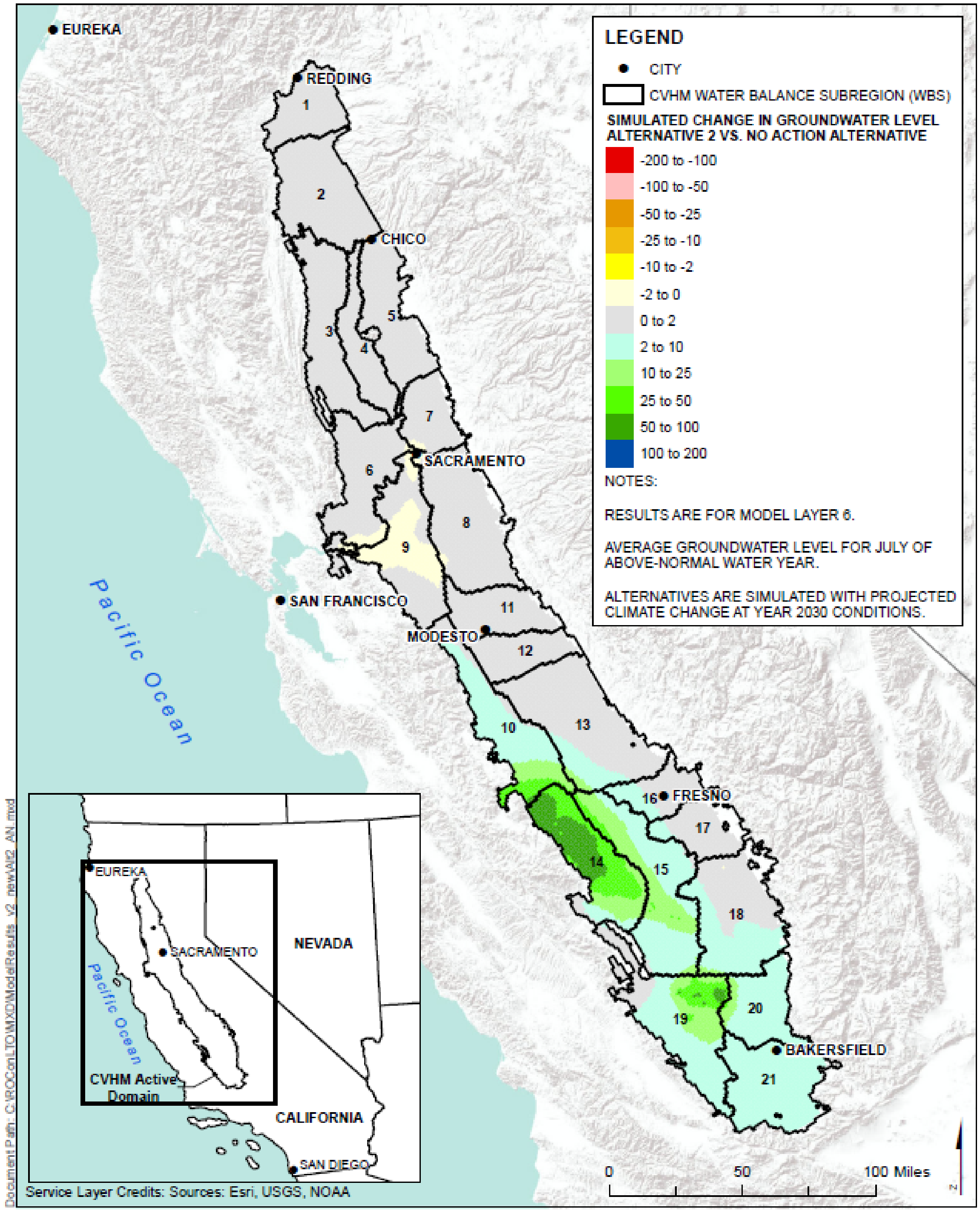

Figure I.2-56. Simulated Change in Groundwater Level, July of Above Normal Years, Alternative 2 versus No Action Alternative

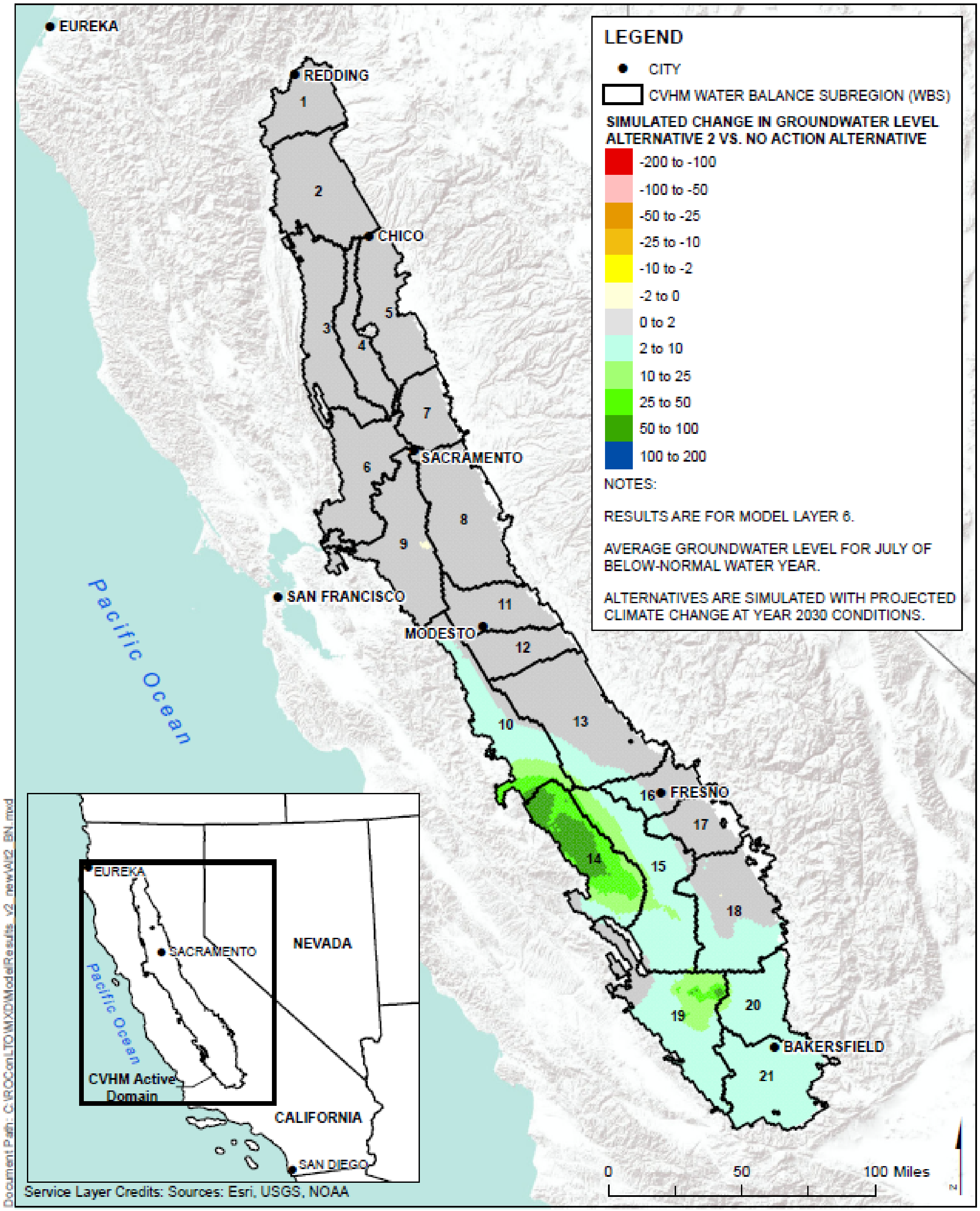

Figure I.2-57. Simulated Change in Groundwater Level, July of Below Normal Years, Alternative 2 versus No Action Alternative

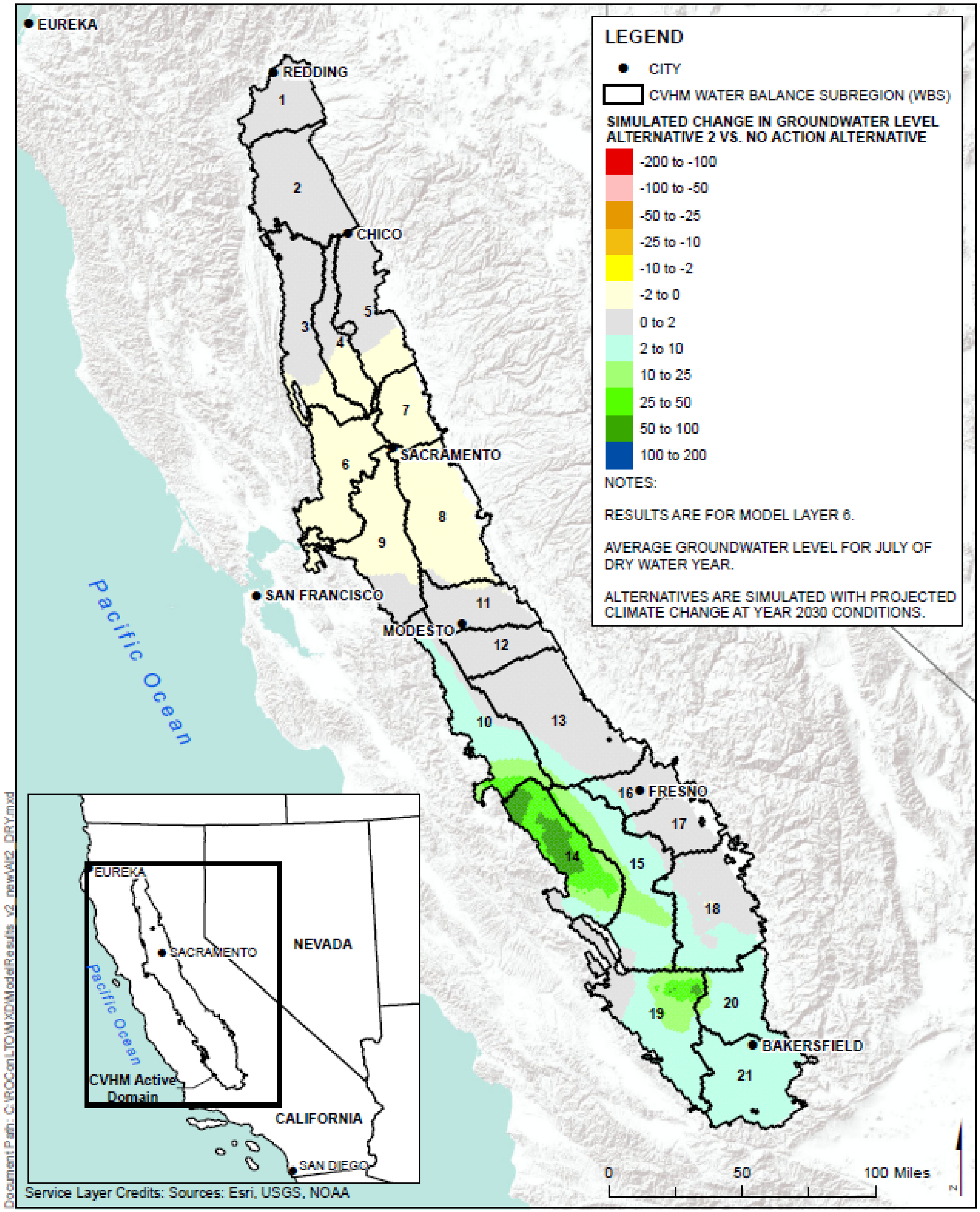

Figure I.2-58. Simulated Change in Groundwater Level, July of Dry Years, Alternative 2 versus No Action Alternative

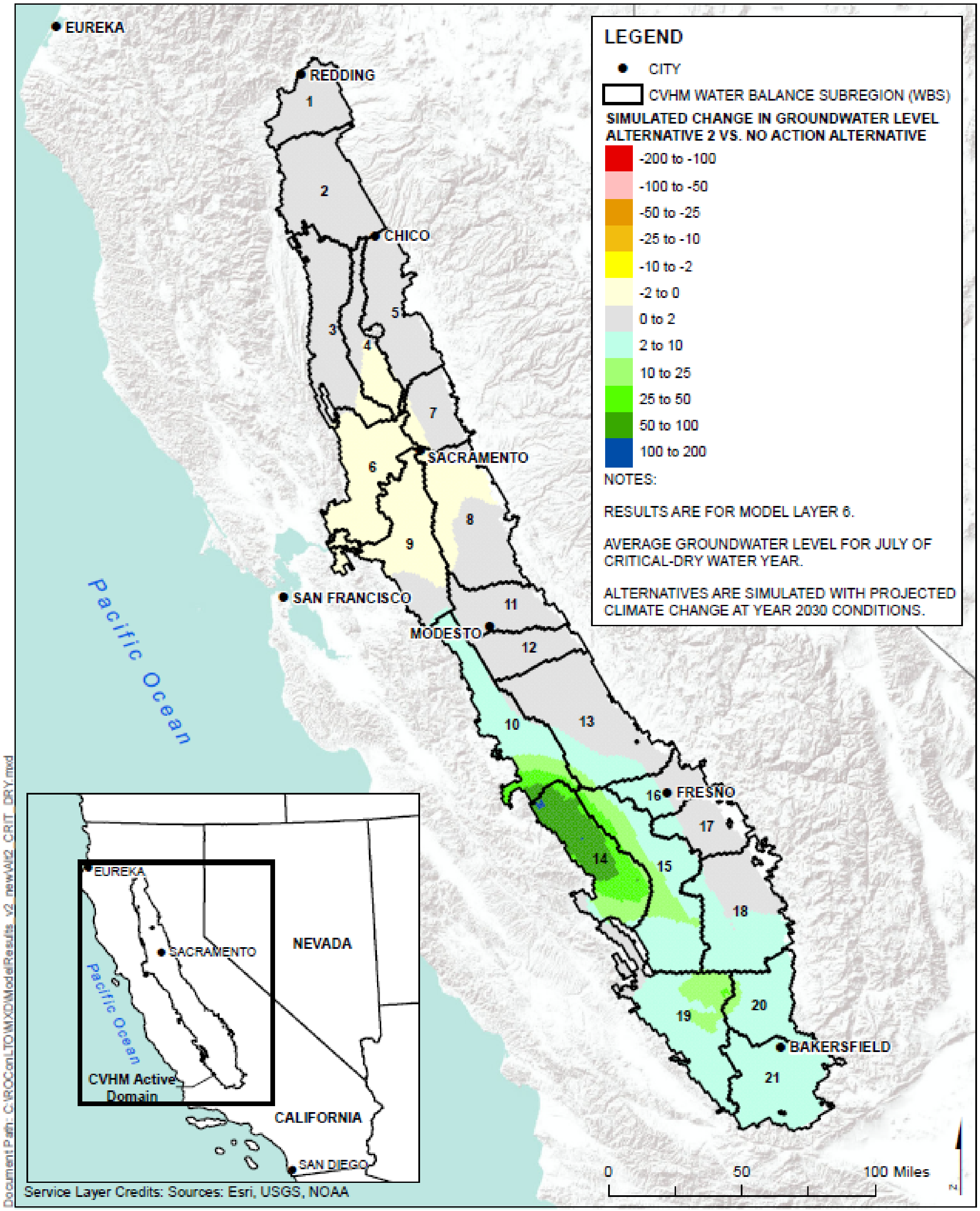

Figure I.2-59. Simulated Change in Groundwater Level, July of Critical Dry Years, Alternative 2 versus No Action Alternative

These figures show that, on average, groundwater levels increase in the areas south of the Delta as a result of Alternative 2 compared with the No Action Alternative. There is a slight decrease in groundwater levels near and north of the Delta in certain water year types.

Central Valley Project and State Water Project Service Areas

There is not expected to be an increase in the amount of groundwater pumping in Alternative 2 compared to the No Action Alternative. If pumping is not increased and groundwater-surface water interaction remains unchanged, groundwater levels in this area would be expected to remain similar to the No Action Alternative or potentially increase.

I.2.4.1.4 Potential Changes in Land Subsidence

Trinity River Region

The fact that the area along the Trinity River is not known to be susceptible to subsidence and that groundwater pumping is not expected to increase in this region suggests that subsidence will not be a concern in this area.

Central Valley Region

Land subsidence is caused by the consolidation of certain subsurface soils when the pore pressure in those soils is reduced. In the Sacramento and San Joaquin Valleys, that reduction in pore pressure is usually caused by groundwater pumping that causes groundwater levels to fall below historical low levels. Given that groundwater levels are generally not expected to decrease, it is unlikely that Alternative 2 would cause additional subsidence compared to the No Action Alternative given that groundwater levels are expected to remain stable or increase.

Central Valley Project and State Water Project Service Areas

Land subsidence is caused by the consolidation of certain subsurface soils when the pore pressure in those soils is reduced. That reduction in pore pressure is usually caused by groundwater pumping that causes groundwater levels to fall below historical low levels. Given that groundwater levels are generally not expected to decrease, it is unlikely that Alternative 2 would cause additional subsidence compared to the No Action Alternative.

I.2.4.2 *Program-Level Effects*

Alternative 2 does not include any program-level components.

I.2.5 Alternative 3

I.2.5.1 *Project-Level Effects*

I.2.5.1.1 Potential Changes in Groundwater Pumping

Trinity River Region

Project level actions in Alternative 3 will likely result in changes in flows of surface water in this region. However, there is expected to be little change to groundwater pumping resulting from these actions because groundwater is not a substantial supply source in this region.

Central Valley Region

Compared to the No Action Alternative, Alternative 3 is expected to result in additional surface water supply to both the Sacramento and San Joaquin Valleys. This increase in supply, especially when made to meet agricultural demands, will result in a decrease in the need for groundwater pumping to meet demands. Most of the change in pumping is expected to be in the San Joaquin Valley.

The changes in CVP and SWP deliveries projected by the CalSim II model to the San Joaquin Valley region were input to the CVHM. The CVHM then simulated the amount of groundwater pumping required to meet agricultural needs as the difference between demand and the supply from surface water. With the increase in surface water supply, the amount of groundwater pumping decreased. Table I.2-1 shows the amount of groundwater pumping simulated by CVHM under the No Action Alternative and Alternative 3. Table I.2-2 shows the percent change in simulated groundwater pumping between Alternative 3 and the No Action Alternative.

The model simulations show that, on average, groundwater pumping is 7.1% lower in Alternative 3 than the No Action Alternative.

Central Valley Project and State Water Project Service Areas

Alternative 3 is expected to increase water supply to the CVP and SWP service areas. With this increase in supply, the reliance on groundwater pumping is expected to stay the same or be reduced compared to the No Action Alternative. Therefore, there is expected to be similar or less groundwater pumping in Alternative 3.

I.2.5.1.2 Potential Changes in Groundwater-Surface Water Interaction

Trinity River Region

Most usable groundwater in the Trinity River Region occurs in widely scattered alluvium-filled valleys, such as those immediately adjacent to the Trinity River. These valleys contain only small quantities of recoverable groundwater and therefore are not considered a major source. Given this hydrogeologic nature of this region, changes in surface water flow will likely result in little change to the groundwater-surface water interaction flow.

Central Valley Region

The amount of groundwater-surface water interaction flow simulated in the CVHM, throughout the Central Valley, is shown in Table I.2-3 for Alternative 3. Table I.2-4 shows the change in groundwater-surface water interaction for Alternative 3 compared to the No Action Alternative. Over the length of the CVHM simulation, the change in groundwater-surface water interaction is 13.4% (additional flow from groundwater to surface water) in Alternative 3 compared with the No Action Alternative.

Central Valley Project and State Water Project Service Areas

Alternative 3 increases water supply to the CVP and SWP service areas and, therefore, likely results in little change, or potentially a reduction, in the amount of groundwater pumping. With little change to groundwater pumping, there would be little change in the groundwater system to result in a change in the amount of groundwater-surface water interaction flow. Therefore, Alternative 3, compared with the No Action Alternative, may result in groundwater levels rising, allowing for additional infiltration of groundwater to surface water features.

I.2.5.1.3 Potential Changes in Groundwater Elevation

Trinity River Region

Given that there is likely to be little change in groundwater pumping and also little change in the groundwater-surface water interaction flow, there will be little change to groundwater levels in the area.

Central Valley Region

The CVHM simulations indicate that the amount of groundwater pumping in Alternative 3 will be less than in the No Action Alternative. Simulations also suggest that less water will recharge to the groundwater system in Alternative 3 than in the No Action Alternative. These two factors combine to potentially affect groundwater elevations. Less groundwater pumping would work to increase groundwater levels, whereas less recharge from surface water to groundwater could lower groundwater levels. CVHM was used to estimate change to groundwater levels resulting from the combined effects of project level changes.

Figures I.2-2 through I.2-25 show the simulated groundwater elevations at 24 arbitrary locations throughout the San Joaquin Valley. Changes in groundwater pumping were not simulated in the Sacramento Valley; therefore, modeled groundwater elevations in the Sacramento Valley are not shown. Figures I.2-26 through I.2-49 show the simulated change in groundwater elevation at these 24 locations.

Figures I.2-60 through I.2-64 show the simulated change in groundwater level spatially across the Central Valley under Alternative 3 compared with the No Action Alternative. These figures show the average change in groundwater levels in July during each of the five water year types (Wet, Above Normal, Below Normal, Dry, Critical Dry).

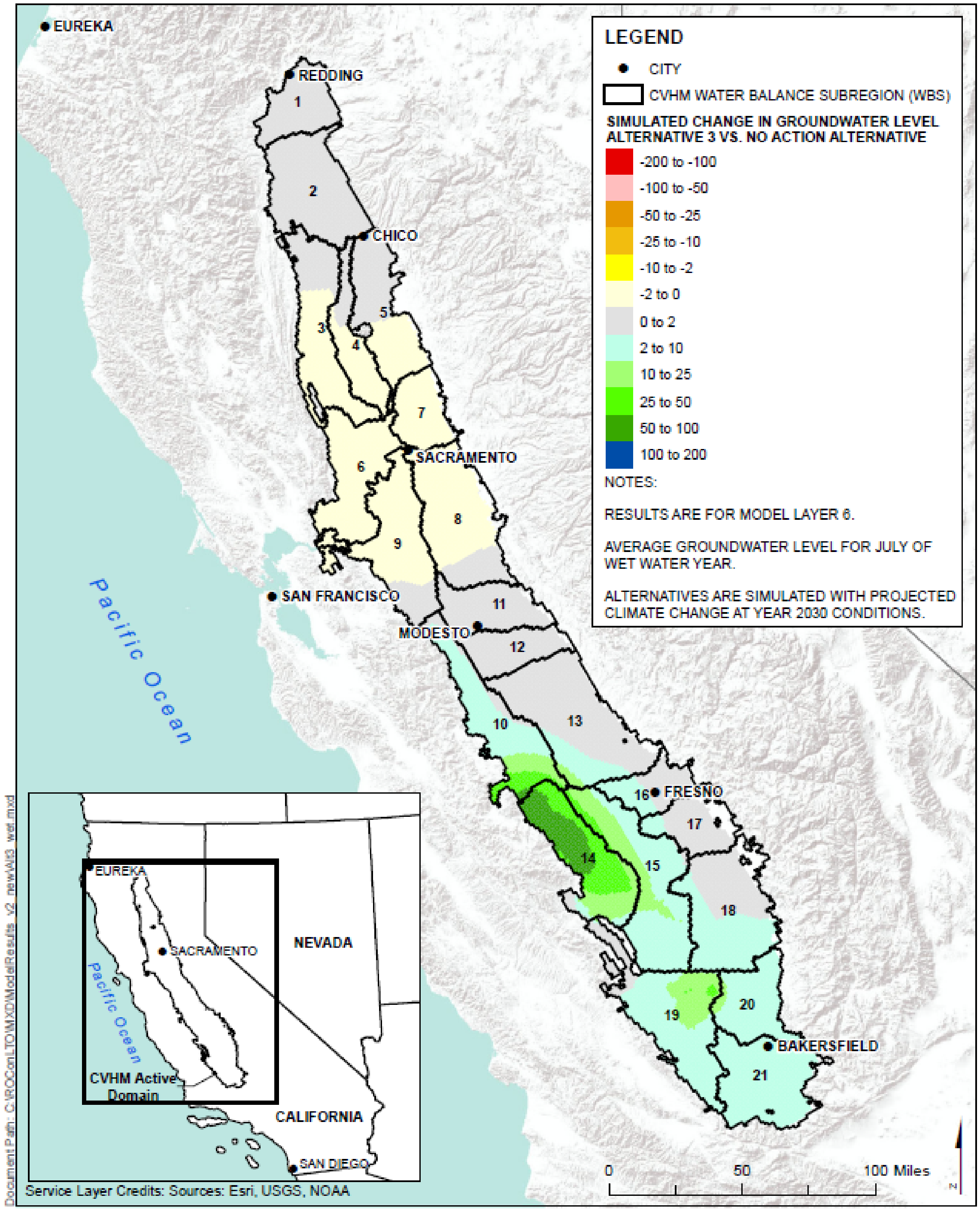

Figure I.2-60. Simulated Change in Groundwater Level, July of Wet Years, Alternative 3 versus No Action Alternative

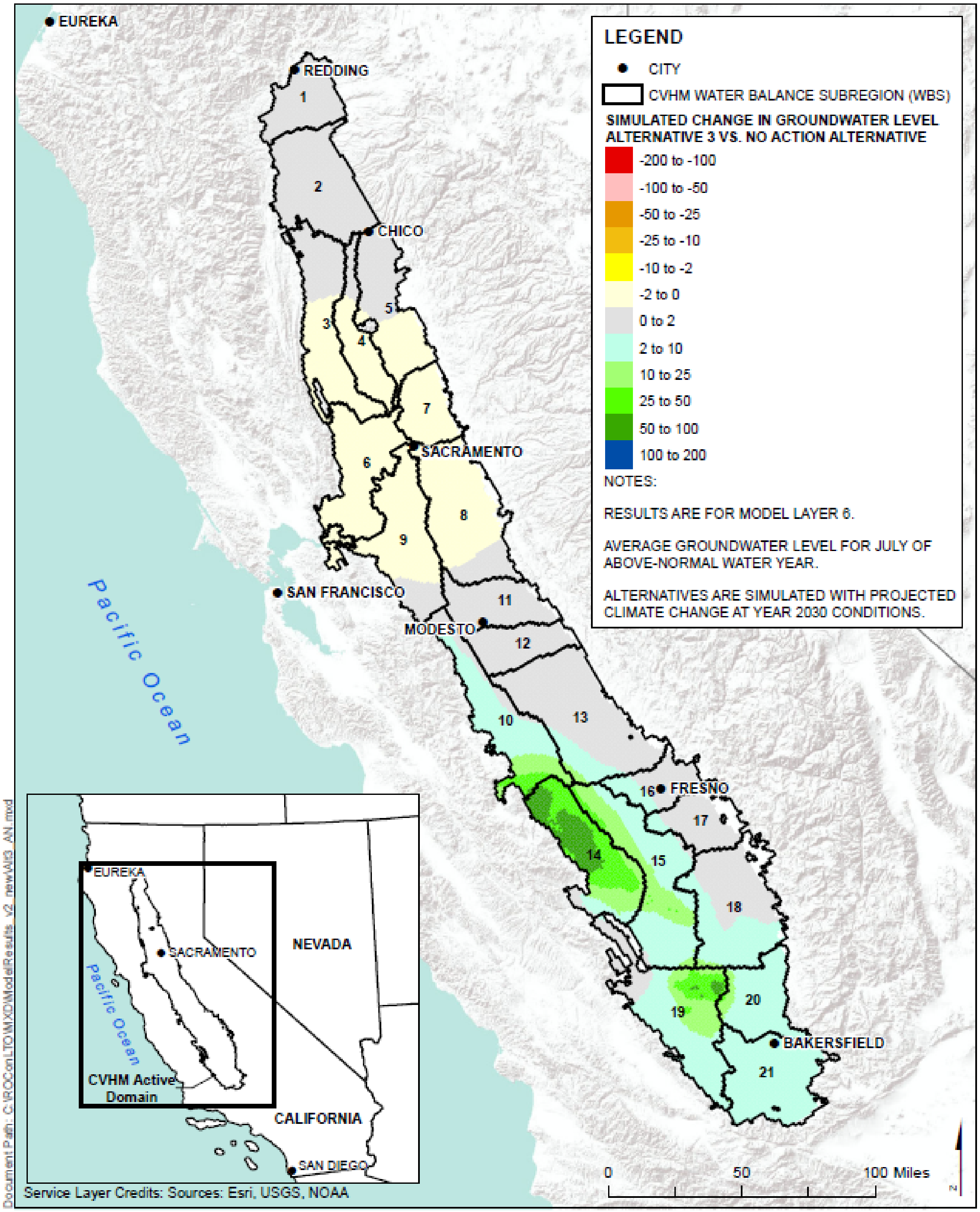

Figure I.2-61. Simulated Change in Groundwater Level, July of Above Normal Years, Alternative 3 versus No Action Alternative

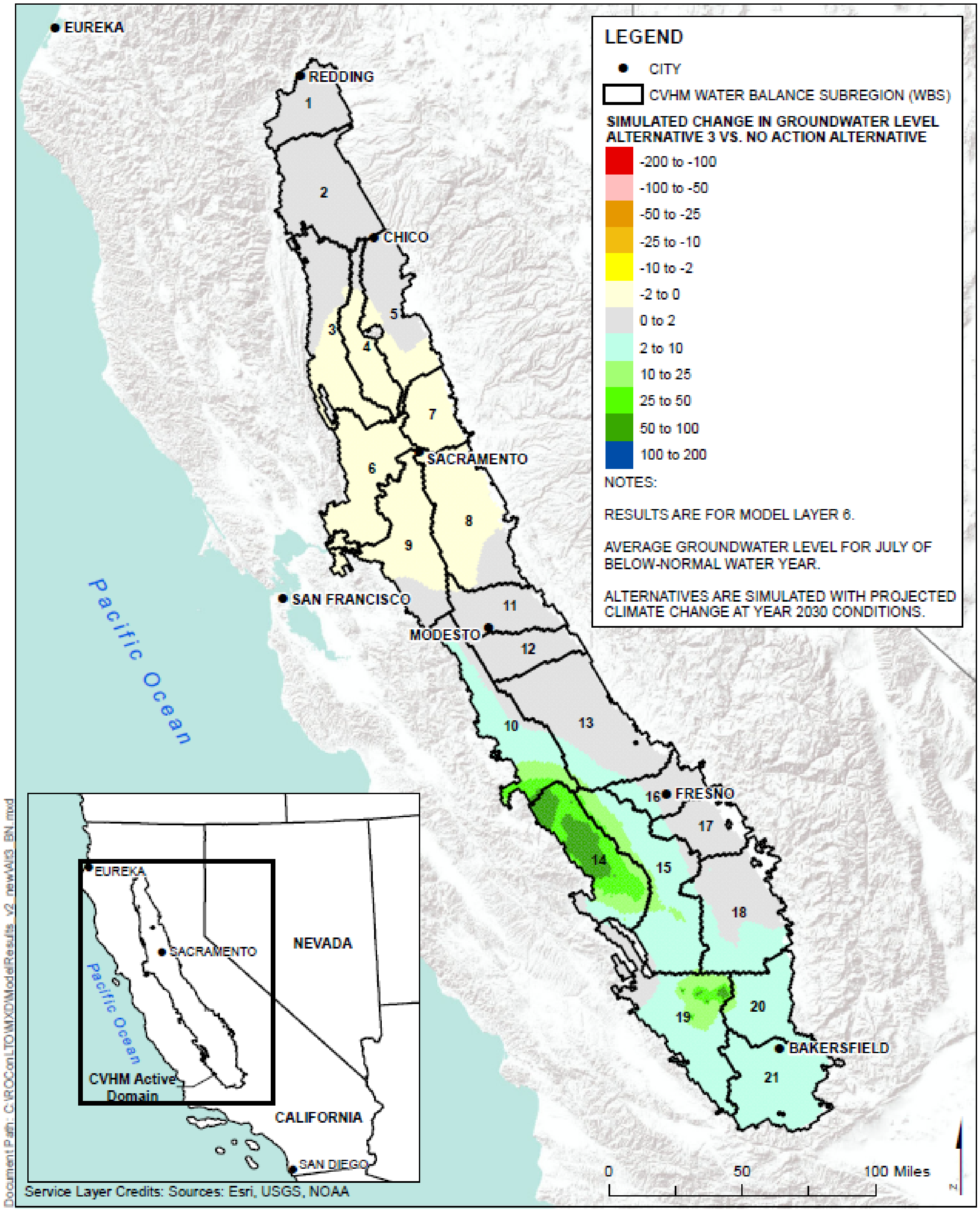

Figure I.2-62. Simulated Change in Groundwater Level, July of Below Normal Years, Alternative 3 versus No Action Alternative

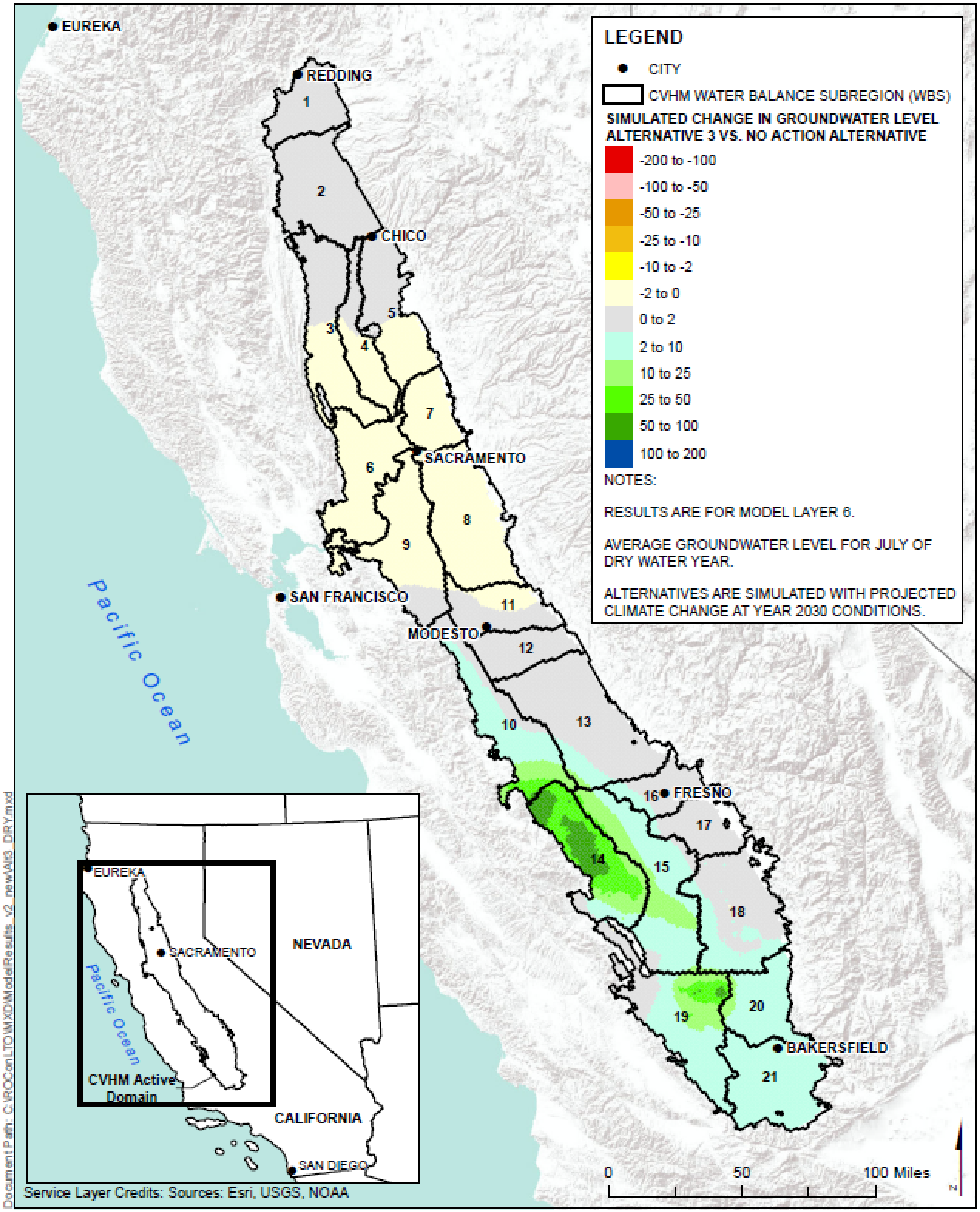

Figure I.2-63. Simulated Change in Groundwater Level, July of Dry Years, Alternative 3 versus No Action Alternative

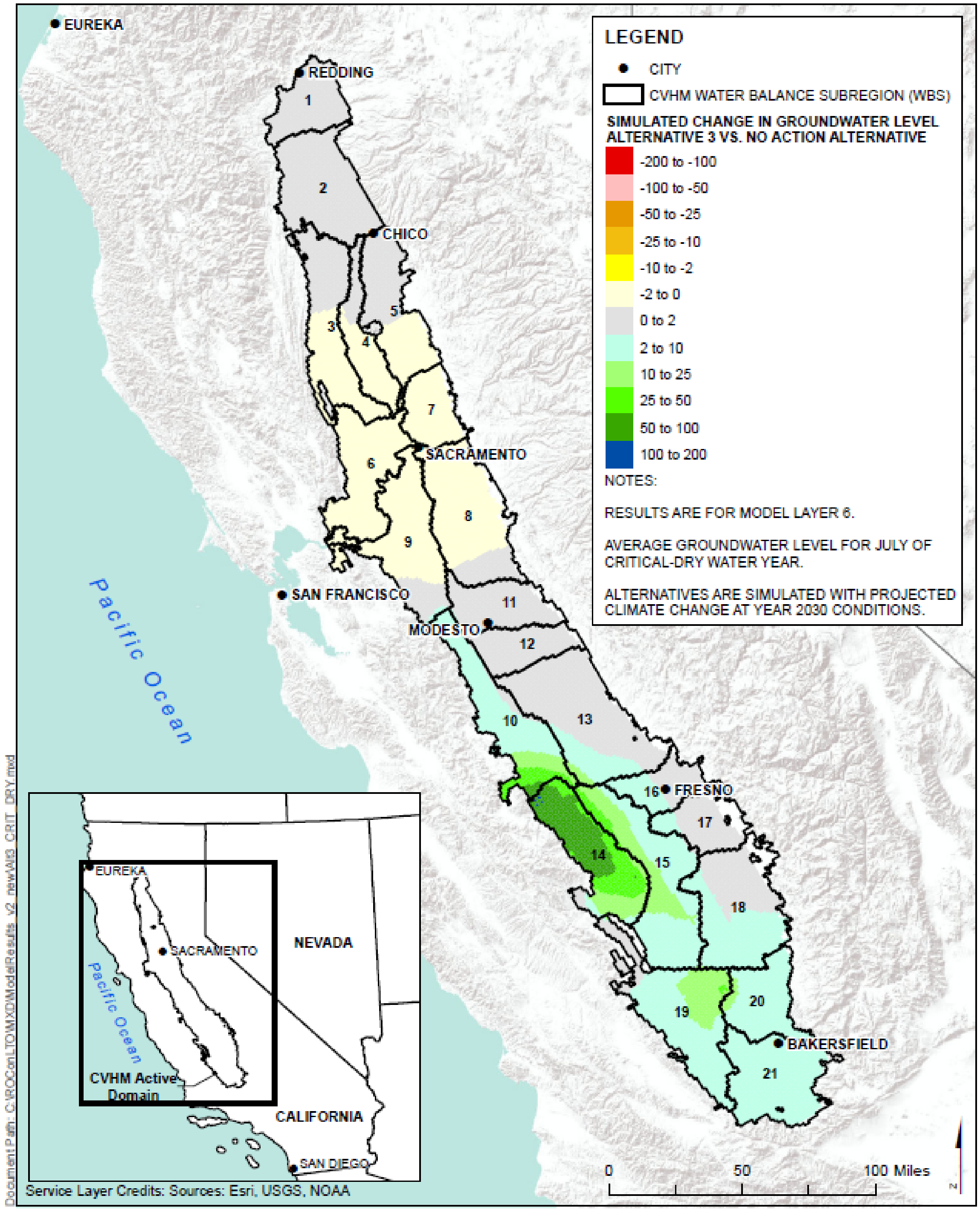

Figure I.2-64. Simulated Change in Groundwater Level, July of Critical Dry Years, Alternative 3 versus No Action Alternative

These figures show that, on average, groundwater levels increase as a result of Alternative 3 compared with the No Action Alternative in the areas south of the Delta. There is a slight decrease in groundwater levels near and north of the Delta.

Central Valley Project and State Water Project Service Areas

There is not expected to be an increase in the amount of groundwater pumping in Alternative 3 compared with the No Action Alternative. If pumping is not increased and groundwater-surface water interaction remains unchanged, groundwater levels in this area would be expected to remain similar to the No Action Alternative or potentially increase.

I.2.5.1.4 Potential Changes in Land Subsidence

Trinity River Region

The fact that the area along the Trinity River is not known to be susceptible to subsidence and that groundwater pumping is not expected to increase in this region suggests that subsidence will not be a concern in this area.

Central Valley Region

Land subsidence is caused by the consolidation of certain subsurface soils when the pore pressure in those soils is reduced. In the Sacramento and San Joaquin Valleys, that reduction in pore pressure is usually caused by groundwater pumping that causes groundwater levels to fall below historical low levels. Given that groundwater levels are generally not expected to decrease, it is unlikely that Alternative 3 would cause additional subsidence compared with the No Action Alternative given that groundwater levels are expected to remain stable or increase.

Central Valley Project and State Water Project Service Areas

Land subsidence is caused by the consolidation of certain subsurface soils when the pore pressure in those soils is reduced. That reduction in pore pressure is usually caused by groundwater pumping that causes groundwater levels to fall below historical low levels. Given that groundwater levels are generally not expected to decrease, it is unlikely that Alternative 3 would cause additional subsidence compared with the No Action Alternative.

I.2.5.2 *Program-Level Effects*

Alternative 3 includes habitat restoration and improvement projects, fish passage improvements, fish hatchery operation programs, and studies to identify further opportunities for habitat improvement. Given their collective implementation to improve habitat conditions and survival rates for the biological resources across the study area, it is assumed that they could improve conditions relative to those resources' future survival and population health. These actions are focused on surface water conditions and/or activities on the ground surface. The effects to groundwater are likely to be minimal as a result of these actions.

I.2.6 Alternative 4

I.2.6.1 *Project-Level Effects*

I.2.6.1.1 Potential Changes in Groundwater Pumping

Trinity River Region

Project-level actions in Alternative 4 will likely result in changes in flows of surface water in this region. However, there is expected to be little change to groundwater pumping resulting from these actions because groundwater is not a substantial supply source in this region.

Central Valley Region

Compared with the No Action Alternative, Alternative 4 is expected to result in surface water supply to both the Sacramento and San Joaquin Valleys increasing and decreasing, depending on the year. An increase in supply, especially when made to meet agricultural demands, will result in a decrease in the need for groundwater pumping to meet demands. A decrease in supply may result in an increase in groundwater pumping. Most of the change in pumping is expected to be in the San Joaquin Valley.

The changes in CVP and SWP deliveries projected by the CalSim II model to the San Joaquin Valley region were input to the CVHM. The CVHM then simulated the amount of groundwater pumping required to meet agricultural needs as the difference between demand and the supply from surface water. With the increase in surface water supply, the amount of groundwater pumping would decrease. Table I.2-1 shows the amount of groundwater pumping simulated by CVHM under the No Action Alternative and Alternative 4. Table I.2-2 shows the percent change in simulated groundwater pumping between Alternative 4 and the No Action Alternative.

The model simulations show that, on average, groundwater pumping is 0.4% higher in Alternative 4 than the No Action Alternative.

Central Valley Project and State Water Project Service Areas

Alternative 4 is expected to decrease water supply to the CVP and SWP service areas. With this decrease in supply, the reliance on groundwater pumping is expected to stay the same or increase compared with the No Action Alternative. Therefore, there is expected to be a similar or increased amount of groundwater pumping in Alternative 4 compared with the No Action Alternative.

I.2.6.1.2 Potential Changes in Groundwater-Surface Water Interaction

Trinity River Region

Most usable groundwater in the Trinity River Region occurs in widely scattered alluvium-filled valleys, such as those immediately adjacent to the Trinity River. These valleys contain only small quantities of recoverable groundwater and therefore are not considered a major source. Given this hydrogeologic nature of this region, changes in surface water flow will likely result in little change to the groundwater-surface water interaction flow.

Central Valley Region

The amount of groundwater-surface water interaction flow simulated in the CVHM for Alternative 4, throughout the Central Valley, is shown in Table I.2-3. Table I.2-4 shows the change in groundwater-surface water interaction for Alternative 4 compared with the No Action Alternative. Over the length of the CVHM simulation, the change in groundwater-surface water interaction is 1.4% (increased flow from groundwater to surface water) in Alternative 4 compared with the No Action Alternative.

Central Valley Project and State Water Project Service Areas

Alternative 4, in general, decreases water supply to the CVP and SWP service areas and therefore likely results in little change (or potentially an increase) in the amount of groundwater pumping because of increased reliance on groundwater compared to the No Action Alternative. With a potential increase in groundwater pumping, there could be a decrease in groundwater levels that may result in a change in the amount of groundwater-surface water interaction flow. Therefore, Alternative 4, compared with the No Action Alternative, may result in groundwater levels decreasing, allowing for additional exfiltration of surface water to groundwater.

I.2.6.1.3 Potential Changes in Groundwater Elevation

Trinity River Region

Given there is likely to be little change in groundwater pumping in this region and also little change in the groundwater-surface water interaction flow, there will be little change to groundwater levels in the area compared with the No Action Alternative.

Central Valley Region

The CVHM simulations indicate that the amount of groundwater pumping in Alternative 4 increases in some years and decreases in other years, with an average increase of approximately 0.7% over the No Action Alternative. Simulations also suggest that less water would recharge to the groundwater system in Alternative 4 than in the No Action Alternative. These two factors (more pumping, less recharge) combine to potentially lower groundwater levels. CVHM was used to estimate change to groundwater levels resulting from the combined effects of project-level changes.

Figures I.2-2 through I.2-25 show the simulated groundwater elevations at 24 arbitrary locations throughout the San Joaquin Valley. Changes in groundwater pumping were not simulated in the Sacramento Valley, therefore, modeled groundwater elevations in the Sacramento Valley are not shown. Figures I.2-26 through I.2-49 show the simulated change in groundwater elevation at these 24 locations.

Figures I.2-64 through I.2-68 show the simulated change in groundwater level spatially across the Central Valley under Alternative 4 compared with the No Action Alternative. These figures show the average change in groundwater levels in July during each of the five water year types (Wet, Above Normal, Below Normal, Dry, Critical Dry).

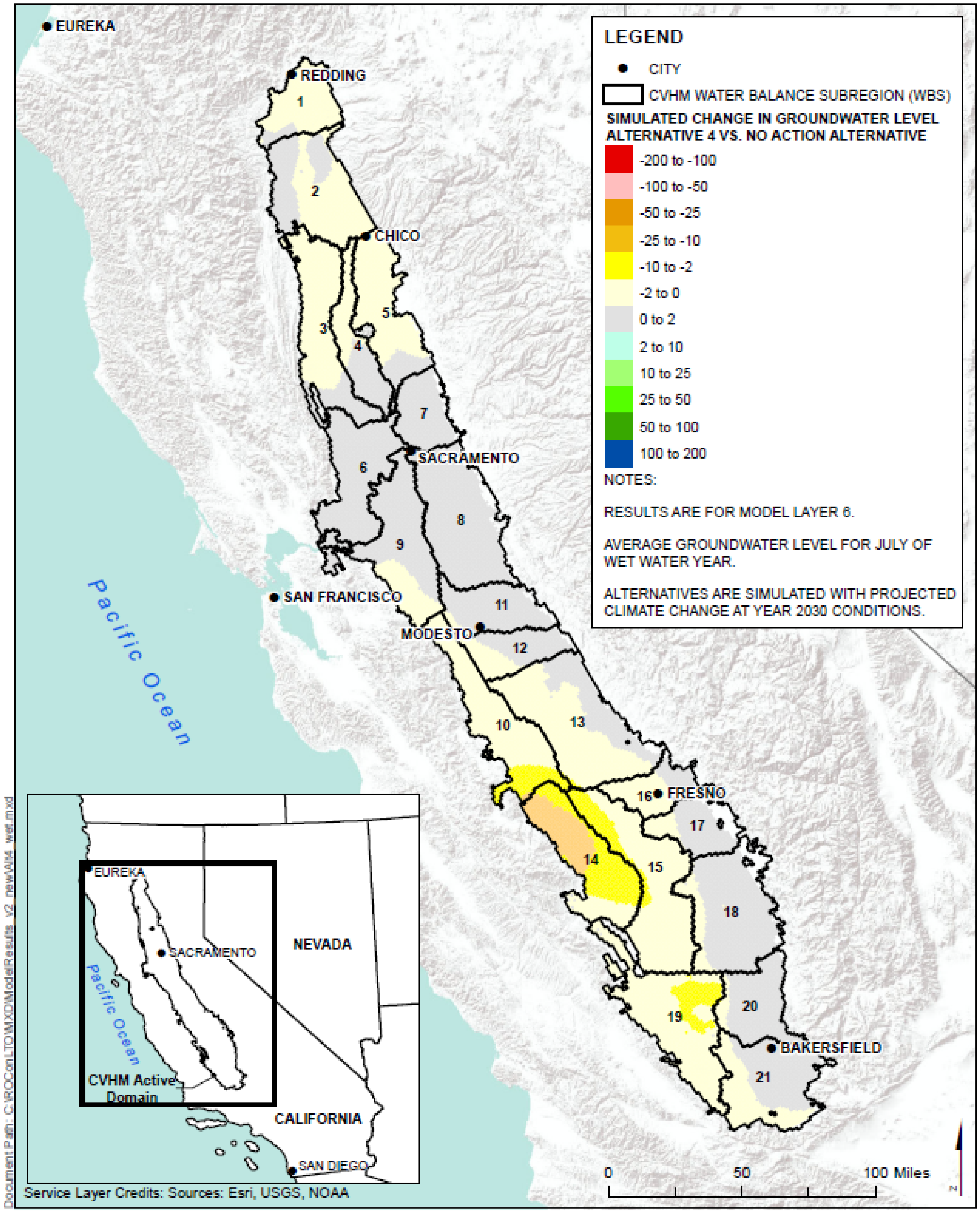

Figure I.2-65. Simulated Change in Groundwater Level, July of Wet Years, Alternative 4 versus No Action Alternative

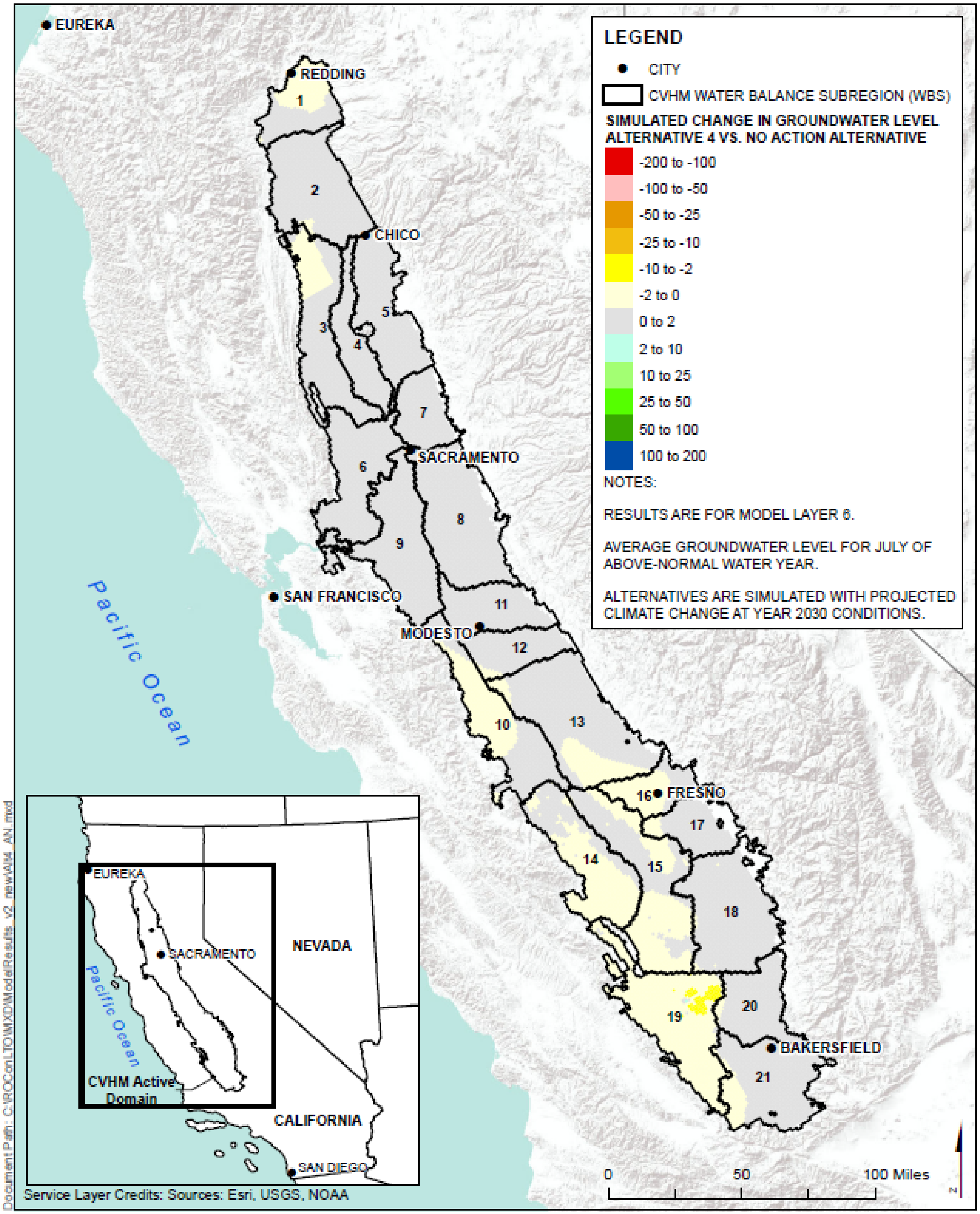

Figure I.2-66. Simulated Change in Groundwater Level, July of Above Normal Years, Alternative 4 versus No Action Alternative

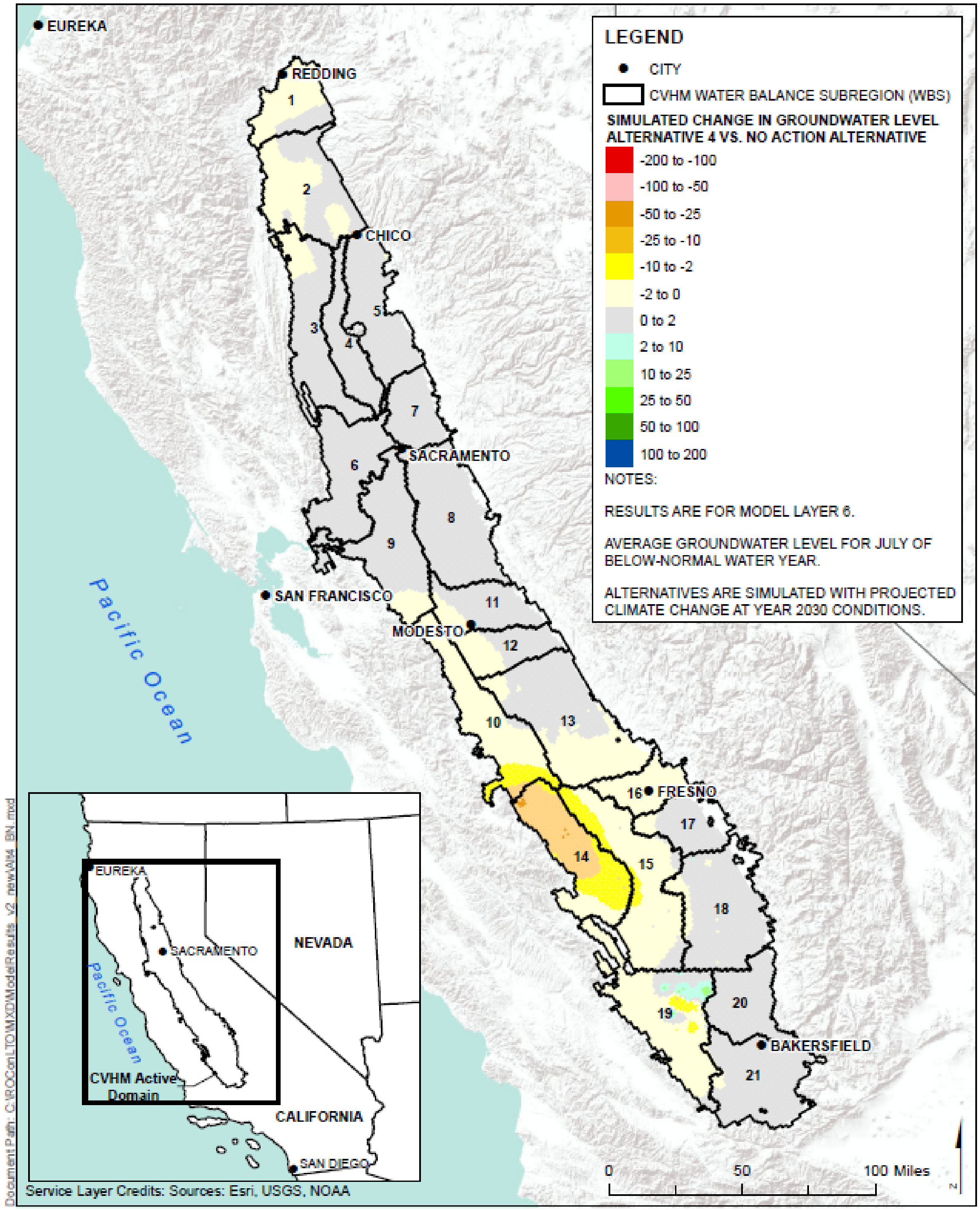

Figure I.2-67. Simulated Change in Groundwater Level, July of Below Normal Years, Alternative 4 versus No Action Alternative

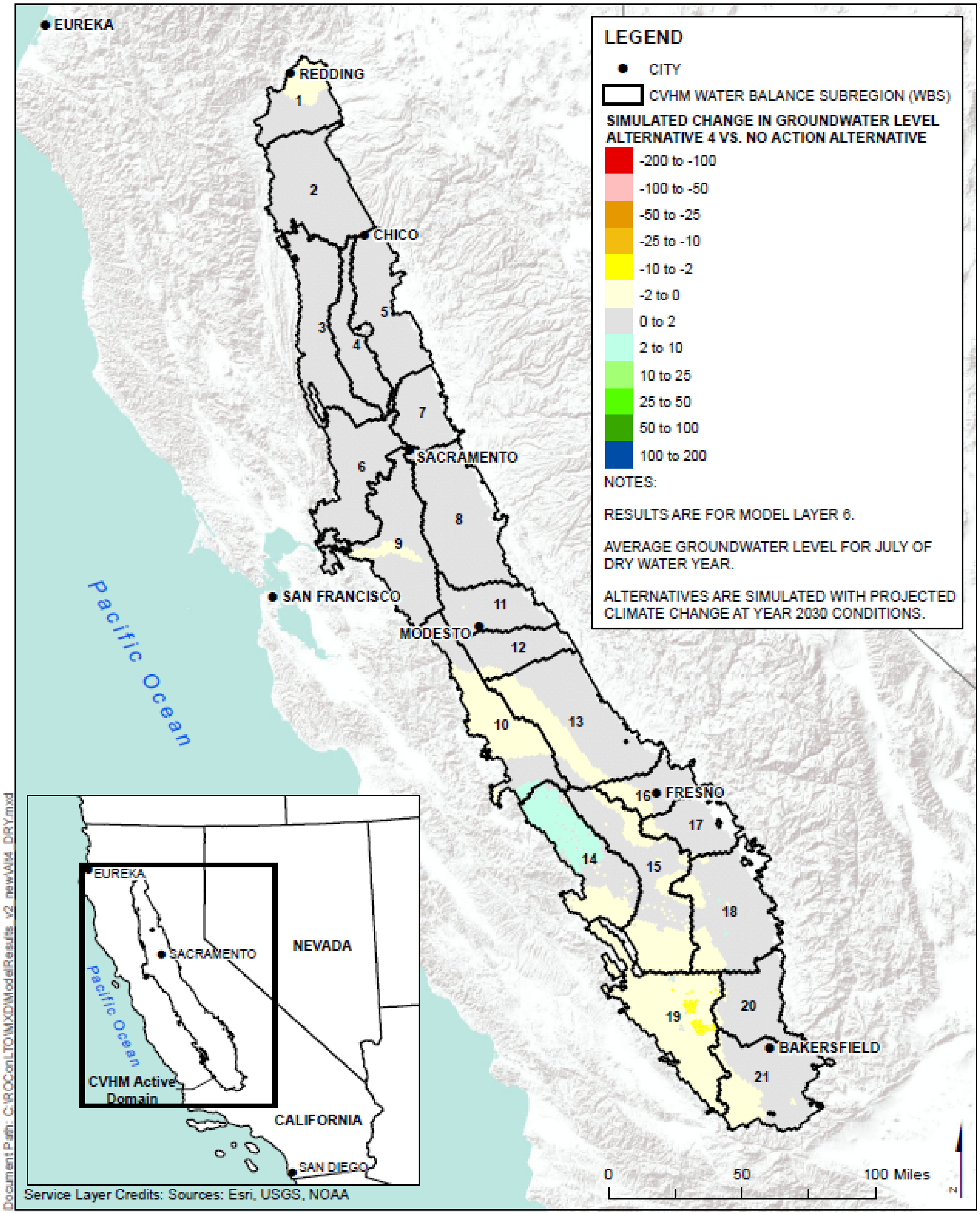

Figure I.2-68. Simulated Change in Groundwater Level, July of Dry Years, Alternative 4 versus No Action Alternative

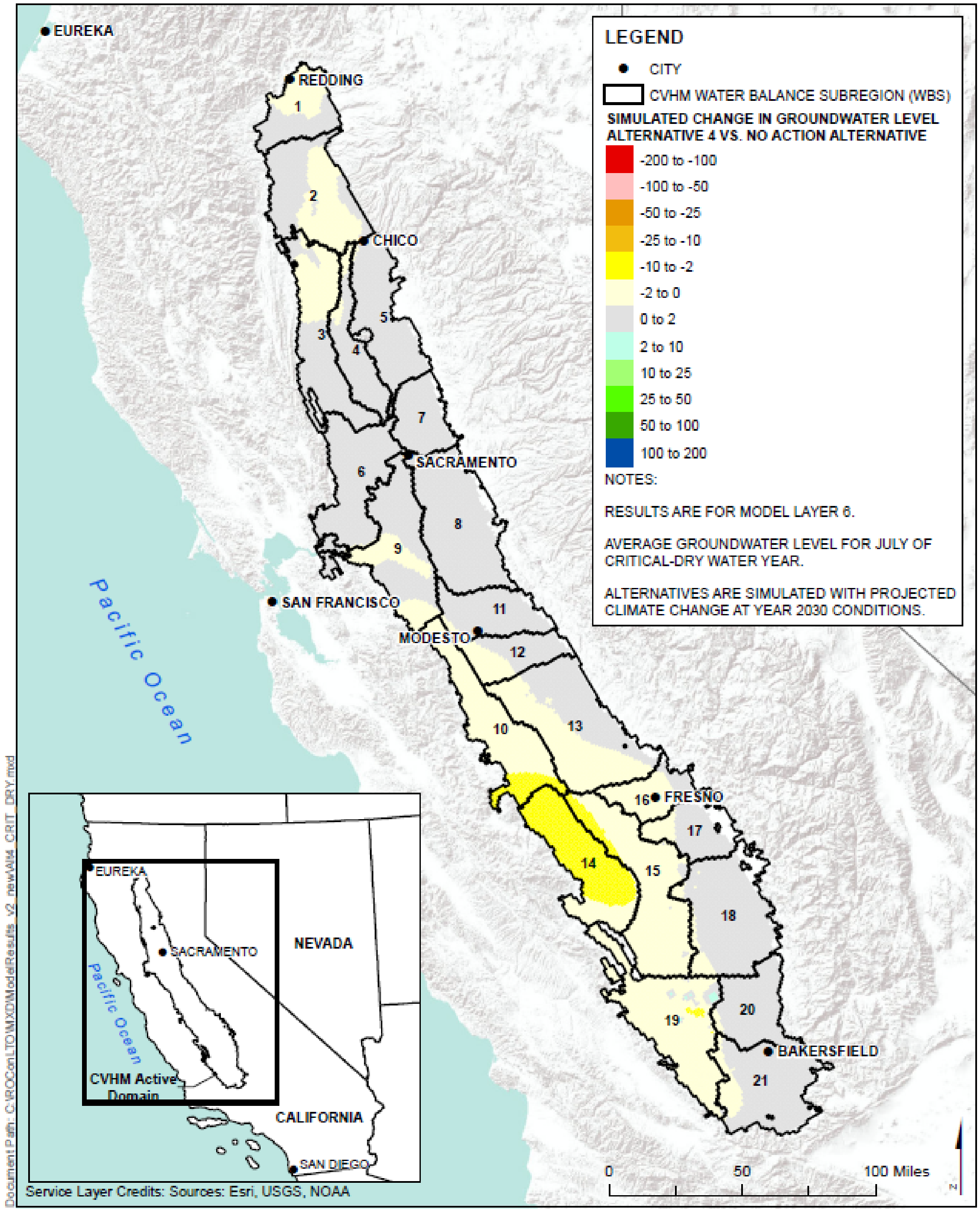

Figure I.2-69. Simulated Change in Groundwater Level, July of Critical Dry Years, Alternative 4 versus No Action Alternative

These figures show that, on average, groundwater levels decrease in the areas south of the Delta as a result of Alternative 4 compared with the No Action Alternative.

Central Valley Project and State Water Project Service Areas

Alternative 4, in general, increases water supply to the CVP and SWP service areas and therefore likely results in little change (or potentially a decrease) in the amount of groundwater pumping because of decreased reliance on groundwater compared to the No Action Alternative. With a potential increase in groundwater pumping, there could be a decrease in groundwater levels. Therefore, Alternative 4, compared with the No Action Alternative, may result in decreased groundwater levels.

I.2.6.1.4 Potential Changes in Land Subsidence

Trinity River Region

The fact that the area along the Trinity River is not known to be susceptible to subsidence and that groundwater pumping is not expected to increase in this region suggests that subsidence will not be a concern in this area.

Central Valley Region

Land subsidence is caused by the consolidation of certain subsurface soils when the pore pressure in those soils is reduced. Portions of the Central Valley, in both the Sacramento and San Joaquin Valleys, contain subsurface sediments that are susceptible to subsidence. In the Central Valley, subsidence is typically associated with a reduction in groundwater pore pressure caused by groundwater pumping. That pumping causes groundwater levels (and pore pressures) to decrease. If those levels are lowered below the historical low values for that area, subsidence can occur.

As noted in previous sections, groundwater pumping may increase under Alternative 4 compared to the No Action Alternative, causing groundwater levels to decrease. A decrease in groundwater levels below historical low levels may occur. However, the certainty of those low levels occurring is not clear because water levels vary from year to year based on hydrologic conditions. If the groundwater levels are lowered below historic low levels in areas that are geologically susceptible to subsidence, it is possible that Alternative 4 would cause additional subsidence compared to the No Action Alternative, given that groundwater levels are expected to remain stable or increase and there are areas of active subsidence in both the Sacramento and San Joaquin Valleys.

Central Valley Project and State Water Project Service Areas

As noted in previous sections, groundwater pumping may increase under Alternative 4 compared to the No Action Alternative, causing groundwater levels to decrease. A decrease in groundwater levels below historical low levels may occur. However, the certainty of those low levels occurring is not clear because water levels vary from year to year based on hydrologic conditions. If the groundwater levels are lowered below historic low levels in areas that are geologically susceptible to subsidence, it is possible that Alternative 4 would cause additional subsidence compared to the No Action Alternative, given that groundwater levels are expected to remain stable or decrease and there are areas of active subsidence in both the Sacramento and San Joaquin Valleys.

I.2.6.2 *Program-Level Effects*

Alternative 4 includes increased water efficiency measures. The implementation of these measures would likely result in decreased reliance on groundwater supplies. A decrease in groundwater supply reliance could reduce the amount of groundwater pumped and therefore increase groundwater levels.

I.2.7 Mitigation Measures

No mitigation measures are identified for the effects acknowledged in this appendix.

I.2.8 Summary of Impacts

Table I.2-5, Impact Summary, includes a summary of effects, the magnitude and direction of those effects, and potential mitigation measures for consideration.

Table I.2-5. Impact Summary

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
Potential Changes in Groundwater Pumping	No Action	No Change	–
	1	There is not expected to be a change in groundwater pumping in the Trinity River region. In the Central Valley region, groundwater pumping is expected to decrease an average of 264 TAF per year (3.7%) compared with the No Action Alternative. In the CVP and SWP service areas, groundwater pumping is expected to remain the same or decrease.	–
	2	There is not expected to be a change in groundwater pumping in the Trinity River region. In the Central Valley region, groundwater pumping is expected to decrease an average of 535 TAF per year (7.5%) compared with the No Action Alternative. In the CVP and SWP service areas, groundwater pumping is expected to remain the same or decrease.	–

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
	3	There is not expected to be a change in groundwater pumping in the Trinity River region. In the Central Valley region, groundwater pumping is expected to decrease an average of 513 TAF per year (7.1%) compared with the No Action Alternative. In the CVP and SWP service areas, groundwater pumping is expected to remain the same or decrease.	–
	4	There is not expected to be a change in groundwater pumping in the Trinity River region. In the Central Valley region, groundwater pumping is expected to increase an average of 26 TAF per year (0.4%) compared with the No Action Alternative. In the CVP and SWP service areas, groundwater pumping is expected to remain the same or slightly increase.	–
Potential Changes in Groundwater-Surface Water Interaction	No Action	No Change	–
	1	Any increased surface water flow in the Trinity River region would potential result in additional recharge to groundwater from surface water. In the Central Valley region, the average change in groundwater/surface water interaction flow is 50 TAF per year (10.3%) of a reduction in surface water discharging to groundwater compared with the No Action Alternative. In the CVP and SWP service areas, there is not expected to be any increased discharge of surface water to groundwater.	–

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
	2	Any increased surface water flow in the Trinity River region would potential result in additional recharge to groundwater from surface water. In the Central Valley region, the average change in groundwater/surface water interaction flow is 64 TAF per year (13.2%) of a reduction in surface water discharging to groundwater compared with the No Action Alternative. In the CVP and SWP service areas, there is not expected to be any increased discharge of surface water to groundwater.	–
	3	Any increased surface water flow in the Trinity River region would potential result in additional recharge to groundwater from surface water. In the Central Valley region, the average change in groundwater/surface water interaction flow is 65 TAF per year (13.4%) of a reduction in surface water discharging to groundwater compared with the No Action Alternative. In the CVP and SWP service areas, there is not expected to be any increased discharge of surface water to groundwater.	–
	4	Any increased surface water flow in the Trinity River region would potential result in additional recharge to groundwater from surface water. In the Central Valley region, the average change in groundwater/surface water interaction flow is an increase of 7 TAF per year (1.4%) of a reduction in surface water discharging to groundwater compared with the No Action Alternative. In the CVP and SWP service areas, there is not expected to be any increased discharge of surface water to groundwater.	–

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
Potential Changes in Groundwater Elevation	No Action	No Change	–
	1	There is expected to be negligible change in groundwater elevation in the Trinity River region. Groundwater elevations in the northern portion of the Central Valley region are expected to remain constant or decrease slightly. Groundwater elevations in the southern portion of Central Valley region are expected to remain constant or increase. Groundwater elevations in the CVP and SWP service area region are expected to remain constant or increase.	–
	2	There is expected to be negligible change in groundwater elevation in the Trinity River region. Groundwater elevations in the northern portion of the Central Valley region are expected to remain constant or decrease slightly. Groundwater elevations in the southern portion of Central Valley region are expected to remain constant or increase. Groundwater elevations in the CVP and SWP service area region are expected to remain constant or increase.	–
	3	There is expected to be negligible change in groundwater elevation in the Trinity River region. Groundwater elevations in the northern portion of the Central Valley region are expected to remain constant or decrease slightly. Groundwater elevations in the southern portion of Central Valley region are expected to remain constant or increase. Groundwater elevations in the CVP and SWP service area region are expected to remain constant or increase.	–

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
	4	There is expected to be negligible change in groundwater elevation in the Trinity River region. Groundwater elevations in the Central Valley region are expected to remain constant or decrease. Groundwater elevations in the CVP and SWP service area region are expected to remain constant or decrease.	–
Potential Changes in Land Subsidence	No Action	No Change	–
	1	There is expected to be negligible change in land subsidence in the Trinity River region. Alternative 1 is not expected to increase land subsidence in the Central Valley region. There is expected to be negligible change in land subsidence in the CVP and SWP service area region.	–
	2	There is expected to be negligible change in land subsidence in the Trinity River region. Alternative 2 is not expected to increase land subsidence in the Central Valley region. There is expected to be negligible change in land subsidence in the CVP and SWP service area region.	–
	3	There is expected to be negligible change in land subsidence in the Trinity River region. Alternative 3 is not expected to increase land subsidence in the Central Valley region. There is expected to be negligible change in land subsidence in the CVP and SWP service area region.	–

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
	4	There is expected to be negligible change in land subsidence in the Trinity River region. Alternative 4 may increase land subsidence in the Central Valley region. There is expected to be negligible change in land subsidence in the CVP and SWP service area region.	–

TAF = thousand acre-feet
CVP = Central Valley Project
SWP = State Water Project

I.2.9 Cumulative Effects

The No Action Alternative would not result in any changes to water operations, and there would be no additional effects on groundwater pumping. As such, the No Action Alternative is not evaluated further in this section.

Alternatives 1, 2, and 3 would generally increase surface water supplies to CVP and SWP contractors. An increase in surface water supply would decrease the reliance on groundwater and result in less groundwater pumping. Alternative 4 would generally decrease surface water supplies to contractors.

The past, present, and reasonably foreseeable projects described in Appendix Y, *Cumulative Methodology*, may have effects on water supply. These cumulative projects include actions across California to develop new water storage capacity, new water conveyance infrastructure, new water recycling capacity, and the reoperation of existing water supply infrastructure, including surface water reservoirs and conveyance infrastructure. The cumulative projects also include ecosystem improvement and habitat restoration actions to improve conditions for species whose special status, in many cases, can constrain water supply delivery operations. Collectively, these cumulative projects would be anticipated to directly or indirectly generate improvements in either local or broader regional water supply conditions. An increase in surface water supply from these cumulative projects would also have the effect of decreasing reliance on groundwater and reducing groundwater pumping.

I.2.9.1 *Changes in Groundwater Pumping*

Alternative 1's contribution to cumulative conditions would not be substantial. In the case of cumulative projects anticipated to potentially generate temporary reductions in water supply deliveries or reduce surplus water supply availability to neighboring water users, Alternative 1's reduction in groundwater pumping would help to reduce the severity of any potential cumulative effect. Alternatives 2 and 3 would have similar effects as Alternative 1 and would not generate substantial contributions to cumulative groundwater pumping conditions.

Alternative 4's contribution to these cumulative conditions is also not expected to be substantial. The increase in groundwater pumping under Alternative 4 is relatively small (0.7%) and would not worsen groundwater conditions.

I.2.9.2 *Potential Changes in Groundwater Elevation*

Alternative 1 would generally decrease the amount of groundwater pumping due to an increase in surface water supplies available to CVP and SWP contractors. The decrease in groundwater pumping would result in an increase in groundwater elevations. Since Alternative 1's contribution to groundwater pumping conditions is not expected to be substantial, Alternative 1's contribution to cumulative changes in groundwater elevation is also not expected to be substantial. Alternatives 2 and 3 would have similar effects as Alternative 1 and would not generate substantial contributions to cumulative groundwater elevations.

Alternative 4 would slightly increase the amount of groundwater pumping due to a decrease in surface water supplies available to CVP and SWP contractors. The increase in groundwater pumping would result in a decrease in groundwater elevations. Since Alternative 4's contribution to groundwater pumping conditions is relatively small (0.7%) and not expected to be substantial, Alternative 4's contribution to cumulative changes in groundwater elevation is also not expected to be substantial.

I.2.9.3 *Potential Changes in Groundwater-Surface Water Interaction*

Alternative 1 would generally decrease the amount of groundwater that discharges to surface water. due to an increase in surface water supplies available to CVP and SWP contractors. The amount of decrease is relatively low (6.6%). Therefore, Alternative 1's contribution to changes in groundwater elevation is also not expected to be substantial. Alternatives 2, 3, and 4 would have similar effects as Alternative 1 and would not generate substantial contributions to cumulative groundwater-surface water interaction.

I.2.9.4 *Potential Changes in Land Subsidence*

Alternative 1's contribution to groundwater pumping conditions is not expected to be substantial; therefore, Alternative 1's contribution to changes in groundwater elevation is also not expected to be substantial. Without a substantial change to groundwater elevations, there would also not be a substantial change to land subsidence. Alternatives 2 and 3 would have similar effects as Alternative 1 and would not generate substantial contributions to cumulative land subsidence.

Alternative 4 has the potential to increase groundwater pumping by approximately 0.7%. An increase in pumping, if occurring in areas susceptible to subsidence, may result in additional subsidence. However, given the relatively low amount of increase in groundwater pumping that occurs during select hydrologic conditions, Alternative 4's contribution to cumulative subsidence is not expected to be substantial.

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Appendix J Indian Trust Assets

This appendix describes Indian Trust Assets (ITAs) in the study area to support the impact analysis in the EIS.

Potential actions that could be implemented under the alternatives evaluated in this EIS could affect ITAs in the areas along the rivers and reservoirs directly affected by changes in the operation of Central Valley Project (CVP) or State Water Project (SWP) reservoirs and in the vicinity of lands served by CVP and SWP water supplies.

The Federal Indian Trust Asset policies, summarized below, have been used to identify potential areas of change to ITAs that could occur due to changes in long-term operation of the CVP and/or SWP facilities.

The ITAs are legal interests in property held in trust by the United States for federally recognized Indian tribes or individual Indians. An Indian trust has three components: (1) the trustee, (2) the beneficiary, and (3) the trust asset. ITAs can include land, minerals, federally reserved hunting and fishing rights, federally reserved water rights, and in-stream flows associated with trust land. Beneficiaries of the Indian trust relationship are federally recognized Indian tribes with trust land; the United States is the trustee. By definition, ITAs cannot be sold, leased, or otherwise encumbered without approval of the U.S. government. The characterization and application of the U.S. trust relationship have been defined by case law that interprets Congressional acts, executive orders, and historic treaty provisions.

The federal government, through treaty, statute or regulation, may take on specific, enforceable fiduciary obligations that give rise to a trust responsibility to federally recognized tribes and individual Indians possessing trust assets. Courts have recognized an enforceable federal fiduciary duty with respect to federal supervision of Indian money or natural resources, held in trust by the federal government, where specific treaties, statutes or regulations create such a fiduciary duty.

Consistent with President William J. Clinton’s 1994 memorandum, “Government-to-Government Relations with Native American Tribal Governments,” U.S. Department of the Interior, Bureau of Reclamation (Reclamation) assesses the effect of its programs on tribal trust resources and federally recognized tribal governments. Reclamation is tasked to actively engage federally recognized tribal governments and consult with such tribes on government-to-government level when its actions affect ITAs (*Federal Register*, Vol. 59, No. 85, May 4, 1994, pages 22951–22952). The U.S. Department of the Interior (DOI) Departmental Manual Part 512.2 ascribes the responsibility for ensuring protection of ITAs to the heads of bureaus and offices. DOI is required to carry out activities in a manner that protects ITAs and avoids adverse effects whenever possible.

J.1 Background Information

The U.S. Government’s trust responsibility for Indian resources requires Reclamation and other agencies to take measures to protect and maintain trust resources. These responsibilities include taking reasonable actions to preserve and restore tribal resources.

Table J.1-1. Federally Recognized Tribes in the Vicinity of the Study Area

Federally Recognized Tribe	EIS Geographical Region	County/Counties	In the Vicinity of this Community
Hoopa Valley Tribal Council	Trinity River	Trinity and Humboldt	Hoopa
Resighini Rancheria Tribe	Trinity River	Del Norte	Klamath
Yurok Tribe of the Yurok Reservation	Trinity River	Trinity, Humboldt, and Del Norte	Klamath
Pit River Tribe	Sacramento River	Shasta	Burney
Redding Rancheria Tribe	Sacramento River	Shasta	Redding
Paskenta Band of Nomlaki Indians of California	Sacramento River	Tehama and Glenn	Corning and Orland
Grindstone Indian Rancheria of Wintun-Wailaki Indians of California	CVP and SWP Service Areas, Sacramento River	Glenn	Elk Creek
Cachil Dehe Band of Wintun Indians of the Colusa Indian Community of the Colusa Rancheria	CVP and SWP Service Areas, Sacramento River	Colusa	Colusa
Cortina Indian Rancheria of Wintun Indians of California	CVP and SWP Service Areas, Sacramento River	Colusa	Williams
Tyme Maidu of Berry Creek Rancheria	CVP and SWP Service Areas	Butte	Oroville
Konkow Maidu of Mooretown Rancheria	CVP and SWP Service Areas	Butte	Oroville
Enterprise Rancheria of Maidu Indians of California	CVP and SWP Service Areas, Sacramento River	Butte	Oroville
Mechoopda Indian Tribe of Chico Rancheria	CVP and SWP Service Areas, Sacramento River	Butte	Chico
Miwok Maidu United Auburn Indian Community of the Auburn Rancheria	American River	Placer	Placer
United Auburn Indian Community of the Auburn Rancheria of California	American River	Placer	Rocklin
Shingle Springs Band of Miwok Indians, including Shingle Springs Rancheria	American River	El Dorado and Nevada	Shingle Springs
Buena Vista Rancheria of Me-Wuk	Sacramento River	Sacramento	Sacramento
Wilton Miwok Indians of the Wilton Rancheria	Sacramento River	Sacramento	Elk Grove
Yocha Dehe Wintun Nation	Sacramento River	Yolo	Brooks
Northfork Rancheria of Mono Indians of California	San Joaquin River	Madera	North Fork
Picayune Rancheria of Chukchansi Indians of California	San Joaquin River	Madera	Coarsegold
California Valley Miwok Tribe	San Joaquin River	San Joaquin	Stockton

Federally Recognized Tribe	EIS Geographical Region	County/Counties	In the Vicinity of this Community
Big Sandy Rancheria of Mono Indians of California	San Joaquin River	Fresno	Auberry
Table Mountain Rancheria	San Joaquin River	Fresno	Friant
Santa Rosa Indian Community of Santa Rosa Rancheria	CVP and SWP Service Areas	Kings	Lemoore
Tule River Indian Tribe of the Tule River Reservation of the Yokut Indians	CVP and SWP Service Areas	Tulare	Porterville
Santa Ynez Band of Chumash Mission Indians of Santa Ynez Reservation	CVP and SWP Service Areas	Santa Barbara	Santa Ynez
Cahuilla Band of Mission Indians of the Cahuilla Reservation	CVP and SWP Service Areas	San Diego	Anza
Campo Band of Diegueno Mission Indians of the Campo Indian Reservation	CVP and SWP Service Areas	San Diego	Campo
Capitan Grande Band of Diegueno Mission Indians of California (Barona Reservation and Viejas Reservation)	CVP and SWP Service Areas	San Diego	Alpine
Ewiiaapaayp Band of Kumeyaay Indians	CVP and SWP Service Areas	San Diego	Alpine
Iipay Nation of Santa Ysabel	CVP and SWP Service Areas	San Diego	Santa Ysabel
Inaja Band of Diegueno Mission Indians of the Inaja and Cosmit Reservation	CVP and SWP Service Areas	San Diego	Escondido
Jamul Indian Village of California	CVP and SWP Service Areas	San Diego	Jamul
La Jolla Band of Luiseño Indians	CVP and SWP Service Areas	San Diego	Pauma Valley
La Posta Band of Diegueno Mission Indians of the La Posta Indian Reservation	CVP and SWP Service Areas	San Diego	Boulevard
Los Coyotes Band of Cahuilla and Cupeno Indians	CVP and SWP Service Areas	San Diego	Warner Springs
Manzanita Band of Diegueno Mission Indians of the Manzanita Reservation	CVP and SWP Service Areas	San Diego	Boulevard
Mesa Grande Band of Diegueno Mission Indians of the Mesa Grande Reservation	CVP and SWP Service Areas	San Diego	Santa Ysabel
Pala Band of Luiseño Mission Indians of the Pala Reservation	CVP and SWP Service Areas	San Diego	Pala
Pauma Band of Luiseño Mission Indians of the Pauma & Yuima Reservation	CVP and SWP Service Areas	San Diego	Pauma Valley
Rincon Band of Luiseño Mission Indians of the Rincon Reservation	CVP and SWP Service Areas	San Diego	Valley Center
San Pasqual Band of Diegueno Mission Indians of California	CVP and SWP Service Areas	San Diego	Valley Center
Sycuan Band of the Kumeyaay Nation	CVP and SWP Service Areas	San Diego	El Cajon
Agua Caliente Band of Cahuilla Indians of the Agua Caliente Indian Reservation	CVP and SWP Service Areas	Riverside	Palm Springs

Federally Recognized Tribe	EIS Geographical Region	County/Counties	In the Vicinity of this Community
Augustine Band of Cahuilla Indians	CVP and SWP Service Areas	Riverside	Coachella
Cabazon Band of Mission Indians	CVP and SWP Service Areas	Riverside	Indio
Morongo Band of Mission Indians	CVP and SWP Service Areas	Riverside	Banning
Pechanga Band of Luiseño Mission Indians of the Pechanga Reservation	CVP and SWP Service Areas	Riverside	Temecula
Ramona Band of Cahuilla	CVP and SWP Service Areas	Riverside	Anza
Santa Rosa Band of Cahuilla Indians	CVP and SWP Service Areas	Riverside	Mountain Center
Soboba Band of Luiseño Indians	CVP and SWP Service Areas	Riverside	San Jacinto
Torres-Martinez Desert Cahuilla Indians	CVP and SWP Service Areas	Riverside	Thermal
Twenty-Nine Palms Band of Mission Indians of California	CVP and SWP Service Areas	Riverside and San Bernardino	Coachella
Chemehuevi Indian Tribe of the Chemehuevi Reservation	CVP and SWP Service Areas	San Bernardino	Needles
San Manuel Band of Mission Indians	CVP and SWP Service Areas	San Bernardino	Highland
Big Lagoon Rancheria	Not within study area	Humboldt	Arcata
Blue Lake Rancheria	Not within study area	Humboldt	Blue Lake
Karuk Tribe	Not within study area	Siskiyou	Happy Camp
Greenville Rancheria of Maidu Indians	Not within study area	Plumas and Tehama	Greenville
Susanville Indian Rancheria	Not within study area	Lassen	Susanville
Lytton Rancheria	Not within study area	Sonoma	Santa Rosa
Chicken Ranch Rancheria of Me-Wuk Indians of California	Not within study area	Tuolumne	Jamestown
Cold Springs Rancheria of Mono Indians	Not within study area	Fresno	Tollhouse
Colorado River Indian Tribes of the Colorado River Indian Reservation	Not within study area	Riverside	Parker, Arizona

J.2 Evaluation of Alternatives

This section describes the technical background for the evaluation of environmental consequences associated with the action alternatives and the No Action Alternative.

J.2.1 Methods and Tools

Changes in CVP and SWP operation under the action alternatives, compared to the No Action Alternative, could change water elevations within the CVP and SWP reservoirs, flow patterns in the rivers downstream of CVP and SWP reservoirs, and CVP and SWP water deliveries. Impacts on existing ITAs would be considered adverse if the action:

- Interfered with the exercise of a federally reserved water right, or degrade water quality where there is a federally reserved water right.
- Interfered with the use, value, occupancy, character or enjoyment of an ITA.
- Failed to protect ITAs from loss, damage, waste, depletion, or other negative effects.

J.2.1.1 *Changes in CVP and SWP Reservoir Elevation*

There are no ITAs within any of the reservoir inundation areas (DWR 2005; Reclamation 2010, 2012, 2013a, 2014; Reclamation et al. 2011; USACE et al. 2012). Therefore, the changes in reservoir elevations would not affect ITAs and are not analyzed in this EIS.

J.2.1.2 *Changes in CVP and SWP Water Deliveries*

There are no ITAs that directly receive CVP or SWP water. Municipalities that use CVP or SWP water supplies, including agencies that serve ITAs, would continue to meet water demands in 2030 if CVP and SWP water supplies are reduced through the increased use of non-CVP and SWP water supplies. Therefore, changes in CVP and SWP water deliveries would not affect water supplies to ITAs and are not analyzed in this EIS.

J.2.2 No Action Alternative

The No Action Alternative would generate no changes to water operations and there would be no improvement in existing limits to water supply availability that impact CVP and SWP water users. Therefore in comparison to existing conditions there would be no impact on water supply. Given the lack of changes under the No Action Alternative to CVP and SWP operations there would also be no change to the water quality conditions. The No Action Alternative would not change the existing impacts on ITAs.

J.2.3 Alternative 1

J.2.3.1 *Project-Level Effects*

Potential changes in erosion or degradation of land or sites of religious or cultural importance to federally recognized Indian tribes

Project-level components of Alternative 1 are primarily operations based and would not involve the use of any land or sites of religious or cultural importance to Native Americans. As described in Appendix X, *Geology and Soils Technical Appendix*, no changes in peak flows are expected under Alternative 1 relative to the No Action Alternative; therefore, stream channel erosion would not occur under Alternative 1.

Potential changes in quality of water utilized by a federally recognized Indian tribe

As described in Appendix G, *Water Quality Technical Appendix*, changes in flow in the study area rivers due to changes in the operation of CVP/SWP under Alternative 1, relative to the No Action Alternative, would not result in increased frequency of exceedances of water quality standards. Therefore, there would be no degradation of water quality delivered to federally recognized tribes.

Potential changes to salmonid populations

Effects to salmonid populations which are an important resource to ITAs would result in an adverse effect to federally recognized Indian tribes which have fishing rights. Effects to salmonids vary in each river in the study area and are summarized by region below. For detailed analysis please refer to Appendix O, *Aquatic Resources Technical Appendix*:

Trinity River

Salmon spawning success and salmonid juvenile rearing success could be reduced due to elevated water temperatures during September and October. Modeled maximum water temperatures under the action alternatives would be at or below the recommended 55°F criterion for spawning and egg incubation (USEPA 2003) from December through May, which would provide substantial protection for these life stages of Coho Salmon, which begin spawning in November, and Steelhead, which begin spawning in January and February.

Modeled maximum water temperatures during November, however, would slightly exceed the 55°F criterion under Alternative 1 (55.2°F) which could compromise spawning success by both Chinook and Coho Salmon during November.

Modeled maximum water temperatures would exceed the recommended 55°F criterion for spawning and incubation during September and October under Alternative 1, likely reducing spawning and incubation success for Spring-Run and Fall-Run Chinook Salmon, which begin spawning in September and October, respectively.

Clear Creek

In Clear Creek below Whiskeytown Dam, CalSim II modeling results indicate that average flows in most water year types under Alternative 1 would be similar or the same as under the No Action Alternative. In all water year types, Alternative 1 would be similar to the No Action Alternative for instream habitat conditions

Sacramento River

Changes in summer/fall water temperature management operations under Alternative 1, especially with respect to the Shasta temperature control device (TCD), are expected to improve temperature and dissolved oxygen conditions experienced by incubating Winter-Run Chinook Salmon eggs and alevins.

The proposed Shasta Dam improved TCD under Alternative 1, as well as Rice Decomposition Smoothing, Spring Management of Spawning Locations, Battle Creek Restoration, and Intake Lowering near Wilkins Slough, would further facilitate increased coldwater storage, resulting in greater protection of the Winter-Run and Spring-Run Chinook Salmon population.

Feather River

Average flows under Alternative 1 are slightly greater than under the No Action Alternative from December to March, so the effects on eggs and rearing juveniles would be negligible and potentially beneficial because of increased availability of habitat for these life stages. Increased flows under the action alternatives from May to June, during Spring-Run Chinook Salmon migration and holding, would provide potential temperature and fish passage benefits.

Modeled maximum water temperatures under Alternative 1 and the No Action Alternative would exceed the recommended 55°F criterion for spawning, egg incubation, and rearing (USEPA 2003) from September to November, a period of Spring-Run Chinook Salmon egg incubation and juvenile rearing, which could reduce survival of these life stages.

Stanislaus River

Alternative 1 flows would be slightly reduced but generally similar to the No Action Alternative.

Compared to the No Action Alternative, Alternatives 1 increases the annual storage and, therefore, the size of the coldwater pool in New Melones Reservoir. Temperature modeling for the Stanislaus River at Ripon shows that there is a small increase in overall annual water temperature for Alternatives 1 relative to the No Action Alternative. Reduced flows in above normal water years and water years may increase water temperatures in these less critical hydrologic conditions, however, this promotes additional storage at New Melones Dam for potential future droughts and preserving the cold water pool to benefit downstream salmonids.

Under Alternative 1, the proposed dissolved oxygen compliance point is protective of salmonids because the majority of salmonid eggs, alevin, and/or fry are found in locations where summer dissolved oxygen levels would be expected to be maintained at or near 7 mg/L, although it reduces the area of suitable dissolved oxygen as compared to the No Action Alternative. However, based on the typical seasonal occurrence of the adult life stages in the river (July to October), adult migrating salmonids would potentially be exposed to the effects of relaxing dissolved oxygen requirements at Ripon.

San Joaquin River

Analyses of flow for Alternatives 1 compared to the No Action Alternative show that releases in the San Joaquin River below Millerton Reservoir would remain the same for all scenarios. Therefore, no change to salmonid populations is anticipated as a result in the upper San Joaquin River.

Bay-Delta

Under Alternative 1, CVP and SWP exports increase during the migration window for juvenile Winter-Run, Spring-Run, and Fall-Run Chinook Salmon as compared to the No Action Alternative. Salvage and loss of juvenile Winter-Run, Spring-Run, and Fall-Run Chinook have been shown to increase as exports increase. However, only a small proportion of the total population is lost at the export facilities. Increased flow in the Sacramento River mainstem would occur under Alternative 1 and higher flow has been shown to increase through-Delta survival of juvenile Chinook Salmon and reduce routing into the interior Delta at Georgiana Slough. The Sacramento River mainstem is the primary migration route for juvenile Winter-

Run, Spring-Run, and Fall-Run Chinook Salmon, thus a much greater proportion of the population would be exposed to the positive effects of greater Sacramento River flows than would be exposed to the negative effects of increased exports as compared to the No Action Alternative. Under Alternative 1, flows in the Sacramento River would be greater during the Winter-Run migration period which would increase survival and reduce routing into the interior Delta at Georgiana Slough (Perry et al 2015) as compared to the No Action Alternative. San Joaquin River-origin juvenile Spring-Run Chinook Salmon are likely to be entrained at the salvage facilities at higher rates under Alternatives 1 as compared to the No Action Alternative. San Joaquin River-origin juvenile Fall-Run Chinook Salmon are likely to be entrained at the salvage facilities at higher rates under all action alternatives as compared to the No Action Alternative.

J.2.3.2 *Program-Level Effects*

Potential changes in erosion or quality of land or sites of religious or cultural importance to federally recognized Indian tribes

As described in Appendix X, *Geology and Soils Technical Appendix*, no changes in peak flows are expected as a result of program-level actions for Alternative 1; therefore, stream channel erosion would be the same as under the No Action Alternative. Proposed restoration components have the potential to be implemented on land or sites of religious or cultural importance. The magnitude of effect would depend upon the size, location, and type of restoration implemented at the land or site and will be examined and evaluated in subsequent analyses.

Potential changes in quality of water utilized by a federally recognized Indian tribe

As described in Appendix G, *Water Quality Technical Appendix*, program-level actions and construction activities could have water quality implications. These include increased turbidity, mercury and selenium bioaccumulation, dissolved organic carbon, and increased sedimentation.

Potential changes to salmonid populations

Alternative 1 proposes to create additional spawning habitat by injecting 15,000 to 40,000 tons of gravel between Keswick Dam and RBDD, which would potentially increase Winter-Run and Spring-Run Chinook Salmon production relative to the No Action Alternative. Alternative 1 also propose to create 40 to 60 acres of side channel and floodplain habitat at approximately 10 sites in the Sacramento River by 2030, which would potentially increase Winter-Run and Spring-Run Chinook Salmon production relative to the No Action Alternative, thereby benefiting the Winter-Run and Spring-Run Chinook Salmon population.

Alternatives 1 includes implementation of spawning and rearing habitat projects in the American River and its tributaries. These habitat projects would result in improved habitat conditions in the American River, including increased total spawning habitat area, increased and improved side channel habitat, improved intragravel incubation conditions, increased and improved total rearing habitat area, improved overall habitat complexity, and cover and refugia.

Alternative 1 includes a provision for rearing habitat restoration in the lower San Joaquin River. The timing and temporary nature and of restoration activities would limit the potential for lasting impacts on the surrounding aquatic community, and the benefit of the restoration would likely result in long-term improvements to the habitat and aquatic inhabitants.

Although construction under Alternative 1 may temporarily affect certain fish species and their habitat, restoration of spawning and rearing habitat would result in long-term improvements to the habitat and aquatic inhabitants, including an increase in riparian vegetation providing instream objects and overhanging object cover, new shaded riverine habitat, and additional areas for food sources.

The proposed 8,000 acres of tidal habitat restoration of the No Action Alternative and Alternative 1 may provide enhanced availability and quality of rearing habitat for Winter-Run, Spring-Run, and Fall-Run Chinook Salmon rearing in the Delta. Variable fractions of each juvenile cohort leave their natal habitat as fry and rear in the Delta for weeks to months prior to entering the ocean. Enhanced food production in restored habitat may increase growth rates of these fish and physical habitat improvements can provide refuge from nonnative predators in the Delta.

Measures proposed as components of Alternative 1 have the potential to reduce predation. A reduction in predation at key locations identified as predation hot spots has the potential to increase through-Delta survival for juvenile Winter-Run, Spring-Run, and Fall-Run Chinook Salmon during their migration. There is considerable uncertainty about the efficacy of predator management for increasing salmonid survival and potential benefits from this action.

Program level actions under Alternative 1 would generally be beneficial for salmonid populations and the ITAs which rely upon them.

J.2.4 Alternative 2

J.2.4.1 *Project-Level Effects*

Potential changes in erosion or quality of land or sites of religious or cultural importance to federally recognized Indian tribes

Project-level components of Alternative 2 are primarily operations based and would not involve the use of any land or sites of religious or cultural importance to Native Americans. As described in Appendix X, *Geology and Soils Technical Appendix*, no changes in peak flows are expected under Alternative 1; therefore, stream channel erosion would not occur under Alternative 2.

Potential changes in quality of water utilized by a federally recognized Indian tribe

As described in Appendix G, *Water Quality Technical Appendix*, changes in flow in Clear Creek and the Stanislaus River due to changes in the operation of CVP/SWP under Alternative 2 would result in increased frequency of exceedances of water quality standards. However, there are no ITAs identified in the vicinity of Clear Creek and Stanislaus River. Therefore, there would be no degradation of water quality and subsequent effect on federally recognized tribes.

Potential changes to salmonid populations

Effects to salmonid populations which are an important resource to ITAs would result in an adverse effect to federally recognized Indian tribes which have fishing rights. Effects to salmonids vary in each river in the study area and are summarized by region below. For detailed analysis please refer to Appendix O, *Aquatic Resources Technical Appendix*:

J.2.4.1.1 Trinity River

Salmon spawning success and salmonid juvenile rearing success could be reduced due to elevated water temperatures during September and October. Modeled maximum water temperatures under Alternative 2 would be at or below the recommended 55°F criterion for spawning and egg incubation (USEPA 2003) from December through May, which would provide substantial protection for these life stages of Coho Salmon, which begin spawning in November, and Steelhead, which begin spawning in January and February.

Modeled maximum water temperatures during November, however, would slightly exceed the 55°F criterion under Alternative 2 (55.1°F) which could compromise spawning success by both Chinook and Coho Salmon during November.

Modeled maximum water temperatures would exceed the recommended 55°F criterion for spawning and incubation during September and October under Alternative 2, likely reducing spawning and incubation success for Spring-Run and Fall-Run Chinook Salmon, which begin spawning in September and October, respectively.

J.2.4.1.2 Clear Creek

In Clear Creek below Whiskeytown Dam, CalSim II modeling results indicate that average flows in all water year types under Alternative 2 would be less than the No Action Alternative.

The flow decreases under Alternative 2 relative to the No Action Alternative and the NMFS (2009) criteria could compromise Spring-Run Chinook Salmon holding and rearing success and potentially lead to increased incidence of disease and physiological stress in holding adults and reduced survival of rearing juveniles, reduced juvenile production, and reduced spawning success by adults. These effects would be most likely to occur in June to August, when water temperatures are predicted to be highest.

J.2.4.1.3 Sacramento River

Changes in summer/fall water temperature management operations under Alternative 2 would potentially result in increased temperature-related mortality of Winter-Run and Spring-Run Chinook Salmon eggs and alevins relative to the No Action Alternative because these action alternatives could result in a depleted coldwater pool in the summer and fall, resulting in reduced protection to incubating Winter-Run Chinook Salmon eggs and alevins.

J.2.4.1.4 Feather River

Average flows under Alternative 2 are slightly greater than under the No Action Alternative from December to March, so the effects on eggs and rearing juveniles would be negligible and potentially beneficial because of increased availability of habitat for these life stages. Increased flows under Alternative 2 from May to June, during Spring-Run Chinook Salmon migration and holding, would provide potential temperature and fish passage benefits.

Modeled maximum water temperatures under Alternative 2 and the No Action Alternative would exceed the recommended 55°F criterion for spawning, egg incubation, and rearing (USEPA 2003) from September to November, a period of Spring-Run Chinook Salmon egg incubation and juvenile rearing, which could reduce survival of these life stages.

J.2.4.1.5 **Stanislaus River**

Flows under Alternative 2 would be substantially reduced below Goodwin Dam from February through September, and at the mouth of the Stanislaus River from March through May, as compared to the No Action Alternative. Reduced flows under Alternative 2 would likely result in reductions to suitable habitat area for juvenile salmonids.

Compared to the No Action Alternative, Alternative 2 increases the annual storage and, therefore, the size of the coldwater pool in New Melones Reservoir, with the largest storage quantities occurring under Alternatives 2 and 3. Temperature modeling for the Stanislaus River at Ripon shows that there is a small increase in overall annual water temperature for Alternative 2 relative to the No Action Alternative. Reduced flows in above normal water years and water years may increase water temperatures in these less critical hydrologic conditions, however, this promotes additional storage at New Melones Dam for potential future droughts and preserving the cold water pool to benefit downstream salmonids.

J.2.4.1.6 **San Joaquin River**

Analyses of flow for Alternative 2 compared to the No Action Alternative show that releases in the San Joaquin River below Millerton Reservoir would remain the same for all scenarios. Therefore, no change to salmonid populations is anticipated as a result in the upper San Joaquin River.

J.2.4.1.7 **Bay-Delta**

Under Alternative 2, CVP and SWP exports increase during the migration window for juvenile Winter-Run, Spring-Run, and Fall-Run Chinook Salmon as compared to the No Action Alternative. Salvage and loss of juvenile Winter-Run, Spring-Run, and Fall-Run Chinook have been shown to increase as exports increase. However, only a small proportion of the total population is lost at the export facilities. Increased flow in the Sacramento River mainstem would occur under Alternative 2 and higher flow has been shown to increase through-Delta survival of juvenile Chinook Salmon and reduce routing into the interior Delta at Georgiana Slough. The Sacramento River mainstem is the primary migration route for juvenile Winter-Run, Spring-Run, and Fall-Run Chinook Salmon, thus a much greater proportion of the population would be exposed to the positive effects of greater Sacramento River flows than would be exposed to the negative effects of increased exports. Effects are similar to those under Alternative 1.

J.2.4.2 *Program-Level Effects*

No programmatic components are proposed for Alternative 2. Therefore, there are no program-level effects.

J.2.5 Alternative 3

J.2.5.1 *Project-Level Effects*

Potential changes in erosion or degradation of land or sites of religious or cultural importance to federally recognized Indian tribes

Project-level components of Alternative 3 are primarily operations based and would not involve the use of any land or sites of religious or cultural importance to Native Americans. As described in Appendix X, *Geology and Soils Technical Appendix*, minor changes in peak flows (approximately 4% during the month of January) are expected under Alternative 3 relative to the No Action Alternative; however, stream channel erosion would not be substantial and there would be no subsequent degradation of land or sites of religious or cultural importance as a result of changes in erosion.

Potential changes in quality of water utilized by a federally recognized Indian tribe

As described in Appendix G, *Water Quality Technical Appendix*, changes in flow in Clear Creek and the Stanislaus River due to changes in the operation of CVP/SWP under Alternative 3 relative to the No Action Alternative would result in increased frequency of exceedances of water quality standards. However, there are no ITAs identified in the vicinity of Clear Creek and the Stanislaus River. Therefore, there would be no degradation of water quality and subsequent effect to federally recognized tribe.

Potential changes to salmonid populations

Effects to salmonid populations which are an important resource to ITAs would result in an adverse effect to federally recognized Indian tribes which have fishing rights. Effects to salmonids vary in each river in the study area and are summarized by region below. For detailed analysis please refer to Appendix O, *Aquatic Resources Technical Appendix*:

J.2.5.1.1 Trinity River

Salmon spawning success and salmonid juvenile rearing success could be reduced due to elevated water temperatures during September and October. Modeled maximum water temperatures under the Alternative 3 would be at or below the recommended 55°F criterion for spawning and egg incubation (USEPA 2003) from December through May, which would provide substantial protection for these life stages of Coho Salmon, which begin spawning in November, and Steelhead, which begin spawning in January and February.

Modeled maximum water temperatures during November, however, would substantially exceed the criterion under Alternative 3 (59.3°F), which could compromise spawning success by both Chinook and Coho Salmon during November.

Modeled maximum water temperatures would exceed the recommended 55°F criterion for spawning and incubation during September and October under Alternative 3, likely reducing spawning and incubation success for Spring-Run and Fall-Run Chinook Salmon, which begin spawning in September and October, respectively.

J.2.5.1.2 Clear Creek, Sacramento River, Feather River, Stanislaus River, San Joaquin River, and Bay-Delta

Project-level effects to salmonid populations under Alternative 3 would be essentially the same as those discussed under Alternative 2 in Clear Creek, Sacrament River, Feather River, Stanislaus River, San Joaquin River, and the Bay-Delta.

J.2.5.2 *Program-Level Effects*

Potential changes in erosion or degradation of land or sites of religious or cultural importance to federally recognized Indian tribes

As described in Appendix X, *Geology and Soils Technical Appendix*, no changes in peak flows are expected as a result of program-level actions under Alternative 3; therefore, stream channel erosion under Alternative 3 would be the same as that under the No Action Alternative. Proposed restoration components have the potential to be implemented on land or sites of religious or cultural importance. The magnitude of effect would depend upon the size, location, and type of restoration implemented at the land or site and will be examined and evaluated in subsequent analyses.

Potential changes in quality of water utilized by a federally recognized Indian tribe

As described in Appendix G, *Water Quality Technical Appendix,* program-level actions and construction activities could have water quality implications. These include increased turbidity, mercury and selenium bioaccumulation, dissolved organic carbon, and increased sedimentation.

Potential changes to salmonid populations

Program-level effects would be the same as those discussed under Alternative 1; however the additional 25,000 acres of tidal habitat restoration proposed under Alternative 3 in the Bay-Delta region would provide additional enhanced availability and quality of rearing habitat for Winter-Run, Spring-Run, and Fall-Run Chinook Salmon rearing in the Delta.

J.2.6 Alternative 4

J.2.6.1 *Project-Level Effects*

Potential changes in erosion or degradation of land or sites of religious or cultural importance to federally recognized Indian tribes

Project-level components of Alternative 1 are primarily operations based and would not involve the use of any land or sites of religious or cultural importance to Native Americans. As described in Appendix X, *Geology and Soils Technical Appendix*, under Alternative 4, an increase in releases from Sacramento Valley tributaries will occur, but will be well within the standard bounds of operational peak flows. Delta outflow will also increase, but overall differences are expected to result in negligible differences in the potential for increased erosion from outflow. There may be an increase in erosion under Alternative 4; however, erosion may occur primarily due to crop reduction as a result of reduced water deliveries and would not affect land or sites of religious or cultural importance. There would not be subsequent degradation of land or sites of religious or cultural importance as a result of increases in erosion due to project-level activities.

Potential changes in quality of water utilized by a federally recognized Indian tribe

As described in Appendix F, *Water Quality Technical Appendix,* changes in flow in the study area rivers resulting from changes in the operations of CVP/SWP under Alternative 4 relative to the No Action Alternative would not result in increased frequency of exceedances of water quality standards. Therefore, there would be no degradation of water quality delivered to federally recognized tribes.

Potential changes to salmonid populations

Effects to salmonid populations, which are an important resource to ITAs, would result in an adverse effect to federally recognized Indian tribes that have fishing rights. Effects to salmonids vary in each river in the study area and are described by region below:

J.2.6.1.1 Trinity River

Although the modeled maximum water temperatures in September and October under all alternatives would exceed the 55°F USEPA (2003) criteria for spawning, egg incubation, and fry emergence and could compromise salmonid reproductive success, there would be little or no potential for adverse effects relative to the No Action Alternative.

Modeled maximum water temperatures under the action alternatives would be at or below the recommended 55°F criterion for spawning, egg incubation, and fry emergence (USEPA 2003) from December through May (Figure 5.9-4), which would provide substantial protection for these life stages of Coho Salmon, which begin spawning in November, and Steelhead and Coastal Cutthroat Trout, which begin spawning in January and September respectively. While water temperatures under the action alternatives would equal or exceed the No Action Alternative in some months during this period, no adverse effects are expected.

Modeled maximum water temperatures during November, however, would slightly exceed the 55°F criterion under Alternative 4 (55.1°F) and would substantially exceed the criterion under Alternative 3 (59.3°F), which could compromise spawning success for Fall-Run Chinook Salmon, Spring-Run Chinook Salmon, Coho Salmon, and Coastal Cutthroat Trout during November. The modeled water temperature exceedances under Alternative 4 are negligible relative to both the USEPA (2003) criteria and the No Action Alternative (54.8°F), and are likely much less than the uncertainty associated with model results. Consequently, no adverse effects are expected.

J.2.6.1.2 Clear Creek

In Clear Creek below Whiskeytown Dam, CalSim II modeling results indicate that average flows in all water year types under Alternative 4 would be higher than under the No Action Alternative from November to May and would be similar or the same as under the No Action Alternative from June to October.

In all water year types, Alternative 4 would improve instream habitat conditions throughout the year compared to Alternative 2 and Alternative 3.

Modeled maximum water temperatures under Alternative 4 would be nearly identical to the No Action Alternative in most months but would be slightly less than the No Action Alternative in September and substantially less in October.

J.2.6.1.3 Sacramento River

Changes in summer/fall water temperature management operations under Alternative 1, especially with respect to the Shasta temperature control device (TCD), are expected to improve temperature and dissolved oxygen conditions experienced by incubating Winter-Run Chinook Salmon eggs and alevins. Alternative 4 is expected to provide a similar level of protection against a depleted coldwater pool to Alternative 1 (Appendix O, Figures SR-1 and SR-2).

J.2.6.1.4 Feather River

Modeled maximum water temperatures under the action alternatives and the No Action Alternative would exceed the recommended 55°F criterion for spawning, egg incubation, and rearing (USEPA 2003) from

September to November, a period of Spring-Run Chinook Salmon egg incubation and juvenile rearing, which could reduce survival of these life stages.

Overall, simulated flows under Alternative 4 and No Action Alternative scenarios are similar, but flows under the No Action Alternative are higher in September of wet and above normal years, and flows under Alternative 4 are higher in April and May of wet water years, from March through June of above normal water years, from January through May of below normal and dry water years, and in June of critically dry water years

Winter-Run Chinook are not likely to be affected by changes in flow under Alternative 4 compared to the No Action Alternative due to their limited distribution in the Feather River. Flow-related actions under Alternative 4 would have beneficial effects on Spring-Run Chinook Salmon and Fall-Run Chinook Salmon.

J.2.6.1.5 Stanislaus River

Alternative 4 flows would be similar to those under Alternative 1 and effects are the same as those described above.

J.2.6.1.6 San Joaquin River

Alternative 4 flows would be similar to those under Alternative 1 and effects are the same as those described above.

J.2.6.1.7 Bay-Delta

Under Alternative 4, CVP and SWP exports are similar to the No Action Alternative during the migration window for juvenile Winter-Run, Spring-Run, and Fall-Run Chinook Salmon. Increased flow in the Sacramento River mainstem would occur under all action alternatives, and higher flow has been shown to increase through-Delta survival of juvenile Chinook Salmon and reduce routing into the interior Delta at Georgiana Slough. The Sacramento River mainstem is the primary migration route for juvenile Winter-Run, Spring-Run, and Fall-Run Chinook Salmon, thus a much greater proportion of the population would be exposed to the positive effects of greater Sacramento River flows than would be exposed to the negative effects of increased exports. Under all action alternatives flows in the Sacramento River would be greater during the Winter-Run migration period which would increase survival and reduce routing into the interior Delta at Georgiana Slough (Perry et al 2015). San Joaquin River-origin juvenile Spring-Run Chinook Salmon are likely to be entrained at the salvage facilities at similar rates under Alternative 4 as compared to the No Action Alternative. San Joaquin River-origin juvenile Fall-Run Chinook Salmon are likely to be entrained at the salvage facilities at higher rates under all action alternatives as compared to the No Action Alternative.

J.2.6.2 *Program-Level Effects*

Potential changes in erosion or quality of land or sites of religious or cultural importance to federally recognized Indian tribes

As described in Appendix X, *Geology and Soils Technical Appendix*, no changes in peak flows are expected as a result of program-level actions for Alternative 4; therefore, stream channel erosion would be the same as under the No Action Alternative. Proposed water use efficiency components have little potential to be implemented on land or sites of religious or cultural importance; rather, they would be implemented on agricultural land and for municipal and industrial uses.

Potential changes in quality of water utilized by a federally recognized Indian tribe

As described in Appendix G, *Water Quality*, program-level actions and construction activities under Alternative 4 could have water quality implications. These effects could include increased turbidity, mercury and selenium bioaccumulation, dissolved organic carbon, and increased sedimentation. However, adverse effects on water quality and violations to water quality standards are not expected to result from the Alternative 4 program-level activities.

Potential changes to salmonid populations

Alternative 4 proposes to implement program-level water use efficiency measures that would improve agricultural and municipal and industrial water use efficiency. Implementation of these measures could reduce reliance upon water supply deliveries, which would reduce the need for exports and provide more water for salmonids in the rivers that supply water to the CVP and SWP. However, this benefit is as yet undefined and would be quantified in subsequent analysis. There are not anticipated to be any construction-related effects to salmonids as a result of implementation of Alternative 4.

J.2.7 Mitigation Measures

Mitigation Measure ITA-1: Consult with Tribal Entities Consistent with Secretarial Order 3175

For programmatic actions, when footprints are determined, and as early as possible in the environmental compliance process, Reclamation will consult with nearby federally recognized Indian tribes in the study area to request their input regarding the identification of any properties to which they might attach religious and cultural significance to within the area of potential effect.

Once these areas are determined, Reclamation will make a good faith effort to avoid land or sites of religious importance and will enter into government-to-government consultations with potentially affected tribes to identify and address concerns for ITAs.

Mitigation Measure WQ-1: Implement a Spill Prevention, Control, and Countermeasure Plan

Mitigation Measure WQ-2: Implement a Stormwater Pollution and Prevention Plan

Mitigation Measure WQ-3: Develop a Turbidity Monitoring Program

Mitigation Measure WQ-4: Develop a Water Quality Mitigation and Monitoring Program

Mitigation Measure AQUA-1: Worker Awareness Training

Mitigation Measure AQUA-2: Construction Best Management Practices and Monitoring

Mitigation Measure AQUA-3: Develop and Implement Program to Expand Adult Holding, Spawning, Egg Incubation, and Fry/Juvenile Rearing Habitat.

Mitigation Measure AQUA-4: Erosion and Sediment Control Plan

Mitigation Measure AQUA-5: Spill Prevention, Containment, and Countermeasure Plan

Mitigation Measure AQUA-6: Disposal of Spoils and Dredged Material

Mitigation Measure AQUA-7: Fish Rescue and Salvage Plan

Mitigation Measure AQUA-8: Underwater Sound Control and Abatement Plan

Mitigation Measure AQUA-9: Methylmercury Management

Mitigation Measure AQUA-10: Noise Abatement

Mitigation Measure AQUA-11: Hazardous Material Management

Mitigation Measure AQUA-12: Construction Site Security

Mitigation Measure AQUA-13: Notification of Activities in Waterways

Mitigation Measure AQUA-14: Fugitive Dust Control

J.2.8 Summary of Impacts

Table J.2-1 includes a summary of impacts, the magnitude and direction of those impacts, and potential mitigation measures for consideration.

Table J.2-1. Impact Summary

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
Potential changes in erosion or quality of land or sites of religious or cultural importance to federally recognized Indian tribes (Project-Level)	No Action	No impact	--
	1	No impact	--
	2	No impact	--
	3	No impact	--
	4	No impact	--
Potential changes in quality of water utilized by a federally recognized Indian tribe (Project-Level)	No Action	No impact	--
	1	No impact	--
	2	No impact	--
	3	No impact	--
	4	No impact	--
Potential changes to salmonid populations (Project-Level)	No Action	No impact	--
	1	Trinity River: Possible minimal, negative effect due to increased likelihood of egg mortality due to red scour, negligible effects from temperature overall. Clear Creek: No effect. Sacramento River: Beneficial effects to tributary species. Feather River: Negligible and potentially beneficial. Stanislaus River: Similar to No Action Alternative. San Joaquin River: Similar to No Action Alternative. Bay-Delta: Negative effects due to increased entrainment rates.	--

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
	2	Trinity River: Possible minimal, negative effect due to increased likelihood of egg mortality due to red scour; Possible minimal, negative and positive effects of water temperature, negligible overall effect Clear Creek: Possible minimal negative effects Sacramento River: Potential for various positive and negative effects to reservoir species; potential minimal, beneficial effects to tributary species. Feather River: Negligible and potentially beneficial. Stanislaus River: Potential minimal negative effects and positive effects. San Joaquin River: Similar to No Action Alternative. Bay-Delta: Negative effects due to increased entrainment rates.	--
	3	Trinity River: Possible minimal, negative effect due to increased likelihood of egg mortality due to red scour; Possible negative effects Clear Creek: Possible minimal negative effects Sacramento River: Potential for various positive and negative effects to reservoir species; potential minimal, beneficial effects to tributary species. Feather River: Negligible and potentially beneficial. Stanislaus River: Similar to No Action Alternative. San Joaquin River: Similar to No Action Alternative. Bay-Delta: Negative effects due to increased entrainment rates.	--

Impact	**Alternative**	**Magnitude and Direction of Impacts**	**Potential Mitigation Measures**
	4	Trinity River: Possible minimal, negative effect due to increased likelihood of egg mortality due to red scour; Potential beneficial effects Clear Creek: Improved habitat conditions Sacramento River: Beneficial effects to tributary species. Feather River: Beneficial effects to Spring and Fall-Run Chinook Salmon. Stanislaus River: Similar to No Action Alternative. San Joaquin River: Similar to No Action Alternative. Bay-Delta: Negative effects due to increased entrainment rates for Fall-Run Chinook. Similar to No Action Alternative for other salmonids.	--
Potential for erosion or degradation of land or sites of religious or cultural importance to federally recognized Indian tribes (Program-Level)	No Action	No impact	--
	1	Programmatic restoration components have the potential to adversely affect important land and sites depending upon design and location.	MM ITA-1
	2	No impact	--
	3	Programmatic restoration components have the potential to adversely affect important land and sites depending upon design and location.	MM ITA-1
	4	Programmatic water use efficiency components have the potential to adversely affect important land and sites depending upon location; however they are not anticipated.	--
	No Action	No impact	--

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
Potential to degrade quality of water utilized by a federally recognized Indian tribe (Program-Level) Potential to change salmonid populations (Program-Level)	1	Potential water quality implications from restoration and construction activities include increased turbidity, mercury and selenium bioaccumulation, dissolved organic carbon, and increased sedimentation.	MM WQ-1 MM WQ-2 MM WQ-3 MM WQ-4
	2	No impact	--
	3	Potential water quality implications from restoration and construction activities include increased turbidity, mercury and selenium bioaccumulation, dissolved organic carbon, and increased sedimentation.	MM WQ-1 MM WQ-2 MM WQ-3 MM WQ-4
	4	Adverse effects on water quality not anticipated.	--
	No Action	No impact	--
	1	Beneficial effect	MM AQUA-1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
	2	No impact	
	3	Beneficial effect	MM AQUA-1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
	4	No impact	--

J.2.9 Cumulative Effects

J.2.9.1 *No Action Alternative*

The No Action Alternative would not result in any changes to water operations or additions to the currently proposed restoration actions. Continued tidal restoration actions could lead to adverse effects; however, the extent of these affects are uncertain and would be dependent on habitat design and locations. Therefore, the No Action Alternative would not contribute to the cumulative changes to ITAs within the study area.

J.2.9.2 *Alternatives 1, 2, 3, and 4*

Implementation of habitat restoration under Alternative 1 and 3 could potentially lead to water quality effects as well as disturbance of land or sites of importance to federally recognized Indian tribes. However, the degree to which these effects would occur is uncertain. Tidal habitat design and location considerations will minimize the degree to which new habitat areas will impact ITAs. Any impacts on ITAs would be consulted and coordinated with potentially affected tribes to identify and address concerns for ITAs. Therefore, there is not anticipated to be a substantial effect on ITAs and the potential adverse effect is not considered cumulatively considerable. Any cumulative effects of the Project on salmonids are discussed in detail in Appendix O.

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Appendix K Cultural Resources and Indian Sacred Sites Technical Appendix

This appendix documents the cultural resources and Indian sacred sites technical analysis to support the impact analysis in the Environmental Impact Statement (EIS).

K.1 Background Information

K.1.1 Prehistoric Context

K.1.1.1 *Introduction to the Prehistoric Context*

The study area has a long and complex cultural history with distinct regional patterns that extend back more than 11,000 years (Reclamation 1997). The first generally agreed upon evidence for the presence of prehistoric peoples in the study area is represented by the distinctive fluted spear points called Clovis points. These artifacts have been found on the margins of extinct lakes in the San Joaquin Valley. The Clovis points are found on the same surface with the bones of animals that are now extinct, such as mammoths, sloths, and camels. The subsequent period from about 10000 to 8000 BP (before present) was characterized by a small number of sites with stemmed spear points instead of fluted spear points. Approximately 8,000 years ago, many California cultures shifted the main focus of their subsistence strategies from hunting to seed gathering as evidenced by the increase in food-grinding implements found in archaeological sites dating to this period. In the last 3,000 years, the archaeological record becomes more complex as specialized adaptations to locally available resources were developed and populations expanded. Many sites dated to this time period contain mortars and pestles or are associated with bedrock mortars, implying that the occupants exploited acorns intensively. The range of subsistence resources that were used increased, exchange systems expanded, and social stratification and craft specialization occurred as indicated by well-made artifacts such as charm stones and beads, which were often found with burials.

K.1.1.2 *Prehistory of the Trinity River Region*

The Trinity River region includes portions of Trinity County including Trinity Lake, Lewiston Reservoir, and Trinity River from Lewiston Reservoir to the Humboldt County boundary (near the eastern boundary of Hoopa Valley Indian Reservation); portions of Humboldt County including the Hoopa Valley Indian Reservation, Trinity River from the Humboldt County border to the Del Norte County border (near the confluence of the Trinity and Klamath rivers); and Del Norte County including the lower Klamath River from the confluence with the Trinity River to the Pacific Ocean.

The area surrounding the present Trinity Lake and the Trinity River to its confluence with the Klamath River and along the Klamath River to the Pacific Ocean was inhabited by the Wintu, Chimariko, Yurok, and Hupa Indians at the time of Euroamerican contact.

K.1.1.3 *Prehistory of the Central Valley*

For the purposes of this analysis, the Central Valley region encompasses the Sacramento Valley, San Joaquin Valley, and Bay-Delta regions of the study area. The Sacramento Valley and San Joaquin Valley are divided into Eastern and Western subregions. Sacramento Valley comprises of the upper Sacramento River, American River, and Feather River. The San Joaquin Valley comprises of the San Joaquin and Stanislaus River regions.

K.1.1.3.1 Prehistory of the Sacramento Valley

The western Sierra Nevada foothills appear to have been first used by Great Basin people around 8000 BP (Reclamation 1997). By approximately 4000 BP, people possibly from the Great Basin were seasonally hunting and gathering in the Sierra Nevada and the Sacramento Valley.

In the northern western portion of Sacramento Valley, between approximately 12,000 and 150 years ago (12000 to 100 BP), the prehistoric societies of northern California underwent a series of slow but significant changes in subsistence and economic orientation, population densities and distribution, and social organization. These changes are thought to reflect migrations of various peoples into the area and displacement of earlier populations (Jensen and Reed 1980; Farber 1985; Reclamation 1997). Early archaeological investigations within Nomlaki and Wintu ethnographic territory, particularly the present Redding area and adjacent tracts of the southern Klamath Mountains, appear to indicate that human occupation of this area began approximately 1050 to 950 BP.

Little is known of human occupation on the floor of the Sacramento Valley prior to 4500 BP (Reclamation 1997). Because of alluvial and colluvial deposition over the past 10,000 years, ancient cultural deposits have been deeply buried in many areas. Initially, humans appeared to adapt to lakes, marshes, and grasslands environments until approximately 8000 to 7000 BP (Placer County 2007). The earliest evidence of widespread villages and permanent occupation of the lower Sacramento Valley, Delta, and Suisun Marsh areas comes from several sites assigned to the Windmiller Pattern (previously, “Early Horizon”), dated circa 4500 to 2500 BP (Ragir 1972; Reclamation 1997; Reclamation et al. 2010).

From circa 2500 to 1500 BP in the Central Valley area, villages were characterized by deep midden deposits, suggesting intensified occupation and a broadened subsistence base (Reclamation 1997, 2005a; Reclamation et al. 2010; Beardsley 1948; Heizer and Fenenga 1939; Moratto 1984).

During the late prehistoric period from 1500 to 100 BP, development may have been initiated due to the southward expansion of Wintuan populations into the Sacramento Valley (Moratto 1984; Reclamation 1997; Reclamation et al. 2010). The period is characterized by intensified hunting, fishing, and gathering subsistence with larger communities, highly developed trade networks, elaborate ceremonial and mortuary practices, and social stratification.

K.1.1.3.2 Prehistory of the San Joaquin Valley

Evidence of prehistoric occupation of the central and southern Sierra Nevada foothills goes back to 9,500 years ago. The vast majority of investigated sites, however, are less than 500 years old, probably representing a relatively recent proliferation of settlements by Yokut Indians (Moratto 1984; Reclamation 1997). The chronological sequence developed in the south-central Sierra Nevada as a result of the Buchanan Reservoir project in present Madera County is still used as a general framework (Reclamation

1997). Similar findings were identified in major settlement sites along the San Joaquin River and in the present New Melones Reservoir area (Reclamation 2010; Reclamation and DWR 2011a).

During the early Holocene period (10,000 to 12,000 years ago), people probably inhabited or passed through the San Joaquin Valley; however, few indications of this period have been discovered, probably due to burial beneath accumulated river sediment (Reclamation 1997, 2012). Examples of early Holocene cultural remains are known primarily from the Tulare Basin in the southern San Joaquin Valley. Evidence along the southern shoreline of the ancient Tulare Lake indicates that human presence may have occurred from 11,000 BP (Reclamation and State Parks 2013).

From approximately 1650 to 950 BP, there is evidence that the people of the eastern San Joaquin Valley may have interacted with people in the Delta area (Reclamation 1997, 2012).

From approximately 450 to 100 BP, the people of the eastern San Joaquin Valley may have interacted with people in the Central Coast and Southern California areas. Material found in Pacheco to Panoche strata indicates a trade relationship with people of the Delta, Central Coast, and Southern California regions (Moratto 1984; Reclamation 1997, 2012).

K.1.1.4 *Prehistory of the Bay-Delta Region*

The prehistory context is different throughout the Bay-Delta region. Human occupation in the northern valley regions of present San Benito County occurred as described above for the western San Joaquin Valley (San Benito County 2010).

Human occupation in the coastal regions of present Contra Costa and Alameda Counties occurred as described above for the southern portion of the Sacramento Valley (Reclamation 1997; DWR 2008; Zone 7 2006). From 5000 to 2500 BP, dense settlements extended from the coastal marshes to interior grasslands and woodlands (Zone 7 2006). From about 2500 to 950 BP, coastal communities relied upon shellfish, and major shellmounds were created near these communities, including near the present Alameda County shorelines and some interior valleys.

Settlement of the interior valleys of the present Contra Costa, Alameda, and Santa Clara Counties occurred during the past 12,000 years. From 6000 to 1700 BP, settlements occurred, as there was less emphasis on nomadic hunting for large animals and increased emphasis on the use of plant materials and hunting, fishing, and shellfish collection (Santa Clara County 2012; CCWD et al. 2009). The communities established economies and traded between the communities.

K.1.2 Ethnographic Context

K.1.2.1 *Introduction to Ethnographic Context*

This section provides brief ethnographic sketches for each native cultural group whose traditional territories are within the study area. Each ethnographic sketch presents the territorial limits of each respective cultural group and then focuses mainly on those aspects of culture that are potentially represented in the archaeological record.

The study area encompasses lands occupied by more than 40 distinct Native American cultural groups. Although most California tribes shared similar elements of social organization and material culture, linguistic affiliation and territorial boundaries primarily distinguish them from each other. Before European settlement of California, an estimated 310,000 native Californians spoke dialects of as many as 80 mutually unintelligible languages representing six major North American language stocks (Cook 1978; Moratto 1984; Reclamation 1997; Shipley 1978).

K.1.2.2 *Ethnography of the Trinity River Region*

The Trinity River region includes portions of Shasta, Trinity, Siskiyou, Humboldt, and Del Norte Counties. This area is bounded by the Sacramento River on the east, the Pacific Ocean on the west, and the middle and upper Klamath Basin on the north. The ethnography of the Yurok, Hupa, Wintu, and Chimariko is described below.

K.1.2.2.1 Yurok

The Yurok inhabited California's northwestern coastline from Little River to Damnation Creek; along the Klamath River from the confluence with the Pacific Ocean up past the Klamath-Trinity confluence to Slate Creek; and approximately 6 miles along the Trinity River upstream of the confluence with the Klamath River (Pilling 1978; USFWS et al. 1999). The Yurok life, communities, society, and ceremonies are deeply connected with the Klamath River (USDOI and CDFG 2012). Yurok culture and traditional stories describe that the Klamath River was created to facilitate the interaction with two neighboring people, the Hupa and the Karuk, and with the salmon that lived in the Klamath River. Both the Hupa and Karuk culture and traditional stories also describe this close interaction of the peoples, salmon, and Klamath River.

Yurok are recognized for their highly stylized art forms and their skills in making redwood canoes, weaving fine baskets, hunting, and especially riverine salmon fishing. The ancient traditions are continued through contemporary times (USFWS et al. 1999). The redwood canoes for ocean conditions can be 30 to 40 feet in length, designed to haul large amounts of fish and seal carcasses, and paddled by 5 to 20 paddlers (USDOI and CDFG 2012). The canoes are used to gather food and materials, transport people and materials, and for ceremonial aspects of the Yurok culture. The Jump and Deerskin ceremonies are held in late fall to give thanks for abundant food supplies. The Deerskin Ceremony includes a Boat Ceremony in which the participants travel down the Klamath River to thank the river for continuing to flow and provide resources.

K.1.2.2.2 Hupa

The Hupa inhabited the area surrounding the lower reaches of the Trinity River from approximately Salyer to approximately 6 miles upstream from the confluence with the Klamath River (Wallace 1978a; USFWS et al. 1999). Hupa life is defined by extended families affiliated with villages. The majority of the tribe are members of the Hoopa Valley Tribe.

The Hupa believe that the Klamath and Trinity Rivers were created to provide interaction with other peoples (Yurok and Karuk) and with the salmon (USDOI and CDFG 2012). Many of the Hupa ceremonies highlight their relationship with the rivers, including world renewal ceremonies and ceremonies for bountiful harvests. The world renewal ceremonies include the White Deerskin and Jump ceremonies to honor the earth and the creator for providing food and other resources. The ceremonies for bountiful harvest of fish and acorns include the First Salmon ceremony and the Acorn Feast.

K.1.2.2.3 Wintu

When the Europeans and Americans first explored California, most of the western side of the Sacramento Valley north of about Suisun Bay was inhabited by Wintun-speaking people (USFWS et al. 1999). Early in the anthropological study of the region, a linguistic and cultural distinction was recognized between the Wintun-speaking people in the southwestern Central Valley (the Patwin) and the people occupying the northwestern Central Valley and Trinity River Valley (LaPena 1978; USFWS et al. 1999).

K.1.2.2.4 Chimariko

The Chimariko lived in a 20-mile-long reach of the Trinity River from approximately Big Bar to the confluence with the South Fork (Silver 1978a; USFWS et al. 1999). Although the Chimariko language is now extinct, early ethnographers recorded some words, and the language is thought to be of Hokan stock.

K.1.2.3 *Ethnography of the Central Valley Region*

K.1.2.3.1 Ethnography of the Sacramento Valley

Maidu, Konkow, and Nisenan

Maidu (also known as northeastern Maidu), Konkow (also known as northwestern Maidu), and Nisenan (also known as southern Maidu) inhabited an area of California from Lassen Peak to the Cosumnes River, and from the Sacramento River to Honey Lake (Reclamation 1997; Shipley 1978). Northeastern Maidu territory extended from Lassen Peak on the west to Honey Lake on the east, Sierra Buttes on the south, and Eagle Lake on the north. The Konkow inhabited the region from the lower Feather River in the north, to the Sutter Buttes in the south, and to the west beyond the Sacramento River. The Nisenan lived in the area east of the Sacramento River and along the Middle Fork Feather River, Bear River, American River, and Cosumnes River from the Sacramento River almost to Lake Tahoe (Riddell 1978; Wilson and Towne 1978; Reclamation 1997, 2005b).

Yana

The Yana of north-central California inhabited an area from Lassen Peak and the southern Cascade foothills on the east, Rock Creek on the south, Pit River on the north, and the eastern bank of the Sacramento River on the west. The western boundary is the most uncertain (Johnson 1978a; Reclamation 1997).

Achumawi, Atsugewi, and Shasta

The Achumawi and Atsugewi of northeastern California are two linguistically and culturally distinct but related groups (Reclamation 1997). The Achumawi and Atsugewi languages belong to the Palaihnihan family, or Hokan stock. The territory of the Achumawi extended generally to Mount Lassen, west to Mount Shasta, northeast to Goose Lake, and east to the Warner Range (Kroeber 1925; Olmsted and Stewart 1978; Garth 1978; Reclamation 1997). Overlapping this area to some extent, the Atsugewi territory ranged from Mount Lassen in the southwest, the Pit River in the north, and Horse Lake to the east.

The Shasta peoples were originally thought to be associated with the Achumawi and Atsugewi but then were considered as a separate group (Kroeber 1925; Reclamation 1997; Shipley 1978). The Shasta peoples inhabited the area from southern Oregon at the Rogue River, south to the present Cecilville, and the area between the Marble and Salmon mountains to Mount Shasta in the west and the Cascade Range in the east. In California, the core areas of settlement were in Shasta Valley, Scotts Valley, and along the Klamath River from about Scotts River to the town of Hornbrook (Silver 1978b).

Plains Miwok

The Plains Miwok established villages along river courses in the foothills located east of Sacramento and the Delta (Reclamation 2005b).

Nomlaki

Two major divisions existed among the Nomlaki: the River and Hill Nomlaki (Goldschmidt 1978; DuBois 1935; Reclamation 1997). The River Nomlaki occupied the Sacramento River Valley in present eastern Tehama County. The Hill Nomlaki occupied the eastern side of the Coast Ranges in present Tehama and Glenn Counties. The Nomlaki and Wintu conducted trading between the peoples (Goldschmidt 1978; DuBois 1935; Reclamation 1997).

Patwin

The Patwin lived along the western side of the Sacramento Valley from the present Princeton to Benicia, including Suisun Marsh (Kroeber 1925; Reclamation 1997; Reclamation et al. 2010). Within this large area, the Patwin have traditionally been divided into River, Hill, and Southern Patwin groups. Settlements generally were located on high ground along the Sacramento River or tributary streams, or in the eastern Coast Range valleys. The ethnographically recorded villages of Aguasto and Suisun were located near San Pablo and Suisun bays (Johnson 1978b; Reclamation 1997; Reclamation et al. 2010).

K.1.2.3.2 Ethnography of the San Joaquin Valley

Eastern Miwok

The Miwok cultures in present California include the Coast Miwok, Lake Miwok, and Eastern Miwok divisions. The Eastern Miwok included five separate groups (Bay, Plains, Northern Sierra, Central Sierra, and Southern Sierra) that inhabited the area from present Walnut Creek in Contra Costa County and the Delta, along the lower Mokelumne and Cosumnes Rivers and along the Sacramento River from present Rio Vista to Freeport, the foothill and mountain areas of the upper Mokelumne River and Calaveras River watersheds, the upper Stanislaus River and Tuolumne River watersheds, and the upper Merced River and Chowchilla River watersheds, respectively (Levy 1978a; Reclamation 1997; Shipley 1978). No one Miwok tribal organization encompassed all the peoples speaking Miwokan languages, nor was there a single tribal organization that encompassed an entire division.

Yokuts

Yokuts are a large and diverse group of people in the San Joaquin Valley and Sierra Nevada foothills of central California, including the Southern San Joaquin Valley Yokuts, Northern San Joaquin Valley Yokuts, and Foothill Yokuts (Reclamation 1997; Reclamation et al. 2011; SJRRP 2011). The three subdivisions of the Yokuts languages belong to the Yokutsan family, or Penutian stock (Shipley 1978).

The Southern Valley Yokuts inhabited the southern San Joaquin Valley from present Fresno to the Tehachapi Mountains (Wallace 1978b). The Northern Valley Yokuts inhabited the northern San Joaquin Valley from Bear Creek to the San Joaquin River near present Mendota, western San Joaquin Valley near present San Luis Reservoir, and eastern present Contra Costa and Alameda Counties (ECCCHCPA and USFWS 2006; Wallace 1978c; Reclamation and DWR 2011a). The Foothill Yokuts inhabited the western slopes of the Sierra Nevada foothills from the Fresno River to the Kern River (Spier 1978; Reclamation and State Parks 2013). Yokuts were mobile hunters and gatherers with semipermanent villages and seasonal travel corridors to food sources.

Dumna and Kechayi

The Dumna and Kechayi lived along the San Joaquin River in the Sierra Nevada foothills near the present Millerton Lake (Reclamation and State Parks 2013).

K.1.2.4 *Ethnography of the San Francisco Bay-Delta Region*

Native inhabitants of the Bay-Delta region include the Miwok, Cholvon Northern Valley Yokuts, and the Costanoan Indians (Reclamation 1997; CCWD et al. 2009; ECCCHCPA and USFWS 2006; EBMUD 2009; Reclamation 2005b; Santa Clara County 2012; San Benito County 2013).

K.1.2.4.1 Miwok

In the Bay-Delta region, the Coast Miwok people lived along lower San Joaquin River and San Pablo Bay and in the interior of the present Contra Costa and Alameda Counties (Reclamation 1997; ECCCHCPA and USFWS 2006; Kelly 1978). The Bay Miwok villages were located in the San Ramon Valley with other settlements on the western slopes of the Diablo Range. The Volvons, speakers of the Bay Miwok language, settled along Marsh Creek and Kellogg Creek on the northern side of the Diablo Range and near the present Los Vaqueros Reservoir (CCWD et al. 2009). The Miwok people may have held lands at the peak of Mount Diablo.

K.1.2.4.2 Costanoan

The Costanoans (also known as Ohlone) are a linguistically defined group with several autonomous tribelets that speak related languages (Levy 1978b; Reclamation 1997; EBMUD 2009; Zone 7 2006; Santa Clara County 2012). The Costanoans inhabited coastal shorelines along San Francisco, San Pablo, and Suisun Bay and along the Pacific Ocean Coast from the Golden Gate to Monterey Bay and interior valleys that extended approximately 60 miles inland, including areas within Santa Clara and San Benito Counties (Reclamation 1997; ECCCHCPA and USFWS 2006; San Benito County 2010).

K.1.3 Historical Context

The historical context presented in this section is focused on historical activities and resources that affected and/or were affected by implementation of water resource actions of Central Valley Project (CVP) and State Water Project (SWP) water users. Changes in CVP and SWP operations under implementation of alternatives considered in this EIS could affect CVP and SWP facilities. These changes also could affect regional and local water supplies, reservoirs, and associated land uses of those that use CVP and SWP water.

K.1.3.1 *Introduction to Historical Context*

Initial contact with Europeans and Americans occurred with Spanish missionaries and soldiers, who entered California from the south in 1769, eventually founding 21 missions along the California coast (Reclamation 1997). This period is characterized by the establishment of missions and military presidios, the development of large tracts of land owned by the missions, and subjugation of the local Indian population for labor. This way of life began to change in 1822 when Mexico became independent of Spain. The mission lands were divided by government grants into large ranchos often consisting of tens of thousands of acres. The owners of these large *estancias* built homes, often of adobe, and maintained large herds of cattle and horses.

During the Spanish and Mexican periods, explorers entered the region. Fort Ross on the Sonoma coast was established by the Russians from 1812 until 1841 to support hunting, fishing, and whaling businesses (Reclamation 1997). American explorer Jedediah Smith and Peter Skene Odgen, chief trader for the Hudson Bay Company, with other members of the Hudson Bay Company also came to California during this period.

In 1848, the Treaty of Guadalupe Hidalgo transferred the lands of California from the Mexican Republic to the United States and initiated what is called the American Period in California history (Reclamation 1997). During that same year, gold was discovered in the foothills of the Sierra Nevada, and thousands of hopeful miners as well as storekeepers, settlers, and farmers entered the region. Mining in the Trinity River region was expanded for both gold and copper mines (Placer County 2007).

To support this growth, extensive transportation systems were created to support wagon routes, steamboats on the major rivers, and numerous railroads (Reclamation 1997). Many of the supply centers and shipment points along these transportation corridors developed into cities, towns, and settlements. Logging and ranching also expanded to meet the needs of the new settlers. American ranchers found Central California ideally suited for grazing large herds of stock. During the latter part of the nineteenth century, American ranchers amassed large tracts of former rancho land, and several great cattle empires were formed. As settlements grew, farming increased. A primary constraint to expansion of crop diversity and areas under cultivation was the lack of water. Irrigation was virtually unknown in California until the 1880s, when large-scale irrigation systems were developed to improve agriculture yields. With the development of irrigation and improved transportation, new crops were added to the grains obtained from dry farming, including vegetables, fruits, and nuts.

Irrigation capabilities further expanded in the 1950s and 1960s with the implementation of multiple water projects. The availability of water also expanded the agricultural and urban water supplies in the Central Valley and Bay-Delta regions.

K.1.3.2 *History of the Trinity River Region*

Explorers from the Philippines and Europe may have visited and interacted with the Yurok people as early as the late 1700s. Peter Skene Odgen and Jedediah Smith initially visited the lower and middle Klamath River reaches in the 1820s. In 1828, Jedediah Smith and his party of explorers were the first white men known to have visited the Trinity River watershed (USFWS et al. 1999).

Although the area was first used extensively by trappers, gold was discovered on the Trinity River in 1848, and by the late 1840s, gold mining was a major activity along the Trinity River (Hoover et al. 1990;

Del Norte County 2003; USFWS et al. 1999). Weaverville was the center of gold mining activity after 1849 with numerous mining camps and settlements along the Trinity River. Mining continued along the Trinity River through the early and mid-1900s with large-scale dragline and bucket dredging operations beginning in 1939. Logging has occurred since the 1880s and continues in the Trinity River region. These activities resulted in significant changes to rivers and may have caused the destruction of many prehistoric or historic archaeological sites (Hoover et al. 1990).

Increased activities within the Trinity River region led to conflicts between the new residents and the Yurok and Hupa people. On November 16, 1855, the Klamath Indian Reservation was established by Executive Order for lands from the mouth of the Klamath River to a location upstream of Tectah Creek that extended 1 mile wide on either side of the river for the approximately 20-mile reach (USDOI and CDFG 2012). The Hoopa Valley Reservation was established in 1864 and expanded in 1891 to include lands from the mouth of the Klamath River to the Hoopa Valley that extended one mile wide on either side of the river including portions of the Klamath Indian Reservation. In 1988, the Hoopa-Yurok Settlement Act (Public Law 100-580) partitioned portions of the previously established reservations into the Yurok Indian Reservation and Hoopa Valley Reservation and established the Resighini Rancheria.

K.1.3.3 *History of the Central Valley Region*

K.1.3.3.1 History of the Sacramento Valley

Europeans, Americans, and Canadians may have initially entered the Sacramento Valley in the late 1700s and early 1800s as part of missionary or military expeditions (Reclamation 1997, 2005a; Reclamation et al. 2006; Placer County 2007). By 1776, José de Cañizares explored areas located south of the present Sacramento community, and in 1813, there was a major battle between the Spanish and the Miwok people near the confluence of the Cosumnes River along the Sacramento River. Fur trappers moved through this area from the 1820s to 1840s.

The first settlements in this area occurred in the 1830s and 1840s on Mexican Land Grants. The New Helvetica Land Grant, which included more than 40,000 acres in the Sacramento Valley, was awarded to John Sutter in 1841 (DSC 2011).

Following the discovery of gold on the New Helvetica Land Grant in 1848 near present-day Coloma, numerous mining-related settlements were established in areas with the Nisenan, Maidu, Konkow, and Atsugewi people in the eastern portion of the Sacramento Valley and in areas with the Nomlaki and Wintu people in the western Sacramento Valley. Many of the Native Americans died after exposure to diseases from the new settlers, including malaria. Numerous other Native American died during battles against the new settlers.

Mining activities in the northern Sacramento Valley foothills and mountains near present Redding primarily were related to gold and copper (Reclamation 2013a). Mining activities in the central Sierra Nevada foothills primarily were related to gold. In 1848, mining started along the Trinity River and upper Sacramento River tributaries, primarily for copper and gold (Reclamation 2013a; Reclamation et al. 2006). Smelters, mills, and communities grew rapidly near the mining areas, including the town of Keswick, and communities were established within and adjacent to the present day Folsom Lake. The development of hydraulic mining in 1851 required establishment of substantial water diversions, flumes, and ditches to convey the water and displacement of vast amounts of sediment into the streams and along the banks of the waterways.

Logging also was a dominant industry in the western Sacramento Valley since the 1850s (Reclamation 1997, 2013a). The logging industry grew as the railroads were extended. Establishment of logging in the Sierra Nevada foothills and mountains also led to development of water infrastructure to move and/or mill the logs. One of the first water system infrastructures developed for these purposes was the original Folsom Dam constructed in 1893 (Reclamation et al. 2006).

Agricultural activities were successful throughout the Sacramento Valley to serve the mining communities (Reclamation 1997). The completion of the first transcontinental railroad in 1869 increased the number of settlers and allowed transport of crops from the Sacramento Valley to Nevada, Utah, and subsequently to other areas of the nation (Reclamation 2005b). The expanded agricultural markets expanded due to the establishment and development of commercial crops, accessibility to markets, and new farming techniques and irrigation.

Construction of hydroelectric power and water storage facilities in the Sacramento Valley foothills started in the early 1900s to provide hydropower and water supplies to local and regional users, as well as export to other portions of the state using CVP, SWP, City and County of San Francisco, and East Bay Municipal Utility District facilities.

K.1.3.3.2 History of the San Joaquin Valley

The San Joaquin Valley area was not widely settled by Europeans or Mexicans when California lands were under Spanish rule (1769 to 1821) or Mexican rule (1821 to 1848). Numerous expeditions travelled through the San Joaquin Valley during this period but did not establish major settlements (Reclamation 2010). During the Spanish rule, several settlements occurred along Fresno Slough (Reclamation and DWR 2011a). There were several settlements along the San Joaquin River and along the western boundary of the San Joaquin Valley during Mexican rule when ranches were established in the Coast Range foothills, including in Pacheco Pass and along Los Banos Creek.

In the latter half of the nineteenth century, agricultural settlements and mining camps were established in the San Joaquin Valley along the railroad corridors (Reclamation 1997; Reclamation and DWR 2011a). The town of Rootville, subsequently renamed Millerton in honor of Major Miller, was established near the present Millerton Lake with a military post, Camp Barbour (later named Fort Miller) to maintain order in the mining camps.

Initially, agricultural activities were related to ranching and dry farming. Livestock ranching expanded in the late 1860s (Reclamation and DWR 2011b). With the increased availability of electric pumps, groundwater and surface water irrigation was used throughout the valley. Many irrigation districts were formed after the passage of the Wright Act in 1877 that provided methods to finance major irrigation projects. One of the first irrigation systems constructed in the eastern San Joaquin Valley was the “Main Canal” as part of the Miller and Lux’s San Joaquin and Kings River Canal and Irrigation Company (Reclamation and State Parks 2013).

Historic resources are related to the settlement of the valley and include homesteads, transportation infrastructure (such as ship landings, ferry ports, and bridges), food processing and other industrial facilities, residential properties, commercial establishments, mining features (in the eastern portion), and government facilities (Reclamation 1997, 2010; Reclamation and DWR 2011a).

K.1.3.3.3 History of the Delta and Suisun Marsh

Communities were not established in the Delta and Suisun Marsh areas until the mid-1800s. There were numerous Spanish expeditions under Spanish rule. In the 1830s and 1840s, Mexico established land grants, including Rancho Suisun located west of present City of Fairfield (Reclamation et al. 2010).

Following the discovery of gold in the Sacramento Valley, settlements occurred in the Delta to provide support services and agricultural products for those traveling to the gold fields and the Sacramento and San Francisco areas. Passage of the Swamp and Overflow Act in 1850 led to the transfer of lands from the U.S. Government in the Delta to the State of California, which subsequently sold the land to individuals. The new settlers in the Delta constructed levees to protect the lands from periodic flooding and drained other lands to reduce the potential for mosquito-borne diseases. By the 1920s, numerous communities were established around food processing and packing houses that supported a wide range of crops such as asparagus, barley, celery, corn, winter grain, sugar beets, onions, and alfalfa for local dairy farms were introduced to the area (DSC 2011; Reclamation et al. 2010). By the 1950s, major food packers and processors moved from the Delta, and many communities became smaller. Recreational opportunities were established in the 1850s with duck hunting opportunities in the Suisun Marsh area.

K.1.3.4 *History of the San Francisco Bay Area Region*

In 1579, Sir Francis Drake and other Spanish explorers led expeditions into the San Francisco Bay Area. However, in general, the Spanish did not settle Northern California until the 1700s when other Europeans established trading settlements for fur, mining, and other products. Initially, the Spanish confined their settlement to the coastline to establish military bases, or presidios (Hoover et al. 1990). Father Junípero Serra and other Franciscans worked with the Spanish explorers to establish missions along the Alta California coastal areas between present Sonoma County (San Francisco Solano established in 1823) to present Ventura County (San Buenaventura established in 1782), including three missions in areas that use CVP and SWP water (Mission San Jose established in 1797, Mission Santa Clara established in 1777, and Mission San Juan Bautista established in 1797).

San Jose was one of the first towns established in Alta California as Pueblo de San José de Guadalupe (Santa Clara County 2012). The Spanish government awarded land grants in the San Francisco Bay Area region (DWR 2008; EBMUD 2009; Hoover et al. 1990; Reclamation 2005b; San Benito County 2010; Zone 7 2006). In 1821, Mexico won independence from Spain, began to establish more secular communities around the missions, and divided many of the ranchos into smaller pueblos (Santa Clara County 2012). These actions supported growth in the present California coastal areas.

Following California statehood in 1849, ranching and farming communities were established in the interior valleys of the San Francisco Bay Area region (Santa Clara County 2012; CCWD et al. 2009; ECCCHCPA and USFWS 2006). Starting in the late 1800s, expansion of the railroads in the area and use of improved irrigation systems led to the expansion of agriculture throughout the area. In mid-1900s, industrial expansion occurred in Contra Costa, Alameda, and Santa Clara Counties.

K.1.4 CVP and SWP Service Areas (south to Diamond Valley) and Nearshore Pacific Ocean on the California Coast

No project or program-level measures or actions would take place with mechanisms for changes in cultural resources conditions in the nearshore Pacific Ocean on the California coast or CVP and SWP service areas. Therefore, no background setting information for these regions is provided for this analysis.

K.2 Known Cultural Resources

The following subsections describe known cultural resources in the counties in the study area, as determined through review of reports prepared for other projects in the study area. No physical or record surveys were conducted for this EIS because no site-specific construction actions were considered in this EIS. Project and program construction activities that constitute an undertaking under Section 106 of the National Historic Preservation Act (NHPA) would be analyzed in greater detail through execution of and compliance with a Section 106 programmatic agreement.

The EIS evaluates alternatives to continue the coordinated long-term operation of the CVP and SWP. The resources described in this subsection indicate the types of resources that occur in areas served by CVP and SWP water and adjacent areas. Therefore, some of the known resources presented in this chapter are located in portions of the counties that are not within the CVP and SWP water service areas.

K.2.1 Known Cultural Resources of the Trinity River Region

A cultural resources records search of the Trinity River region in Trinity County was conducted for the Trinity River Mainstem Fishery Restoration EIS/Environmental Impact Report (EIR) (USFWS et al. 1999). The area covered included 660 feet on either side of the Trinity River from Trinity Lake to the eastern boundary of Hoopa Valley Indian Reservation and the inundation areas of the Trinity Lake and Lewiston Reservoir. More than 150 recorded cultural resources were identified along the mainstem of Trinity River within Trinity County, including 20 types of prehistoric and historic sites. Among these were Native American villages, camps, and lithic scatters; historic Indian sites; mines; ditches; cabins; structures; a school; U.S. Fish and Wildlife Service stations and campgrounds; cemeteries; a rock wall; trails; a wagon road; and a bridge. Fifty-one sites are inundated within Trinity Lake and Lewiston Reservoir. Few of these sites have been evaluated for eligibility to be included in the National Register of Historic Places (NRHP). With respect to more recent historic sites in Trinity County, none of the sites listed in the NRHP, California State Historical Landmarks, California Register of Historical Resources (CRHR), and/or Points of Interest is located within or along banks of the Trinity River (CSPOHP 2014a).

In Humboldt County, numerous culturally sensitive areas are located along the lower Klamath and lower Trinity Rivers. The culturally sensitive areas include the areas along the riverbanks associated with religious and/or resource-producing important sites, in addition to specific known cultural resources. Many cultural resource locations are in the Hoopa Valley Indian Reservation and Yurok Reservation, including villages, cemeteries, ceremonial and gathering areas, and along ridgeline corridors that were used for traveling between villages (Humboldt County 2012). With respect to more recent historic sites in Humboldt County, none of the sites listed in the NRHP, California State Historical Landmarks, CRHR, and/or Points of Interest is located within or along banks of the Trinity or Klamath Rivers (CSPOHP 2014b).

In Del Norte County, numerous culturally sensitive areas are located along the lower Klamath River, including areas within the Yurok Reservation and the Resighini Rancheria along the southern shoreline of the mouth of the Klamath River at the Pacific Ocean (Del Norte County 2003). The mouth of the Klamath River is of great spiritual significance for the Yurok people (Yurok Tribe 2005). The Yurok Tribe has suggested that the entire Klamath River, including the lower Klamath River, be designated as a Cultural Riverscape and be submitted for consideration for listing in the NRHP (Yurok Tribe 2005). With respect to more recent historic sites in Del Norte County, none of the sites listed in the NRHP, California State Historical Landmarks, CRHR, and/or Points of Interest is located within or along banks of the Klamath River (CSPOHP 2014c).

K.2.2 Previously Recorded Cultural Resources in the Central Valley Region

The Central Valley region is rich in both historic- and prehistoric-period resources (Reclamation 1997), including large, deep midden sites (which generally contain waste materials that indicate human inhabitation) that provide information on prehistoric culture extending over thousands of years.

As described above, implementation of the action alternatives considered in this EIS could affect cultural resources at CVP and SWP reservoir facilities and in areas that use CVP and SWP water. These areas could experience land uses because of changes in CVP and SWP water supply availability.

K.2.2.1 *Cultural Resources at CVP and SWP Reservoir Facilities in the Sacramento Valley*

Previous cultural resource studies were conducted at and/or near Shasta Lake, Lake Oroville, and Folsom Lake.

The studies near Shasta Lake surveyed approximately 8% of the study area and identified 261 cultural resources, including 190 prehistoric properties, 45 historic resources, and 26 properties with prehistoric and historic resources (Reclamation 2013a). The prehistoric sites include habitation sites, artifact and lithic scatters, caves used as shelter, and cemeteries. The historic sites included bridges, railways, a dam, buildings, ranches, orchards, mines, towns, and cemeteries. Several prehistoric and historic cemeteries located within the inundation area were moved prior to completion of the Shasta Lake complex. The Dog Creek Bridge is the only resource in this area that is listed on the NRHP. The Shasta and Keswick dams were determined to be NRHP-eligible.

The studies near Lake Oroville identified 261 cultural resources areas, including 234 prehistoric properties, 462 historic resources, and 91 properties with prehistoric and historic resources (DWR 2004, 2007). Within the Lake Oroville inundation area, 93 prehistoric properties and 19 historic sites were identified prior to the completion of the reservoir. The prehistoric sites include habitation sites, milling sites, quarries, artifact and lithic scatters, caves used as shelter, rock art, fishing and hunting grounds, battle sites, trails, and cemeteries. The historic sites included bridges, railways, a dam, buildings, ranches, orchards, mines, towns, and cemeteries.

Oroville Dam and peripheral dams, Thermalito Diversion Dam, Thermalito Forebay and Afterbay, Fish Barrier Dam, Hyatt Pumping-Generating Plant and Intake Structure, Thermalito Power Plant and Power Canal, Lake Oroville Visitor Center and Visitor Viewing Platform, and Feather River Fish Hatchery were determined to be NRHP-eligible.

The studies near Folsom Lake identified 185 prehistoric properties and 59 historic sites (Reclamation 2005b; Reclamation et al. 2006). The prehistoric sites include habitation sites, middens, groundstones, and artifact and lithic scatters. The historic sites included buildings, mining areas, and refuse dumps. Folsom Dam was determined to be NRHP-eligible.

K.2.2.2 *Cultural Resources at CVP and SWP Reservoir and Pumping Plant Facilities in the San Joaquin Valley*

Previous cultural resource studies were conducted at and/or near New Melones Reservoir, San Luis Reservoir, and Millerton Lake and San Joaquin River downstream of Friant Dam.

The studies near New Melones Reservoir surveyed approximately 78% of the study area and identified 725 cultural resources within the New Melones Reservoir area or within 0.25 mile of this area (Reclamation 2010). The prehistoric sites include habitation sites, artifact and lithic scatters, mortars, caves, rock art, and cemeteries. The historic sites included bridges, buildings, ranches, orchards, towns, water and power systems, transportation infrastructure, and cemeteries. Many of the sites are located within the inundation area. However, substantial surveys were conducted prior to construction of New Melones Reservoir in the 1980s.

The studies near San Luis Reservoir identified 51 prehistoric and historic cultural resources (Reclamation and State Parks 2013). The prehistoric sites include habitation sites and artifact and lithic scatters. The historic sites included bridges, water infrastructure, buildings, ranches, orchards, towns, and cemeteries. One of the major historic sites in this area is the remnant locations of Rancho San Luis Gonzaga. Many portions of the ranch are located within the inundation area. However, many of the structures were moved to a site near Pacheco Pass. The remaining portions of the ranch were deeded to the State of California in 1992 to become part of the Pacheco State Park. Rancho San Luis Gonzaga, a historic stock ranch landscape, has been designated by the state to be a Historic District/Cultural Landscape that is potentially NRHP-eligible and CRHR-eligible.

Recent studies along the San Joaquin River identified 19 prehistoric sites within the seasonal inundation area of Millerton Lake (Reclamation and DWR 2011a; Reclamation and State Parks 2013). Additional sites are located within the area of the lake that is constantly inundated. Some of the known sites include the remains of Kuyu Illik; the Dumna “head” village; the Kechaye/“Dumna” village of Sanwo Kianu; remains of Fort Miller, Millerton, and Collins Sulphur Springs; and prehistoric sites with housepits, mortars, grinding sticks, and rock alignments (Reclamation and State Parks 2013).

Along the San Joaquin River downstream of Friant Dam (which forms Millerton Lake) to the confluence of the Merced River, 84 prehistoric sites, 18 historic sites, and 7 sites with both prehistoric and historic resources were identified as part of the San Joaquin River Restoration Program. The prehistoric sites include habitation sites, artifact and lithic scatters, and bedrock milling features. The historic sites included bridges, buildings, ranches, orchards, towns, water and power systems, and transportation infrastructure.

The Friant Dam, Friant-Kern Canal, associated features (berms, siphons, control structures, inlets, outlets, and check structures), approximately 40 bridges that cross the canal, and Little Dry Creek Wasteway Facility are considered historic resources (Reclamation and State Parks 2013; Reclamation and DWR 2011b). The Friant Dam and Friant-Kern Canal was determined to be NRHP-eligible.

K.2.2.3 *Cultural Resources in the areas that use CVP and SWP Water Supplies in the Central Valley*

Numerous cultural and historical resources are in the Central Valley, as summarized in Table K.2-1. Most of the cultural resources are located within areas that would not be affected by land use changes that could result from changes in CVP and SWP water supplies. The resources listed in Table K.2-1 also include the sites described above near CVP and SWP facilities.

Table K.2-1. Previously Recorded Cultural and Historical Resources of the Central Valley Region

County	Historic Site Types	Prehistoric Site Types
Butte	26 NRHP properties, 8 California Historical Landmarks, and 21 California Points of Historical Interest (Reclamation 1997; CSPOHP 2014e).	1,198 Known Prehistoric Site Types (Reclamation 1997).
Colusa	7 NRHP properties, 3 California Historical Landmarks, and 3 California Points of Historical Interest (Reclamation 1997; CSPOHP 2014g).	115 Known Prehistoric Site Types (Reclamation 1997).
El Dorado	18 NRHP properties, 30 California Historical Landmarks, 8 California Points of Historical Interest; numerous historic sites, such as mining features, building foundations, trash scatters, and bridges, were inundated by Folsom Lake (Reclamation 1997; CSPOHP 2014h).	595 Known Prehistoric Site Types (Reclamation 1997).
Fresno	38 NRHP properties, 8 California Historic Landmarks, and 13 of which are California Points of Historical Interest (Reclamation 1997; CSPOHP 2014i).	2,603 Known Prehistoric Site Types (Reclamation 1997).
Glenn	2 NRHP properties, 2 California Historical Landmarks, and 17 California Points of Historical Interest (Reclamation 1997; CSPOHP 2014j).	373 Known Prehistoric Site Types (Reclamation 1997).
Kern	20 NRHP properties, 47 California Historic Landmarks, and 11 California Points of Historical Interest (Reclamation 1997; CSPOHP 2014k).	3,850 Known Prehistoric and Historic Site Types (Reclamation 1997).
Kings	4 NRHP properties, 3 California Historic Landmarks; the San Luis Canal, the only CVP facility in Kings County, has no historic or architectural resources in its vicinity (Reclamation 1997; CSPOHP 2014l).	56 Known Prehistoric Site Types (Reclamation 1997).
Madera	2 NRHP property, 1 California Historic Landmarks, and 9 California Points of Historical Interest (Reclamation 1997; CSPOHP 2014n).	2,043 Known Prehistoric Site Types (Reclamation 1997).

County	Historic Site Types	Prehistoric Site Types
Merced	14 NRHP properties, 5 California Historic Landmarks, 1 CRHR properties, and 8 California Points of Historical Interest (Reclamation 1997; CSPOHP 2014p).	316 Known Prehistoric Site Types (Reclamation 1997).
Napa	76 NRHP properties, 17 California Historical Landmarks, and 13 California Points of Historical Interest (Reclamation 1997; CSPOHP 2014q).	700 Known Prehistoric Site Types (Reclamation 1997).
Placer	18 NRHP properties, 20 California Historical Landmarks, 21 California Points of Historical Interest; numerous historic sites, such as mining features, building foundations, trash scatters, and bridges, were inundated by Folsom Lake, which is a CVP facility (Reclamation 1997; CSPOHP 2014s).	627 Known Prehistoric Site Types (Reclamation 1997).
Plumas	6 NRHP properties, 13 California Historical Landmarks, and 5 California Points of Historical Interest (Reclamation 1997; CSPOHP 2014t).	1,639 prehistoric sites in Plumas County (Plumas County 2012).
Sacramento	90 NRHP properties, 56 California Historical Landmarks, 4 CRHR properties, 20 California Points of Historical Interest; numerous historic sites, such as mining features, building foundations, trash scatters, and bridges, were inundated by Folsom Lake; the Folsom Mining District surrounds Lake Natoma (Reclamation 1997; CSPOHP 2014u). There are over 40 historic sites along the Sacramento River between Sutter County boundary and Freeport (Reclamation 2005b); including Natomas Main Drainage Canal, Town of Freeport, Sacramento Weir, Yolo Bypass, homes and farms, and a church. There are 14 historic sites along the American River between Folsom Dam and the confluence with the Sacramento River (Reclamation 2005b).	407 Known Prehistoric Site Types (Reclamation 1997). There are 24 prehistoric sites along the Sacramento River between Sutter County boundary and Freeport (Reclamation 2005b). There are 22 prehistoric sites along the American River between Folsom Dam and the confluence with the Sacramento River (Reclamation 2005b).
San Joaquin	31 NRHP properties, 25 California Historic Landmarks, 3 CRHR properties, and 7 are California Points of Historical Interest (Reclamation 1997; CSPOHP 2014v).	189 Known Prehistoric Site Types (Reclamation 1997).
Shasta	26 NRHP properties, 19 California Historical Landmarks, 1 CRHR properties, 15 California Points of Historical Interest (Reclamation 1997; CSPOHP 2014w).	1,419 Known Prehistoric Site Types. Many of these sites occur along the Sacramento River near Redding and between Battle Creek and Table Mountain (Reclamation 2013a).

County	Historic Site Types	Prehistoric Site Types
	The Anderson-Cottonwood Irrigation District Diversion Dam has been determined to be eligible for NRHP listing (Reclamation 2013a).	
Solano	23 NRHP properties, 14 California Historical Landmarks, and 9 California Points of Historical Interest (Reclamation 1997; CSPOHP 2014x).	300 Known Prehistoric Site Types (Reclamation 1997).
Stanislaus	21 NRHP properties, 5 California Historic Landmarks, and 7 are California Points of Historical Interest; the former right-of-way for the Patterson and Western Railroad, which was constructed in 1916, bisects the Delta-Mendota Canal (Reclamation 1997; CSPOHP 2014y).	280 Known Prehistoric Site Types (Reclamation 1997).
Sutter	7 NRHP properties, 2 California Historical Landmarks, and 22 California Points of Historical Interest (Reclamation 1997; CSPOHP 2014z).	62 Known Prehistoric Site Types (Reclamation 1997).
Tehama	10 NRHP properties, 3 California Historical Landmarks, and 1 California Point of Historical Interest (Reclamation 1997; CSPOHP 2014aa).	1,415 Known Prehistoric Site Types (Reclamation 1997).
Tulare	34 NRHP properties, 8 California Historic Landmarks, and no California Points of Historical Interest (Reclamation 1997; CSPOHP 2014ab).	1,857 Known Prehistoric Site Types (Reclamation 1997).
Yolo	21 NRHP properties, 2 California Historical Landmarks, 1 CRHR properties, and 8 California Points of Historical Interest (Reclamation 1997; CSPOHP 2014ad).	175 Known Prehistoric Site Types (Reclamation 1997). Includes possible fishing stations along Putah and Cache Creeks, the Sacramento, and ephemeral tributaries to these watercourses.
Yuba	10 NRHP properties, 6 California Historical Landmarks, and 14 California Points of Historical Interest (Reclamation 1997; CSPOHP 2014ae).	1,112 Known Prehistoric Site Types (Reclamation 1997).

NRHP = National Register of Historic Places
CRHR = California Register of Historic Resources

K.2.3 Previously Recorded Cultural Resources in the Bay-Delta Region

The Bay-Delta region is highly urbanized and that development has affected archaeological resources. Numerous cultural and historical resources are in the Bay-Delta region, as summarized in Table K.2-2. Most of the cultural resources are located within areas that would not be affected by land use changes that could result from changes in CVP and SWP water supplies.

Table K.2-2. Previously Recorded Cultural Resources of the Bay-Delta Region

County	Historic Site Types	Prehistoric Site Types
Alameda	141 NRHP properties, 34 California Historical Landmarks, 2 CRHR properties, and 4 California Points of Historical Interest (CSPOHP 2014af).	No comprehensive inventory of prehistoric sites in Alameda County (Zone 7 2006).
Contra Costa	40 NRHP properties, 13 California Historical Landmarks, 1 CRHR property, and 12 California Points of Historical Interest (CSPOHP 2014ag).	No comprehensive inventory of prehistoric sites in Contra Costa County (Contra Costa County 2005). Up to 41 sites were identified in the Kellogg Creek Historic District near Los Vaqueros Reservoir (CCWD et al. 2009).
San Benito	12 NRHP properties, 5 California Historic Landmarks, and 2 California Points of Historical Interest (Reclamation 1997; CSPOHP 2014ah).	180 Known Prehistoric Site Types (Reclamation 1997).
Santa Clara	101 NRHP properties, 41 California Historical Landmarks, and 58 California Points of Historical Interest (CSPOHP 2014ai; Santa Clara County 1994).	Between 1912 and 1960, 43 sites were recorded in the Santa Clara Valley portion of Santa Clara County (Santa Clara County 2012).

NRHP = National Register of Historic Places
CRHR = California Register of Historic Resources

K.2.3.1 *Indian Sacred Sites*

Indian Sacred Sites are primarily identified during the process of tribal consultation. Because of this, an analysis of Indian Sacred Sites was not possible for the purposes of this document. Once a project is identified, the lead federal agency is required to consult with any tribes that have cultural affiliation with the proposed project area. It is during this process that any Indian Sacred Sites that could be affected by the proposed project would be identified.

K.3 Evaluation of Alternatives

This section describes the technical background for the evaluation of environmental consequences associated with the action alternatives and the No Action Alternative.

K.3.1 Methods and Tools

This analysis identifies potential project and program-level effects of implementation of the action alternatives on archaeological and built-environment historic properties. The effects analysis considers the known historic property environmental setting in the plan area, as well as the potential for previously undocumented historic properties and physical effects (i.e., disturbance, trenching, demolition) to known and previously undocumented properties that could result from implementation of the action alternatives. The analysis is also informed by the requirements of federal and state laws and regulations that apply to cultural resources.

There are three key potential impacts on cultural resources: (1) disturbance or destruction of archaeological historic properties; (2) exposure of buried archaeological historic properties; and (3) the alteration, destruction, or demolition of built-environment historic properties. Each alternative has been considered for its potential to involve activities that would include ground disturbance that could disturb or destroy archaeological historic properties, cause erosion that could expose buried archaeological historic properties, or damage, alter, or demolish built-environment historic properties.

K.3.1.1 *Section 106 of the National Historic Preservation Act*

Because the coordinated long-term operation of the CVP and SWP is subject to Section 106 of the NHPA, Reclamation will oversee compliance with Section 106. Section 106 requires Federal agencies to consider the effects of their undertakings on historic properties, properties determined eligible for inclusion in the NRHP, and to afford the Advisory Council on Historic Preservation an opportunity to comment. Compliance with Section 106 follows a series of steps, identified in its implementing regulations found at 36 Code of Federal Regulations (CFR) Part 800, that include identifying consulting and interested parties, delineating an area of potential effects, identifying historic properties within the area of potential effect, and assessing effects on any identified historic properties, and resolving adverse effects through consultations with the State Historic Preservation Officer, Indian tribes, and other consulting parties.

Resolution of adverse effects may result in a memorandum of agreement or programmatic agreement stipulating how historic properties will be treated.

Project-level activities under the action alternatives will not result in changes to peak flows or reservoir levels compared to the No Action Alternative. As a result, project-level actions have no potential adverse effects on historic properties and do not require further consideration under Section 106 of the NHPA.

Program-level activities under the action alternatives have the potential to cause adverse effects on historic properties due to changes river flows, reservoir levels, and construction of new habitat restoration sites and a new conservation hatchery facility. However, since program-level activities are broad in scope and not fully defined, these activities will be subject to additional environmental compliance procedures in the future. Once a program alternative is selected, the federal agency carrying out the action will comply with Section 106 and the consideration of effects on historic properties. This may be in the form of a Programmatic Agreement or other Section 106 compliance efforts depending on supplemental National Environmental Policy Act documents or phasing of program level activities.

K.3.2 No Action Alternative

The No Action Alternative means that Reclamation and DWR would continue with current operations of the CVP and SWP. Implementation of the No Action Alternative would add approximately 8,000 acres of tidal habitat relative to existing conditions in Suisun Marsh and/or the north Delta. This would require construction activities resulting in ground disturbance that could disturb or destroy archaeological historic properties and/or human remains, and construction activities that would lead to the alteration or removal of historic built-environment resources. Consequently, there is a potential for new indirect or direct effects on cultural resources to occur compared to the existing conditions.

K.3.3 Alternative 1

Operation of the CVP and SWP under Alternative 1 would change river flows and reservoir levels, compared to the No Action Alternative, which would change existing flow conditions. If peak river flows or reservoir levels have substantive increases beyond the No Action Alternative, it could result in erosion in areas with buried archaeological resources and therefore adversely affect the resources. However, evaluation of changes in peak flow rates taken from the surface water supply analysis conducted using the CalSim II model (as described in Appendix F, *Model Documentation*) indicates that none of the actions under Alternative 1 will result in changes to peak flows compared to the No Action Alternative.

Implementation of the project under Alternative 1 at the program level would require construction activities and ground disturbance that could disturb or destroy archaeological historic properties and/or human remains, and construction activities that would lead to the alteration or removal of historic built-environment resources.

K.3.3.1 *Project-Level Effects*

Potential changes to archaeological historic properties and/or human remains as a result of ground disturbance or flows.

Project-level actions under Alternative 1 do not have the potential to disturb or destroy archaeological historic properties and/ or human remains because no actions that would result in ground disturbance are proposed.

Potential changes in erosion that could expose buried archaeological historic properties and/or human remains.

Project-level actions proposed under Alternative 1 do not have the potential to expose buried archaeological historic properties and/or human remains because none of the actions proposed under Alternative 1 will increase peak flows beyond the No Action Alternative.

Potential changes to built-environment historic properties.

Project-level actions under Alternative 1 do not have the potential to affect historic properties because no actions that would result in alteration, damage, or demolition of built environment historic properties are proposed.

K.3.3.2 *Program-Level Effects*

Potential changes to archaeological historic properties and/or human remains as a result of ground disturbance.

Program-level actions proposed under Alternative 1 that would require construction and habitat restoration activities do have potential to disturb or destroy archaeological historic properties and/or human remains because associated ground disturbance could affect archaeological historic properties and/or human remains.

Potential changes in erosion that could expose buried archaeological historic properties and/or human remains.

Program-level actions proposed under Alternative 1 do not have the potential to expose buried archaeological historic properties and/or human remains because none of the actions proposed under Alternative 1 will increase peak flows beyond the No Action Alternative.

Potential changes to built-environment historic properties.

Program-level actions proposed under Alternative 1 that would require construction and habitat restoration sites and conservation hatchery production do have potential to affect historic properties because associated alteration, damage, or demolition of built-environment resources could affect built-environment historic properties.

K.3.4 Alternative 2

Operation of the CVP and SWP under Alternative 2 includes potential changes in hydropower generation, fish transport, groundwater pumping, water transfers, and construction of facilities. These project activities do not have the potential to adversely affect buried archaeological historic properties and/or human remains. There are no program-level elements under Alternative 2.

K.3.4.1 *Project-Level Effects*

Potential changes to archaeological historic properties and/or human remains as a result of ground disturbance or flows.

Project-level actions under Alternative 2 do not have the potential to affect archaeological historic properties and/or human remains because no actions that would result in ground disturbance are proposed.

Potential changes in erosion that could expose buried archaeological historic properties and/or human remains.

Project-level actions proposed under Alternative 2 do not have the potential to expose buried archaeological historic properties and/or human remains because none of the actions proposed under Alternative 2 will increase peak flows beyond the No Action Alternative.

Potential changes to built-environment historic properties.

Project-level actions under Alternative 2 do not have the potential to affect historic properties because no actions that would result in alteration, damage, or demolition of built-environment historic properties are proposed.

K.3.5 Alternative 3

Operation of the CVP and SWP under Alternative 3 would change river flows and reservoir levels, compared to the No Action Alternative, which would change existing flow conditions. If river flows or reservoir levels have substantive declines or increases resulting in erosion in areas with buried archaeological resources, the flows could adversely affect the resources.

K.3.5.1 *Project-Level Effects*

Potential changes to archaeological historic properties and/or human remains as a result of ground disturbance or flows.

Project-level actions under Alternative 3 do not have the potential to affect archaeological historic properties and/or human remains because no actions that would result in ground disturbance are proposed.

Potential changes in erosion that could expose buried archaeological historic properties and/or human remains.

Project-level actions proposed under Alternative 3 do not have the potential to expose buried archaeological historic properties and/or human remains because none of the actions proposed under Alternative 3 will increase peak flows beyond the No Action Alternative.

Potential changes to built-environment historic properties.

Project-level actions under Alternative 3 do not have the potential to affect historic properties because no actions that would result in alteration, damage, or demolition of built-environment historic properties are proposed.

K.3.5.2 *Program-Level Effects*

Potential changes to archaeological historic properties and/or human remains as a result of ground disturbance or flows.

Program-level actions proposed under Alternative 3 that would require construction and habitat restoration activities do have potential to affect archaeological historic properties and/or human remains because associated ground disturbance could affect archaeological historic properties and/or human remains.

Potential changes in erosion that could expose buried archaeological historic properties and/or human remains.

Program-level actions proposed under Alternative 3 do not have potential to expose buried archaeological historic properties and/or human remains because none of the actions proposed under Alternative 3 will increase peak flows beyond the No Action Alternative.

Potential changes to built-environment historic properties.

Program-level actions proposed under Alternative 3 that would require construction of habitat restoration sites and conservation hatchery production do have the potential to affect historic properties because associated alteration, damage, or demolition of built-environment resources could affect built-environment historic properties.

K.3.6 Alternative 4

Operation of the CVP and SWP under Alternative 4 would change river flows and reservoir levels, compared to the No Action Alternative, which would change existing flow conditions. If peak river flows or reservoir levels have substantive increases beyond the No Action Alternative, it could result in erosion in areas with buried archaeological resources and therefore adversely affect the resources. However, evaluation of changes in peak flow indicates that none of the actions under Alternative 4 will result in changes to peak flows compared to the No Action Alternative.

Implementation of the project under Alternative 4 at the program level (actions to increase water use efficiency) would require construction activities and ground disturbance that could disturb or destroy archaeological historic properties and/or human remains, and construction activities that would lead to the alteration or removal of historic built-environment resources**.**

K.3.6.1 *Project-Level Effects*

Potential changes to archaeological historic properties and/or human remains as a result of ground disturbance or flows.

Project-level actions under Alternative 4 do not have the potential to disturb or destroy archaeological historic properties and/ or human remains because no actions that would result in ground disturbance are proposed.

Potential changes in erosion that could expose buried archaeological historic properties and/or human remains.

Project-level actions proposed under Alternative 4 have the potential to expose buried archaeological historic properties and/or human remains as there would be periods where flows under Alternative 4 are higher than those under the No Action Alternative. However, peak flows would not exceed peak flood flows and, as discussed in Appendix X, *Geology and Soils*, riverbed erosion is not likely to occur as a result of increased flows within the rivers.

Potential changes to built-environment historic properties.

Project-level actions under Alternative 4 do not have the potential to affect historic properties because no actions that would result in alteration, damage, or demolition of built environment historic properties are proposed.

K.3.6.2 *Program-Level Effects*

Potential changes to archaeological historic properties and/or human remains as a result of ground disturbance or flows.

Program-level actions that would require ground disturbing activities such as installation of irrigation systems proposed under Alternative 4 do have potential to disturb or destroy archaeological historic properties and/or human remains because associated ground disturbance could affect archaeological historic properties and/or human remains.

Potential changes in erosion that could expose buried archaeological historic properties and/or human remains.

Program-level actions proposed under Alternative 4 do not have the potential to expose buried archaeological historic properties and/or human remains because none of the program-level actions proposed under Alternative 4 will increase peak flows beyond the No Action Alternative.

Potential changes to built-environment historic properties.

Program-level actions that would require ground disturbing activities such as installation of irrigation systems proposed under Alternative 4 do have potential to affect historic properties because associated alteration, damage, or demolition of built-environment resources could affect built-environment historic properties.

K.3.7 Mitigation Measures

Mitigation measures are included in this document to avoid, minimize, or compensate for adverse environmental effects of alternatives compared to the No Action Alternative.

Mitigation Measure CUL-1: Conduct Archaeological Surveys before the Beginning of Any Project or Program–Related Action and Implement Further Mitigation as Necessary.

Before the beginning of any project or program-related action that could affect cultural resources, qualified archaeologists survey all portions of the site. The survey is conducted during a time when vegetation can be reduced or cleared from the affected area, so the natural ground surface can be examined for traces of prehistoric and/or historic-era cultural resources. Surveys of these areas would not be necessary if it is determined that they would not be affected by any project or program construction-related activity, including equipment staging or material stockpiling. If the survey reveals the presence of cultural resources on the project site, the procedures outlined in Mitigation Measure CUL-2 will be followed.

Mitigation Measure CUL-2: Restrict Ground Disturbance and Implement Measures to Protect Archaeological Resources if Discovered during Surveys or Ground-Disturbing Activities.

If unrecorded cultural resources (e.g., unusual amounts of shell, animal bone, bottle glass, ceramics, structure/building remains, etc.) are encountered during surveys where ground disturbance is planned or during project-related ground-disturbing activities, all ground-disturbing activities will be restricted from being conducted within a 100-foot radius of the find. A qualified archaeologist will identify the materials, determine their possible significance according to NRHP criteria, and formulate appropriate measures for their treatment, which will be implemented by the lead agency and its contractors. Potential treatment methods for important and potentially important resources may include, but would not be limited to, no action (i.e., resources determined not to be important), avoidance of the resource through changes in construction methods or project design, and implementation of a program of testing and data recovery, in accordance with all applicable Federal and State requirements.

Mitigation Measure CUL-3: Stop Potentially Damaging Work if Human Remains Are Uncovered During Construction, Assess the Significance of the Find, and Pursue Appropriate Management.

If Native American human remains are discovered on federal lands, the Native American Graves Protection and Repatriation Act (NAGPRA) requires that the individual notify the federal land manager of the discovery in writing. All ground disturbing activities within 100 feet of the find will cease, and the materials are to be protected until the land manager can assess the find. Upon receipt of written confirmation of the discovery, the manager is required to: 1) certify receipt of the notification; 2) take immediate steps, if necessary, to further protect the materials; 3) notify by telephone, with written confirmation, the tribes likely to be culturally affiliated with the materials; and 4) initiate consultation with such tribes. If, after consultation with tribes, the manager determines that the material will be protected adequately *in situ*, without the need to excavate or remove the material from the area of discovery, then the requirements under NAGPRA will have been completed. If, after consultation with the tribes, the manager determines that the circumstances warrant intentional excavation or removal of the materials from the area of discovery, then 43 CFR 10.3 applies, and the manager must complete steps outlined therein for intentional excavations.

If Native American human remains are discovered outside of federal lands, California Health and Safety Code §7050.5 and §7052 and California Public Resources Code (PRC) §5097 procedures are to be followed. In accordance with the California Health and Safety Code, if human remains are uncovered during ground-disturbing activities, all such activities within a 100-foot radius of the find will be halted immediately and a Reclamation cultural resources specialist (CRS) will be contacted. The Reclamation CRS will immediately notify the county coroner. The coroner is required to examine all discoveries of human remains within 48 hours of receiving notice of a discovery on non-federal lands (Health and Safety Code Section 7050.5[b]). If the coroner determines that the remains are those of a Native American, he or she must contact the Native American Heritage Commission (NAHC) within 24 hours of making that determination (Health and Safety Code Section 7050[c]). The NAHC will immediately designate and contact the Most Likely Descendent (MLD), who has 48 hours from completion of their examination of the find in which to make recommendations for treatment of the remains, as required by PRC 5097.98(a). Reclamation will then contact the landowner. Reclamation, the MLD, and the landowner will then devise a mitigation plan for treatment of the remains. Work in the area will continue only after the remains have been treated according to the above mitigation plan and Reclamation certifies that the mitigation plan was properly implemented.

If the remains are found not to be Native American in origin and do not appear to be in an archaeological context, construction will proceed at the direction of the coroner and Reclamation CRS. Once the remains have been appropriately and legally treated, construction may resume in the discovery area upon receipt of Reclamation’s express authorization to proceed and under the direction of the CRS.

Mitigation Measure CUL-4: Complete Built-Environment Inventory and Evaluation prior to Construction and Implement Treatment Measures for Adverse Effects.

Mitigation for program or project effects on historic built-environment resources consists of identification and evaluation of built-environment historic properties and assessing program or project effects. Reclamation will ensure that a qualified architectural historian meeting Secretary of Interior’s Professional Qualifications Standards for work in history and/or architectural history per 36 CFR Part 61 conducts a historic built-environment inventory and evaluation of unsurveyed parcels that have potential to be affected by the proposed action. All historic built-environment resources located during the survey will be photographed, mapped, and recorded on applicable California Department of Parks and Recreation (DPR) 523 forms. For multi-faceted resources such as cultural landscapes and historic districts, locational data will be collected with a global positioning system (GPS) receiver. The significance of any identified historic built-environment resource will be evaluated for NRHP eligibility. The United States Bureau of Reclamation will forward the resulting DPR 523 forms to the representative California Historical Resources Information System.

To mitigate for adverse effects on identified built-environment historic properties, a plan for detailed documentation of the historic property will be prepared prior to initiation of the project or program action; in cases when the action would prevent adequate completion of the documentation effort, documentation will be completed prior to initiating the program or project. This could include a range of specific mitigation measures to be determined in Section 106 consultation with the State Office of Historic Preservation. Documentation of identified built-environment historic properties could include a range of options, such as interpretive displays, online resources, archival quality photographic documentation, or historic contexts.

K.3.8 Summary of Impacts

Table K.4-1 includes a summary of impacts, the magnitude and direction of those impacts, and potential mitigation measures for consideration.

Table K.4-1. Impact Summary

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
Potential changes to archaeological historic properties and/or human remains as a result of ground disturbance or flows. (Project-Level)	No Action	Ground disturbance associated with habitat restoration could affect archaeological historic properties and/or human remains.	–
	1	No impact	–
	2	No impact	–
	3	No impact	–
	4	No impact	–
Potential changes to archaeological historic properties and/or human remains as a result of ground disturbance or flows. (Program-Level)	No Action	Ground disturbance associated with habitat restoration could affect archaeological historic properties and/or human remains.	–
	1	Potential to cause impact at program level because associated ground disturbance could affect archaeological historic properties and/or human remains.	MM CUL-1-3
	2	No impact	–

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
	3	Potential to cause impact at program level because associated ground disturbance could affect archaeological historic properties and/or human remains.	MM CUL-1-3
	4	Potential to cause impact at program level because associated ground disturbance could affect archaeological historic properties and/or human remains.	MM CUL-1-3
Potential changes in erosion that could expose buried archaeological historic properties and/or human remains. (Project and Program-Level)	No Action	No impact	–
	1	No impact at the project or program levels.	–
	2	No impact at the project or program levels	–
	3	No impact at the project or program levels.	–
	4	No impact at the project or program levels.	-
Potential changes to built-environment historic properties. (Project-Level)	No Action	Potential for restoration activities to alteration, damage, or demolition of built-environment historic properties.	–
	1	No impact	–
	2	No impact	–
	3	No impact	–
	4	No impact	–
Potential changes to built-environment historic properties. (Program-Level)	No Action	Potential for restoration activities to alteration, damage, or demolition of built-environment historic properties.	–
	1	Potential to impact cultural resources at program-level due to alteration, damage, or demolition of built-environment historic properties.	MM CUL-4
	2	No impact	–
	3	Potential to impact cultural resources at program level due alteration, damage, or demolition of built-environment historic properties.	MM CUL-4
	4	Potential to impact cultural resources at program-level due to alteration, damage, or demolition of built-environment historic properties.	MM CUL-4

CVP = Central Valley Project
SWP = State Water Project

K.3.9 Cumulative Effects

K.3.9.1 *No Action Alternative*

The No Action Alternative would not result in changes to water operations. Anticipated tidal habitat restoration in the Delta may result in an adverse impact on cultural resources through those activities which require ground disturbing actions and/or alteration of a built historic property to implement (i.e., ecosystem restoration, hatchery construction, etc.) However, the extent of these construction activities, when compared to the probable projects included in the analysis would not be considered cumulatively considerable. Therefore, the No Action Alternative would not contribute to cumulative effects on cultural resources that may occur as a result of other projects within the study area. As such, the No Action Alternative is not evaluated further in this section.

K.3.9.2 *Alternatives 1, 3, and 4*

Alternatives 1, 3, and 4, along with the past, present, and reasonably foreseeable projects, described in Appendix Y, *Cumulative Methodology*, may result in an adverse impact on cultural resources through those activities which require ground disturbing actions and/or alteration of a built historic property to implement (e.g., ecosystem restoration, hatchery construction, irrigation system installation). However, the combined extent of the cumulative projects when compared to the probable projects included in the analysis would not be considered cumulatively considerable.

In the short-term, the implementation of Alternatives 1, 3, and 4, resource management plans, restoration measures, and water efficiency measures each have equal potential to contribute to cumulative impacts on cultural resources. However, until subsequent environmental review is completed, it can not be determined if individual alternative impacts are substantial in comparison to the cumulative projects.

K.3.9.3 *Alternative 2*

Alternative 2 would not result in any activities that could require ground disturbance or alteration of a built historic property. Therefore, Alternative 2 would not contribute to cumulative effects on cultural resources that may occur as a result of other projects within the study area.

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Appendix L Air Quality Technical Appendix

This appendix documents the air quality technical analysis to support the impact analysis in the EIS.

L.1 Background Information

This section describes the area of analysis and ambient air quality and conditions in the study area.

The discussion in this appendix is organized by the action areas and air basins. The counties, air basins and air quality management districts in California, including those in the action area, do not specifically align with the action areas, as noted below and in the description of each air basin (California Air Resources Board [ARB] 2019a, 2019b). The action areas include the following air basins and counties.

- Trinity River region: Trinity Reservoir and Trinity River downstream of Lewiston Reservoir
    - This region is located within the North Coast Air Basin.
    - This region is located within Humboldt and Trinity Counties.
- Sacramento River region: Sacramento River from Shasta Lake downstream to and including the Sacramento-San Joaquin Delta
    - This region is located within the Sacramento Valley Air Basin.
    - This region is located within Shasta, Tehama, Glenn, Colusa, Sutter, Yolo, and Sacramento Counties.
- Clear Creek region: Clear Creek from Whiskeytown Reservoir to its confluence with the Sacramento River
    - This region is located within the Sacramento Valley Air Basin.
    - This region is located within Shasta County.
- Feather River region: Feather River from the FERC boundary downstream to its confluence with the Sacramento River
    - This region is located within the Sacramento Valley Air Basin.
    - This region is located within Butte, Yuba, and Sutter Counties.
- American River region: American River from Folsom Reservoir downstream to its confluence with the Sacramento River
    - This region is located within the Sacramento Valley Air Basin.
    - This region is located within Placer, Sacramento, and Yolo Counties.
- Stanislaus River region: Stanislaus River from New Melones Reservoir to its confluence with the San Joaquin River
    - This region is located within portions of the San Joaquin Valley and Mountain Counties Air Basins.

  - This region is located within Calaveras, Tuolumne, Stanislaus, San Joaquin, and Merced Counties.
- San Joaquin River region: San Joaquin River from Friant Dam downstream to and including the Sacramento-San Joaquin Delta
  - This region is located within the San Joaquin Valley Air Basin.
  - This region is located within Fresno, Madera, Merced, Stanislaus, and San Joaquin Counties.
- Bay-Delta region: San Francisco Bay, Suisun Marsh, and Delta
  - This region is located within portions of the Sacramento Valley, San Joaquin Valley, and San Francisco Bay Air Basins.
  - This region is located within Solano, Sacramento, San Joaquin, Contra Costa, San Francisco, and Alameda Counties.
- CVP and SWP Service Areas region: CVP and SWP service areas (south to Diamond Valley)
  - This region is located within portions of the San Francisco Bay, North Central Coast, San Joaquin Valley, Mojave Desert, South Coast, San Diego, and Salt on Sea Air Basins.
  - This region is located within Santa Clara, San Benito, Kings, Kern, Ventura, Los Angeles, San Bernardino, Orange, Riverside, San Diego, and Imperial Counties.
- Nearshore Pacific Ocean region: nearshore Pacific Ocean on the coast from Point Conception to Cape Falcon in Oregon
  - This region is located within portions of the South Central Coast, North Central Coast, San Francisco Bay, and North Coast Air Basins.
  - This region borders Santa Barbara, San Luis Obispo, Monterey, Santa Cruz, San Mateo, San Francisco, Marin, Sonoma, Mendocino, Humboldt, and Del Norte Counties.

L.1.1 Ambient Air Quality

Air quality conditions and potential impacts in the action area are evaluated and discussed qualitatively. The following subsections briefly describe the existing air quality environmental setting by air basin for the action area. The counties within each air basin in the action area are presented in Table L.1-1, along with nonattainment designations to characterize existing ambient air quality. Nonattainment designations indicate that concentrations of pollutants measured in ambient air exceed the applicable ambient air quality standards. As shown in Table L.1-1, many of the counties included in the action area are designated as nonattainment for the federal and/or state ozone and particulate matter standards. Particulate matter issues may be exacerbated under dry conditions because when irrigation water supplies are decreased, there is increased potential for the formation and transport of fugitive dust.

Table L.1-1. Areas and Pollutants Designated as Nonattainment for Federal and State Ambient Air Quality Standards

County	Air Basin	Air Quality Management District	Federal Nonattainment Designations[1]	State Nonattainment Designations[2]
Trinity River Region				
Humboldt	North Coast	North Coast Unified	–	PM_{10}
Trinity	North Coast	North Coast Unified	–	–
Sacramento River Region				
Shasta	Sacramento Valley	Shasta	–	Ozone
Tehama	Sacramento Valley	Tehama	Ozone (Tuscan Buttes)	Ozone, PM_{10}
Glenn	Sacramento Valley	Glenn	–	PM_{10}
Colusa	Sacramento Valley	Colusa	–	PM_{10}
Sutter	Sacramento Valley	Feather River	Ozone (Sutter Buttes)	Ozone, PM_{10}
Yolo	Sacramento Valley	Yolo-Solano	Ozone, $PM_{2.5}$	Ozone, PM_{10}
Sacramento	Sacramento Valley	Sacramento Metro	Ozone, $PM_{2.5}$	Ozone, PM_{10}
Clear Creek Region				
Shasta	Sacramento Valley	Shasta	–	Ozone
Feather River Region				
Butte	Sacramento Valley	Butte	Ozone	Ozone, $PM_{2.5}$, PM_{10}
Yuba	Sacramento Valley	Feather River	–	Ozone, PM_{10}
Sutter	Sacramento Valley	Feather River	Ozone (Sutter Buttes)	Ozone, PM_{10}
American River Region				
Placer	Sacramento Valley, Mountain Counties, Lake Tahoe	Placer	Ozone (Sacramento Metro AQMD portion), $PM_{2.5}$ (Sacramento Metro AQMD portion)	Ozone, PM_{10}
Sacramento	Sacramento Valley	Sacramento Metro	Ozone, $PM_{2.5}$	Ozone, PM_{10}
Yolo	Sacramento Valley	Yolo-Solano	Ozone, $PM_{2.5}$	Ozone, PM_{10}
Stanislaus River Region				
Calaveras	Mountain Counties	Calaveras	Ozone	Ozone, PM_{10}
Tuolumne	Mountain Counties	Tuolumne	Ozone	Ozone
Stanislaus	San Joaquin Valley	San Joaquin Valley Unified	Ozone, $PM_{2.5}$	Ozone, $PM_{2.5}$, PM_{10}
San Joaquin	San Joaquin Valley	San Joaquin Valley Unified	Ozone, $PM_{2.5}$	Ozone, $PM_{2.5}$, PM_{10}
Merced	San Joaquin Valley	San Joaquin Valley Unified	Ozone, $PM_{2.5}$	Ozone, $PM_{2.5}$, PM_{10}

County	Air Basin	Air Quality Management District	Federal Nonattainment Designations[1]	State Nonattainment Designations[2]
San Joaquin River Region				
Fresno	San Joaquin Valley	San Joaquin Valley Unified	Ozone, $PM_{2.5}$	Ozone, $PM_{2.5}$, PM_{10}
Madera	San Joaquin Valley	San Joaquin Valley Unified	Ozone, $PM_{2.5}$	Ozone, $PM_{2.5}$, PM_{10}
Merced	San Joaquin Valley	San Joaquin Valley Unified	Ozone, $PM_{2.5}$	Ozone, $PM_{2.5}$, PM_{10}
Stanislaus	San Joaquin Valley	San Joaquin Valley Unified	Ozone, $PM_{2.5}$	Ozone, $PM_{2.5}$, PM_{10}
San Joaquin	San Joaquin Valley	San Joaquin Valley Unified	Ozone, $PM_{2.5}$	Ozone, $PM_{2.5}$, PM_{10}
Bay-Delta Region				
Solano	Sacramento Valley, San Francisco Bay	Yolo-Solano, Bay Area	Ozone (Bay Area AQMD portion)	Ozone, PM_{10}
Sacramento	Sacramento Valley	Sacramento Metro	Ozone, $PM_{2.5}$	Ozone, PM_{10}
San Joaquin	San Joaquin Valley	San Joaquin Valley Unified	Ozone, $PM_{2.5}$	Ozone, $PM_{2.5}$, PM_{10}
Contra Costa	San Francisco Bay	Bay Area	Ozone, $PM_{2.5}$	Ozone, $PM_{2.5}$, PM_{10}
San Francisco	San Francisco Bay	Bay Area	Ozone, $PM_{2.5}$	Ozone, $PM_{2.5}$, PM_{10}
Alameda	San Francisco Bay	Bay Area	Ozone, $PM_{2.5}$	Ozone, $PM_{2.5}$, PM_{10}
CVP and SWP Service Areas Region				
Santa Clara	San Francisco Bay	Bay Area	Ozone	Ozone, $PM_{2.5}$, PM_{10}
San Benito	North Central Coast	Monterey Bay Unified	–	Ozone, PM_{10}
Kings	San Joaquin Valley	San Joaquin Valley Unified	Ozone, $PM_{2.5}$	Ozone, $PM_{2.5}$, PM_{10}
Kern	San Joaquin Valley, Mojave Desert	San Joaquin Valley Unified, Kern	Ozone (Eastern Kern), $PM_{2.5}$, PM_{10} (Eastern Kern)	Ozone, $PM_{2.5}$ (Eastern Kern), PM_{10}
Ventura	South Central Coast	Ventura	Ozone	Ozone, PM_{10}
Los Angeles	South Coast, Mojave Desert	South Coast, Antelope Valley	Ozone, $PM_{2.5}$	Ozone, $PM_{2.5}$ (Eastern Los Angeles), PM_{10}
San Bernardino	South Coast, Mojave Desert	South Coast, Mojave Desert	Ozone, $PM_{2.5}$	Ozone, $PM_{2.5}$ (South-Eastern San Bernardino), PM_{10}
Orange	South Coast	South Coast	Ozone, $PM_{2.5}$	Ozone, $PM_{2.5}$, PM_{10}
Riverside	South Coast, Salt on Sea, Mojave Desert	South Coast, Mojave Desert	Ozone, $PM_{2.5}$, PM_{10} (Coachella Valley)	Ozone, $PM_{2.5}$ (Eastern Riverside), PM_{10}
San Diego	San Diego	San Diego	Ozone	Ozone, $PM_{2.5}$, PM_{10}
Imperial	Salt on Sea	Imperial	Ozone, $PM_{2.5}$, PM_{10}	Ozone, PM_{10}

County	Air Basin	Air Quality Management District	Federal Nonattainment Designations[1]	State Nonattainment Designations[2]
Nearshore Pacific Ocean Region				
Santa Barbara	South Central Coast	Santa Barbara	–	Ozone, PM_{10}
San Luis Obispo	South Central Coast	San Luis Obispo	Ozone (eastern portion)	Ozone, PM_{10}
Monterey	North Central Coast	Monterey Bay Unified	–	Ozone, PM_{10}
Santa Cruz	North Central Coast	Monterey Bay Unified	–	Ozone, PM_{10}
San Mateo	San Francisco Bay	Bay Area	Ozone, $PM_{2.5}$	Ozone, $PM_{2.5}$, PM_{10}
San Francisco	San Francisco Bay	Bay Area	Ozone, $PM_{2.5}$	Ozone, $PM_{2.5}$, PM_{10}
Marin	San Francisco Bay	Bay Area	Ozone, $PM_{2.5}$	Ozone, $PM_{2.5}$, PM_{10}
Sonoma	North Coast, San Francisco Bay	Northern Sonoma, Bay Area	Ozone (Bay Area AQMD portion), $PM_{2.5}$ (Bay Area AQMD portion)	Ozone (Bay Area AQMD portion), $PM_{2.5}$ (Bay Area AQMD portion), PM_{10} (Bay Area AQMD portion)
Mendocino	North Coast	Mendocino	–	PM_{10}
Humboldt	North Coast	North Coast Unified	–	PM_{10}
Del Norte	North Coast	North Coast Unified	–	–

Sources: USEPA 2019; ARB 2018a.
AQMD = Air Quality Management District
Bay Area = San Francisco Bay Area
PM2.5 = particulate matter of 2.5 microns diameter and smaller
PM10 = particulate matter of 10 microns diameter and smaller
[1] Areas designated as nonattainment by U.S. Environmental Protection Agency related to National Ambient Air Quality Standards as of January 31, 2019.
[2] Areas designated as nonattainment by California Air Resources Board related to California Ambient Air Quality Standards as of December 28, 2018. Changes to the state area designations were proposed for 2019.

L.1.1.1 *North Coast Air Basin*

The North Coast Air Basin includes Humboldt, Del Norte, Trinity, and Mendocino Counties, and northern Sonoma County (ARB 2019a). This air basin contains the Trinity River region and portions of the nearshore Pacific Ocean region of the action area. The basin is sparsely populated and stretches along the northern coastline through forested mountains. Prevailing winds blow clean air inland from the Pacific Ocean, and air quality is typically good. Del Norte, Trinity, and north Sonoma Counties are designated attainment for the federal and state air quality standards while the remainder of the air basin is designated nonattainment for at least one criteria pollutant (USEPA 2019; ARB 2018a).

L.1.1.2 *Sacramento Valley Air Basin*

The Sacramento Valley Air Basin encompasses 9 air districts and 11 counties, including all of Shasta, Tehama, Glenn, Colusa, Butte, Sutter, Yuba, Sacramento, and Yolo Counties; the westernmost portion of Placer County; and the northeastern half of Solano County. The air basin is bounded by tall mountains: the Coast Ranges to the west, the Cascade Range to the north, and the Sierra Nevada to the east. This air basin contains the Sacramento River, Clear Creek, Feather River, and American River regions, and portions of the Bay-Delta region of the action area.

Winters are wet and cool, and summers are hot and dry. When air stagnates, or is trapped by an inversion layer in the valley, ambient pollutant concentrations can reach or exceed ambient air quality standards. On-road vehicles are the largest source of smog-forming pollutants, and particulate matter emissions are primarily from area sources, such as fugitive dust from paved and unpaved roads and vehicle travel (ARB 2013a).

To characterize the existing ambient air quality in the Sacramento Valley Air Basin, analysts reviewed data from area monitoring stations (ARB 2019c, 2019d). For the three years of 2015–2017, monitoring data indicated the following:

- Concentrations of 8-hour ozone (O_3) and 24-hour $PM_{2.5}$ have exceeded the National Ambient Air Quality Standards (NAAQS) and California Ambient Air Quality Standards (CAAQS).
- Concentrations of 24-hour PM_{10} have exceeded the CAAQS. Concentrations of 24-hour PM_{10} were below the NAAQS in 2015 and 2016, but exceeded the NAAQS in 2017.
- Measured concentrations of nitrogen dioxide (NO_2) have complied with the NAAQS and CAAQS.
- Monitored sulfur dioxide (SO_2) and lead concentrations are extremely low.

L.1.1.3 *Mountain Counties Air Basin*

The Mountain Counties Air Basin includes the mountainous areas of the central and northern Sierra Nevada range, from Plumas County south to Mariposa County, including Plumas, Sierra, Nevada, Central Placer, West El Dorado, Amador, Calaveras, Tuolumne, and Mariposa Counties (ARB 2019a). This air basin includes portions of the Stanislaus River region of the action area.

The area is sparsely populated, and motor vehicles are the primary source of emissions in the air basin. Air quality issues often result when eastward surface winds transport pollution from more populated air basins to the west and south. Wood smoke from stoves and fireplaces contributes to elevated ambient PM_{10} concentrations during winter. Amador, Calaveras, El Dorado, Nevada, Placer, Mariposa, and Tuolumne Counties are designated as nonattainment for the state ozone standards (ARB 2018b). El Dorado, Nevada, Placer, Plumas, and Sierra Counties are designated as nonattainment for the state PM_{10} standards (ARB 2018b).

L.1.1.4 *San Francisco Bay Area Air Basin*

The San Francisco Bay Area Air Basin consists of a single air district and nine counties, including all of Napa, Marin, San Francisco, Contra Costa, Alameda, San Mateo, and Santa Clara Counties; the southern portion of Sonoma County; and the southwestern portion of Solano County (ARB 2019a). The hills of the Coast Ranges bound the San Francisco and San Pablo Bays and the inland valleys of the air basin. This air basin includes portions of the Bay-Delta and nearshore Pacific Ocean regions of the action area.

The San Francisco Bay Area Air Basin includes the second largest urban area in California, hosting industry, airports, international ports, freeways, and surface streets. On-road vehicles are the largest source of smog-forming pollutants, and PM_{10} emissions are primarily from area sources, such as fugitive dust from paved and unpaved roads and vehicle travel (ARB 2013a). Air quality in the San Francisco Bay Area (Bay Area) is often good, as sea breezes blow clean air from the Pacific Ocean into the air basin, but transport of pollutants from the San Francisco Bay Area can exacerbate air quality problems in the downwind portions of the San Francisco Bay Area Air Basin, as well as in the Sacramento Valley and San Joaquin Valley air basins.

To characterize the existing ambient air quality for the San Francisco Bay Area Air Basin, analysts reviewed data from area monitoring stations (ARB 2019c, 2019d). For the three years from 2015 to 2017, monitoring data indicated the following:

- Concentrations of 8-hour O_3 and 24-hour $PM_{2.5}$ have exceeded the NAAQS and CAAQS.
- Concentrations of 24-hour PM_{10} exceeded the CAAQS in 2015 and 2017, but were below the CAAQS in 2016. Concentrations of 24-hour PM_{10} were below the NAAQs. Concentrations of 1-hour O_3 exceeded the CAAQS. Concentrations of 1-hour O_3 were below the NAAQS in 2015 and 2016, but exceeded the NAAQS in 2017.
- Measured concentrations of NO_2 have complied with the NAAQS and CAAQS.
- Monitored SO_2 and lead concentrations are extremely low.

L.1.1.5 *San Joaquin Valley Air Basin*

The San Joaquin Valley Air Basin encompasses eight counties, including all of San Joaquin, Stanislaus, Madera, Merced, Fresno, Kings, and Tulare Counties; and western Kern County. It is bounded on the west by the Coast Range, on the east by the Sierra Nevada, and in the south by the Tehachapi Mountains. This air basin contains the San Joaquin River Region and portions of the Stanislaus River and Bay-Delta regions of the action area.

Winters are cool and wet and summers are dry and very hot. The area is heavily agricultural, and hosts other localized industries such as forest products, oil and gas production, and oil refining. On-road vehicles are the largest source of smog-forming pollutants, and PM_{10} emissions are primarily from sources such as agricultural operations and fugitive dust from paved and unpaved roads and vehicle travel (ARB 2013a). Air quality issues may be exacerbated under dry conditions. When water supplies and irrigation levels are decreased in urban, rural, and agricultural areas, there is increased potential for the formation and transport of fugitive dust.

To characterize the existing ambient air quality for the San Joaquin Valley Air Basin, data from area monitoring stations were reviewed (ARB 2019c, 2019d). For the three years of 2015–2017, monitoring data indicated the following:

- Concentrations of 8-hour O_3, 1-hour O_3, and 24-hour $PM_{2.5}$ have exceeded the NAAQS and CAAQS.
- Concentrations of 24-hour PM_{10} have exceeded the CAAQS. Concentrations of 24-hour PM_{10} were below the NAAQS in 2015 and 2016 but exceeded the NAAQS in 2017.
- Measured concentrations of NO_2 have complied with the NAAQS and CAAQS.
- Monitored SO_2 and lead concentrations are extremely low.

Concentrations of PM_{10} and $PM_{2.5}$ have been a continuing concern in the San Joaquin Valley Air Basin. The San Joaquin Valley Air Pollution Control District (SJVAPCD) is the local regulatory agency with jurisdiction over air quality issues in the San Joaquin Valley area. In response to the area's historical air quality problems with dust and particulate matter, the SJVAPCD was the first agency in the state to regulate emissions from on-field agricultural operations. In 2004, the agency adopted Rule 4550, the Conservation Management Practices rule, and Rule 3190, the Conservation Management Practices Fee rule. To comply with these rules, farmers with 100 acres or more of contiguous land must prepare and implement biennial Conservation Management Plans to reduce dust and particulate matter emissions from on-farm sources, such as unpaved roads and equipment yards, land preparation, harvest activities, and other farming activities. The SJVAPCD published a handbook titled *Agricultural Air Quality Conservation Management Practices for San Joaquin Valley Farms* and a list of conservation management practices in 2004 to provide guidance to farmers (SJVAPCD 2004a, 2004b). Examples of conservation management practices include activities that reduce or eliminate the need for soil disturbance, activities that protect soil from wind, use of dust suppressants, alternatives to burning agricultural wastes, and reduced travel speeds on unpaved roads and equipment yards. Lands not currently under cultivation or used for pasture are exempt from Rule 4550, other than recordkeeping to document the exemption. Fees vary depending on the size of the farm, and include an initial application fee, and a biennial renewal fee.

In addition to requirements for on-field agricultural practices, the SJVAPCD rules and regulations address avoidance of nuisance conditions (Rule 4102), prohibitions on opening burning (Rule 4103), and fugitive-dust control (Regulation VIII). Specifically, the SJVAPCD dust-control rules include Rule 8021 for control of PM_{10} from construction, demolition, excavation, extraction, and other earthmoving activities; Rule 8031 for control of PM_{10} from handling and storage of bulk materials; Rule 8051 for control of PM_{10} from disturbed open areas; Rule 8061 for control of PM_{10} from travel on paved and unpaved roads; Rule 8071 for control of PM_{10} from unpaved vehicle and equipment traffic areas; and Rule 8081 for off-field agricultural sources, such as bulk materials handling and transport and travel on unpaved roads. Each of these rules requires fugitive dust control, often through application of water, gravel, or chemical dust stabilizers.

L.1.1.6 *South Central Coast Air Basin*

The South Central Coast Air Basin includes San Luis Obispo, Santa Barbara and Ventura Counties. It is bordered by the Pacific Ocean on the south and west and lies just north of the highly populated South Coast Air Basin. This air basin includes portions of the nearshore Pacific Ocean region of the action area.

Sources of pollutants in the air basin include powerplants, oil production and refining, vehicle travel, and agricultural operations. San Luis Obispo, Santa Barbara, and Ventura Counties are designated as nonattainment for the state PM_{10} standards. San Luis Obispo and Ventura Counties are designated as nonattainment for the state ozone standards while Santa Barbara County is designated as nonattainment-transitional for the state ozone standard. Eastern San Luis Obispo and Ventura Counties are designated as nonattainment for the federal ozone standard (USEPA 2019). Wind patterns link Ventura and Santa Barbara Counties, resulting in pollutant transport between the South Central Coast Air Basin and South Coast Air Basin. San Luis Obispo County is separated from these counties by mountains, and the air quality in San Luis Obispo County is linked more with conditions in the San Francisco Bay Area Air Basin and San Joaquin Valley Air Basin. Additionally, air emissions from the South Coast Air Basin can be blown offshore, and then carried to the coastal cities of the South Central Coast Air Basin. Under some conditions, the reverse air flow can carry pollutants from the South Central Coast Air Basin to the South Coast Air Basin and contribute to ozone violations there (ARB 2013a).

L.1.1.7 *North Central Coast Air Basin*

The North Central Coast Air Basin includes Santa Cruz, San Benito and Monterey Counties (ARB 2019a). This air basin includes portions of the nearshore Pacific Ocean region of the action area.

The North Central Coast Air Basin is in attainment for all NAAQS, and is designated as nonattainment for the state ozone and PM_{10} standards (ARB 2019b). Although the air basin is separated from the Bay Area by the Santa Cruz Mountains and Coast Ranges to the north, wind can transport air pollution from the San Francisco Bay Area Air Basin and contribute to elevated ozone concentrations in the North Central Coast Air Basin (ARB 2013a).

L.2 Evaluation of Alternatives

This section describes the technical background for the evaluation of environmental consequences associated with the action alternatives and the No Action Alternative.

L.2.1 Methods and Tools

Potential air quality impacts were assessed for each component of each alternative. Where possible, the direction (positive or negative effect on air quality) and magnitude of change were identified for emissions of criteria pollutants, which are seven common pollutants for which the U.S. Environmental Protection Agency (USEPA) has set NAAQS according to health-based criteria. The criteria pollutants are carbon monoxide (CO), nitrogen dioxide (NO_2), ozone, particulate matter of 10 microns diameter and smaller (PM_{10}), particulate matter of 2.5 microns diameter and smaller ($PM_{2.5}$), reactive organic gases (ROG), and sulfur dioxide (SO_2). Ozone emissions are not calculated because ozone is not emitted directly from sources but is formed in the atmosphere from chemical reactions of the ozone precursor chemicals nitrogen oxides (NO_x) and ROG. Therefore, potential ozone impacts are assessed based on emissions of NO_x and ROG. The primary actions that could affect emissions are described as follows.

Potential changes in emissions from fossil-fueled powerplants (hydropower generation)

The action alternatives would change operations of the CVP and SWP, which could change river flows and reservoir levels. These changes could affect the amount of power the hydroelectric facilities in the system could generate. Where flows increase on rivers that have hydroelectric facilities then hydropower generation could increase. The additional hydroelectric power is expected to displace power that must be purchased from suppliers connected to the regional electric system (grid). To the extent that the displaced power would have been generated by fossil-fueled powerplants, emissions of criteria pollutants from these plants would decrease. (In 2016, approximately 50% of grid electricity in California was generated by fossil-fueled plants [USEPA 2018].) Conversely, if hydropower generation decreases, the decrease must be offset by purchased power from the grid to meet demand for power. To the extent that the additional purchased power would have been generated by fossil-fueled powerplants, emissions from these plants would increase.

Operations of the CVP and SWP also entail transfers of water. Many, but not all, transfers require water to be pumped. For those transfers that require pumping, changes in the quantities of water transferred could affect emissions by changing the amount of electricity required. If the amount of water transferred increases, the electrical energy required for pumping also would increase. To the extent that the increased electricity would be purchased from the grid and would be generated by fossil-fueled powerplants, emissions from these plants would increase. Conversely, if the amount of water transferred decreases, the electrical energy required for pumping also would decrease. To the extent that the amount of purchased electricity that is generated by fossil-fueled powerplants decreases, emissions from these plants would decrease. Under Alternatives 1, 2, 3, and 4, the quantities of water transferred would be the same as under the No Action Alternative. Consequently, there would be no change in emissions associated with water transfers, and the air quality impacts of the project would not be affected by water transfers.

Air quality effects resulting from changes in hydropower generation (including power required for water transfers), and consequently in the demand for grid power, were evaluated on a project-wide basis in terms of air pollutant emissions from fossil-fueled powerplants. For the details of the power modeling on which the air quality analysis was based, see Appendix U, *Power and Energy Technical Appendix*. The power modeling estimated energy usage in terms of net generation, defined as the difference between the amount of electricity generated by CVP/SWP hydropower facilities and the amount of electricity used by CVP/SWP for water transfers and facility operations. A positive value for net generation means that CVP/SWP generated more power than it used, and the excess was sold to the grid. A negative value for net generation means that CVP/SWP used more power than it generated, and offset the deficit by purchasing the additional power from the grid. Table L.2-1 summarizes the results of the power modeling and shows the estimated net generation for each alternative for a long-term average year. The emissions calculations reflect net generation for the entire CVP/SWP system, as shown in the last line in the table.

Table L.2-1. Summary of Power Modeling Results

		Energy (Gigawatt-hours per average year)				
Facilities	**Energy Component**	**No Action**	**Alt 1**	**Alt 2**	**Alt 3**	**Alt 4**
CVP	Energy Generation[1]	4,533	4,539	4,609	4,610	4,489
	Energy Use[2]	1,207	1,322	1,420	1,415	1,117
	Net Generation[3]	3,326	3,217	3,189	3,195	3,372
SWP	Energy Generation[1]	4,074	4,349	4,679	4,658	3,971
	Energy Use[2]	7,304	8,377	9,630	9,557	6,972
	Net Generation[3]	-3,230	-4,028	-4,951	-4,898	-3,001
Total	Energy Generation[1]	8,607	8,888	9,288	9,269	8,459
	Energy Use[2]	8,511	9,698	11,050	10,972	8,088
	Net Generation[3]	96	-810	-1,762	-1,703	371

Source: Appendix U, Power and Energy Technical Appendix.
1 Hydropower generated
2 Energy used for facility operation and water transfers
3 Net generation equals hydropower generation minus energy use. Net generation of zero would indicate that hydropower generation exactly equals energy use. Negative net generation values indicate that energy use exceeds energy generation and the additional energy needed is purchased from the grid. Positive net generation values indicate that energy generation exceeds energy use and the additional energy generated is sold to the grid.
Alt = Alternative
CVP = Central Valley Project
SWP = State Water Project
1 gigawatt-hour = 1,000 megawatt-hours = 1,000,000 kilowatt-hours

The changes in annual net generation estimated by the power modeling were multiplied by emission factors (mass of pollutant emitted per unit of energy generated) to derive annual emissions. Emission factors for NO_x and SO_2 were obtained from the USEPA eGRID model and represent averages for the California statewide mix of powerplants in 2016, which is the most recent year of data available (USEPA

2018). eGRID does not provide emission factors for CO, PM_{10}, $PM_{2.5}$, and ROG, so emission factors for these pollutants were derived from data for the electric utility sector in the ARB emission inventory for 2012, which is the most recent year of data available (ARB 2013b). Table L.2-2 lists the emission factors that were used in the air quality analysis.

Table L.2-2. Emission Factors Used in Air Quality Analysis

Pollutant	Electric Generation (lb/Mwh)	Diesel Pump Engines (g/hp-hr)
CO	0.850	3.449
NO_x	0.475	3.497
PM_{10}	0.169	0.217
$PM_{2.5}$	0.152	0.217
ROG	0.073	0.429
SO_2	0.037	0.006

Sources: electric generation – ARB 2013b, USEPA 2018; diesel pump engines – SCAQMD 2017.
g/hp-hr = grams per horsepower-hour
lb/Mwh = pounds per megawatt-hour
CO = carbon monoxide
NO_x = nitrogen oxides
PM_{10} = particulate matter of 10 microns diameter and smaller
$PM_{2.5}$ = particulate matter of 2.5 microns diameter and smaller
ROG = reactive organic gases
SO_2 = sulfur dioxide

Table L.2-3 shows the estimated emissions from fossil-fueled grid powerplants associated with net generation, based on the net generation values given in Table L.2-1. Figure L.2-1, Emissions from Grid Power Generation, and Figure L.2-2, Changes in Emissions from Grid Power Generation Compared to the No Action Alternative, show the emissions of each pollutant for grid power generation and the changes compared to the No Action Alternative, respectively.

Table L.2-3. Emissions from Net Generation

	Emissions (U.S. tons per average year)				
Pollutant	No Action	Alt 1	Alt 2	Alt 3	Alt 4
CO	-41.0	344.6	749.0	724.1	-157.7
NO_x	-22.9	192.5	418.4	404.5	-88.1
PM_{10}	-8.1	68.5	149.0	144.1	-31.4
$PM_{2.5}$	-7.3	61.7	134.2	129.8	-28.3
ROG	-3.5	29.8	64.7	62.5	-13.6
SO_2	-1.8	15.0	32.6	31.5	-6.9

Values represent the emissions effects of net generation, i.e., CVP/SWP hydropower generation minus CVP/SVP energy use. Emissions of zero would indicate that CVP/SWP hydropower generation exactly equals CVP/SWP energy use. Negative emission values indicate decreases in emissions because net generation is positive and displaces grid power; positive emission values indicate increases in emissions because net generation is negative and CVP/SWP purchases the needed power from the grid.
Alt = Alternative
CO = carbon monoxide
NOx = nitrogen oxides
PM_{10} = particulate matter of 10 microns diameter and smaller

$PM_{2.5}$ = particulate matter of 2.5 microns diameter and smaller
ROG = reactive organic gases
SO_2 = sulfur dioxide

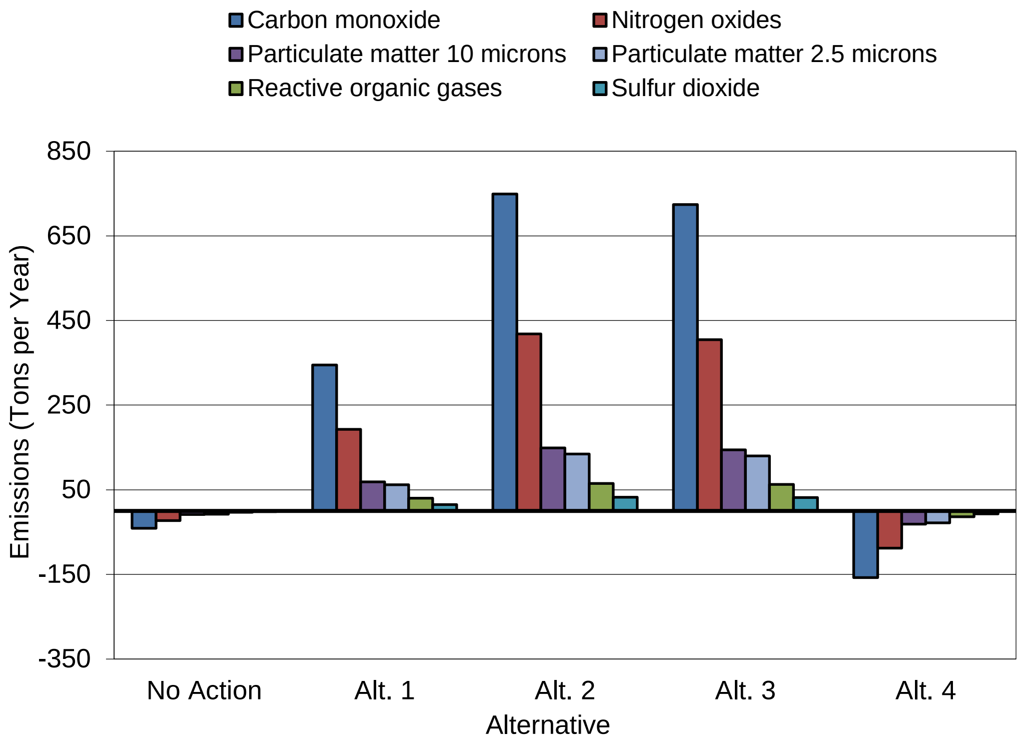

Figure L.2-1. Emissions from Grid Power Generation

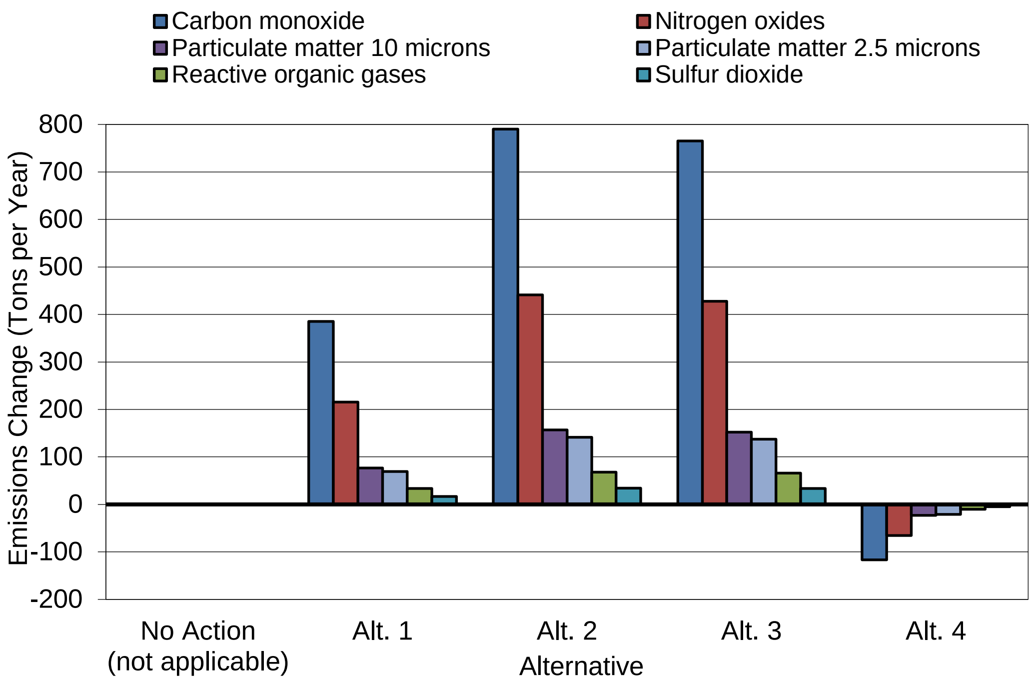

Figure L.2-2. Changes in Emissions from Grid Power Generation Compared to the No Action Alternative

Under Alternative 1 in an average year, net generation would decrease compared to the No Action Alternative, as shown in Table L.2-1. As a result, emissions from fossil-fueled grid powerplants would increase, as shown in Table L.2-3. Under Alternative 2 in an average year, net generation would decrease more than under Alternative 1 and emissions would increase more. The emissions increase under Alternative 2 would be roughly twice that under Alternative 1, compared to the No Action Alternative. Under Alternative 3 in an average year, net generation would decrease and emissions would increase compared to the No Action Alternative. The emissions increases under Alternative 3 would be greater than under Alternative 1 but less than under Alternative 2. In contrast with the other action alternatives, under Alternative 4 in an average year, net generation would increase compared to the No Action Alternative. As a result, emissions from fossil-fueled grid powerplants would decrease.

Potential changes in emissions from fossil-fueled powerplants (groundwater pumping)

The action alternatives would change operation of the CVP and SWP, which could change river flows and reservoir levels. These changes could affect the amount of water available for agricultural irrigation. If surface water availability decreases, farmers could make up the difference in water supply by increasing groundwater pumping. Approximately 85% of groundwater pumps are electric (USDA 2014), so increased pumping would increase the demand for grid power. To the extent that the additional purchased power would be generated by fossil-fueled powerplants, emissions from these plants would increase. Although the specific power purchases that water users may make in the future are not known, approximately 50% of the grid electricity in California was generated by fossil-fueled plants in 2016, as noted above. Approximately 15% of groundwater pumps are powered by engines (USDA 2014), so increased use of these pumps would increase engine exhaust emissions. Conversely, if surface water availability increases, farmers could decrease the amount of groundwater they pump, which would lead to a decrease in emissions.

Air quality effects resulting from changes in groundwater pumping were evaluated on a project-wide basis in terms of air pollutant emissions from the fossil-fueled powerplants (for electrically-powered pumps) and from engines (for engine-powered pumps). For the details of the groundwater modeling on which the air quality analysis was based, see Appendix H, *Groundwater Technical Appendix*. The groundwater modeling estimated that for a long-term average year, the project-wide quantities of water pumped would be 7,111,000 acre-feet (ac-ft) under the No Action Alternative, 6,847,000 ac-ft under Alternative 1, 6,577,000 ac-ft under Alternative 2, 6,598,000 ac-ft under Alternative 3, and 7,137,000 ac-ft under Alternative 4.

The quantities of water pumped estimated by the groundwater modeling were converted to the amounts of energy required and the result was multiplied by emission factors to derive annual emissions. The amount of energy required to pump water varies widely due to several factors, among them the depth to groundwater (the amount of lift) that the pump has to overcome, which varies greatly spatially; the design of the well; the efficiency of the pump engine or motor; and the efficiency of the pump itself. A reasonable range for the average amount of energy required in California is 400 to 1,200 kilowatt-hours per acre-foot (Kwh/ac-ft) (CEC 2015). For this analysis the midpoint of the range (800 Kwh/ac-ft) was assumed.

For an electric pump, the energy requirement of 800 Kwh/ac-ft represents the electricity usage at the pump motor. There are energy losses in the electric distribution system from the powerplant to the motor, so that in order to deliver a particular amount of energy to the pump, the powerplant must generate slightly more energy. The California statewide average loss rate is approximately 4.23% (USEPA 2018). The energy requirements for electric pumps were adjusted by this percentage for this analysis. The resulting emissions from fossil-fueled powerplants were calculated in the same way as explained above, using the number of acre-feet of water pumped, the adjusted energy requirement, the fraction of pumps that are electric (85%), and the emission factors listed in Table L.2-2.

For an engine-powered pump, the energy requirement of 800 Kwh/ac-ft represents the energy supplied to the pump by the engine, and is expressed in horsepower-hours per acre-foot (hp-hr/ac-ft). As noted above, approximately 15% of groundwater pumps are powered by engines: 13% diesel-fueled and 2% fueled by natural gas, LP gas, propane, and butane (USDA 2014). Of these fuels, diesel generally has the highest emissions, so to produce a conservative (high) estimate of emissions all engine-powered pumps were assumed to be diesel-fueled.

Table L.2-4 shows the estimated energy usage for groundwater pumping. For engines, Table L.2-4 displays the energy requirements in both kilowatt-hours per year (Kwh/yr) consistent with the unit for electric pumps, and horsepower-hours per year (hp-hr/yr) consistent with the emission factor unit in Table L.2-4 for engines.

Table L.2-4. Estimated Energy Usage for Groundwater Pumping

Energy Source	Unit	No Action	Alt 1	Alt 2	Alt 3	Alt 4
Electric pumps (energy at powerplant)	Kwh/yr	5,040,094,139	4,852,660,662	4,661,214,163	4,676,309,490	5,058,617,807
Pump engines (energy at pump)	Kwh/yr	853,332,416	821,598,275	789,184,693	791,740,465	856,468,637
	hp-hr/yr	1,144,318,770	1,101,763,286	1,058,296,673	1,061,723,963	1,148,524,442
Sum	Kwh/yr	5,893,426,556	5,674,258,937	5,450,398,855	5,468,049,955	5,915,086,444

Source: Appendix H, Groundwater Technical Appendix.
Water quantities were converted to energy usage using an average rate of 800 Kwh/ac-ft (CEC 2015).
Alt = Alternative
Kwh/ac-ft = kilowatt-hours per acre-foot
Kwh/yr = kilowatt-hours per year
hp-hr/yr = horsepower-hours per year

The energy usage for groundwater pumping shown in Table L.2-4 was multiplied by the emission factors shown in Table L.2-2 to derive annual emissions. Emission factors given in Table L.2-2 for engines were obtained from the ARB-approved CalEEMod model (SCAQMD 2017). CalEEMod provides emission factors specific to calendar year and horsepower range, and the values corresponding to 2019 and an average pump rating of 96 horsepower (USDA 2014) were used in this analysis.

Table L.2-5 shows the estimated emissions from groundwater pumping. Figure L.2-5, Emissions from Groundwater Pumping, and Figure L.2-4, Changes in Emissions from Groundwater Pumping Compared to the No Action Alternative, show the emissions of each pollutant and the changes compared to the No Action Alternative for groundwater pumping, respectively.

Table L.2-5. Emissions from Groundwater Pumping

Pollutant	Emissions (U.S. tons per average year)				
	No Action	**Alt 1**	**Alt 2**	**Alt 3**	**Alt 4**
Electric Pumps					
CO	2,143	2,063	1,982	1,988	2,151
NO_x	1,197	1,153	1,107	1,111	1,201
PM_{10}	426	410	394	396	428
$PM_{2.5}$	384	370	355	356	385
ROG	185	178	171	172	186
SO_2	93	90	86	87	94
Diesel Pumps					
CO	4,351	4,189	4,024	4,037	4,367
NO_x	4,411	4,247	4,080	4,093	4,427
PM_{10}	274	264	253	254	275
$PM_{2.5}$	274	264	253	254	275
ROG	541	521	500	502	543
SO_2	8	7	7	7	8
Total Pumping Emissions[1]					
CO	6,493	6,252	6,005	6,025	6,517
NO_x	5,608	5,400	5,187	5,203	5,629
PM_{10}	700	674	647	650	703
$PM_{2.5}$	658	633	608	610	660
ROG	726	699	672	674	729
SO_2	101	97	93	94	101

[1] Sum of individual values may not equal total due to rounding.
Alt = Alternative
CO = carbon monoxide
NO_x = nitrogen oxides
PM_{10} = particulate matter of 10 microns diameter and smaller
$PM_{2.5}$ = particulate matter of 2.5 microns diameter and smaller
ROG = reactive organic gases
SO_2 = sulfur dioxide

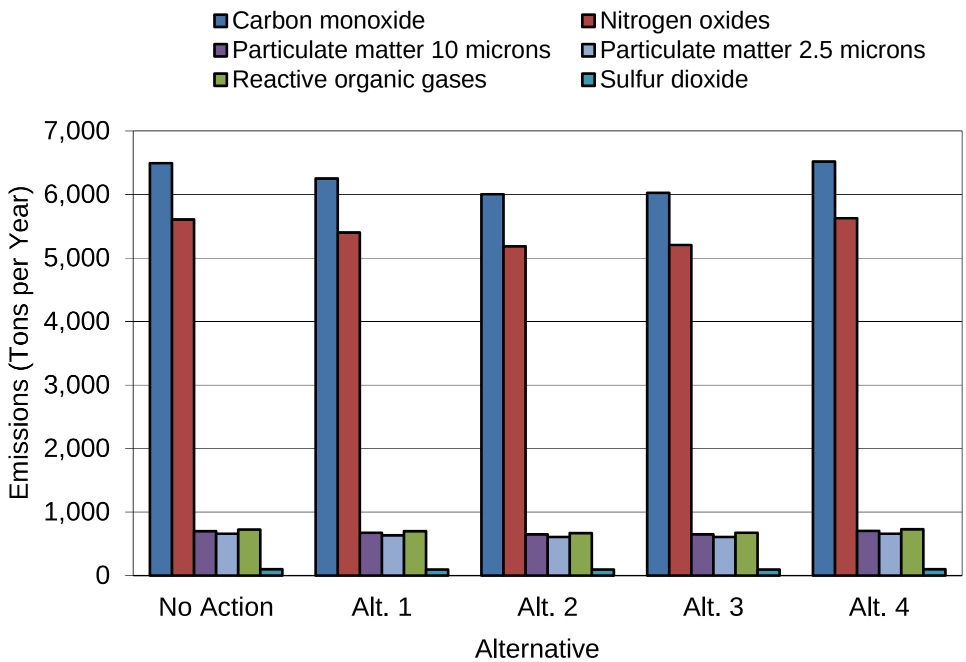

Figure L.2-3. Emissions from Groundwater Pumping

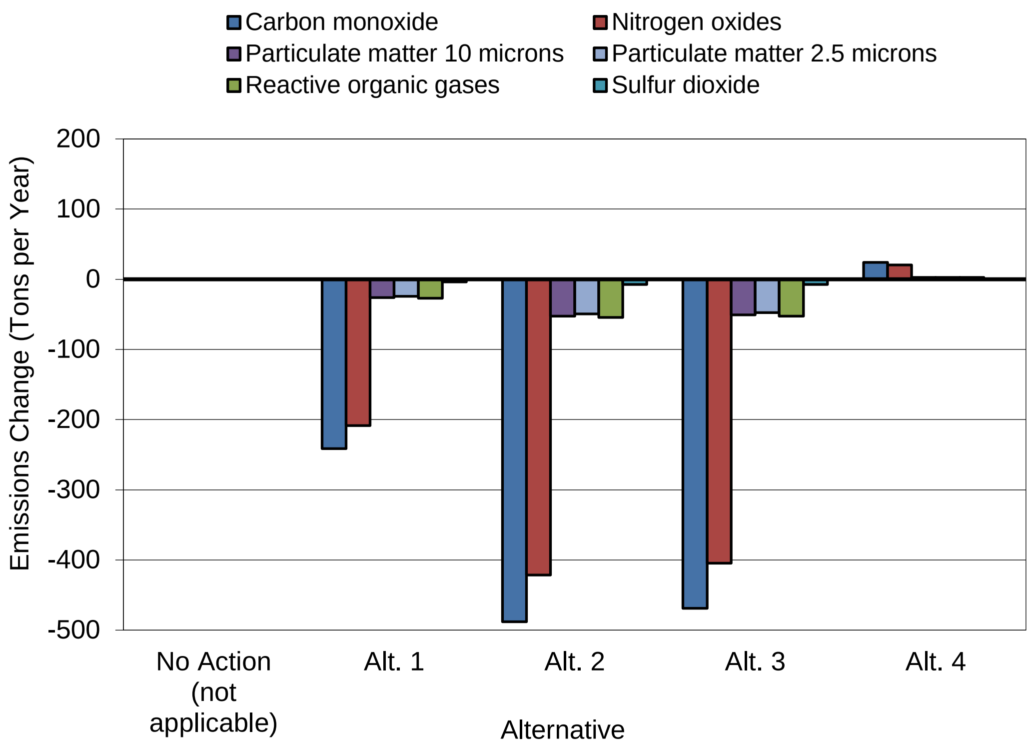

Figure L.2-4. Changes in Emissions from Groundwater Pumping Compared to the No Action Alternative

Under Alternative 1 in an average year, groundwater pumping would decrease compared to the No Action Alternative. As a result, the associated emissions also would decrease, as shown in Table L.2-5. Under Alternative 2 in an average year, groundwater pumping and emissions would decrease more than under Alternative 1. The emissions decrease under Alternative 2 would be roughly twice that under Alternative 1, compared to the No Action Alternative. Under Alternative 3 in an average year, groundwater pumping and emissions would decrease compared to the No Action Alternative. The emissions decreases under Alternative 3 would be greater than under Alternative 1 but less than under Alternative 2. In contrast to the other action alternatives, under Alternative 4 in an average year, groundwater pumping would increase compared to the No Action Alternative. As a result, the associated emissions also would increase.

The total emissions associated with the project are the sum of the emissions from net generation (Table L.2-3) and groundwater pumping (Table L.2-5). Table L.2-6 shows the estimated total project emissions for a long-term average year. Figure L.2-5, Emissions from All Sources, and Figure L.2-6, Changes in Emissions from All Sources Compared to the No Action Alternative, show the overall emissions of each pollutant for all emission sources, and the changes in emissions compared to the No Action Alternative, respectively.

Table L.2-6. Total Project Emissions

	Emissions (U.S. tons per average year)				
Pollutant	**No Action**	**Alt 1**	**Alt 2**	**Alt 3**	**Alt 4**
CO	6,452	6,597	6,754	6,749	6,360
NO_x	5,585	5,592	5,605	5,608	5,541
PM_{10}	692	743	796	794	671
$PM_{2.5}$	650	695	743	740	632
ROG	723	729	736	736	715
SO_2	99	112	126	125	94

Values represent the sum of emissions from fossil-fueled powerplants (for CVP/SWP purchases of grid power and for electrically-powered groundwater pumps) and emissions from diesel engines (for engine-powered groundwater pumps).
Alt = Alternative
CO = carbon monoxide
NO_x = nitrogen oxides
PM_{10} = particulate matter of 10 microns diameter and smaller
$PM_{2.5}$ = particulate matter of 2.5 microns diameter and smaller
ROG = reactive organic gases
SO_2 = sulfur dioxide

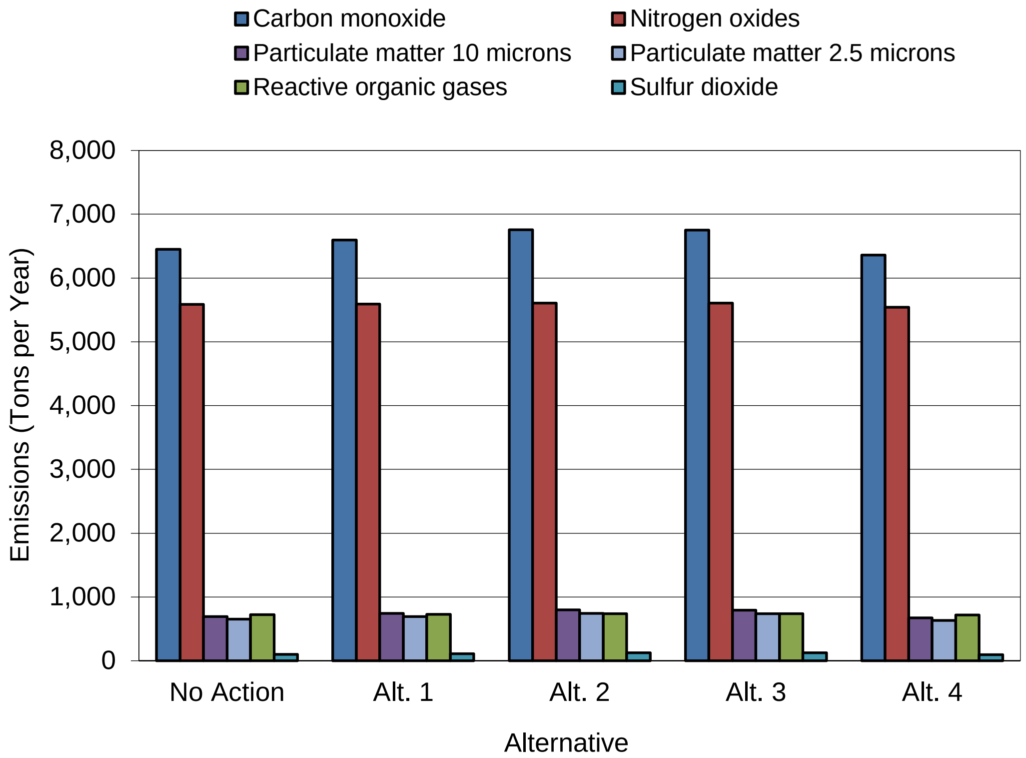

Figure L.2-5. Emissions from All Sources

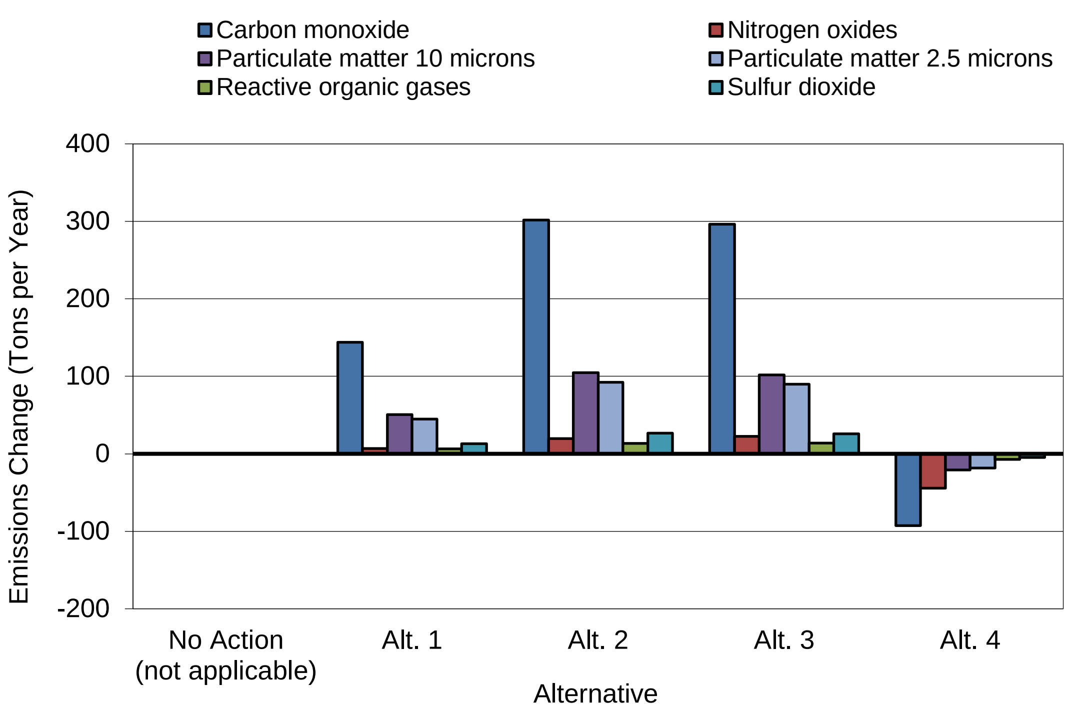

Figure L.2-6. Changes in Emissions from All Sources Compared to the No Action Alternative

Under Alternative 1 in an average year, overall emissions would increase compared to the No Action Alternative, as shown in Table L.2-6. Under Alternative 2 in an average year, emissions would increase more than under Alternative 1. Under Alternative 3 in an average year, emissions would increase compared to the No Action Alternative. The emissions increases under Alternative 3 would be greater than under Alternative 1 but less than under Alternative 2. In contrast to the other action alternatives, under Alternative 4 in an average year, overall emissions would decrease compared to the No Action Alternative.

Potential for exhaust emissions from engines of construction equipment and vehicles, and fugitive particulate matter (dust) from the action of tires on the ground surface. Exposed earth surfaces and material stockpiles also could produce fugitive dust emissions from wind action

Because the details of construction and transport activities are unknown at present, construction-related impacts were assessed qualitatively. Construction activities would produce temporary, localized increases in emissions. These increases can be lessened through implementation of mitigation measures/best management practices (BMPs). Section L.2.6.2, *Construction*, provides a list of typical BMPs that could be implemented to reduce emissions from construction.

L.2.2 No Action Alternative

Under the No Action Alternative, the actions described under Alternatives 1 through Alternative 4 would not take place. The CVP/SWP system would continue to be managed in accordance with current plans and programs. The population of the regional study area is expected to grow over time. Development in the region to accommodate the population growth, including residential, commercial, industrial, transportation, and other projects, would continue under the No Action Alternative and result in associated effects on air quality. These effects would contribute to regional air quality conditions. Air quality plans and emission control programs administered by the State and the respective air quality management districts are expected to result in slowly improving air quality over time despite the effects of regional growth and development.

L.2.3 Alternative 1

The potential air quality effects of Alternative 1 are described in the following sections.

L.2.3.1 *Project-Level Effects.*

Potential changes in emissions from fossil-fueled powerplants (hydropower generation)

Under Alternative 1, CVP/SWP-Wide Actions could have air quality effects to the extent that Shasta Critical Determinations would result in reduced releases to contractors in critical years, which could reduce hydropower generation, leading to increases in grid power generation and the associated emissions. Estimated increases in emissions for an average year are included in Table L.2-3.

Actions in the upper Sacramento Trinity/Clear Creek, Feather River, American River, Stanislaus, and Bay-Delta regions, and actions associated with operations, could increase or decrease releases and flows, depending on conditions in a particular region, year, and season. Hydropower generation could change accordingly, leading to either increases or decreases in emissions. Under Alternative 1 in an average year, net generation would decrease compared to the No Action Alternative. As a result, emissions from fossil-fueled powerplants would increase compared to the No Action Alternative, as shown in Table L.2-3.

If the Summer-Fall Delta Smelt Habitat action includes operations of the SMSCG or a Fall X2 action, the water requirements in summer and fall could be greater than estimated for Alternative 1. Increased water releases could increase the amount of hydropower generated and decrease the demand for grid electricity and the associated emissions. Alternative 1 estimates increased emissions compared to the No Action Alternative. In years with operations of the SMSCG or a Fall X2 action, actual emissions may be less than those estimated in Table L.2-3.

Fish intervention actions would not change the amount of hydropower generation, so there would be no change in emissions due to these actions under Alternative 1.

There would be no project-level effects on hydropower generation associated with actions in the San Joaquin River region or with habitat restoration or facility improvements actions under Alternative 1.

Potential changes in emissions from fossil-fueled powerplants (groundwater pumping)

CVP/SWP-wide actions could have air quality effects to the extent that Shasta Critical Determinations would result in reduced releases to contractors in critical years, which could reduce the amount of available irrigation water and lead to increased groundwater pumping and the associated emissions. Such emissions increases from these actions would be included within the overall decreases shown in Table L.2-5.

Actions in the upper Sacramento River, Trinity/Clear Creek, Feather River, American River, Stanislaus River, and Bay-Delta regions, and actions associated with operations, could increase or decrease releases and flows, depending on conditions in a particular year and season, as described above for hydropower generation. The amount of groundwater pumping could change accordingly, leading to either increases or decreases in emissions. Under Alternative 1 in an average year, groundwater pumping would decrease compared to the No Action Alternative. As a result, the associated emissions also would decrease, as shown in Table L.2-5.

If the Summer-Fall Delta Smelt Habitat action includes operations of the SMSCG or a Fall X2 action, the water requirements in summer and fall could be greater than estimated for Alternative 1. Increased water releases could increase the amount of available irrigation water and lead to decreased groundwater pumping and the associated emissions. Alternative 1 estimates decreased emissions from groundwater pumping actions compared to the No Action Alternative. In years with operations of the SMSCG or a Fall X2 action, actual emissions may be less than those estimated in Table L.2-4.

Fish intervention actions would not change the amount of groundwater pumping, so there would be no change in emissions due to these actions under Alternative 1.

There would be no project-level effects on groundwater pumping associated with actions in the San Joaquin River region or with habitat restoration or facility improvements actions under Alternative 1.

Potential for exhaust and fugitive dust emissions from construction equipment and vehicles.

Under Alternative 1 there would be no construction associated with project-level actions, and therefore, no air quality effects.

L.2.3.2 *Program-Level Effects*

Potential changes in emissions from fossil-fueled powerplants (hydropower generation)

There would be no program-level effects on hydropower generation associated with actions under Alternative 1, and therefore, no air quality effects.

Potential changes in emissions from fossil-fueled powerplants (groundwater pumping)

There would be no program-level effects on groundwater pumping associated with actions under Alternative 1, and therefore, no air quality effects.

Potential changes in emissions from fossil-fueled powerplants (water transfers)

There would be no program-level effects on water transfers associated with actions under Alternative 1, and therefore, no air quality effects.

Potential for exhaust and fugitive dust emissions from construction equipment and vehicles

Program-level actions that include construction or repair of facilities or the transport of fish or materials are proposed in the upper Sacramento River, American River, Stanislaus River, and San Joaquin River regions, as well as for habitat restoration, facility improvements, and fish intervention actions. The details of construction currently are not known in sufficient detail to estimate emissions. Potential construction impacts would not be expected to lead to new exceedance of the CAAQS or NAAQS or to worsen existing exceedances if appropriate BMPs are implemented. Section L.2.6.2 provides a list of typical BMPs that could be implemented to reduce emissions from construction.

There would be no program-level CVP/SWP-wide actions, and no program-level actions in the Trinity/Clear Creek, Feather River, and Bay-Delta regions.

L.2.4 Alternative 2

The potential air quality effects of Alternative 2 are described in the following sections.

L.2.4.1 *Project-Level Effects*

Potential changes in emissions from fossil-fueled powerplants (hydropower generation)

Under Alternative 2, CVP/SWP-wide actions could have air quality effects to the extent that Shasta Critical Determinations would result in reduced releases to contractors in critical years, which could reduce the amount of hydropower generated and increase the demand for grid electricity and the associated emissions. Estimated increases in emissions for an average year are included in Table L.2-3.

Actions in the upper Sacramento River, Trinity/Clear Creek, Feather River, American River, Stanislaus River, and Bay-Delta regions, and actions associated with operations, could increase or decrease releases and flows, depending on conditions in a particular region, year, and season. Hydropower generation could change accordingly, leading to either increases or decreases in emissions. Under Alternative 2 in an average year, net generation would decrease compared to the No Action Alternative. As a result, emissions from fossil-fueled powerplants would increase compared to the No Action Alternative, as shown in Table L.2-3.

There would be no project-level effects on hydropower generation associated with actions in the San Joaquin River region under Alternative 2.

Potential changes in emissions from fossil-fueled powerplants (groundwater pumping)

CVP/SWP-wide actions could have air quality effects to the extent that Shasta Critical Determinations would result in reduced releases to contractors in critical years, which could reduce the amount of available irrigation water and lead to increased groundwater pumping and the associated emissions. Such emissions increases from these actions would be included within the overall decreases shown in Table L.2-5.

Actions in the upper Sacramento River, Trinity/Clear Creek, Feather River, American River, Stanislaus River, and Bay-Delta regions could increase or decrease releases and flows, depending on conditions in a particular year and season, as described above for hydropower generation. The amount of groundwater pumping could change accordingly, leading to either increases or decreases in emissions. Under Alternative 2 in an average year, groundwater pumping would decrease compared to the No Action Alternative. As a result, the associated emissions also would decrease, as shown in Table L.2-5.

There would be no project-level effects on groundwater pumping associated with actions in the San Joaquin River region under Alternative 2.

Potential changes in emissions from fossil-fueled powerplants (water transfers)

Under Alternative 2, the quantity of water transferred would be the same as under the No Action Alternative, so there would be no change in emissions associated with water transfers.

Potential for exhaust and fugitive dust emissions from construction equipment and vehicles

Under Alternative 2 there would be no construction associated with project-level actions, and therefore, no air quality effects.

L.2.4.2 *Program-Level Effects*

Potential changes in emissions from fossil-fueled powerplants (hydropower generation)

There would be no program-level actions under Alternative 2, and therefore, no air quality effects.

Potential changes in emissions from fossil-fueled powerplants (groundwater pumping)

There would be no program-level actions under Alternative 2, and therefore, no air quality effects.

Potential changes in emissions from fossil-fueled powerplants (water transfers)

There would be no program-level actions under Alternative 2, and therefore, no air quality effects.

Potential for exhaust and fugitive dust emissions from construction equipment and vehicles

There would be no program-level actions under Alternative 2, and therefore, no air quality effects.

L.2.5 Alternative 3

The potential air quality effects of Alternative 3 are described in the following sections.

L.2.5.1 *Project-Level Effects*

Potential changes in emissions from fossil-fueled powerplants (hydropower generation)

Under Alternative 3, CVP/SWP-wide actions could have air quality effects to the extent that Shasta Critical Determinations would result in reduced releases to contractors in critical years, which could reduce the amount of hydropower generated and increase the demand for grid electricity and the associated emissions. Estimated increases in emissions for an average year are included in Table L.2-3.

Actions in the upper Sacramento River, Trinity/Clear Creek, Feather River, American River, Stanislaus, and Bay-Delta regions, and actions associated with operations, could increase or decrease releases and flows, depending on conditions in a particular region, year, and season. Hydropower generation could change accordingly, leading to either increases or decreases in emissions. Under Alternative 3 in an average year, net generation would decrease compared to the No Action Alternative. As a result, emissions from fossil-fueled powerplants would increase compared to the No Action Alternative, as shown in Table L.2-3.

Fish intervention actions would not change the amount of hydropower generation, so there would be no change in emissions due to these actions under Alternative 3.

There would be no project-level effects on hydropower generation associated with actions in the San Joaquin River region or with habitat restoration or facility improvements actions under Alternative 3.

Potential changes in emissions from fossil-fueled powerplants (groundwater pumping)

CVP/SWP-wide actions could have air quality effects to the extent that Shasta Critical Determinations would result in reduced releases to contractors in critical years, which could reduce the amount of available irrigation water and lead to increased groundwater pumping and the associated emissions. Such emissions increases from these actions would be included within the overall decreases shown in Table L.2-5.

Actions in the upper Sacramento River, Trinity/Clear Creek, Feather River, American River, Stanislaus River, and Bay-Delta regions, and actions associated with operations, could increase or decrease releases and flows, depending on conditions in a particular year and season, as described above for hydropower generation. The amount of groundwater pumping could change accordingly, leading to either increases or decreases in emissions. Under Alternative 3 in an average year, groundwater pumping would decrease compared to the No Action Alternative. As a result, the associated emissions also would decrease, as shown in Table L.2-5.

Fish intervention actions would not change the amount of groundwater pumping, so there would be no change in emissions due to these actions under Alternative 3.

There would be no project-level effects on groundwater pumping associated with actions in the San Joaquin River region or with habitat restoration or facility improvements actions.

Potential changes in emissions from fossil-fueled powerplants (water transfers)

Under Alternative 3, the quantity of water transferred would be the same as under the No Action Alternative, so there would be no change in emissions associated with water transfers.

L.2.5.2 *Program-Level Effects*

Potential changes in emissions from fossil-fueled powerplants (hydropower generation)

There would be no program-level effects on hydropower generation associated with actions under Alternative 3, and therefore, no air quality effects.

Potential changes in emissions from fossil-fueled powerplants (groundwater pumping)

There would be no program-level effects on groundwater pumping associated with actions under Alternative 3, and therefore, no air quality effects.

Potential changes in emissions from fossil-fueled powerplants (water transfers)

There would be no program-level effects on water transfers associated with actions under Alternative 3, and therefore, no air quality effects.

Potential for exhaust and fugitive dust emissions from construction equipment and vehicles

Program-level actions that include construction or repair of facilities or the transport of fish or materials are proposed in the upper Sacramento River, American River, Stanislaus River, and San Joaquin River regions, as well as for habitat restoration, facility improvements, and fish intervention actions. The details of construction currently are not known in sufficient detail to estimate emissions. Potential construction impacts would not be expected to lead to new exceedances of the CAAQS or NAAQS or to worsen existing exceedances if appropriate mitigation/BMPs are implemented. Section L.2.6.2 provides a list of typical BMPs that could be implemented to reduce emissions from construction.

There would be no program-level actions that include construction of facilities or the transport of fish or materials in the Bay-Delta regions.

There would be no program-level CVP/SWP-wide actions, and no program-level actions in the Trinity/Clear Creek or Feather River regions.

L.2.6 Alternative 4

The potential air quality effects of Alternative 4 are described in the following sections.

L.2.6.1 *Project-Level Effects*

Potential changes in emissions from fossil-fueled powerplants (hydropower generation)

Under Alternative 4, CVP/SWP-wide actions could have air quality effects to the extent that Shasta Critical Determinations would result in reduced releases to contractors in critical years, which could reduce the amount of hydropower generated and increase the demand for grid electricity and the associated emissions. Such emissions increases from these actions would be included within the overall decreases in an average year, as shown in Table L.2-3.

Actions in the upper Sacramento River, Trinity/Clear Creek, Feather River, American River, Stanislaus, and Bay-Delta regions, and actions associated with operations, could increase or decrease releases and flows, depending on conditions in a particular region, year, and season. Hydropower generation could change accordingly, leading to either increases or decreases in emissions. Under Alternative 4 in an average year, net generation would increase compared to the No Action Alternative. As a result, emissions from fossil-fueled powerplants would decrease compared to the No Action Alternative, as shown in Table L.2-3.

There would be no project-level effects on hydropower generation associated with actions in the San Joaquin River region under Alternative 4.

Potential changes in emissions from fossil-fueled powerplants (groundwater pumping)

CVP/SWP-wide actions could have air quality effects to the extent that Shasta Critical Determinations would result in reduced releases to contractors in critical years, which could reduce the amount of available irrigation water and lead to increased groundwater pumping and the associated emissions. Estimated increases in emissions are included in Table L.2-5.

Actions in the upper Sacramento River, Trinity/Clear Creek, Feather River, American River, Stanislaus River, and Bay-Delta regions, and actions associated with operations, could increase or decrease releases and flows, depending on conditions in a particular year and season, as described above for hydropower generation. The amount of groundwater pumping could change accordingly, leading to either increases or decreases in emissions. Under Alternative 4 in an average year, groundwater pumping would increase compared to the No Action Alternative. As a result, the associated emissions also would increase, as shown in Table L.2-5.

There would be no project-level effects on groundwater pumping associated with actions in the San Joaquin River region under Alternative 4.

Potential changes in emissions from fossil-fueled powerplants (water transfers)

Under Alternative 4, the quantity of water transferred would be the same as under the No Action Alternative, so there would be no change in emissions associated with water transfers.

L.2.6.2 *Program-Level Effects*

Potential changes in emissions from fossil-fueled powerplants (hydropower generation)

There would be no program-level effects on hydropower generation associated with actions under Alternative 4, and therefore, no air quality effects.

Potential changes in emissions from fossil-fueled powerplants (groundwater pumping)

There would be no program-level effects on groundwater pumping associated with actions under Alternative 4, and therefore, no air quality effects.

Potential changes in emissions from fossil-fueled powerplants (water transfers)

There would be no program-level effects on water transfers associated with actions under Alternative 4, and therefore, no air quality effects.

Potential for exhaust and fugitive dust emissions from construction equipment and vehicles

Program-level actions to increase water use efficiency for CVP and SWP contractors south of the Delta include construction actions. The details of construction currently are not known in sufficient detail to estimate emissions. Potential construction impacts would not be expected to lead to new exceedances of the CAAQS or NAAQS or to worsen existing exceedances if appropriate mitigation/BMPs are implemented. Section L.2.7.2 provides a list of typical BMPs that could be implemented to reduce emissions from construction.

There would be no program-level actions in the upper Sacramento, Trinity/Clear Creek, Feather River, American River, Stanislaus River, San Joaquin River, or Bay-Delta regions.

L.2.7 Mitigation Measures

L.2.7.1 *Energy*

Grid-generated electric power comprises the output of numerous powerplants across California and in other states, and no specific powerplant can be associated with power purchased by CVP/SVP. Fossil-fueled powerplants are subject to the air quality permitting requirements of the air quality management district in which they are located. To obtain a permit, the plant must demonstrate to the satisfaction of the district that its maximum air quality impacts will not exceed the CAAQS or NAAQS. The plant also may be required to comply with USEPA requirements for Best Available Control Technology or Lowest Achievable Emissions Rate. Therefore, no additional mitigation is proposed for energy-related air quality impacts.

Groundwater pump engines produce exhaust emissions that potentially can affect air quality in the local area around the pump. Pump engines are subject to USEPA and CARB emissions standards for criteria pollutants. Most pump engines are relatively small (less powerful than a typical automobile engine) and usually are located in agricultural areas without dense development in the immediate vicinity. Therefore, human exposure to pump engine exhaust is expected to be low, and no mitigation is proposed.

L.2.7.2 *Construction*

Mitigation measures are recommended to minimize potential air quality impacts from construction activities. The following are common mitigation measures that may be applicable depending on the activity and the equipment being used. These or similar measures are often required by air quality management districts and local jurisdictions to minimize construction air quality impacts.

L.2.7.2.1 Measures to Minimize Generation of Fugitive Dust

Mitigation Measure AQ-1: Develop and Implement a Fugitive Dust Control Plan

Mitigation Measure AQ-2: Pave, Apply Gravel, or Otherwise Stabilize the Surfaces of Access Roads

Mitigation Measure AQ-3: Apply Water or Dust Palliatives to Access Roads as Necessary during High Wind Conditions

Mitigation Measure AQ-4: Post and Enforce Speed Limits on Unpaved Access Roads

Mitigation Measure AQ-5: Stage Activities to Limit the Area of Disturbed Soils Exposed at Any One Time

Mitigation Measure AQ-6: Water, Stabilize, or Cover Disturbed or Exposed Earth Surfaces and Stockpiles of Dust-Producing Materials, As Necessary

Mitigation Measure AQ-7: Install Wind Fences around Disturbed Earth Areas if Windborne Dust Is Likely to Affect Sensitive Areas beyond the Site Boundaries (e.g., Nearby Residences)

Mitigation Measure AQ-8: Cover the Cargo Areas of Vehicles Transporting Loose Materials

Mitigation Measure AQ-9: Inspect and Clean Dirt from Vehicles, As Necessary, at Access Road Exits to Public Roadways

Mitigation Measure AQ-10: Remove from Public Roadways Visible Trackout or Runoff Dirt from the Activity Site (e.g., Using Street Vacuum Sweeping)

L.2.7.2.2 Measures to Minimize Exhaust Emissions

Mitigation Measure GHG-1: Minimize Potential Increases in GHG Emissions from Exhaust Associated with Construction Activities

L.2.8 Summary of Impacts

Table L.2-7 shows a summary of impacts and potential mitigation measures for consideration.

Table L.2-7. Impact Summary

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
Potential changes in hydropower generation could affect emissions from fossil-fueled powerplants (Project-Level)	No Action	No impact	Not applicable
	1	Increase in emissions compared to No Action Alternative.	None proposed
	2	Increase in emissions compared to No Action Alternative. Greater increase than under Alternative 1.	None proposed
	3	Increase in emissions compared to No Action Alternative. Greater increase than under Alternative 1 but less than under Alternative 2.	None proposed

Impact	**Alternative**	**Magnitude and Direction of Impacts**	**Potential Mitigation Measures**
	4	Decrease in emissions compared to No Action Alternative.	None proposed
Potential changes in the amount of groundwater pumping could affect emissions from fossil-fueled powerplants (Project-Level)	No Action	No impact	Not applicable
	1	Decrease in emissions compared to No Action Alternative.	None proposed
	2	Decrease in emissions compared to No Action Alternative. Greater decrease than under Alternative 1.	None proposed
	3	Decrease in emissions compared to No Action Alternative. Greater decrease than under Alternative 1 but less than under Alternative 2.	None proposed
	4	Increase in emissions compared to No Action Alternative.	None proposed
Potential changes in pumping for water transfers could affect emissions from fossil-fueled powerplants (Project-Level)	No Action	No impact	Not applicable
	1	Impact is included within that of changes in hydropower generation and grid emissions above.	None proposed
	2	Impact is included within that of changes in hydropower generation and grid emissions above.	None proposed
	3	Impact is included within that of changes in hydropower generation and grid emissions above.	None proposed
	4	Impact is included within that of changes in hydropower generation and grid emissions above.	None proposed
Combined impact of hydropower generation, grid emissions, groundwater pumping, and water transfers (Project-Level)	1	Increase in emissions compared to No Action Alternative.	None proposed
	2	Increase in emissions compared to No Action Alternative. Greater increase than under Alternative 1.	None proposed

Impact	**Alternative**	**Magnitude and Direction of Impacts**	**Potential Mitigation Measures**
	3	Increase in emissions compared to No Action Alternative. Greater increase than under Alternative 1 but less than under Alternative 2.	None proposed
	4	Decrease in emissions compared to No Action Alternative.	None proposed
Actions that include construction of facilities or the transport of fish or materials require the use of construction equipment and vehicles, which would produce exhaust and fugitive dust emissions (Project-Level)	No Action	No impact	None proposed
	1	No impact	None proposed
	2	No impact	None proposed
	3	No impact	None proposed
	4	No impact	None proposed
Potential changes in hydropower generation could affect emissions from fossil-fueled powerplants (Program-Level)	1	No impact	Not applicable
	2	No impact	None proposed
	3	No impact	None proposed
	4	No impact	None proposed
Potential changes in the amount of groundwater pumping could affect emissions from fossil-fueled powerplants (Program-Level)	No Action	No impact	None proposed
	1	No impact	None proposed
	2	No impact	None proposed
	3	No impact	None proposed
	4	No impact	None proposed
Potential changes in pumping for water transfers could affect emissions from fossil-fueled powerplants (Program-Level)	No Action	No impact	None proposed
	1	No impact	None proposed
	2	No impact	None proposed
	3	No impact	None proposed
	4	No impact	None proposed
Combined impact of hydropower generation, grid emissions, groundwater pumping, and water transfers (Program-Level)	No Action	No impact	None proposed
	1	No impact	None proposed
	2	No impact	None proposed
	3	No impact	None proposed

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
	4	No impact	None proposed
Actions that include construction of facilities or the transport of fish or materials require the use of construction equipment and vehicles, which would produce exhaust and fugitive dust emissions (Program-Level)	1	The details of construction currently are not known in sufficient detail to estimate emissions. Potential construction impacts would not be expected to lead to exceedance of the CAAQS or NAAQS if appropriate mitigation/BMPs are implemented.	MM AQ-1–MM AQ-10
	2	No impact	None proposed
	3	The details of construction currently are not known in sufficient detail to estimate emissions. Potential construction impacts would not be expected to lead to exceedance of the CAAQS or NAAQS if appropriate mitigation/BMPs are implemented.	MM —GHG-1
	4	The details of construction currently are not known in sufficient detail to estimate emissions. Potential construction impacts would not be expected to lead to exceedance of the CAAQS or NAAQS if appropriate mitigation/BMPs are implemented.	MM AQ-1–MM AQ-10

BMP = best management practices
CAAQS = California Ambient Air Quality Standards
NAAQS = National Ambient Air Quality Standards

L.2.9 Cumulative Effects

The cumulative effects analysis considers projects, programs, and policies that are not speculative and that are based upon known or reasonably foreseeable long-range plans, regulations, operating agreements, or other information that establishes them as reasonably foreseeable. Appendix Y, *Cumulative Methodology*, presents a list of actions that could have cumulative effects.

The No Action Alternative would not result in any changes to facility operations and so would not have air quality impacts. Thus, no cumulative effects of the project on air quality would occur under the No Action Alternative.

As described above, Alternative 1 would lead to increases in regional emissions of CO, NO_x, PM_{10}, $PM_{2.5}$, ROG, and SO_2, compared to the No Action Alternative. Past, present, and reasonably foreseeable projects, described in Appendix Y, may have cumulative effects on air quality as well, to the extent that they could increase regional emissions. The cumulative projects include actions across California to develop new water storage capacity, new water conveyance infrastructure, new water recycling capacity, and the reoperation of existing water supply infrastructure, including surface water reservoirs and conveyance infrastructure. The cumulative projects also include ecosystem improvement and habitat restoration actions to improve conditions for special status species whose special status in many cases constrains water supply delivery operations. Some of the projects described in Appendix Y could increase emissions through the same mechanisms discussed above for the action alternatives, that is, if the projects lead to increases in grid power generation, groundwater pumping, and use of construction equipment and vehicles. The emissions from Alternative 1 are expected to be relatively small compared to the emissions from past, present, and reasonably foreseeable projects. Consequently, the emissions from Alternative 1, when combined with emissions from past, present, and reasonably foreseeable projects, are not expected to result in pollutant concentrations that would lead to new exceedances of the CAAQS or NAAQS or to worsen existing exceedances. Therefore, the cumulative air quality impact of Alternative 1 and past, present, and reasonably foreseeable projects would not be substantial. Accordingly, no mitigation is proposed for cumulative air quality impacts of Alternative 1.

Alternatives 2 and 3 would have cumulative impacts similar to those of the Alternative 1. Compared to the No Action Alternative and Alternative 1, Alternative 2 would result in greater emissions of CO, NO_x, PM_{10}, $PM_{2.5}$, ROG, and SO_2. Alternative 3 also would result in greater emissions of these pollutants compared to the No Action Alternative and Alternative 1, but the increases would be less than under Alternative 2. As with Alternative 1, the emissions from Alternatives 2 and 3 are expected to be relatively small compared to the emissions from past, present, and reasonably foreseeable projects. Consequently, the cumulative air quality impacts of Alternatives 2 and 3 along with past, present, and reasonably foreseeable projects are not expected to lead to new exceedances of the CAAQS or NAAQS or to worsen existing exceedances. Therefore, the cumulative air quality impact of Alternatives 2 and 3 and past, present, and reasonably foreseeable projects would not be substantial. Accordingly, no mitigation is proposed for cumulative air quality impacts of Alternatives 2 and 3.

Alternative 4 would lead to decreases in regional emissions of CO, NO_x, PM_{10}, $PM_{2.5}$, ROG, and SO_2, compared to the No Action Alternative. Because emissions would decrease under Alternative 4, the cumulative air quality impacts of Alternative 4 along with past, present, and reasonably foreseeable projects are not expected to lead to new exceedances of the CAAQS or NAAQS or to worsen existing exceedances. Therefore the cumulative air quality impact of Alternative 4 and past, present, and reasonably foreseeable projects would not be substantial. Accordingly, no mitigation is proposed for cumulative air quality impacts of Alternative 4.

Construction air quality impacts are temporary and localized. Because of the long time horizon of the project and the large size of the study area, construction of reasonably foreseeable projects described in Appendix Y is unlikely to overlap in time and space with construction of projects under Alternatives 1, 2, 3, and 4. Therefore, the cumulative air quality impacts of construction under Alternatives 1, 2, 3, and 4 along with past, present, and reasonably foreseeable projects are not expected to lead to new exceedances of the CAAQS or NAAQS or to worsen existing exceedances, and so would not be substantial. Accordingly, no mitigation beyond the BMPs recommended in Section 2.6.2 above is proposed for cumulative air quality impacts of Alternatives 1, 2, 3, and 4.

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Appendix M Greenhouse Gas Emissions Technical Appendix

This appendix documents the technical analysis of greenhouse gas (GHG) emissions to support the impact analysis in the EIS.

M.1 Background Information

This section presents an overview of the greenhouse effect and climate change, and potential sources of GHG emissions and information related to climate change and GHG emissions in California. GHG emissions and their climate-related impacts are not limited to specific geographic locations, but occur on global or regional scales. GHG emissions contribute cumulatively to the overall heat-trapping capability of the atmosphere, and the effects of the warming, such as climate change, are manifested in different ways across the planet.

M.1.1 Greenhouse Gas Emissions Regulations and Analyses

Global warming is the name given to the increase in the average temperature of the Earth's near-surface air and oceans since the mid-twentieth century and its projected continuation. Warming of the climate system is now considered to be unequivocal (DWR 2010) with global surface temperature increasing approximately 1.33 degrees Fahrenheit (˚F) over the last 100 years. Continued warming is projected to increase global average temperature between 2˚F and 11˚F over the next 100 years.

The causes of this global warming have been identified as both natural processes and as the result of human actions. The Intergovernmental Panel on Climate Change (IPCC) concludes that variations in natural phenomena such as solar radiation and volcanoes produced most of the warming from pre-industrial times to 1950 and had a small cooling effect afterward. However, the IPCC has concluded that human influence has warmed the global climate system after 1950, and that solar forcing, volcanoes, and internal variability are no longer the strongest drivers of warming (IPCC 2013). These basic conclusions have been endorsed by more than 45 scientific societies and academies of science, including all of the national academies of science of the major industrialized countries.

Increases in GHG concentrations in the Earth's atmosphere are thought to be the main cause of human-induced climate change. GHGs naturally trap heat by impeding the exit of solar radiation that has hit the Earth and is reflected back into space. Some GHGs occur naturally and are necessary for keeping the Earth's surface inhabitable. However, increases in the concentrations of these gases in the atmosphere during the last 100 years have decreased the amount of solar radiation that is reflected back into space, intensifying the natural greenhouse effect and resulting in the increase of global average temperature (DWR 2010).

The principal GHGs are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulfur hexafluoride (SF_6), perfluorocarbons (PFCs), and hydrofluorocarbons (HFCs), in accordance with the California Health and Safety Code Section 38505(g) (DWR 2010). This EIS considers only CO_2, CH_4, and N_2O because the project has no sources of SF_6, PFCs, or HFCs. Each of the principal GHGs has a long atmospheric lifetime (1 year to several thousand years). In addition, the potential heat-trapping ability of each of these gases varies significantly from one another, and also vary over time. For example, CH_4 is 30 times as potent as CO_2; while SF_6 is 23,500 times more potent than CO_2 with a 100-year time horizon (IPCC 2013).

For calculating emissions, the California Air Resources Board (ARB) (2018) uses a metric developed by the IPCC to account for these differences and to provide a standard basis for calculations. The metric, called the global warming potential (GWP), is used to compare the future climate impacts of emissions of various long-lived GHGs. The GWP of each GHG is indexed to the heat-trapping capability of CO_2, and allows comparison of the global warming influence of each GHG relative to CO_2. The GWP is used to translate emissions of each GHG to emissions of carbon dioxide equivalents, or CO_2e. In this way, emissions of various GHGs can be summed, and total GHG emissions can be inventoried in common units of metric tons per year of CO_2e. Most international inventories, including the United States inventory, use GWP values from the IPCC Fourth Assessment Report, per international consensus (IPCC 2007; USEPA 2012).

The primary human-made processes that release these GHGs are the burning of fossil fuels for transportation, heating, and electricity generation; agricultural practices that release CH_4, such as livestock grazing and crop residue decomposition; and industrial processes that release smaller amounts of high GWP gases such as SF_6, PFCs, and HFCs (DWR 2010). Deforestation and land cover conversion have also been identified as contributing to global warming by reducing the Earth's capacity to remove CO_2 from the air and altering the Earth's albedo or surface reflectance, allowing more solar radiation to be absorbed.

M.1.2 Overview of the Greenhouse Effect

The greenhouse effect is a natural phenomenon that is essential to keeping the Earth's surface warm (DWR 2010). Like a greenhouse window, GHGs allow sunlight to enter and then prevent heat from leaving the atmosphere. Solar radiation enters the Earth's atmosphere from space. A portion of this radiation is reflected by particles in the atmosphere back into space, and a portion is absorbed by the Earth's surface and emitted back into space. The portion absorbed by the Earth's surface and emitted back into space is emitted as lower-frequency infrared radiation. This infrared radiation is absorbed by various GHGs present in the atmosphere. While these GHGs are transparent to the incoming solar radiation, they are effective at absorbing infrared radiation emitted by the Earth's surface. Therefore, some of the lower-frequency infrared radiation emitted by the Earth's surface is retained in the atmosphere, creating a warming of the atmosphere.

M.1.2.1 *Global Climate Trends and Associated Impacts*

The rate of increase in global average surface temperature over the last 100 years has not been consistent (DWR 2010). The last three decades have warmed at a much faster rate than the previous seven decades—on average 0.32°F per decade. Nine of the 10 warmest years have occurred since 2005, with the last 5 years (2014–2018) ranking as the 5 warmest years on record (NOAA 2019).

Increased global warming has occurred concurrently with many other changes in other natural systems (DWR 2010). Global sea levels have risen on average 1.8 millimeters per year; precipitation patterns throughout the world have shifted, with some areas becoming wetter and while others become drier; tropical storm activity in the North Atlantic has increased; peak runoff timing of many glacial and snow-fed rivers has shifted earlier; as well as numerous other observed conditions. Though it is difficult to prove a definitive cause and effect relationship between global warming and other observed changes to natural systems, there is high confidence in the scientific community that these changes are a direct result of increased global temperatures.

M.1.2.2 *Overview of Greenhouse Gas Emission Sources*

Naturally occurring GHGs include water vapor, CO_2, CH_4, and N_2O. Water vapor is introduced to the atmosphere from oceans and the natural biosphere. Water vapor introduced directly to the atmosphere from agricultural or other activities is not long lived, and thus does not contribute substantially to a warming effect (NAS 2005). Carbon and nitrogen contained in CO_2, CH_4, and N_2O naturally cycle from gaseous forms to organic biomass through processes such as plant and animal respiration and seasonal cycles of plant growth and decay (USEPA 2012). Although naturally occurring, the emissions and sequestration of these gases are also influenced by human activities, and in some cases, are caused by human activities (anthropogenic). In addition to these GHGs, several classes of halogenated substances that contain fluorine, chlorine, or bromine also contribute to the greenhouse effect. However, these compounds are the product of industrial activities for the most part.

CO_2 is a byproduct of burning fossil fuels and biomass, as well as land-use changes and other industrial processes (USEPA 2012). It is the principal anthropogenic GHG that contributes to the Earth's radiative balance, and it represents the dominant portion of GHG emissions from activities that result from the combustion of fossil fuels (e.g., industry, electrical generation, and transportation).

M.1.3 California Climate Trends and Greenhouse Gas Emissions

Maximum (daytime) and minimum (nighttime) temperatures are increasing almost everywhere in California but at different rates. The annual minimum temperature averaged over all of California has increased 0.33˚F per decade during the period 1920 to 2003, while the average annual maximum temperature has increased 0.1˚F per decade (DWR 2010).

With respect to California's water resources, the most significant impacts of global warming have been changes to the water cycle and sea-level rise. Over the past century, the precipitation mix between snow and rain has shifted in favor of more rainfall and less snow, and snow pack in the Sierra Nevada is melting earlier in the spring (DWR 2010). The average early spring snowpack in the Sierra Nevada has decreased by about 10% during the last century, a loss of 1.5 million acre-feet of snowpack storage. These changes have significant implications for water supply, flooding, aquatic ecosystems, energy generation, and recreation throughout the state.

During the same period, sea levels along California's coast have risen. The Fort Point tide gauge in San Francisco was established in 1854 and is the longest continually monitored gauge in the United States. Sea levels measured at this gauge and two other West Coast gauges indicate that the sea levels have risen at an average rate of about 7.9 inches/century (0.08 inch/year) over the past 150 years (BCDC 2011). Continued sea-level rise associated with global warming may threaten coastal lands and infrastructure, increase flooding at the mouths of rivers, place additional stress on levees in the Sacramento–San Joaquin Delta (Delta), and intensify the difficulty of managing the Delta as the heart of the state's water supply system (DWR 2010).

M.1.3.1 *Potential Effects of Global Climate Change in California*

Warming of the atmosphere has broad implications for the environment. In California, one of the effects of climate change could be increases in temperature that could affect the timing and quantity of precipitation. California receives most of its precipitation in the winter months, and a warming environment would raise the elevation of snow pack and result in reduced spring snowmelt and more winter runoff. These effects on precipitation and water storage in the snow pack could have broad implications on the environment in California.

The following are some of the potential effects of a warming climate in California (California Climate Change Portal 2007):

- Loss of snowpack storage will cause increased winter runoff that generally would not be captured and stored because of the need to reserve flood capacity in reservoirs during the winter.
- Less spring runoff would mean lower early summer storage at major reservoirs, which would result in less hydroelectric power production.
- Higher temperatures and reduced snowmelt would compound the problem of providing suitable cold water habitat for salmonid species. Lower reservoir levels would also contribute to this problem, reducing the flexibility of cold water releases.
- Sea-level rise would affect the Delta, worsening existing levee problems, causing more saltwater intrusion, and adversely affecting many coastal marshes and wildlife reserves. Release of water to streams to meet water quality requirements could further reduce storage levels.
- Increased temperatures would increase the agricultural demand for water and increase the level of stress on native vegetation, potentially allowing for an increase in pest and insect epidemics and a higher frequency of large, damaging wildfires.

Future climate scenarios have also been evaluated in the U.S. Global Change Research Program National Climate Assessments. The most recent assessment, *Fourth National Climate Assessment Volume II: Impacts, Risks, and Adaptation in the United States*, was released in 2018 (USGCRP 2018). For the southwest region of the United States (defined by the National Climate Assessment as Arizona, California, Colorado, Nevada, New Mexico, and Utah), the report projects that water supply availability would be reduced compared to recent conditions due to reduced snowpack and declining stream flows. Rising temperatures in the future would increase disruptions to electricity generation, which could further reduce water availability. The National Climate Assessment also indicates that mitigation policies and other factors have lowered the United States' nationwide GHG emissions in recent years; however, substantial global emissions reductions are needed to avoid many of the predicted consequences. A considerable amount of planning for resilience and adaptation is underway, but implementation of adaptive measures has been limited in scope.

M.1.3.2 *Current California Emission Sources*

The recent California's GHG emission inventory was released on July 11, 2018. The GHG emissions in California have been estimated for each year from 2000 to 2016, and are reported for several large sectors of emission sources. The estimates for 2016 are summarized in Table M.1-1, reported by sector as metric tons per year of CO_2e (ARB 2018).

Table M.1-1 California Greenhouse Gas Emissions by Sector in 2016

Sector	Total Emissions[1] (metric tons/year of CO_2e)	Percent of Statewide Total Gross Emissions
Agriculture and Forestry	33.84	8
Commercial and Residential	51.28	12
Electric Power	68.95	16
Industrial	100.37	23
Transportation	174.01	41
Solvents and Chemicals[2]	0.79	<1
Total	429.4	100

Source: ARB 2018.
[1] Table includes human-caused GHG emissions only.
[2] Solvents and chemical use are not attributed to an individual sector.
CO_2e = carbon dioxide equivalent

Total gross statewide GHG emissions in 2016 were estimated to be 429.4 metric tons per year of CO_2e. The two largest sectors contributing to emissions in California are transportation and industrial. The agricultural sector represents only 8% of the total gross statewide emissions. The agricultural sector includes manure management, enteric fermentation, agricultural residue burning, and soils management.

The California Global Warming Solutions Act of 2006 (California Assembly Bill [AB] 32) requires California to reduce statewide emissions to 1990 levels by 2020. Executive Order EO B-30-15, signed by Governor Jerry Brown in 2015, established a goal for 2030 of reducing GHG emissions by 40% below 1990 levels.

In December 2007, in accordance with AB 32, ARB adopted an emission limit for 2020 of 427 metric tons per year of CO_2e. Increases in the statewide renewable energy portfolio and reductions in importation of coal-based electrical power will contribute to meeting California's near-term GHG emission reduction goals. The ARB estimates that a reduction of 82 million metric tons net CO_2e emissions below the business-as-usual would be required by 2020 to meet the 1990 levels (ARB 2018). This amounts to approximately a 16% reduction from projected business-as-usual levels in 2020.

M.2 Evaluation of Alternatives

This section describes the technical background for the evaluation of environmental consequences associated with the action alternatives and the No Action Alternative.

M.2.1 Methods and Tools

Potential GHG emissions impacts were assessed for each component of each alternative. Where possible, the direction (positive or negative effect on GHG emissions) and magnitude of change were identified. The predominant potential effect is changes in GHG emissions from fossil-fueled powerplants. The primary actions that could affect GHG emissions are described in this section.

Potential changes in GHG emissions from fossil-fueled powerplants (hydropower generation)

The action alternatives would change operations of the CVP and SWP, which could change river flows and reservoir levels. These changes could affect the amount of power the hydroelectric facilities in the system could generate. Where flows increase on rivers that have hydroelectric facilities then hydropower generation could increase. The additional hydroelectric power is expected to displace power that must be purchased from suppliers connected to the regional electric system (grid). To the extent that the displaced power would have been generated by fossil-fueled powerplants, emissions of GHGs from these plants would decrease. (In 2016, approximately 50% of grid electricity in California was generated by fossil-fueled plants [USEPA 2018].) Conversely, if hydropower generation decreases, the decrease must be offset by purchased power from the grid to meet demand for power. To the extent that the additional purchased power would have been generated by fossil-fueled powerplants, GHG emissions from these plants would increase.

Operations of the CVP and SWP also entail transfers of water. Many, but not all, transfers require water to be pumped. For those transfers that require pumping, changes in the quantities of water transferred could affect GHG emissions by changing the amount of electricity required. If the amount of water transferred increases, the electrical energy required for pumping also would increase. To the extent that the increased electricity would be purchased from the grid and would be generated by fossil-fueled powerplants, GHG emissions from these plants would increase. Conversely, if the amount of water transferred decreases, the electrical energy required for pumping also would decrease. To the extent that the amount of purchased electricity that is generated by fossil-fueled powerplants decreases, GHG emissions from these plants would decrease. Under Alternatives 1, 2, 3, and 4, the quantities of water transferred would be the same as under the No Action Alternative. Consequently, there would be no change in GHG emissions associated with water transfers.

GHG emissions from fossil-fueled powerplants resulting from changes in hydropower generation (including power required for water transfers), and consequently in the demand for grid power, were evaluated. Emissions of the principal GHGs (CO_2, CH_4, and N_2O) were reported as well as the CO_2e emissions for each alternative, consistent with the USEPA GHG inventory. For the details of the power modeling on which the GHG emission analysis was based, see Appendix U, *Power Technical Appendix*. The power modeling estimated energy usage in terms of *net generation*, defined as the difference between the amount of electricity generated by CVP/SWP hydropower facilities and the amount of electricity used by CVP/SWP for water transfers and facility operations. A positive value for net generation means that CVP/SWP generated more power than it used, and the excess was sold to the grid. A negative value for net generation means that CVP/SWP used more power than it generated, and offset the deficit by purchasing the additional power from the grid. Table M.2-1 summarizes the results of the power modeling and shows the estimated net generation for each alternative for a long-term average year. The GHG emissions calculations reflect net generation for the entire CVP/SWP system, as shown in the last line in the table.

Table M.2-1 Summary of Power Modeling Results

Facilities	Energy Component	Energy (Gigawatt-hours per average year)				
		No Action	Alt 1	Alt 2	Alt 3	Alt 4
CVP	Energy Generation[1]	4,533	4,539	4,609	4,610	4,489
	Energy Use[2]	1,207	1,322	1,420	1,415	1,117
	Net Generation[3]	3,326	3,217	3,189	3,195	3,372
SWP	Energy Generation[1]	4,074	4,349	4,679	4,658	3,971
	Energy Use[2]	7,304	8,377	9,630	9,557	6,972
	Net Generation[3]	-3,230	-4,028	-4,951	-4,898	-3,001
Total	Energy Generation[1]	8,607	8,888	9,288	9,269	8,459
	Energy Use[2]	8,511	9,698	11,050	10,972	8,088
	Net Generation[3]	96	-810	-1,762	-1,703	371

Source: Appendix U: Power Technical Appendix.
[1] Hydropower generated
[2] Energy used for facility operation and water transfers
[3] Net generation equals hydropower generation minus energy use. Net generation of zero would indicate that hydropower generation exactly equals energy use. Negative net generation values indicate that energy use exceeds energy generation and the additional energy needed is purchased from the grid. Positive net generation values indicate that energy generation exceeds energy use and the additional energy generated is sold to the grid.
Alt = Alternative
CVP = Central Valley Project
SWP = State Water Project
1 gigawatt-hour = 1,000 megawatt-hours = 1,000,000 kilowatt-hours

The changes in annual net generation estimated by the power modeling were multiplied by emission factors (mass of GHG emitted per unit of energy generated) to derive annual emissions. Emission factors for GHGs were obtained from the U.S. Environmental Protection Agency (USEPA) eGRID model and represent averages for the California statewide mix of powerplants in 2016, which is the most recent year of data available (USEPA 2018). Table M.2-2 lists the emission factors that were used in the GHG emission analysis.

Table M.2-2 Emission Factors Used in GHG Emission Analysis

Pollutant	Electric Generation (lb/Mwh)	Diesel Pump Engines (g/hp-hr)
CO_2	452.541	568.299
CH_4	0.026	0.038
N_2O	0.003	0.0038
CO_2e	454.085	570.372

Sources: USEPA 2018; SCAQMD 2017.
g/hp-hr = grams per horsepower-hour
lb/Mwh = pounds per megawatt-hour
CO_2 = carbon dioxide
CH_4 = methane
N_2O = nitrous oxide
CO_2e = carbon dioxide equivalent

Table M.2-3 shows the estimated GHG emissions from fossil-fueled grid powerplants associated with net generation, based on the net generation values given in Table M.2-1. Figure M.2-1, *GHG Emissions from Grid Power Generation*, and Figure M.2-2, *Changes in GHG Emissions from Grid Power Generation Compared to the No Action Alternative*, show the emissions of CO_2e for grid power generation and the changes compared to the No Action Alternative, respectively.

Table M.2-3 GHG Emissions from Net Generation

Pollutant	Emissions (metric tons per average year)				
	No Action	**Alt 1**	**Alt 2**	**Alt 3**	**Alt 4**
CO_2	-19,773.8	166,348.9	361,605.9	349,615.7	-76,113.0
CH_4	-1.1	9.6	20.8	20.1	-4.4
N_2O	-0.1	1.1	2.4	2.3	-0.5
CO_2e	-19,841.2	166,916.5	362,839.6	350,808.6	-76,372.7

Values represent the GHG emissions effects of net generation, that is, CVP/SWP hydropower generation minus CVP/SVP energy use. Emissions of zero would indicate that CVP/SWP hydropower generation exactly equals CVP/SWP energy use. Negative emission values indicate decreases in GHG emissions because net generation is positive and displaces grid power; positive emission values indicate increases in GHG emissions because net generation is negative and CVP/SWP purchases the needed power from the grid.
Alt = Alternative
CO_2 = carbon dioxide
CH_4 = methane
N_2O = nitrous oxide
CO_2e = carbon dioxide equivalent

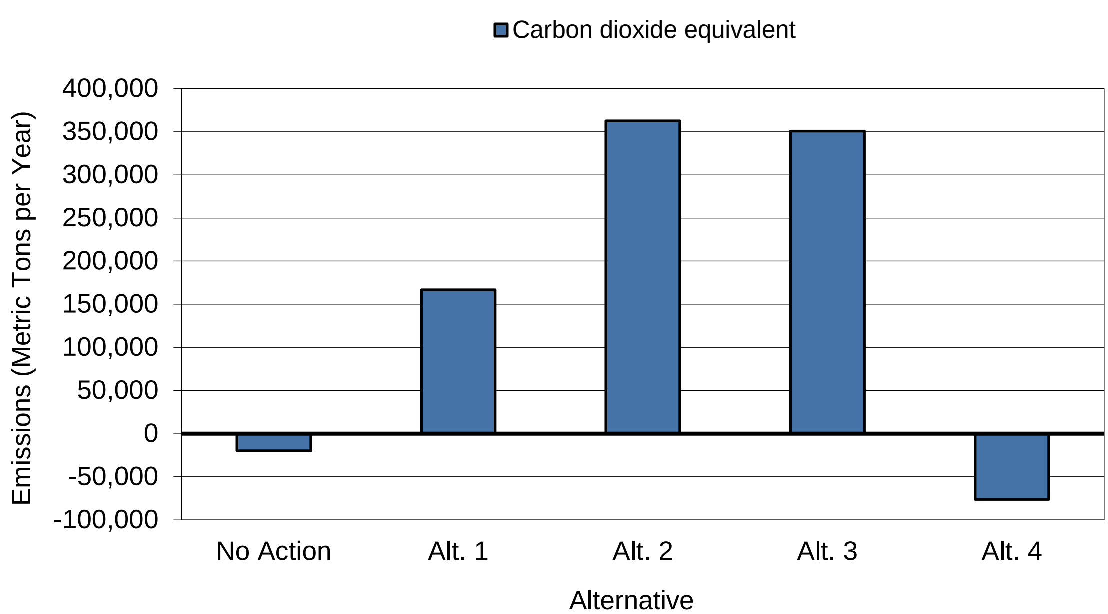

Figure M.2-1 GHG Emissions from Grid Power Generation

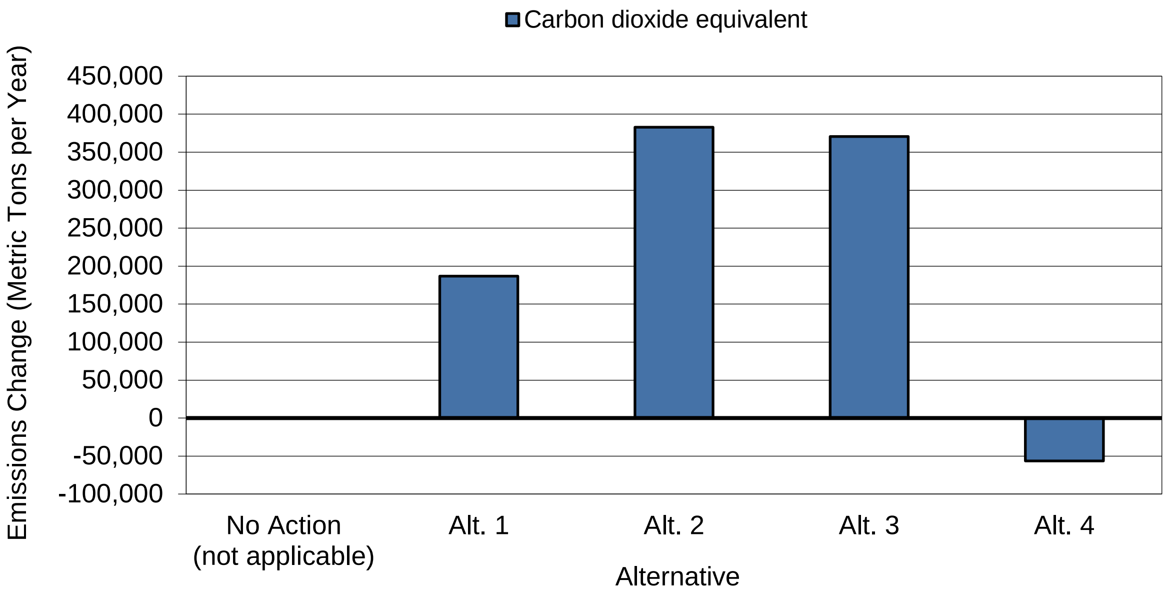

Figure M.2-2 Changes in GHG Emissions from Grid Power Generation Compared to the No Action Alternative

Under Alternative 1 in an average year, net generation would decrease compared to the No Action Alternative, as shown in Table M.2-1. As a result, GHG emissions from fossil-fueled grid powerplants would increase, as shown in Table M.2-3. Under Alternative 2 in an average year, net generation would decrease more than under Alternative 1 and GHG emissions would increase more. The GHG emissions increase under Alternative 2 would be roughly twice that under Alternative 1, compared to the No Action Alternative. Under Alternative 3 in an average year, net generation would decrease and GHG emissions would increase compared to the No Action Alternative. The GHG emissions increases under Alternative 3 would be greater than under Alternative 1 but less than under Alternative 2. In contrast with the other action alternatives, under Alternative 4 in an average year, net generation would increase compared to the No Action Alternative. As a result, GHG emissions from fossil-fueled grid powerplants would decrease.

Potential changes in emissions from fossil-fueled powerplants (groundwater pumping)

The action alternatives would change operation of the CVP and SWP, which could change river flows and reservoir levels. These changes could affect the amount of water available for agricultural irrigation. If surface water availability decreases, farmers could make up the difference in water supply by increasing groundwater pumping. Approximately 85% of groundwater pumps are electric (USDA 2014), so increased pumping would increase the demand for grid power. To the extent that the additional purchased power would be generated by fossil-fueled powerplants, GHG emissions from these plants would increase. Although the specific power purchases that the CVP and SVP may make in the future are not known, approximately 50% of the grid electricity in California was generated by fossil-fueled plants in 2016. Approximately 15% of groundwater pumps are powered by engines (USDA 2014), so increased use of these pumps would increase GHGs from engine exhaust emissions. Conversely, if surface water availability increases, farmers could decrease the amount of groundwater they pump, which would lead to a decrease in GHG emissions.

GHG emissions from the fossil-fueled powerplants (for electrically-powered pumps) and GHG emissions from engines (for engine-powered pumps) resulting from changes in groundwater pumping were evaluated. Emissions of the principal GHGs (CO_2, CH_4, and N_2O) were reported as well as the CO_2e emissions for each alternative, consistent with the USEPA GHG inventory. For the details of the groundwater modeling on which the GHG emission analysis was based, see Appendix I, *Groundwater Technical Appendix*. The groundwater modeling estimated that for a long-term average year, the quantities of water pumped would be 7,111,000 acre-feet under the No Action Alternative, 6,847,000 acre-feet under Alternative 1, 6,577,000 acre-feet under Alternative 2, 6,598,000 acre-feet under Alternative 3, and 7,137,000 acre-feet under Alternative 4.

The quantities of water pumped estimated by the groundwater modeling were converted to the amounts of energy required and the result was multiplied by emission factors to derive annual GHG emissions. The amount of energy required to pump water varies widely due to several factors, among them the depth to groundwater (the amount of lift) that the pump has to overcome, which varies greatly spatially; the design of the well; the efficiency of the pump engine or motor; and the efficiency of the pump itself. A reasonable range for the average amount of energy required in California is 400 to 1,200 kilowatt-hours per acre-foot (Kwh/ac-ft) (CEC 2015). For this analysis the midpoint of the range (800 Kwh/ac-ft) was assumed.

For an electric pump, the energy requirement of 800 Kwh/ac-ft represents the electricity usage at the pump motor. There are energy losses in the electric distribution system from the powerplant to the motor, so that to deliver a particular amount of energy to the pump, the powerplant must generate slightly more energy. The California statewide average loss rate is approximately 4.23% (USEPA 2018). The energy requirements for electric pumps were adjusted by this percentage for this analysis. The resulting GHG emissions from fossil-fueled powerplants were calculated in the same way as explained above, using the number of acre-feet of water pumped, the adjusted energy requirement, the fraction of pumps that are electric (85%), and the emission factors listed in Table M.2-2.

For an engine-powered pump, the energy requirement of 800 Kwh/ac-ft represents the energy supplied to the pump by the engine, and is expressed in horsepower-hours per acre-foot (hp-hr/ac-ft). As noted above, approximately 15% of groundwater pumps are powered by engines: 13% diesel-fueled and 2% fueled by natural gas, LP gas, propane, and butane (USDA 2014). Of these fuels, diesel generally has the highest GHG emissions, so to produce a conservative (high) estimate of GHG emissions all engine-powered pumps were assumed to be diesel-fueled.

Table M.2-4 shows the estimated energy usage for groundwater pumping. The energy requirements for pump engines are shown in two units: kilowatt-hours per year (Kwh/yr) (consistent with the unit for electric pumps), and horsepower-hours per year (hp-hr/yr) (consistent with the emission factor unit for engines).

Table M.2-4 Estimated Energy Usage for Groundwater Pumping

Energy Source	Unit	No Action	Alt 1	Alt 2	Alt 3	Alt 4
Electric pumps (energy at powerplant)	Kwh/yr	5,040,094,139	4,852,660,662	4,661,214,163	4,676,309,490	5,058,617,807
Pump engines (energy at pump)	Kwh/yr	853,332,416	821,598,275	789,184,693	791,740,465	856,468,637
	hp-hr/yr	1,144,318,770	1,101,763,286	1,058,296,673	1,061,723,963	1,148,524,442
Sum	Kwh/yr	5,893,426,556	5,674,258,937	5,450,398,855	5,468,049,955	5,915,086,444

Source: Appendix H, *Water Supply Technical Appendix*. Water quantities were converted to energy usage using an average rate of 800 Kwh/ac-ft (CEC 2015).
Alt = Alternative
Kwh/ac-ft = kilowatt-hours per acre-foot
Kwh/yr = kilowatt-hours per year
hp-hr/yr = horsepower-hours per year

The energy usage for groundwater pumping shown in Table M.2-4 was multiplied by the emission factors shown in Table M.2-2 to derive annual GHG emissions. Emission factors given in Table M.2-2 for engines were obtained from the ARB-approved CalEEMod model (SCAQMD 2017). CalEEMod provides emission factors specific to calendar year and horsepower range, and the values corresponding to 2019 and an average pump rating of 96 horsepower (USDA 2014) were used in this analysis.

Table M.2-5 shows the estimated GHG emissions from groundwater pumping. Figure M.2-3, GHG *Emissions from Groundwater Pumping*, and Figure M.2-4, *Changes in GHG Emissions from Groundwater Pumping Compared to the No Action Alternative*, show the CO_2e emissions and the changes compared to the No Action Alternative for groundwater pumping, respectively.

Table M.2-5 GHG Emissions from Groundwater Pumping

	Emissions (metric tons per average year)				
Pollutant	**No Action**	**Alt 1**	**Alt 2**	**Alt 3**	**Alt 4**
Electric Pumps					
CO_2	1,034,570	996,096	956,798	959,897	1,038,373
CH_4	59	57	55	55	60
N_2O	7	7	6	6	7
CO_2e	1,038,100	999,495	960,063	963,172	1,041,915
Diesel Pumps					
CO_2	650,315	626,131	601,429	603,377	652,705
CH_4	43	42	40	40	44
N_2O	4	4	4	4	4
CO_2e	652,687	628,415	603,622	605,577	655,086
Total Pumping Emissions[1]					
CO_2	1,684,886	1,622,227	1,558,227	1,563,274	1,691,078
CH_4	103	99	95	95	103
N_2O	11	11	10	10	11
CO_2e	1,690,787	1,627,909	1,563,685	1,568,749	1,697,001

[1] Sum of individual values may not equal total due to rounding.
Alt = Alternative
CO_2 = carbon dioxide
CH_4 = methane
N_2O = nitrous oxide

CO_2e = carbon dioxide equivalent

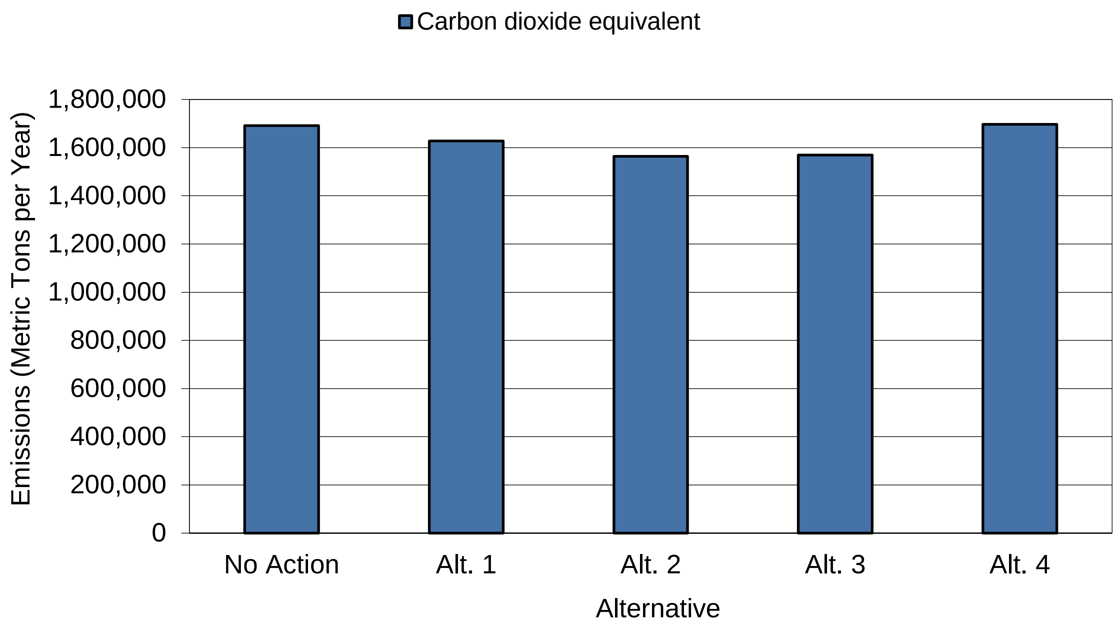

Figure M.2-3 GHG Emissions from Groundwater Pumping

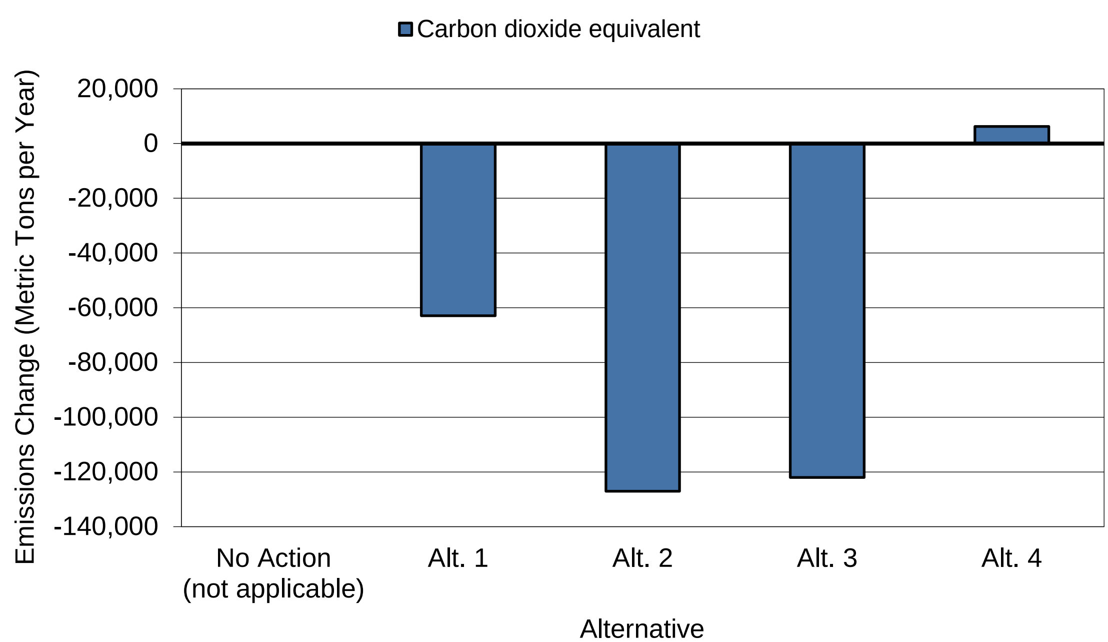

Figure M.2-4 Changes in GHG Emissions from Groundwater Pumping Compared to the No Action Alternative

Under Alternative 1 in an average year, groundwater pumping would decrease compared to the No Action Alternative. As a result, the associated GHG emissions also would decrease, as shown in Table M.2-5. Under Alternative 2 in an average year, groundwater pumping and GHG emissions would decrease more than under Alternative 1. The GHG emissions decrease under Alternative 2 would be roughly twice that under Alternative 1, compared to the No Action Alternative. Under Alternative 3 in an average year, groundwater pumping and GHG emissions would decrease compared to the No Action Alternative. The GHG emissions decreases under Alternative 3 would be greater than under Alternative 1 but less than under Alternative 2. In contrast to the other action alternatives, under Alternative 4 in an average year, groundwater pumping would increase compared to the No Action Alternative. As a result, the associated GHG emissions also would increase.

The total GHG emissions associated with the project are the sum of the GHG emissions from net generation (Table M.2-3) and groundwater pumping (Table M.2-5). Table M.2-6 shows the estimated total project GHG emissions for a long-term average year. Figure M.2-5, *GHG Emissions from All Sources*, and Figure M.2-6, *Changes in GHG Emissions from All Sources Compared to the No Action Alternative*, show the overall CO_2e emissions for all emission sources, and the changes in CO_2e emissions compared to the No Action Alternative, respectively.

Table M.2-6 Total Project GHG Emissions

Pollutant	Emissions (metric tons per average year)				
	No Action	**Alt 1**	**Alt 2**	**Alt 3**	**Alt 4**
CO_2	1,665,112	1,788,576	1,919,833	1,912,889	1,614,965
CH_4	102	109	116	116	99
N_2O	11	12	13	13	11
CO_2e	1,670,946	1,794,826	1,926,525	1,919,558	1,620,629

Values represent the sum of GHG emissions from fossil-fueled powerplants (for CVP/SWP purchases of grid power and for electrically-powered groundwater pumps) and GHG emissions from diesel engines (for engine-powered groundwater pumps).
Alt = Alternative
CO_2 = carbon dioxide
CH_4 = methane
N_2O = nitrous oxide
CO_2e = carbon dioxide equivalent

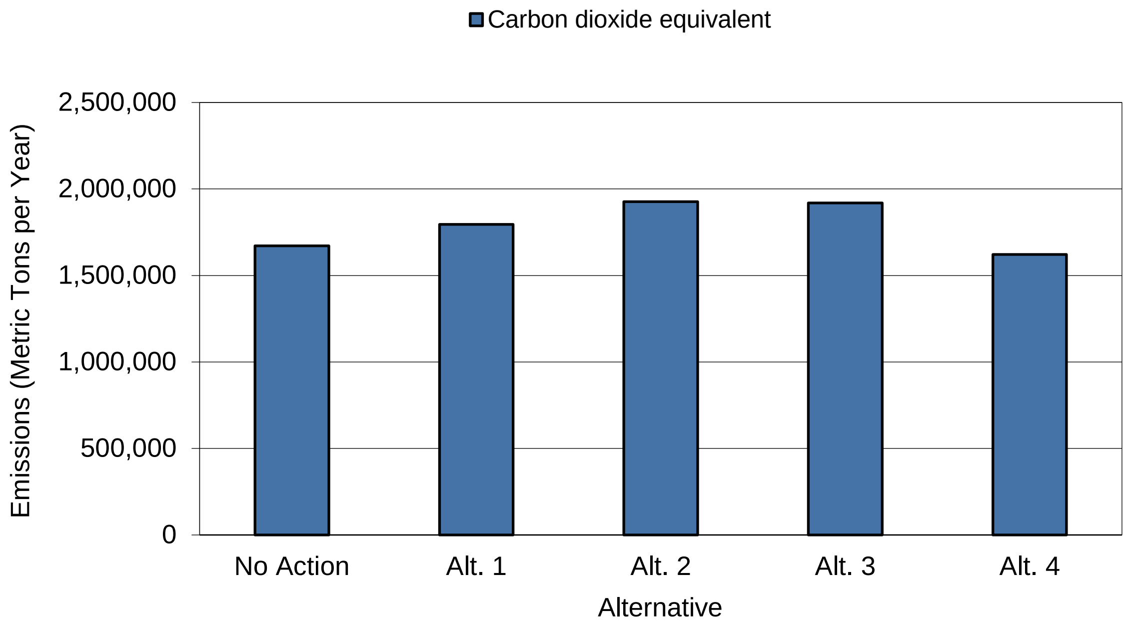

Figure M.2-5 GHG Emissions from All Sources

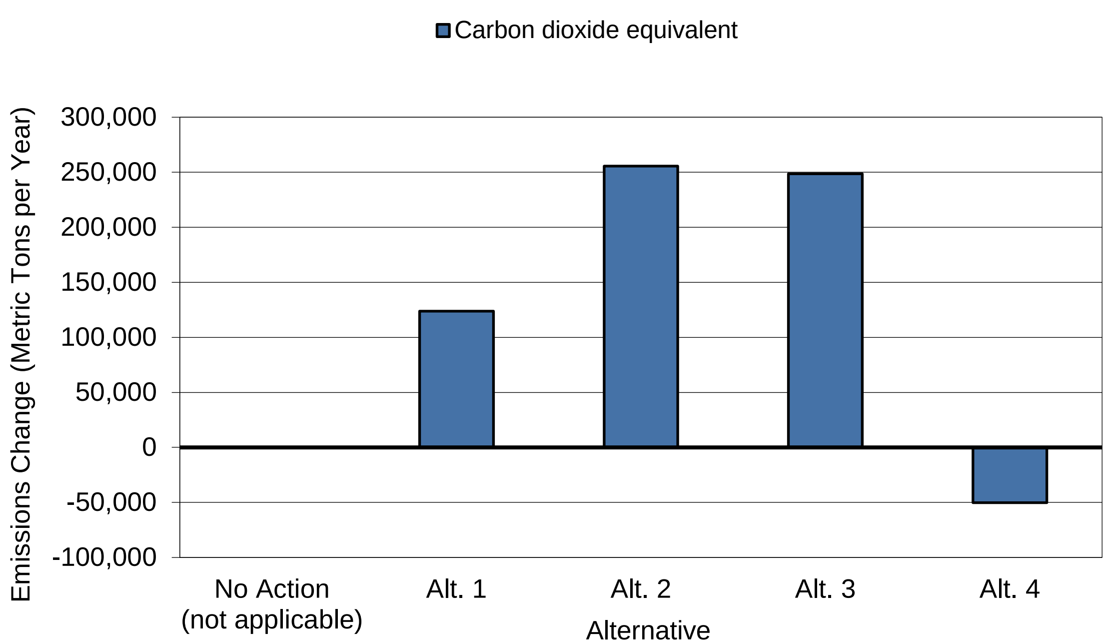

Figure M.2-6 Changes in GHG Emissions from All Sources Compared to the No Action Alternative

Under Alternative 1 in an average year, overall GHG emissions would increase compared to the No Action Alternative, as shown in Table M.2-6. Under Alternative 2 in an average year, GHG emissions would increase more than under Alternative 1. Under Alternative 3 in an average year, GHG emissions would increase compared to the No Action Alternative. The GHG emissions increases under Alternative 3 would be greater than under Alternative 1 but less than under Alternative 2. In contrast to the other action alternatives, under Alternative 4 in an average year, overall GHG emissions would decrease compared to the No Action Alternative.

Potential for exhaust GHG emissions from engines of construction equipment and vehicles

Because the details of construction and transport activities are unknown at present, construction-related impacts were assessed qualitatively. Construction activities would produce temporary increases in GHG emissions from the use of motorized construction equipment. These increases can be lessened through implementation of mitigation measures. Section M.2.7.2, *Construction*, provides a mitigation measure that could be implemented to reduce GHG emissions from construction.

M.2.2 No Action Alternative

Under the No Action Alternative, the actions described under Alternatives 1 through Alternative 4 would not take place. The CVP/SWP system would continue to be managed in accordance with current plans and programs. The population of the regional study area is expected to grow over time. Development in the region to accommodate the population growth, including residential, commercial, industrial, transportation, and other projects, would continue under the No Action Alternative and result in associated effects on GHG emissions. These effects would contribute to regional GHG emissions and global climate change. Climate change action plans and emission control programs administered by the state and the respective air quality management districts would remain in place to address GHG emission rates in the region and statewide.

M.2.3 Alternative 1

The potential effects on GHG emissions of Alternative 1 are described in the following sections.

M.2.3.1 *Project-Level Effects*

Potential changes in GHG emissions from fossil-fueled powerplants (hydropower generation)

Under Alternative 1, CVP/SWP-wide actions could have effects on GHG emissions to the extent that Shasta Critical Determinations would result in reduced releases to contractors in critical years, which could reduce hydropower generation, leading to increases in grid power generation and the associated GHG emissions. Estimated increases in GHG emissions for an average year are included in Table M.2-3.

Actions in the upper Sacramento Trinity/Clear Creek, Feather River, American River, Stanislaus, and Bay-Delta regions, and actions associated with operations, could increase or decrease releases and flows, depending on conditions in a particular region, year, and season. Hydropower generation could change accordingly, leading to either increases or decreases in GHG emissions. Under Alternative 1 in an average year, net generation would decrease compared to the No Action Alternative. As a result, GHG emissions from fossil-fueled powerplants would increase compared to the No Action Alternative, as shown in Table M.2-3.

If the Summer-Fall Delta Smelt Habitat action includes operations of the SMSCG or a Fall X2 action, the water requirements in summer and fall could be greater than estimated for Alternative 1. Increased water releases could increase the amount of hydropower generated and decrease the demand for grid electricity and the associated GHG emissions. Alternative 1 estimates increased GHG emissions compared to the No Action Alternative. In years with operations of the SMSCG or a Fall X2 action, actual GHG emissions may be less than those estimated in Table M.2-3.

Fish intervention actions would not change the amount of hydropower generation, so there would be no change in GHG emissions due to these actions under Alternative 1.

There would be no project-level effects on hydropower generation associated with actions in the San Joaquin River region or with habitat restoration or facility improvements actions under Alternative 1.

Potential changes in GHG emissions from fossil-fueled powerplants (groundwater pumping)

CVP/SWP-wide actions could have effects on GHG emissions to the extent that Shasta Critical Determinations would result in reduced releases to contractors in critical years, which could reduce the amount of available irrigation water and lead to increased groundwater pumping and the associated GHG emissions. Such GHG emission increases from these actions would be included within the overall decreases shown in Table M.2-5.

Actions in the upper Sacramento River, Trinity/Clear Creek, Feather River, American River, Stanislaus River, and Bay-Delta regions, and actions associated with operations, could increase or decrease releases and flows, depending on conditions in a particular year and season, as described above for hydropower generation. The amount of groundwater pumping could change accordingly, leading to either increases or decreases in GHG emissions. Under Alternative 1 in an average year, groundwater pumping would decrease compared to the No Action Alternative. As a result, the associated GHG emissions also would decrease, as shown in Table M.2-5.

If the Summer-Fall Delta Smelt Habitat action includes operations of the SMSCG or a Fall X2 action, the water requirements in summer and fall could be greater than estimated for Alternative 1. Increased water releases could increase the amount of available irrigation water and lead to decreased groundwater pumping and the associated GHG emissions. Alternative 1 estimates decreased GHG emissions from groundwater pumping actions compared to the No Action Alternative. In years with operations of the SMSCG or a Fall X2 action, actual emissions may be less than those estimated in Table M.2-4.

Fish intervention actions would not change the amount of groundwater pumping, so there would be no change in GHG emissions due to these actions under Alternative 1.

There would be no project-level effects on groundwater pumping associated with actions in the San Joaquin River region or with habitat restoration or facility improvements actions under Alternative 1.

Potential for exhaust GHG emissions from engines of construction equipment and vehicles

Under Alternative 1 there would be no construction associated with project-level actions, and therefore, no effects on GHG emissions.

M.2.3.2 *Program-Level Effects*

Potential changes in GHG emissions from fossil-fueled powerplants (hydropower generation)

There would be no program-level effects on hydropower generation associated with actions under Alternative 1, and therefore, no effects on GHG emissions.

Potential changes in GHG emissions from fossil-fueled powerplants (groundwater pumping)

There would be no program-level effects on groundwater pumping associated with actions under Alternative 1, and therefore, no effects on GHG emissions.

Potential changes GHG emissions from fossil-fueled powerplants (water transfers)

There would be no program-level effects on water transfers associated with actions under Alternative 1, and therefore, no effects on GHG emissions.

Potential for GHG emissions from engine exhaust from construction equipment and vehicles

Program-level actions that include construction or repair of facilities or the transport of fish or materials are proposed in the upper Sacramento River, American River, Stanislaus River, and San Joaquin River regions, as well as for habitat restoration, facility improvements, and fish intervention actions. The details of construction currently are not known in sufficient detail to estimate GHG emissions. Potential temporary increases in GHG emissions would be lessened if appropriate BMPs are implemented. Section M.2.7.2 provides a list of typical BMPs that could be implemented as mitigation to reduce GHG emissions from construction.

There would be no program-level CVP/SWP-wide actions, and no program-level actions in the Trinity/Clear Creek, Feather River, and Bay-Delta regions.

M.2.4 Alternative 2

The potential effects on GHG emissions of Alternative 2 are described in the following sections.

M.2.4.1 *Project-Level Effects*

Potential changes in GHG emissions from fossil-fueled powerplants (hydropower generation)

Under Alternative 2, CVP/SWP-wide actions could have effects on GHG emissions to the extent that Shasta Critical Determinations would result in reduced releases to contractors in critical years, which could reduce the amount of hydropower generated and increase the demand for grid electricity and the associated GHG emissions. Estimated increases in GHG emissions for an average year are included in Table M.2-3.

Actions in the upper Sacramento River, Trinity/Clear Creek, Feather River, American River, Stanislaus River, and Bay-Delta regions, and actions associated with operations, could increase or decrease releases and flows, depending on conditions in a particular region, year, and season. Hydropower generation could change accordingly, leading to either increases or decreases in GHG emissions. Under Alternative 2 in an average year, net generation would decrease compared to the No Action Alternative. As a result, GHG emissions from fossil-fueled powerplants would increase compared to the No Action Alternative, as shown in Table M.2-3.

There would be no project-level effects on hydropower generation associated with actions in the San Joaquin River region under Alternative 2.

Potential changes in GHG emissions from fossil-fueled powerplants (groundwater pumping)

CVP/SWP-wide actions could have effects on GHG emissions to the extent that Shasta Critical Determinations would result in reduced releases to contractors in critical years, which could reduce the amount of available irrigation water and lead to increased groundwater pumping and the associated GHG emissions. Such GHG emission increases from these actions would be included within the overall decreases shown in Table M.2-5.

Actions in the upper Sacramento River, Trinity/Clear Creek, Feather River, American River, Stanislaus River, and Bay-Delta regions could increase or decrease releases and flows, depending on conditions in a particular year and season, as described above for hydropower generation. The amount of groundwater pumping could change accordingly, leading to either increases or decreases in GHG emissions. Under Alternative 2 in an average year, groundwater pumping would decrease compared to the No Action Alternative. As a result, the associated GHG emissions also would decrease, as shown in Table M.2-5.

There would be no project-level effects on groundwater pumping associated with actions in the San Joaquin River region under Alternative 2.

Potential changes in GHG emissions from fossil-fueled powerplants (water transfers)

Under Alternative 2, the quantity of water transferred would be the same as under the No Action Alternative, so there would be no change in GHG emissions associated with water transfers.

Potential for GHG emissions from engine exhaust from construction equipment and vehicles

Under Alternative 2 there would be no construction associated with project-level actions, and therefore, no effects on GHG emissions.

M.2.4.2 *Program-Level Effects*

Potential changes in GHG emissions from fossil-fueled powerplants (hydropower generation)

There would be no program-level actions under Alternative 2, and therefore, no effects on GHG emissions.

Potential changes in GHG emissions from fossil-fueled powerplants (groundwater pumping)

There would be no program-level actions under Alternative 2, and therefore, no effects on GHG emissions.

Potential changes in GHG emissions from fossil-fueled powerplants (water transfers)

There would be no program-level actions under Alternative 2, and therefore, no effects on GHG emissions.

Potential for GHG emissions from engine exhaust from construction equipment and vehicles

There would be no program-level actions under Alternative 2, and therefore, no effects on GHG emissions.

M.2.5 Alternative 3

The potential effects on GHG emissions of Alternative 3 are described in the following sections.

M.2.5.1 *Project-Level Effects*

Potential changes in GHG emissions from fossil-fueled powerplants (hydropower generation)

Under Alternative 3, CVP/SWP-wide actions could have effects on GHG emissions to the extent that Shasta Critical Determinations would result in reduced releases to contractors in critical years, which could reduce the amount of hydropower generated and increase the demand for grid electricity and the associated GHG emissions. Estimated increases in GHG emissions for an average year are included in Table M.2-3.

Actions in the upper Sacramento River, Trinity/Clear Creek, Feather River, American River, Stanislaus, and Bay-Delta regions, and actions associated with operations, could increase or decrease releases and flows, depending on conditions in a particular region, year, and season. Hydropower generation could change accordingly, leading to either increases or decreases in GHG emissions. Under Alternative 3 in an average year, net generation would decrease compared to the No Action Alternative. As a result, GHG emissions from fossil-fueled powerplants would increase compared to the No Action Alternative, as shown in Table M.2-3.

Fish intervention actions would not change the amount of hydropower generation, so there would be no change in GHG emissions due to these actions under Alternative 3.

There would be no project-level effects on hydropower generation associated with actions in the San Joaquin River region or with habitat restoration or facility improvements actions under Alternative 3.

Potential changes in GHG emissions from fossil-fueled powerplants (groundwater pumping)

CVP/SWP-wide actions could have effects on GHG emissions to the extent that Shasta Critical Determinations would result in reduced releases to contractors in critical years, which could reduce the amount of available irrigation water and lead to increased groundwater pumping and the associated GHG emissions. Such GHG emission increases from these actions would be included within the overall decreases shown in Table M.2-5.

Actions in the upper Sacramento River, Trinity/Clear Creek, Feather River, American River, Stanislaus River, and Bay-Delta regions, and actions associated with operations, could increase or decrease releases and flows, depending on conditions in a particular year and season, as described above for hydropower generation. The amount of groundwater pumping could change accordingly, leading to either increases or decreases in GHG emissions. Under Alternative 3 in an average year, groundwater pumping would decrease compared to the No Action Alternative. As a result, the associated GHG emissions also would decrease, as shown in Table M.2-5.

Fish intervention actions would not change the amount of groundwater pumping, so there would be no change in GHG emissions due to these actions under Alternative 3.

There would be no project-level effects on groundwater pumping associated with actions in the San Joaquin River region or with habitat restoration or facility improvements actions.

Potential changes in GHG emissions from fossil-fueled powerplants (water transfers)

Under Alternative 3, the quantity of water transferred would be the same as under the No Action Alternative, so there would be no change in GHG emissions associated with water transfers.

Potential for GHG emissions from engine exhaust from construction equipment and vehicles

Under Alternative 3 there would be no construction associated with project-level actions, and therefore, no effects on GHG emissions.

M.2.5.2 *Program-Level Effects*

Potential changes in GHG emissions from fossil-fueled powerplants (hydropower generation)

There would be no program-level effects on hydropower generation associated with actions under Alternative 3, and therefore, no effects on GHG emissions.

Potential changes in GHG emissions from fossil-fueled powerplants (groundwater pumping)

There would be no program-level effects on groundwater pumping associated with actions under Alternative 3, and therefore, no effects on GHG emissions.

Potential changes in GHG emissions from fossil-fueled powerplants (water transfers)

There would be no program-level effects on water transfers associated with actions under Alternative 3, and therefore, no effects on GHG emissions.

Potential for GHG emissions from engine exhaust from construction equipment and vehicles

Program-level actions that include construction or repair of facilities or the transport of fish or materials are proposed in the upper Sacramento River, American River, Stanislaus River, and San Joaquin River regions, as well as for habitat restoration, facility improvements, and fish intervention actions. The details of construction currently are not known in sufficient detail to estimate GHG emissions. Potential temporary increases in GHG emissions would be lessened if appropriate BMPs are implemented. Section M.2.7.2 provides a list of typical BMPs that could be implemented as mitigation to reduce GHG emissions from construction.

There would be no program-level actions that include construction of facilities or the transport of fish or materials in the Bay-Delta regions.

There would be no program-level CVP/SWP-wide actions, and no program-level actions in the Trinity/Clear Creek or Feather River regions.

M.2.6 Alternative 4

The potential effects on GHG emissions of Alternative 4 are described in the following sections.

M.2.6.1 *Project-Level Effects*

Potential changes in GHG emissions from fossil-fueled powerplants (hydropower generation)

Under Alternative 4, CVP/SWP-wide actions could have effects on GHG emissions to the extent that Shasta Critical Determinations would result in reduced releases to contractors in critical years, which could reduce the amount of hydropower generated and increase the demand for grid electricity and the associated GHG emissions. Such emissions increases from these actions would be included within the overall decreases in an average year, as shown in Table M.2-3.

Actions in the upper Sacramento River, Trinity/Clear Creek, Feather River, American River, Stanislaus, and Bay-Delta regions, and actions associated with operations, could increase or decrease releases and flows, depending on conditions in a particular region, year, and season. Hydropower generation could change accordingly, leading to either increases or decreases in GHG emissions. Under Alternative 4 in an average year, net generation would increase compared to the No Action Alternative. As a result, GHG emissions from fossil-fueled powerplants would decrease compared to the No Action Alternative, as shown in Table M.2-3.

There would be no project-level effects on hydropower generation associated with actions in the San Joaquin River region under Alternative 4.

Potential changes in GHG emissions from fossil-fueled powerplants (groundwater pumping)

CVP/SWP-wide actions could have effects on GHG emissions to the extent that Shasta Critical Determinations would result in reduced releases to contractors in critical years, which could reduce the amount of available irrigation water and lead to increased groundwater pumping and the associated GHG emissions. Estimated increases in emissions are included in Table M.2-5.

Actions in the upper Sacramento River, Trinity/Clear Creek, Feather River, American River, Stanislaus River, and Bay-Delta regions, and actions associated with operations, could increase or decrease releases and flows, depending on conditions in a particular year and season, as described above for hydropower generation. The amount of groundwater pumping could change accordingly, leading to either increases or decreases in GHG emissions. Under Alternative 4 in an average year, groundwater pumping would increase compared to the No Action Alternative. As a result, the associated GHG emissions also would increase, as shown in Table M.2-5.

There would be no project-level effects on groundwater pumping associated with actions in the San Joaquin River region under Alternative 4.

Potential changes in GHG emissions from fossil-fueled powerplants (water transfers)

Under Alternative 4, the quantity of water transferred would be the same as under the No Action Alternative, so there would be no change in GHG emissions associated with water transfers.

Potential for GHG emissions from engine exhaust from construction equipment and vehicles

Under Alternative 4 there would be no construction associated with project-level actions, and therefore, no effects on GHG emissions.

M.2.6.2 *Program-Level Effects*

Potential changes in GHG emissions from fossil-fueled powerplants (hydropower generation)

There would be no program-level effects on hydropower generation associated with actions under Alternative 4, and therefore, no effects on GHG emissions.

Potential changes in GHG emissions from fossil-fueled powerplants (groundwater pumping)

There would be no program-level effects on groundwater pumping associated with actions under Alternative 4, and therefore, no effects on GHG emissions.

Potential changes in GHG emissions from fossil-fueled powerplants (water transfers)

There would be no program-level effects on water transfers associated with actions under Alternative 4, and therefore, no effects on GHG emissions.

Potential for GHG emissions from engine exhaust from construction equipment and vehicles

Program-level actions to increase water use efficiency for CVP and SWP contractors south-of-Delta include construction actions. The details of construction currently are not known in sufficient detail to estimate GHG emissions. Potential temporary increases in GHG emissions would be lessened if appropriate BMPs are implemented. Section M.2.7.2 provides a list of typical BMPs that could be implemented as mitigation to reduce GHG emissions from construction.

There would be no program-level actions in the upper Sacramento, Trinity/Clear Creek, Feather River, American River, Stanislaus River, San Joaquin River, or Bay-Delta regions.

M.2.7 Mitigation Measures

M.2.7.1 *Energy*

Fossil-fueled powerplants are subject to the air quality permitting requirements of the air quality management district in which they are located. Permit conditions may include requirements to reduce or minimize GHG emissions. Under AB 32, California regulations require utility companies to ensure that one third of their electricity comes from the sun, the wind, and other renewable sources by 2030, a portion that will rise to 50% by 2030. Therefore, no additional mitigation is proposed for energy-related GHG emissions.

M.2.7.2 *Construction*

Mitigation Measure GHG-1: Minimize Potential Increases in GHG Emissions from Exhaust Associated with Construction Activities

Best management practices (BMPs) are recommended to minimize potential increases in GHG emissions from exhaust associated with construction activities. The following are common BMPs that may be applicable depending on the activity and the equipment being used. These or similar practices are often required by air quality management districts and local jurisdictions to minimize construction impacts on GHG emissions.

1. Ensure that all equipment and vehicles are maintained regularly to meet manufacturer specifications to achieve efficient combustion and minimum emissions.
2. Ensure that all diesel engines are properly fueled (i.e., ultra-low sulfur diesel with a maximum 15 parts per million sulfur content).
3. Limit idling of engines to no more than 5 minutes unless necessary for proper operation.
4. Where feasible, use electric rather than engine-powered equipment. This may include using electric starting aids (such as block heaters) to warm engines.
5. Develop and implement a traffic management plan.
6. Where offsite traffic congestion is a concern, limit use of vehicles on public roads during peak traffic hours.
7. Where offsite traffic congestion is a concern, or to limit vehicle volumes traveling to remote sites, require workers to park in designated areas and provide shuttle buses to work sites.

M.2.8 Summary of Impacts

Table M.2-1 shows a summary of impacts and potential mitigation measures for consideration.

Table M.2-1. Impact Summary

Impact	**Alternative**	**Magnitude and Direction of Impacts**	**Potential Mitigation Measures**
Potential changes in hydropower generation could affect GHG emissions from fossil-fueled powerplants (Project-Level)	No Action	No impact	Not applicable
	1	Increase in GHG emissions compared to No Action Alternative.	None proposed
	2	Increase in GHG emissions compared to No Action Alternative. Greater increase than under Alternative 1.	None proposed
	3	Increase in GHG emissions compared to No Action Alternative. Greater increase than under Alternative 1 but less than under Alternative 2.	None proposed
	4	Decrease in GHG emissions compared to No Action Alternative.	None proposed
	No Action	No impact	Not applicable

Impact	**Alternative**	**Magnitude and Direction of Impacts**	**Potential Mitigation Measures**
Potential changes in the amount of groundwater pumping could affect GHG emissions from fossil-fueled powerplants (Project-Level)	1	Decrease in GHG emissions compared to No Action Alternative.	None proposed
	2	Decrease in GHG emissions compared to No Action Alternative. Greater decrease than under Alternative 1.	None proposed
	3	Decrease in GHG emissions compared to No Action Alternative. Greater decrease than under Alternative 1 but less than under Alternative 2.	None proposed
	4	Increase in GHG emissions compared to No Action Alternative.	None proposed
Potential changes in pumping for water transfers could affect GHG emissions from fossil-fueled powerplants (Project-Level)	No Action	No impact	Not applicable
	1	Impact is included within that of changes in hydropower generation and grid emissions above.	None proposed
	2	Impact is included within that of changes in hydropower generation and grid emissions above.	None proposed
	3	Impact is included within that of changes in hydropower generation and grid emissions above.	None proposed
	4	Impact is included within that of changes in hydropower generation and grid emissions above.	None proposed
Changes in river flows and reservoir levels could result in a combined impact of hydropower generation, grid emissions, groundwater pumping, and water transfers (Project-Level)	1	Increase in GHG emissions compared to No Action Alternative.	None proposed
	2	Increase in GHG emissions compared to No Action Alternative. Greater increase than under Alternative 1.	None proposed
	3	Increase in GHG emissions compared to No Action	None proposed

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
		Alternative. Greater increase than under Alternative 1 but less than under Alternative 2.	
	4	Decrease in GHG emissions compared to No Action Alternative.	None proposed
Actions that include construction of facilities or the transport of fish or materials require the use of construction equipment and vehicles, which would produce GHG emissions from engine exhaust (Project-Level)	No Action	No impact	None proposed
	1	No impact	None proposed
	2	No impact	None proposed
	3	No impact	None proposed
	4	No impact	None proposed
Potential changes in hydropower generation could affect GHG emissions from fossil-fueled powerplants (Program-Level)	1	No impact	Not applicable
	2	No impact	None proposed
	3	No impact	None proposed
	4	No impact	None proposed
Potential changes in the amount of groundwater pumping could affect GHG emissions from fossil-fueled powerplants (Program-Level)	No Action	No impact	None proposed
	1	No impact	None proposed
	2	No impact	None proposed
	3	No impact	None proposed
	4	No impact	None proposed
Potential changes in pumping for water transfers could affect GHG emissions from fossil-fueled powerplants (Program-Level)	No Action	No impact	None proposed
	1	No impact	None proposed
	2	No impact	None proposed
	3	No impact	None proposed
	4	No impact	None proposed
Changes in river flows and reservoir levels could result in a combined impact of hydropower generation, grid emissions, groundwater pumping, and water transfers (Program-Level)	No Action	No impact	None proposed
	1	No impact	None proposed
	2	No impact	None proposed
	3	No impact	None proposed
	4	No impact	None proposed

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
Actions that include construction of facilities or the transport of fish or materials require the use of construction equipment and vehicles, which would produce GHG emissions from engine exhaust (Program-Level)	1	The details of construction currently are not known in sufficient detail to estimate GHG emissions. Potential temporary increases in GHG emissions would be lessened if appropriate mitigation/BMPs are implemented.	GHG-1
	2	No impact	None proposed
	3	The details of construction currently are not known in sufficient detail to estimate GHG emissions. Potential temporary increases in GHG emissions would be lessened if appropriate mitigation/BMPs are implemented.	GHG-1
	4	The details of construction currently are not known in sufficient detail to estimate GHG emissions. Potential temporary increases in GHG emissions would be lessened if appropriate mitigation/BMPs are implemented.	GHG-1

GHG = greenhouse gas
BMP = best management practices

M.2.9 Cumulative Effects

The cumulative effects analysis considers projects, programs, and policies that are not speculative and that are based upon known or reasonably foreseeable long-range plans, regulations, operating agreements, or other information that establishes them as reasonably foreseeable. Appendix Y, *Cumulative Methodology*, presents a list of actions that could have cumulative effects.

The No Action Alternative would not result in any changes to facility operations and so would not have impacts on GHG emissions. Thus, no cumulative effects of the project on GHG emissions would occur under the No Action Alternative.

As described above, Alternative 1 would lead to increases in regional emissions of CO_2, CH_4, N_2O, and CO_2e, compared to the No Action Alternative. Past, present, and reasonably foreseeable projects, described in Appendix Y, may have cumulative effects as well, to the extent that they could increase regional GHG emissions. The cumulative projects include actions across California to develop new water storage capacity, new water conveyance infrastructure, new water recycling capacity, and the reoperation of existing water supply infrastructure, including surface water reservoirs and conveyance infrastructure. The cumulative projects also include ecosystem improvement and habitat restoration actions to improve conditions for special status species whose special status in many cases constrains water supply delivery operations. Some of the projects described in Appendix Y could increase GHG emissions through the same mechanisms discussed above for the action alternatives, that is, if the projects lead to increases in grid power generation, groundwater pumping, and use of construction equipment and vehicles. The GHG emissions from Alternative 1 are expected to be relatively small compared to the emissions from past, present, and reasonably foreseeable projects. Consequently, the impacts of Alternative 1, when combined with those of past, present, and reasonably foreseeable projects, are not expected to lead to significant cumulative impacts on global climate change. Accordingly, no mitigation is proposed for cumulative GHG emission impacts of Alternative 1.

Alternatives 2 and 3 would have cumulative impacts similar to those of the Alternative 1. Compared to the No Action Alternative and Alternative 1, Alternative 2 would result in greater emissions of CO_2, CH_4, N_2O, and CO_2e. Alternative 3 also would result in greater emissions of these pollutants compared to the No Action Alternative and Alternative 1, but the increases would be less than under Alternative 2. As with Alternative 1, the GHG emissions from Alternatives 2 and 3 are expected to be relatively small compared to the emissions from past, present, and reasonably foreseeable projects. Consequently, the cumulative GHG emission impacts of Alternatives 2 and 3 along with past, present, and reasonably foreseeable projects are not expected to lead to significant cumulative impacts on global climate change. Accordingly, no mitigation is proposed for cumulative GHG emission impacts of Alternatives 2 and 3.

Alternative 4 would lead to decreases in regional emissions of CO_2, CH_4, N_2O, and CO_2e, compared to the No Action Alternative. Because GHG emissions would decrease under Alternative 4, the cumulative GHG emission impacts of Alternative 4 along with past, present, and reasonably foreseeable projects are not expected to lead to significant cumulative impacts on global climate change. Accordingly, no mitigation is proposed for cumulative GHG emission impacts of Alternative 4.

GHG emissions from construction activities are temporary. The GHG emissions from construction under Alternatives 1, 2, 3 and 4 are expected to be relatively small compared to the emissions associated with past, present, and reasonably foreseeable projects. Consequently, The cumulative GHG emission impacts of construction under Alternatives 1, 3, and 4 (Alternative 2 does not include construction) along with past, present, and reasonably foreseeable projects are not expected to lead to significant cumulative impacts on global climate change. Accordingly, no mitigation beyond the BMPs recommended in Section M.2.7.2 above is proposed for cumulative GHG emission impacts from construction activities of Alternatives 1, 3, and 4.

M.3 References

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Appendix N Visual Quality Technical Appendix

This appendix documents the visual quality technical analysis to support the impact analysis in the EIS.

This section describes visual resources that could be potentially affected by the implementation of the action alternatives considered in the EIS. Effects on visual resources resulting from the continuation of operations and some proposed changes in Central Valley Project (CVP) and State Water Project (SWP) operations may occur in the Trinity River region, Sacramento River region, San Joaquin Valley, Bay-Delta region, and CVP and SWP Service Areas in the nearshore coastal regions.

Physical form and visual character are the result of the interaction of natural and engineered elements. Natural elements of topography, hydrology, vegetation, and climate create the physical context. Engineered elements, such as buildings, roads, infrastructure, and settlement patterns, are secondary elements that act on the natural physical context to establish a visual environment.

Both the natural and engineered landscape features contribute to perceived views and the aesthetic value of those views. In areas considered to have high resource value and scenic character, it is important to evaluate and protect the visual character and aesthetic value of landscapes that may undergo alteration.

N.1 Background Information

N.1.1 Trinity River Region

The Trinity River region includes Trinity Reservoir and Trinity River downstream of Lewiston Reservoir.

N.1.2 Trinity River Watershed

The Trinity River drains an area of the Coast Ranges, northwest of the Sacramento Valley. Dams on the river form Trinity Lake and Lewiston Lake, both of which are in the Whiskeytown-Shasta-Trinity National Recreation Area. The Trinity River flows through lightly populated and heavily forested, mountainous terrain with jagged cliffs that are in view when people pursue recreational activities, such as fishing, hiking, rafting, kayaking, and canoeing. The forests offer visual resources that include snow-covered peaks, volcanoes, rock outcroppings, mountain creeks, lakes, meadows, and a wide variety of trees and vegetation. Downstream of Lewiston Dam, the Trinity River corridor is characterized by gravel bars, riparian vegetation, and human-built features (NCRWQCB et al. 2013). Artificial lights are present from passing vehicles, marinas and houseboats, campgrounds, and local residential and commercial buildings. Glare related to the water surfaces may occur at some view locations.

N.1.2.1 *Wild and Scenic Rivers and Scenic Highways in the Trinity River Watershed*

On January 19, 1981, the Secretary of the Interior designated portions of the Trinity River watershed as part of the National Wild and Scenic Rivers System, including the Trinity River downstream of Lewiston Dam and portions of the South Fork, North Fork, and New River (BLM et al. 2018). The State of

California adopted similar reaches as wild and scenic under Public Resources Code Sections 5093.54 and 5093.545.

The Trinity River region includes two highways in Trinity County and one highway in Humboldt County that are eligible for State Scenic Highway designation. The two eligible highways in Trinity County are Siskiyou-Trinity Scenic Byway (State Route [SR] 3, which extends from south of Hayfork to north of Trinity Lake to Interstate [I-] 5) and Trinity Scenic Byway (SR 299, which extends from the Pacific Ocean to Redding). In Humboldt County, SR 96 along the Trinity River from Willow Creek to the confluence with the Klamath River is eligible for State Scenic Highway designation (Caltrans 2019).

N.1.3 Sacramento Valley

The Sacramento Valley is generally identified as the region extending upstream from the Delta to the Redding metropolitan area, and includes Shasta Lake, Keswick Reservoir, Whiskeytown Lake, Sacramento River between Keswick Dam and the Delta, Lake Oroville and the Thermalito Afterbay, the Yuba River from between New Bullards Bar and the Feather River, the Bear River between Camp Far West Reservoir and the Feather River, the Feather River between Thermalito Dam and the Sacramento River, Folsom Lake and Lake Natoma, the American River between Nimbus Dam and the Sacramento River, and refuges that use CVP water supplies. For the purposes of this analysis, the Sacramento Valley includes the Sacramento River, Clear Creek, American River, and Feather River regions.

The Sacramento Valley extends from the northern mountainous areas to the less dramatic landscapes of the Central Valley at the lower elevations. The mountainous areas are characterized by rugged and deep river canyons and valleys that extend from jagged peaks to forested areas with pine and deciduous trees. Large rivers flow from the mountain areas through the foothills into the agricultural areas and communities along the valley floor. Oak woodlands are located at middle and lower elevations of the foothills and along riparian corridors on the valley floor.

N.1.3.1 *Shasta Lake and Whiskeytown Lake*

Shasta Lake and Whiskeytown Lake are in the Whiskeytown-Shasta-Trinity National Recreation Area. These watersheds in which these reservoirs are located provide opportunities for high quality, natural visual experiences, such as mountains, forests, waterfalls, streams, open water, and sky views that can be accessed during recreational activities such as boating, water skiing, swimming, fishing, camping, picnicking, hiking, hunting, and mountain biking. Panoramic views for travelers through the area can be seen from many locations, including SR 151 vista point, Shasta Dam Visitor Center, and I-5. The contrast between the open water bodies and surrounding mountains provides a wide diversity of views. The quality and diversity of visual resources at the lakes and the surrounding areas is influenced by human-built features such as highways, railroads, resorts, bridges, communities, and electrical transmission facilities. The visual quality of open waters is influenced by fluctuating water levels. Typically, the water levels decline from an annual maximum in May to a minimum in October. In extremely dry years, exposed bare mineral soils in a “bathtub ring” substantially contrast the open water and the upslope vegetation (Reclamation 2013).

Pine and oak forests predominate in the areas surrounding the lakes, with intermittent chaparral and rock outcrops. The landscape features mountain ranges, volcanoes, waterways, and, below the reservoir, the agricultural vistas and communities of the Central Valley.

N.1.3.1.1 Sacramento River Watershed: Keswick Reservoir to Feather River

The scenic qualities of the upper reaches of the Sacramento River watershed south of Keswick Reservoir are generally considered to be high quality, especially in areas where there is little to no development. Varied topography, geologic formations, and natural and human-made water bodies provide visual interest and striking vistas. Similar conditions are found in the Sierra Nevada and foothills near the upper and middle Feather, Yuba, American, Mokelumne, Calaveras, and Stanislaus river watersheds.

The foothills provide views of rolling hills, open grasslands, and scattered oak and pine woodlands. In the lower elevations of the Sacramento Valley, the human-built environment becomes more dominant, and detracts from views of the natural landscape. Outside of urban and suburban areas, land use is rural in character, with agricultural areas of irrigated row crops, orchards, and grazing lands. Sporadically, flooded agricultural fields, especially rice fields managed for wetlands, are used heavily by migrating birds.

Between the Keswick Reservoir and the Feather River confluence with the Sacramento River, the landscape also includes human-built reservoirs and canals. Black Butte Reservoir is operationally integrated with the CVP, and the canal system includes the CVP Corning Canal, Tehama-Colusa Canal, and Glenn-Colusa Irrigation District’s canal. The canals provide visual interest in localized areas with limited viewing opportunities (Reclamation 2015). Several wildlife refuges in the Sacramento Valley provide views of water and vegetation, enhanced seasonally by waterfowl and wildflowers.

N.1.3.1.2 Scenic Highways in the Sacramento Valley Area

In the Sacramento Valley, there are several designated State Scenic Highways and several roads that are eligible for this designation within the study area, including the following roadways:

- Shasta County: SR 151 from Shasta Dam to Lake Boulevard is designated as a State Scenic Highway because of views of the Sacramento River, Shasta Lake, and distant hills. SRs 299, 44, and 89 are eligible for State Scenic Highway designation (Caltrans 2019).
- Tehama County: SRs 89 and 36 are eligible for State Scenic Highway designation (Caltrans 2019).
- Yolo County: A portion of SR 16 is eligible for State Scenic Highway designation (Caltrans 2019).
- Solano County: A portion of SR 37 is eligible for State Scenic Highway designation (Caltrans 2019).
- Napa County: Portions of SRs 29 and 121 are eligible for State Scenic Highway designation (Caltrans 2019).

N.1.3.2 *Feather River to the Delta*

Antelope Lake, Lake Davis, Frenchman Lake, Lake Oroville, and Thermalito Afterbay on the Feather River are human-built reservoirs providing visual contrast with surrounding natural and human-manipulated terrain.

N.1.3.2.1 Upper Feather River

Antelope Lake, Lake Davis, and Frenchman Lake are located in the upper Feather River watershed. Antelope Lake, located on Indian Creek, has the longest dam of the three reservoirs. This remote lake, surrounded by pine and fir trees, can be viewed from Fruit Growers Boulevard and Indian Creek Road.

Lake Davis is formed by Grizzly Dam on Big Grizzly Creek, and is the largest of the three dams. It is located in the upper watershed surrounded by many trees, and can be viewed from Beckwourth-Taylorsville Road and Lake Davis Road. Frenchman Lake, located on Last Chance Creek, is formed by the tallest dam of the three dams. This lake also is surrounded by trees to the waterline and can be viewed from Little Last Chance Creek Road and Frenchman Lake Road (Reclamation 2015).

N.1.3.2.2 Lake Oroville and Thermalito Reservoir

The terrain adjacent to Lake Oroville is generally quite steep with limited vehicular access. Most views of the water are from the bridges on SR 162, SR 70, and several county roads. Some residents live in the lands around Lake Oroville and Thermalito Afterbay. The residents can easily view the water and visitors can view the structures. As described above for Shasta Lake and other reservoirs in the upper Sacramento River watershed, Lake Oroville water levels decline as summer progresses, leaving a ring of bare soil along the water's edge. In extremely dry years at Lake Oroville, more than 200 vertical feet of bare mineral soils in a "bathtub ring" may be exposed when the surface water elevation approaches 710 feet above mean sea level (DWR 2007).

The Diversion Pool between Oroville Dam and Thermalito Diversion Dam extends about 4.5 miles along the Feather River and meanders through hillsides with substantial vegetation in widths ranging from 50 to 200 feet (DWR 2007). Vistas of the Diversion Pool are primarily viewed by recreationists on the water or along the adjacent trails. A 1.9-mile-long concrete Thermalito Power Canal appears as a contrast from SR 70 and county roads to the undeveloped landscape between the Diversion Dam and the Thermalito Forebay. The Thermalito Forebay is a 630-acre reservoir, approximately 3 miles in length that can be viewed by recreationists along or within the open water and travelers along SR 70 as the roadway extends from the foothills to the valley floor. Water levels in these human-built features generally vary by 2 to 4 feet during a week. When the water levels are low, exposed bare soils create a "bathtub ring" effect.

Thermalito Afterbay is located in a more flat terrain than Lake Oroville and can be viewed from many locations and residences. The Thermalito Afterbay Dam is parallel to SR 99 and rises over 30 feet above the roadway (DWR 2007). The Thermalito Afterbay is approximately 4,300 acres and is visible from SR 162, several county roads, recreation areas, and neighboring residences. Because the afterbay is located on flat lands with minimal foothills, vistas from the water or lands surrounding the afterbay extend from the Sierra Nevada foothills to the Feather River on the valley floor. Water levels in the afterbay generally vary by 2 to 6 feet during a week, but can decline by as much as 11 feet. When the water levels are low, exposed bare soils create a "bathtub ring" effect (Reclamation 2015).

The low flow channel of the Feather River extends from the Thermalito Diversion Dam through the community of Oroville (DWR 2007). Urban land uses and other buildings, including the Feather River Fish Hatchery, are located along the channel upstream of the SR 70 bridge. The Oroville Wildlife Area extends from SR 70 on the east, downstream of the bridge, and includes the Thermalito Afterbay area. Dredge tailings from hydraulic mining that occurred over 100 years ago occur along the low flow channel with some of the tailings reaching heights of more than 40 feet above the roadway.

The remaining portions of the Sacramento Valley between the Feather River and the San Francisco Bay Area region contain the Delta and areas located to the east and west of the Delta. Land uses located to the south of the Feather River and outside of the Delta include agricultural, open space, and major urban centers that all use SWP water supplies. Much of this reach of the Sacramento River flows along private property. The urban areas are the cities of Vacaville, Fairfield, and Vallejo in Solano County and unincorporated areas of Napa County.

N.1.3.2.3 Wild and Scenic Rivers and Scenic Highways in the Feather River Watershed

Within the Feather River region considered in this Appendix, the Middle Fork Feather River (from Beckworth to Lake Oroville) was designated as part of Public Law 90-542 (Wild and Scenic Rivers Act) to be part of the National Wild and Scenic Rivers System on October 2, 1968.

In the Feather River watershed and the adjacent Bear River watershed, there is one designated State Scenic Highway and several roads that are eligible for this designation, including the following roadways.

- Butte County: SR70 is eligible for State Scenic Highway designation (Caltrans 2019).
- Plumas County: SRs 70 and 89 are eligible for State Scenic Highway designation (Caltrans 2019).
- Nevada County: SR 20 from Skillman Flat Campground to a half-mile east of Lowell Hill Road is designated a State Scenic Highway and a "U.S. Forest Service (USFS) Scenic Byway" because of views of pine forests and the dramatic results of hydraulic mining. I-80 and SRs 20, 49, and 174 are eligible for State Scenic Highway designation (Caltrans 2019).

N.1.3.2.4 Clear Creek Watershed

The upper portion of lower Clear Creek is characterized by a deep gorge with flowing, cascading water surrounded by a forested upland landscape. The lower portion is characterized by broad alluvial floodplains, meandering gravel bars, and lush riparian vegetation. Varying sections of this reach of lower Clear Creek are influenced by visual impacts from residential homes, industrial areas, commercial developments and SR 273. In addition, mine tailings are visible in areas from past gold dredger and placer mining operations (BLM 2008).

The public lands administered by BLM within the stream reach from the southern Whiskeytown National Recreation Area boundary downstream to Clear Creek Road Bridge have been determined to be eligible as a component of the National Wild and Scenic Rivers System and have been classified as Scenic (BLM 2008) based on the presence of outstandingly remarkable Recreation and Scenic Quality values.

N.1.3.2.5 American River Watershed

The middle and lower American River watershed extends through Placer, El Dorado, and Sacramento Counties. Upstream of Folsom Dam, much of Placer and El Dorado Counties are characterized by undeveloped rolling grasslands and oak woodlands with sporadic agricultural activities related to orchards, vineyards, ornamental flowers, and Christmas tree farms in the wooded foothills. Communities throughout the counties are located especially near I-80, US 50, and SRs 49 and 89.

Folsom Lake, on the American River, is a human-built reservoir providing visual contrast with the foothill landscape. Views from the water surface provide panoramic vistas of the foothills with open grasslands, oak woodlands, and pine woodlands. Folsom Lake is generally considered to provide a pleasing visual setting for recreationists, residences, and from roadways along the foothills above the reservoir, especially from the Lake Overlook and the Folsom Dam Observation Point vista points. Scenic views from around the edges of the lake are of the water and of human-built structures such as electric transmission facilities, roadways, dams, and residential subdivisions. Reservoir levels fluctuate and decline as summer progresses, leaving a "bathtub ring" of bare soil along the water's edge. The visual quality also degrades because visitors drive vehicles onto the exposed soils which cause tire tracks and erosion (Reclamation et al. 2006).

Lake Natoma extends from Folsom Dam along the American River to Nimbus Dam. The land along the river is mostly undeveloped and includes wooded canyon areas, sheer bluffs, and dredge tailings from the gold mining era. Residential and community developments have been constructed along the foothills that overlook the canyon, and these structures can be seen by recreationists from the water or adjacent trails. Lake Natoma can be viewed from US 50 and local roads.

Downstream of Nimbus Dam to Gristmill Recreation Area (downstream of William B. Pond Recreation Area and approximately 2 miles upstream from the Watt Avenue Bridge), the American River flows through a landscape characterized by steep bluffs, terraces, mid-river sand and gravel bars, backwater areas along the edges, and riparian vegetation. This viewshed is seen from the recreational areas on the water and adjoining trails, from the bridge crossings, and from residences along the terraces and foothills. Downstream of the Gristmill Dam Recreation Area, the visual characteristics are less complex with an increased number of bridges, water treatment plant intakes, and artificial bank protection. The communities along the American River corridor include the cities of Folsom, Roseville, Rancho Cordova, and Sacramento and unincorporated areas. The communities, transportation infrastructure, and water-river corridor are visible from multiple vantage points.

N.1.3.2.6 Wild and Scenic Rivers and Scenic Highways in the American River Watershed

Within the American River watershed, the lower American River from Nimbus Dam to the confluence with the Sacramento River were designated by the Secretary of the Interior to be part of the National Wild and Scenic Rivers System on January 19, 1981. The State of California also designated the lower American River as wild and scenic under Public Resources Code sections 5093.54 and 5093.545. In addition, the state designated the North Fork American River from the source to Iowa Hill Bridge as wild and scenic.

In the portion of the American River watershed in the study area, there is one roadway designated as a State Scenic Highway and one road that is eligible for this designation. In El Dorado County, US 50 from Government Center Interchange in Placerville to South Lake Tahoe is designated as a State Scenic Highway because of vistas of the American River canyon, suburban foothills, granite peaks, and Lake Tahoe. Also in El Dorado County, SR 49 is eligible for State Scenic Highway designation (Caltrans 2019).

N.1.4 San Joaquin Valley

For the purposes of this analysis, the San Joaquin Valley includes the San Joaquin River and Stanislaus River regions. The San Joaquin Valley land cover ranges from high alpine vegetation near the crest of the Sierra Nevada, through coniferous forest, mixed forest, oak woodlands, and oak savanna to grasslands and agricultural areas at the lower elevations (Reclamation 1997, 2005a, 2005b). Water bodies include reservoirs, natural lakes and ponds, rivers, and tributary streams. The San Joaquin, Stanislaus, Merced, and Tuolumne Rivers are the principal water features that flow from the Sierra Nevada foothills. One or more reservoirs are located along each of these rivers, including the CVP New Melones Reservoir on the Stanislaus River and Millerton Lake on the San Joaquin River. The human-built environment is more dominant at lower elevations, and includes roadways, communities, roadside businesses, and transmission lines, detracting from views of the natural environment. On the valley floor, the San Joaquin Valley is characterized by agricultural lands, including many that are irrigated with CVP and/or SWP water supplies. The valley is arid to semi-arid, and there are few natural lakes or streams on the valley floor. The Tehachapi Mountains rise abruptly along the southern boundary of the valley.

Several wetlands have been established as wildlife refuges in the San Joaquin Valley, providing views of water and vegetation, enhanced seasonally by waterfowl and wildflowers.

The predominant land use is agricultural, with sparse to moderate populated areas. I-5 and major railroads pass along the western San Joaquin Valley at the base of the Coast Range foothills. SR 99 and other railroads are located along the eastern San Joaquin Valley at the base of the Sierra Nevada foothills. I-580 and SRs 152, 198, and 46 cross the San Joaquin Valley from east to west between I-5 and SR 99. Larger cities have been established in the northern San Joaquin Valley, including Lodi, Stockton, Lathrop, Manteca, and Tracy; and along SR 99, including Merced, Fresno, Visalia, and Bakersfield. Both I-5 and SR 99 are extensively traveled and provide numerous viewing opportunities (Reclamation 2015).

N.1.4.1 *New Melones Reservoir*

The CVP New Melones Reservoir is in the western foothills of the Sierra Nevada along the Stanislaus River. The area is characterized by foothills, ridges, and small valleys with vegetated slopes and the open water surface (Reclamation 2010). The vegetation is primarily grasslands and oak woodlands of varying densities, with gray pine and low shrubs along some slopes. Views of the water are primarily from the water surface, adjacent recreation areas, and SR 49. The surrounding lands are rural and undeveloped except for the infrastructure associated with the dam, canals, power generation facilities, and some minor structures associated with the recreation areas and utility lines. When the water level of the reservoir is drawn down, broad bands of bare soil are exposed.

N.1.4.2 *Tulloch Reservoir*

Tulloch Reservoir is on the Stanislaus River just downstream of New Melones Reservoir and upstream of the Goodwin Dam. Accessible via mostly private lands and docks, there is substantial residential development on the Calaveras County portion of its shoreline.

N.1.4.3 *Millerton Lake*

Millerton Lake is also located in the western foothills of the Sierra Nevada along the San Joaquin River in an area that ranges from grasslands and rolling hills near Friant Dam to steep, craggy slopes in the upper reaches of the lake (Reclamation 2015). The lake, dam infrastructure, and surrounding hills can be viewed from the lake surface and adjacent county roads. Development has occurred along the hillsides that can be viewed from the lake surface and adjacent recreation areas; however; future development will be regulated by Madera and Fresno Counties to protect visual and scenic resources. When the water level of the reservoir is drawn down, broad bands of bare soil are exposed. The Madera Canal and Friant-Kern Canal extend from Millerton Lake to the north and south, respectively. The canals are located along the Sierra Nevada foothills through mostly agricultural landscapes and limited residences (Reclamation 2015). The canals are only intermittently visible from county roads.

N.1.4.4 *San Luis Reservoir Complex*

The CVP and SWP San Luis Reservoir complex is located within the western Coast Range foothills on the western side of the northern San Joaquin Valley; and the CVP and SWP water supply canals are located at the base of the foothills to the north and south of the San Luis Reservoir. This area is sparsely populated and characterized by mountainous to hilly terrain with grasslands and scattered oak woodlands along narrow streams.

The CVP and SWP water supply facilities are prominent features in the overall viewshed of the San Joaquin Valley, including facilities at or near the San Luis Reservoir, Delta-Mendota Canal, San Luis Canal-California Aqueduct, Cross Valley Canal, New Melones Reservoir, and Millerton Lake. SR 152 is along the northern and eastern rims of the San Luis Reservoir and the western rim of the O'Neill Forebay. The O'Neill Forebay and Los Banos Creek Reservoir can be seen to the west from I-5. The reservoirs are also part of the visual resources for the San Luis Reservoir State Recreation Area and Cottonwood Creek Wildlife Area (which are described in Appendix S, *Recreation Technical Appendix*). The shorelines of the reservoirs are undeveloped, except for recreational facilities. Views include annual grassland, coastal sage, and riparian woodland. When the reservoir waters are drawn down, broad bands of bare soil are exposed. Open water viewing opportunities also occur to the south of the San Luis complex at the Little Panoche Reservoir located to the west of I-5 (Reclamation 2015).

The open water and canal infrastructure of the Delta-Mendota Canal, San Luis Canal-California Aqueduct, Cross Valley Canal, and irrigation district canals can be seen from I-5 and the railroad lines along the western San Joaquin Valley. The open water of Mendota Pool is at the terminus of the Delta Mendota Canal and can be viewed from county roads.

N.1.4.5 *Wild and Scenic Rivers and Scenic Highways in the San Joaquin Valley*

In or near the San Joaquin Valley region, four rivers are designated to be part of the National Wild and Scenic Rivers System. Portions of the Tuolumne River from the source waters to the Don Pedro Reservoir were designated through Public Law 98-425 as wild and scenic. Portions of the Merced River were designated through Public Laws 100-149 and 102-432 as wild and scenic, including the entire South Fork and the mainstem from the source waters to Lake McClure. Portions of the Kings River were designated as wild and scenic through Public Law 100-150, including the Middle Fork and South Fork from their respective sources to the confluences with the mainstem; and the mainstem from these confluences to an elevation of 1595 feet above mean sea level (upstream of the confluence with the North Fork and Pine Flat Lake). Portions of the Kern River were designated as wild and scenic through Public Law 100-174, including the North Fork from the source to the Tulare County/Kern County boundary; and the South Fork from the source to the Domeland Wilderness. Most of these reaches are located outside of the San Joaquin Valley region; however, the flows from these reaches could influence the visual resources of downstream reaches in the San Joaquin Valley region and elsewhere.

In the San Joaquin Valley, there are five roadway sections designated as a State Scenic Highway and seven roadway sections that are eligible for this designation.

- San Joaquin County and Alameda County: I-580 from I-5 to SR 205 is designated as a State Scenic Highway because of vistas of the Coast Ranges and Central Valley. I-5 from the Stanislaus County boundary to I-580 is designated as a State Scenic Highway because of vistas of agricultural lands and the Delta Mendota Canal and California Aqueduct (Caltrans 2019).
- Stanislaus County: I-5 from the San Joaquin County boundary to the Merced County boundary is designated as a State Scenic Highway because of vistas of agricultural lands and the Delta Mendota Canal and California Aqueduct (Caltrans 2019).
- Merced County: I-5 from SR 152 to the Stanislaus County boundary is designated as a State Scenic Highway because of vistas of agricultural lands and the Delta Mendota Canal and California Aqueduct. SR 152 from I-5 to the Santa Clara County boundary is designated as a State Scenic

Highway because of vistas of agricultural lands and the San Luis Reservoir State Recreational Area (Caltrans 2019).

- Fresno County: SR 168, 180, and 198 are eligible for State Scenic Highway designation (Caltrans 2019).
- Tulare County: SRs 190 and 198 are eligible for State Scenic Highway designation (Caltrans 2019).
- Kern County: SRs 14 and 58 are eligible for State Scenic Highway designation (Caltrans 2019).

N.1.5 Bay-Delta Region

The Bay-Delta region includes the Delta and Suisun Marsh, which extends south to San Francisco Bay. Most of the Delta is used for agricultural purposes with major waterways and sloughs that connect the Sacramento, San Joaquin, Mokelumne, Cosumnes, and Calaveras Rivers (CALFED 2000). Flood management and irrigation facilities include levees, impoundments, pumping plants, and control gate structures. Bodies of open water occur where historic levee failures were not repaired, including Franks Tract and Liberty Island. The Sacramento Deep Water Ship Channel is a large water feature between levees that extends from the Sacramento River near Rio Vista to West Sacramento. Cities in the Delta are the southern portion of Sacramento, Isleton, West Sacramento, Rio Vista, Lathrop, western portions of Stockton and Manteca, Tracy, Brentwood, Oakley, Antioch, and Pittsburg. Smaller communities include Freeport, Clarksburg, Hood, Courtland, Locke, Walnut Grove, Ryde, Thornton, Knightsen, and Collinsville. Vistas of the Delta can be seen from residences and agricultural areas in the Delta, open water areas used by recreationists, and from vehicles on roadways and railroads that cross the Delta. Waterfront industries are located along the rivers, especially along the San Joaquin River.

Suisun Marsh is characterized by tidal and freshwater wetlands and riparian woodlands (Reclamation et al. 2011). The area is bounded by I-80 and SR 12 on the north; the Montezuma Hills and Sulphur Springs Mountains on the east and west, respectively; and on the south by the open waters of Suisun Bay, Grizzly Bay, and Honker Bay with adjoining wetlands, marshes, and riparian forests. The marsh is relatively flat and composed primarily of tidal marsh and submerged lands. Upland areas serve as a backdrop with grasslands and nearby rolling foothills. Vistas of Suisun Marsh can be viewed from adjacent roadways, railroads, and trails within the marsh; a few residences within the marsh; and open water that can be accessed by boats, kayaks, and canoes. Much of Suisun Marsh is managed wetlands and provides habitat for resident and migrating birds and waterfowl.

The San Francisco Bay Area includes portions of Contra Costa, Alameda, Santa Clara, and San Benito Counties that are within the CVP and SWP service areas. The San Francisco Bay Area ranges in topography from sea level up to the foothills of the East Bay and South Bay that reach elevations of 3,500 feet and higher (CALFED 2000; WTA 2003). The physical and natural environment is diverse, with a wide range of visual resources. Typical views and landscapes include urban development, natural and altered open-space areas, major ridgelines, and scenic waterways. The terrain ranges from alluvial plains to gently sloping hills and wooded ravines. Striking views of iconic scenes are available throughout the area: the San Francisco Bay, the San Francisco skyline, Angel Island, Mount Tamalpais, Peninsula foothills, and the East Bay hills. Views to the east are dominated by Mount Diablo and adjacent Diablo Ridge and valleys. Views in the South Bay extend through the baylands along Contra Costa, San Mateo, Santa Clara, and Alameda Counties' shorelines; the river floodplains of the Guadalupe River and Coyote Creek in Santa Clara County; and toward the Santa Cruz Mountains (Santa Clara County 1994).

Urban and industrial areas are located throughout the San Francisco Bay Area region, including along the San Francisco Bay shoreline. Smaller, localized scenic resources include wetlands, isolated hilltops, rock outcroppings, mature stands of trees, lakes, reservoirs, and other natural features. City parks and recreation areas, open-space areas adjacent to ravines, golf courses, and resource preserves provide visual opportunities in urban areas. The reservoirs that store CVP or SWP water or water from other surface water sources are human-built reservoirs in the foothills or at the edge of the foothills. The water can be viewed from roadways at elevations higher than the reservoirs and by recreationists on the reservoirs. Agricultural areas that use CVP and SWP water are in coastal valleys, especially the Livermore and Amador Valleys of Alameda County, southern Santa Clara County, and northern San Benito County.

N.1.5.1 *Scenic Highways in the Bay-Delta*

In the Bay-Delta Region, there are six roadway sections designated as a State Scenic Highway and several roadway sections that are eligible for this designation.

- Sacramento County: SR 160 between the southern limits of the city of Sacramento to the Contra Costa County boundary is designated as a State Scenic Highway because of the views of historic Delta agriculture and small towns along the Sacramento River (Caltrans 2019).
- Contra Costa County: SR 160 from the Antioch Bridge to SR 4 and SR 4 continuing on toward Brentwood are eligible for State Scenic Highway designation (Caltrans 2019).
- Contra Costa County: SR 24 from the Alameda County boundary to I-680, and I-680 from SR 24 to I-580 at the Alameda County boundary are designated as State Scenic Highways because of the views of Mount Diablo and attractive residential and commercial areas (Caltrans 2019).
- Alameda County: I-580 between I-80 and SR 92 is designated as a State Scenic Highway. Portions of I-680 from the Contra Costa County line to Mission Boulevard in Fremont and portions of SR 84 are designated as State Scenic Highways because of vistas of wooded hillsides and valleys. Other portions of I-580 are eligible for State Scenic Highway designation (Caltrans 2019).
- Santa Clara County: Portions of SRs 152 and 280 within the San Francisco Bay area are eligible for State Scenic Highway designation (Caltrans 2019).
- San Benito County: Portions of SRs 156 and 25 within the San Francisco Bay Area are eligible for State Scenic Highway designation (Caltrans 2019).

N.1.6 CVP and SWP Service Areas (south to Diamond Valley) and Nearshore Pacific Ocean on the California Coast

No project or program-level measures or actions would take place with mechanisms for changes in visual resources conditions in the nearshore coastal region or CVP and SWP export areas. Therefore, no background setting information for these regions is provided for this analysis.

N.2 Evaluation of Alternatives

This section describes potential mechanisms and analytical methods for change in visual resources associated with the No Action Alternative as compared to Alternatives 1, 2, 3, and 4. This section describes the results of the impact analysis, potential mitigation measures, and cumulative effects.

N.2.1 Potential Mechanisms for Change and Analytical Methods

This impact analysis considers changes in visual resources conditions related to continuation of CVP and SWP operations, with some changes, under Alternatives 1, 2, 3, and 4, as compared to the No Action Alternative.

Continuation of CVP and SWP operations, with some changes, under the action alternatives as compared to the No Action Alternative could change the vistas at reservoirs that store CVP and SWP water during dry and critical dry water years and at irrigated agricultural lands during dry and critical dry water years when the crops are idle. Visual changes may occur in the short-term related to construction at the Tracy Fish Collection Facility, the Skinner Fish Facility, and the Delta Fish Species Conservation Hatchery.

N.2.1.1 *Changes in Visual Resources at Tributaries and Reservoirs that Store CVP and SWP Water*

Vistas at tributaries and reservoirs that store CVP and SWP water provide a wide diversity of visual experiences related to the contrasts between the open water surface and surrounding vegetated banks, foothills, or mountainsides. By the end of September, the surface water elevations generally decline, and a bare mineral “bathtub ring” appears in contrast to the open water and the upslope vegetation. Changes in CVP and SWP operations under the action alternatives would have only minor changes to the water levels in tributaries and reservoirs. Figure S.2.3.1-4 of Appendix S, *Recreation Technical Appendix*, shows changes in Shasta Lake water elevations as an example; other reservoirs show similar patterns of elevations compared to the No Action Alternative. As such, water levels at tributaries and reservoirs under the action alternatives would have only small changes and would not affect visual quality at these locations. The flow changes are relatively small during each year type and would not result in substantive changes to the visual resources.

N.2.1.2 *Changes in Vistas at Irrigated Agricultural Lands*

Farmland vistas of irrigated row crops, orchards, and grazing lands intermixed within a landscape of grasslands, large water canals, isolated riparian corridors, and several small communities exist throughout the San Joaquin Valley, Bay-Delta, and Nearshore Coastal regions. Changes in CVP and SWP operations under the action alternatives could change the irrigated acreages and the associated agrarian vistas over the long-term average condition and in dry and critical dry years as compared to the No Action Alternative. As described in Appendix R, *Land Use and Agricultural Resources Technical* Report, the extents of irrigated acreage under the action alternatives would be similar to the existing irrigated acreage under the No Action Alternative; however, restoration and temperature change could result in reduction of agricultural land. Changes in CVP and SWP operations would not generally change irrigated acreage and as a result they are not analyzed in this technical appendix.

N.2.1.3 *Effects Related to Project Actions*

Project and program-level actions in the CVP and SWP operations areas may include habitat restoration, facility improvements, or fish intervention (hands on measures to affect fish directly, rather than affecting their habitat). Most actions are analyzed in this technical appendix at a programmatic level, and would be subject to future, site-specific analysis on a case-by-case basis. Therefore, projecting future visual conditions related to programmatic activities is included in this analysis at a broad level. Furthermore, many project actions would have minor or no direct visual effects, such as ongoing maintenance activities, replacement of aging apparatus with similar apparatus, gravel placement, drought temperature management, control of nutrients in the water, and study and monitoring of specific habitats or species. However, there are three project-specific conservation measures that are analyzed for visual effects herein: the Tracy Fish Collection Facility, the Skinner Fish Facility, and the Delta Fish Species Conservation Hatchery.

N.2.2 No Action Alternative

Under the No Action Alternative, operations would continue as they currently are under the existing condition. Operations changes and non-flow habitat and facility improvements, as well as the proposed conservation measures (habitat restoration, facility improvements, or fish intervention), would not take place with the exception of 8,000 acres of tidal habitat restoration required by the U.S. Fish and Wildlife Service (USFWS) Biological Opinion (BO) (USFWS 2008) in the Suisun Marsh and/or the north Delta.

The No Action Alternative is evaluated based on 2030 conditions. Changes that would occur over the next 11 years without implementation of the action alternatives are not analyzed in this technical appendix. However, the changes to visual resources that are assumed to occur by 2030 under the No Action Alternative are summarized in this section.

N.2.2.1 *Common Changes in Conditions under the No Action Alternative*

Conditions in 2030 would be different than existing conditions because of the following factors:

- Climate change and sea-level rise
- General plan development throughout California, including increased water demands in portions of the Sacramento Valley
- Implementation of reasonable and foreseeable water resources management projects to provide water supplies

It is anticipated that climate change would result in more short-duration high-rainfall events and less snowpack in the winter and early spring months. The reservoirs would be full more frequently by the end of April or May by 2030 than in recent historical conditions. However, as the water is released in the spring, there would be less snowpack to refill the reservoirs. This condition would reduce reservoir storage and available water supplies to downstream uses in the summer. The reduced end-of-September storage would also reduce the ability to release stored water to downstream regional reservoirs. These conditions would occur for all reservoirs in the California foothills and mountains, including reservoirs that are not part of the CVP and SWP.

These changes would result in a decline of the long-term average CVP and SWP water supply deliveries by 2030 as compared to recent historical long-term average deliveries under the No Action Alternative.

Under the No Action Alternative, land uses in 2030 would occur in accordance with adopted general plans. Development under the general plans would change visual resources, especially near municipal areas.

The No Action Alternative assumes completion of water resources management and environmental restoration projects, including regional and local recycling projects, surface water and groundwater storage projects, conveyance improvement projects, and desalination projects. The No Action Alternative also assumes implementation of actions included in the 2008 USFWS BO and 2009 National Marine

Fisheries Service (NMFS) BO that would have been implemented by 2030. These include two projects that would affect visual resources:

- Restoration of more than 10,000 acres of intertidal and associated subtidal wetlands in Suisun Marsh and Cache Slough; and at least 17,000 to 20,000 acres of seasonal floodplain restoration in Yolo Bypass
- Restoration of Battle Creek

N.2.3 Alternative 1

N.2.3.1 *Project-Level Effects*

N.2.3.1.1 Sacramento Valley

Potential changes in visual resources at tributaries and reservoirs that store CVP and SWP water

Alternative 1 would make changes to: Whiskeytown Reservoir operations, Clear Creek flows, and Spring Creek Debris Dam. These actions could affect seasonal water levels at the following tributaries: Clear Creek, Spring Creek, Sacramento River. Seasonal water levels could also be affected at the following reservoirs: Buckhorn, Whiskeytown, Trinity, Kenswick, and Shasta. Changes in visual resources at tributaries and reservoirs that store CVP and SWP water supplies are assumed to be related to changes in water deliveries over long-term conditions for this analysis. Monthly deliveries are not necessarily indicative of reservoir storage because all or a portion of the water deliveries could be directly conveyed to water users in any specific month. Therefore, annual deliveries are considered to be relatively proportional to the amount of water that could be stored over all water year types. As stated above, it is assumed that visual resources related to surface water elevations in the tributaries and reservoirs mentioned above that store CVP and SWP water supplies would be affected minimally or not at all by Alternative 1 related to reduced or fluctuating surface water and potentially increased “bathtub ring” conditions.

Potential effects on visual resources related to cross Delta water transfers

Potential effects on visual resources could be similar to those identified in a recent environmental analysis conducted by Reclamation for long-term water transfers from the Sacramento Valley to San Joaquin Valley (Reclamation 2014). Potential effects on visual resources were identified as changes in reservoir surface water elevations, streams, irrigated acreage, and water elevations in canals that would convey transferred water. The analysis indicated that these potential impacts would not be substantial because the conditions with and without the water transfers would be similar.

Under Alternative 1, the timing of cross Delta water transfers would be limited to July through November and include annual volumetric limits, in accordance with the 2008 USFWS BO and 2009 NMFS BO.

Potential changes in visual resources at Shasta Dam

Under Alternative 1, Reclamation would enlarge Shasta Dam and Reservoir by raising the dam crest 18.5 feet (which would be analyzed under a separate ESA consultation for construction). Under Alternative 1, the average water elevation of Shasta Lake would increase slightly from September through December compared to the No Action Alternative but would remain similar to existing conditions from February through August, as shown in Figure S.2.3.1-4 of Appendix S, Recreation Technical Appendix. Raising the Shasta Dam could increase Shasta Lake average elevations; however, the dam raise has not been explicitly modeled. Changes in visual resources, particularly surface water levels and the “bathtub ring” effect at Shasta Dam would be reduced in all water year types because the end-of-September surface water elevations would potentially be increased.

N.2.3.1.2 Bay-Delta Region

Potential changes in visual resources related to Clifton Court aquatic weed removal

Under Alternative 1, the California Department of Water Resources (DWR) would apply two additional types of herbicides and expand the treatment season to more effectively control aquatic weeds and algal blooms in Clifton Court Forebay. These actions are consistent with those under the No Action Alternative. Therefore, changes to visual resources would not occur.

Potential changes in visual resources at Tracy Fish Collection Facility and Skinner Fish Facility

Under Alternative 1, Reclamation would continue to screen fish from Jones Pumping Plant with the Tracy Fish Collection Facility, and from Banks Pumping Plant with the Skinner Fish Facility. The result of these operations at Tracy Fish Collection Facility and Skinner Fish Facility to visual resources would be minimal because these operations would be a continuation of current procedures. Additionally, truck haul trips that return salvaged fish to the Delta would be temporary and short-term and would not substantially change visual resources.

N.2.3.2 *Program-Level Effects*

N.2.3.2.1 Trinity River Region

Potential effects on visual resources related to Trinity ROD flows and Lower Klamath augmentation flows

Under Alternative 1, Reclamation would continue Trinity ROD Flows and Lower Klamath Augmentation Flows that are described in the No Action Alternative, and would also continue under Alternatives 2 and 3, but additionally would pulse flows between March 1 and April 15 to mobilize gravel, and implement October and November releases for Coho spawning, to the extent feasible. This could have a potential long-term improvement of water clarity and overall visual quality of the river corridor, related to late summer algal blooms in the Lower Klamath River watershed.

N.2.3.2.2 American River Region

Potential changes in visual resources at Folsom Reservoir related to American River Division flows

Under Alternative 1, Reclamation would make changes to American River Division flows that would affect Folsom Reservoir’s water levels. Visual resources related to surface water elevations in Folsom Reservoir would be minimally or not at all affected, as discussed above, related to reduced or fluctuating surface water and “bathtub ring” conditions, because such changes would not be visually noticeable.

N.2.3.2.3 Bay-Delta Region

Potential changes in visual resources at Delta Fish Species Conservation Hatchery

Under Alternative 1, Reclamation would partner with DWR to construct and operate a new conservation hatchery for Delta Smelt. Potential changes to visual resources could occur in the Delta region related to short-term, temporary construction activities, including truck hauling, construction vehicle use and storage, and equipment and materials storage..

N.2.4 Alternative 2

N.2.4.1 *Project-Level Effects*

Alternative 2 includes flows required by D-1641, which provides protection for fish and wildlife, municipal and industrial (M&I) water quality, agricultural water quality, and Suisun Marsh salinity. These project-level changes would not directly affect visual resources or cause substantial changes to visual quality. Project-level visual effects under Alternative 2 would therefore be similar to the No Action Alternative. Additionally, under Alternative 2, project-level visual effects would be less than those under Alterative 1 because the Shasta Dam Raise, habitat restoration, and intervention measures would not occur, as they would under Alternative 1.

N.2.4.2 *Program-Level Effects*

No program-level actions are proposed as part of Alternative 2. Alternative 2 would have fewer visual effects than Alternatives 1 and 3, and similar effects to Alternative 4, because it would not include the program-level fish intervention (conservation) action to construct the Delta Fish Species Conservation Hatchery. The U.C. Davis Fish Culture Center Refugial Population program would continue, as it would under the No Action Alternative.

N.2.5 Alternative 3

Alternative 3 includes flows required by D-1641, which provides protection for fish and wildlife, M&I water quality, agricultural water quality, and Suisun Marsh salinity and habitat restoration and intervention measures (agricultural barriers, Clifton Court weed removal, fish collection facility improvements, and predator hotspot removal). More specifically, these include Sacramento River intervention measures (small screens, adult rescue, juvenile trap and haul), spawning and rear habitat restoration on the American and Stanislaus Rivers, San Joaquin River restoration program flows, and Lower San Joaquin River rearing habitat restoration.

N.2.5.1 *Project-Level Effects*

Alternative 3 project-level visual effects would be less than those under Alterative 1 because the Shasta Dam Raise would not occur.

N.2.5.2 *Program-Level Effects*

Alternative 3 involves approximately 25,000 more acres of habitat restoration plans than Alternative 1. While restoration efforts (such as creation or rehabilitation of spawning and rearing habitat, adult rescue, juvenile trap and haul, and small screen programs) would have no visual effects once operational, there could be short-term construction effects. Construction vehicles, trucks, and other construction equipment and activities could temporary effect the quality of visual resources and views during habitat restoration activities at Sacramento, American, Stanislaus, and San Joaquin Rivers, and the Bay-Delta region.

Alternative 3 includes construction of the program-level fish intervention (conservation) action to build the Delta Fish Species Conservation Hatchery.

Other program-level changes and project-level actions under Alternative 3 would be the same regarding visual resources impacts as described above under Alternative 1.

N.2.6 Alternative 4

N.2.6.1 *Project-Level Effects*

Alternative 4 would have decreased exports compared to the No Action Alternative. This would result in a range of no fluctuation to minor fluctuations of increased water elevations (zero to approximately 13 feet) in the following regions: Trinity River, Sacramento River, Clear Creek, Feather River, American River, Stanislaus River, San Joaquin River, and Bay-Delta. In the CVP and SWP Service Area under Alternative 4, increased water fluctuation would be as high as 20 feet at San Luis Reservoir between August and March. Similar to Alternatives 1, 2, and 3, the minor increases in water levels would not directly affect visual resources or cause substantial changes to visual quality. Project-level visual effects under Alternative 4 would therefore be similar to the No Action Alternative.

N.2.6.2 *Program-Level Effects*

Alternative 4 does not include additional habitat restoration and fish intervention actions and, similar to Alternative 2, would have fewer visual effects than Alternatives 1 and 3 because there would be no short-term construction impacts on visual resources. Water efficiency use measures under this alternative would have no visual impacts. Program-level visual effects under Alternative 4 would therefore be similar to the No Action Alternative.

N.2.7 Potential Mitigation Measures

Changes in CVP and SWP operations under Alternatives 1 through 4, as compared to the No Action Alternative, would not result in adverse changes to visual resources. Therefore, there would be no adverse impacts to visual resources and no mitigation measures are required.

N.2.8 Summary of Impacts

Table N-1 includes a summary of impacts by alternative, the magnitude and direction of those impacts, and potential mitigation measures for consideration.

Table N-1. Impact Summary

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
Potential changes in visual resources at tributaries and reservoirs that store CVP and SWP water. (Project-Level)	No Action	No effect	–
	1	No impact	–
	2	No effect	–
	3	No effect	–

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
	4	No effect	–
Potential effects on visual resources related to cross Delta water transfers. (Project-Level)	No Action	No effect	–
	1	Not substantial	–
	2	Not substantial	–
	3	Not substantial	–
	4	No effect	–
Potential changes in visual resources at Shasta Dam. (Project-Level)	No Action	No effect	–
	1	“Bathtub ring” effect at Shasta Dam reduced in all water year types because the end-of-September surface water elevations would be potentially increased.	–
	2	No effect	–
	3	No effect	–
	4	No effect	–
Potential changes in visual resources related to Clifton Court aquatic weed removal. (Project-Level)	No Action	No effect	–
	1	No effect	–
	2	No effect	–
	3	No effect	–
	4	No effect	–
Potential changes in visual resources at Tracy Fish Collection Facility and Skinner Fish Facility. (Project-Level)	No Action	No effect	–
	1	Not substantial	–
	2	Not substantial	–
	3	Not substantial	–
	4	No effect	–

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
Potential changes in visual resources at Delta Fish Species Conservation Hatchery. (Program-Level)	No Action	No effect	–
	1	Short-term: construction impacts	–
	2	No effect	–
	3	Short-term: construction impacts	–
	4	No effect	–
Potential effects related to Trinity ROD flows and Lower Klamath augmentation flows. (Program-Level)	No Action	Potential long-term improvement on water clarity and overall visual quality	–
	1	Potential long-term improvement on water clarity and overall visual quality	–
	2	Potential long-term improvement on water clarity and overall visual quality	–
	3	Potential long-term improvement on water clarity and overall visual quality	–
	4	Potential long-term improvement on water clarity and overall visual quality	–
Potential changes in visual resources at Folsom Reservoir related to American River Division flows. (Program-Level)	No Action	No effect	–
	1	No effect	–
	2	No effect	–
	3	No effect	–
	4	No effect	–

N.2.9 Cumulative Effects

As described in Appendix Y, *Cumulative Methodology*, the cumulative effects analysis considers projects, programs, and policies that are not speculative and are based upon known or reasonably foreseeable long-range plans, regulations, operating agreements, or other information that establishes them as reasonably foreseeable.

The action alternatives would have minimal adverse effects on visual resources and visual quality, therefore the action alternatives are not expected to contribute to cumulative visual quality impacts.

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Appendix O Aquatic Resources Technical Appendix

This appendix describes the fish and aquatic resources that occur in the portions of the project area that could be affected as a result of implementing the alternatives evaluated in this draft Environmental Impact Statement (EIS). Implementation of the alternatives could affect aquatic resources through changes in ecological attributes as a result of potential changes in long-term operation of the Central Valley Project (CVP) and State Water Project (SWP) and ecosystem restoration.

O.1 Regulatory Environment and Compliance Requirements

Potential actions implemented under the alternatives evaluated in this EIS could affect fish and aquatic resources. Actions located on public agency lands, or implemented, funded, or approved by federal and state agencies, would need to be compliant with appropriate federal and state agency policies and regulations.

O.2 Background Information

This section describes fish and aquatic resources that could be affected by the implementation of the alternatives considered in this EIS. Changes in aquatic resources due to changes in CVP and SWP operations may occur in the study area.

The following description of the affected environment focuses on CVP and SWP reservoirs, rivers downstream of CVP and SWP reservoirs, the Sacramento-San Joaquin Rivers Delta Estuary (Delta), and conditions downstream of the Delta that are affected by operation of the CVP and SWP.

This section is organized by geographic area, generally in an upstream to downstream direction. This format does not necessarily coincide with the use by fish and aquatic species, which can move among geographic areas either seasonally or during different phases of their life history.

The descriptions of species and biological and hydrodynamic processes in this chapter frequently use the terms *Delta* and *San Francisco Estuary*. The *Delta* refers to the Sacramento–San Joaquin Delta, as legally defined in the Delta Protection Act. The *San Francisco Estuary* refers to the portion of the Sacramento–San Joaquin Rivers watershed downstream of Chipps Island that is influenced by tidal action and where fresh water and salt water mix, which includes the following water bodies: Suisun, San Pablo, and San Francisco Bays.

O.2.1 Fish and Aquatic Species Evaluated

Many fish and aquatic species use the action area during all or some portion of their lives; however, certain fish and aquatic species were selected to be the focus of this analysis based on their sensitivity and their potential to be affected by changes in the operation of the CVP and SWP implemented under the alternatives considered in this EIS, as summarized in Table O.2-1. While many of the species identified in Table O.2-1 also occur in tributaries to the major rivers, the focus of this EIS is on the water bodies influenced by operations of the CVP and SWP. Operation of the CVP and SWP would not directly affect ocean conditions; however, operations have the potential to affect Southern Resident Killer Whales indirectly by influencing the number of Chinook Salmon (produced in the Sacramento and San Joaquin Rivers and associated tributaries) that enter the Pacific Ocean and become available as a food supply for the whales.

These focal species are fish and marine mammal species listed as threatened or endangered or at risk of being listed threatened or endangered, legally protected, or are otherwise considered sensitive by the U.S. Fish and Wildlife Service (USFWS), National Marine Fisheries Service (NMFS), or California Department of Fish and Wildlife (CDFW), and that have tribal, commercial, or recreational importance. In addition, Salmon, Steelhead, Sturgeon, Striped Bass, and American Shad are managed in accordance with Section 3406 of the Central Valley Project Improvement Act. Details on the status, life history, habitat requirements, and population trends for each of the aquatic focal species are provided in the Final Biological Assessment for the Reinitiation of Consultation on the Long-Term Operation of the Central Valley Project and State Water Project.

Table O.2-1 Focal Fish Species by Region of Occurrence

Species or *Population*	**Federal Status**	**State Status[2]**	**Tribal, Commercial, or Recreational Importance**	**Occurrence within Study Area**
Coho Salmon *Southern Oregon/Northern California Coast ESU*	Threatened	Threatened	Yes	Trinity River
Green Sturgeon *Southern DPS*	Threatened	Species of Special Concern	Yes	Trinity River
Spring-Run Chinook Salmon *Upper Klamath-Trinity River ESU*	None	Species of Special Concern	Yes	Trinity River
Steelhead (Winter- and Summer-Run) *Klamath Mountains Province DPS*	None	Species of Special Concern[3]	Yes	Trinity River
Coastal Cutthroat Trout	None	Species of Special Concern	Yes	Trinity River
American Shad	None	None	Yes	Trinity River
Pacific Lamprey	Species of Concern	Species of Special Concern	Yes	Trinity River
White Sturgeon	None	Species of Special Concern	Yes	Trinity River
Black Bass (Largemouth, Smallmouth, Spotted)	None	None	Yes	Trinity River
Winter-Run Chinook Salmon *Sacramento River ESU*	Endangered	Endangered	Yes	Sacramento River, Delta, and Suisun Marsh

Species or *Population*	**Federal Status**	**State Status[2]**	**Tribal, Commercial, or Recreational Importance**	**Occurrence within Study Area**
Spring-Run Chinook Salmon *Central Valley ESU*	Threatened	Threatened	Yes	Clear Creek, Sacramento River, Feather River, American River, Delta, and Suisun Marsh
Steelhead *Central Valley DPS*	Threatened	None	Yes	Clear Creek, Feather River, Sacramento River; American River, Stanislaus River, San Joaquin River, Delta and Suisun Marsh
Green Sturgeon *Southern DPS*	Threatened	Species of Special Concern	Yes	Feather River, Sacramento River, Delta and Suisun Marsh
Delta Smelt	Threatened	Endangered	No	Delta and Suisun Marsh
Longfin Smelt *Bay Delta DPS*	Candidate	Threatened, Species of Special Concern	No	Delta and Suisun Marsh
Fall- /Late Fall-Run Chinook Salmon *Central Valley ESU*	Species of Concern	Species of Special Concern	Yes	Clear Creek, Feather River, Sacramento River, American River, Stanislaus River, San Joaquin River, Delta and Suisun Marsh
Sacramento Splittail	None	Species of Special Concern	No	Feather River, American River, Sacramento River, Delta and Suisun Marsh, San Joaquin River
Hardhead	None	Species of Special Concern	No	Clear Creek, Feather River, Sacramento River, American River, Delta, Stanislaus River, San Joaquin River
Sacramento-San Joaquin Roach	None	Species of Special Concern	No	Clear Creek, Feather River, American River, Sacramento River, Delta, Stanislaus River, San Joaquin River
River Lamprey	None	Species of Special Concern	Yes	Feather River, American River, Sacramento River, Delta and Suisun Marsh, Stanislaus River, San Joaquin River
Pacific Lamprey	Species of Concern	Species of Special Concern	Yes	Clear Creek, Feather River, Sacramento River, American River, Delta, Stanislaus River, San Joaquin River
White Sturgeon	None	Species of Special Concern	Yes	Feather River, Sacramento River, American River, San Joaquin River, Delta and Suisun Marsh

Species or *Population*	**Federal Status**	**State Status[2]**	**Tribal, Commercial, or Recreational Importance**	**Occurrence within Study Area**
American Shad	None	None	Yes	Feather River, American River, Sacramento River, Delta and Suisun Marsh, Stanislaus River, San Joaquin River
Black Bass (Largemouth, Smallmouth, Spotted)	None	None	Yes	Feather River, American River, Sacramento River, Delta and Suisun Marsh, Stanislaus River, San Joaquin River
Striped Bass	None	None	Yes	Feather River, American River, Sacramento River, Delta and Suisun Marsh, Stanislaus River, San Joaquin River
Steelhead *Central California Coast DPS*	Threatened	None	Yes	Bay-Delta
Killer Whale *Southern Resident DPS*	Endangered	None	Yes	Nearshore Coastal

ESU = evolutionarily significant unit
DPS = distinct population segment

The life history attributes (e.g., timing of juvenile out-migration) for most of the species listed above, along with the ecological attributes important to the species and potentially influenced by the alternatives, are discussed in this appendix according to the geographic areas (regions/subregions) where the species occurs. Pacific Lamprey, Green Sturgeon, White Sturgeon, American Shad, and Striped Bass are discussed in detail only in those regions where they spend the majority of their life cycle such that geographic information is available. For several species (i.e., River Lamprey, Central California Roach, and Hardhead) little geographic information is available; therefore, they are not discussed in detail in this appendix, but are described in the species accounts presented in the Final Biological Assessment of the Reinitiation of Consulation on the Coordinated Long-Term Operation of the Central Valley Project and State Water Project. Additionally, these species are only generally addressed in the analysis of impacts presented in Section O.3, *Evaluation of Alternatives*.

The level of detail presented here is tailored to correspond the level of resolution of the analysis, which relies on modeling tools that broadly characterize the changes in CVP and SWP operations on reservoir storage and flows. This level of detail is intended to support an understanding of the resources potentially affected and the context within which the project is evaluated. The inclusion of unnecessary detail is avoided.

O.2.2 Critical Habitat

Critical habitat refers to areas designated by USFWS or NMFS for the conservation of their jurisdictional species listed as threatened or endangered under the Endangered Species Act (ESA) of 1973. When a species is proposed for listing under the ESA, USFWS or NMFS considers whether there are certain areas essential to the conservation of the species. Critical habitat is defined in Section 3, Provision 5 of the ESA as follows.

> *5)(A) The term "critical habitat" for a threatened or endangered species means–*

> *(i) the specific areas within the geographical area occupied by a species at the time it is listed in accordance with the Act, on which are found those physical or biological features (I) essential to the conservation of the species, and (II) which may require special management considerations or protection; and*
>
> *(ii) specific areas outside the geographical area occupied by a species at the time it is listed in accordance with the provisions of section 4 of this Act, upon a determination by the Secretary that such areas are essential for the conservation of the species.*

Any federal action (permit, license, or funding) in critical habitat requires that the federal agency consult with USFWS or NMFS if the action has potential to adversely modify the habitat for the listed species.

ESA regulations state that the physical and biological features essential to the conservation of the species include: space for individual and population growth and for normal behavior; food, water, air, light, minerals, or other nutritional or physiological requirements; cover or shelter; sites for breeding, reproduction, and rearing of offspring; and habitats that are protected from disturbance or are representative of the historical geographical and ecological distribution of a species. These principal biological and physical features are known as Primary Constituent Elements (PCEs)[1]. Specific PCEs identified for salmonids, Green Sturgeon, Delta Smelt, and Eulachon are described below.

O.2.2.1 *Anadromous Salmonids*

In designating critical habitat for anadromous salmonids (70 *Federal Register* [FR] 52536), NMFS identified the following PCEs as essential to the conservation of the listed populations:

- Freshwater spawning sites with water quantity and quality conditions and substrate that support spawning, incubation, and larval development.
- Freshwater rearing sites with:
  - Water quantity and floodplain connectivity to form and maintain physical habitat conditions and support juvenile growth and mobility.
  - Water quality and forage supporting juvenile development.
  - Natural cover such as shade, submerged and overhanging large wood, log jams and beaver dams, aquatic vegetation, large rocks and boulders, side channels, and undercut banks.
- Freshwater migration corridors free of obstruction and excessive predation with water quantity and quality conditions and natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, side channels, and undercut banks supporting juvenile and adult mobility and survival.
- Estuarine areas free of obstruction and excessive predation with:
  - Water quality, water quantity, and salinity conditions supporting juvenile and adult physiological transitions between fresh water and salt water.

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[1] The USFWS and NMFS have proposed discontinuing the use of the term *Primary Constituent Elements* to simplify and clarify the critical habitat process and to provide consistency with the language contained in the Endangered Species Act, which uses the term *physical or biological features*.

- Natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, and side channels.
- Juvenile and adult forage, including aquatic invertebrates and fishes, supporting growth and maturation.

Critical habitat in nontidal waters includes the stream channels in the designated stream reaches, the lateral extent of which generally is defined by the ordinary high-water line.

O.2.2.2 *Central Valley Spring-Run Chinook Salmon ESU*

This evolutionarily significant unit (ESU) consists of Spring-Run Chinook Salmon in the Sacramento River basin, including Spring-Run Chinook Salmon from the Feather River Hatchery. Designated critical habitat for Central Valley Spring-Run Chinook Salmon includes stream reaches of the American, Feather, Yuba, and Bear Rivers; tributaries of the Sacramento River, including Big Chico, Butte, Deer, Mill, Battle, Antelope, and Clear Creeks; and the main stem of the Sacramento River from Keswick Dam through the Delta. Designated critical habitat in the Delta includes portions of the Delta Cross Channel (DCC), Yolo Bypass, and portions of the network of channels in the northern Delta. Critical habitat for Spring-Run Chinook Salmon was not designated for the Stanislaus or San Joaquin Rivers.

The Spring-Run Chinook Salmon critical habitat potentially affected by operation of the CVP and SWP includes the network of channels in the northern Delta, Sacramento River up to Keswick Dam, Clear Creek up to Whiskeytown Dam, the Feather River up to the Fish Barrier Dam, and the American River up to Watt Avenue. The section of the American River denoted as critical habitat serves only as juvenile nonnatal rearing habitat; Spring-Run Chinook Salmon do not spawn in the American River. Operation of the CVP and SWP would have no effect on designated critical habitat for Spring-Run Chinook Salmon in the Yuba River and Big Chico, Butte, Deer, Mill, Battle, and Antelope Creeks or other tributaries of the Sacramento River. Operation of the CVP and SWP could affect designated critical habitat in the San Francisco Bay/Sacramento–San Joaquin Delta (Bay-Delta) region. There is no designated critical habitat for Spring-Run Chinook Salmon in the San Joaquin River region.

O.2.2.3 *Sacramento River Winter-Run Chinook Salmon ESU*

The Sacramento River Winter-Run Chinook Salmon ESU consists of only one population confined to the upper Sacramento River. This ESU includes all fish spawning naturally in the Sacramento River and its tributaries, as well as fish that are propagated at the Livingston Stone National Fish Hatchery (NFH), which is operated by USFWS (NMFS 2005a). Critical habitat was delineated as the Sacramento River from Keswick Dam to Chipps Island at the westward margin of the Delta; all waters from Chipps Island westward to the Carquinez Bridge, including Honker Bay, Grizzly Bay, Suisun Bay, and the Carquinez Strait; all waters of San Pablo Bay westward of the Carquinez Bridge; and all waters of San Francisco Bay (north of the San Francisco-Oakland Bay Bridge) to the Golden Gate Bridge (NMFS 1993).

O.2.2.4 *Central Valley Steelhead DPS*

The California Central Valley Steelhead DPS includes all naturally spawned populations of Steelhead in the Sacramento and San Joaquin Rivers and their tributaries, excluding Steelhead from San Francisco and San Pablo Bays and their tributaries. Two artificial propagation programs, the Coleman NFH and Feather River Hatchery Steelhead hatchery programs, are considered to be part of the DPS. Critical habitat for Central Valley Steelhead includes stream reaches of the American, Feather, Yuba, and Bear Rivers and their tributaries, and tributaries of the Sacramento River including Deer, Mill, Battle, Antelope, and Clear Creeks in the Sacramento River basin; the Mokelumne, Calaveras, Stanislaus, Tuolumne, and Merced

Rivers in the San Joaquin River basin; and portions of the Sacramento and San Joaquin Rivers. Designated critical habitat in the Delta includes portions of the DCC, Yolo Bypass, Ulatis Creek, and portions of the network of channels in the Sacramento River portion of the Delta; and portions of the San Joaquin, Cosumnes, and Mokelumne Rivers and portions of the network of channels in the San Joaquin portion of the Delta.

The Central Valley Steelhead critical habitat potentially affected by operation of the CVP and SWP includes the Sacramento River up to Keswick Dam, Clear Creek up to Whiskeytown Dam, the Feather River up to the Fish Barrier Dam, and the American River up to Nimbus Dam in the Sacramento Valley subregion. Operation of the CVP and SWP would have no effect on designated critical habitat for Steelhead in the Yuba River and Big Chico, Butte, Deer, Mill, Battle, and Antelope Creeks or other tributaries of the Sacramento River.

O.2.2.5 *Central California Coast Steelhead DPS*

The Central California Coast Steelhead DPS includes all naturally spawned populations of Steelhead in streams from the Russian River to Aptos Creek, in Santa Cruz County (inclusive). It also includes the drainages of San Francisco and San Pablo Bays. Critical habitat for Central California Coast Steelhead includes stream reaches in the Russian River, Bodega, Marin Coastal, San Mateo, Bay Bridge, Santa Clara, San Pablo, and Big Basin Hydrologic Units. Operation of the CVP and SWP would not affect designated critical habitat for this DPS of Central California Coast Steelhead, and NMFS (2009a) concluded that operation would not likely adversely affect individual fish; therefore, this species is not addressed in this EIS.

O.2.2.6 *Southern Oregon/Northern California Coastal Coho Salmon ESU*

The Southern Oregon/Northern California Coast Coho Salmon ESU consists of populations from Cape Blanco, Oregon, to Punta Gorda, California, including Coho Salmon in the Trinity River. In the Trinity River region, all Trinity River reaches downstream of Lewiston Dam, the south fork of the Trinity River, and the entire lower Klamath River are designated as critical habitat with the exception of tribal lands (NMFS 1999).

O.2.2.7 *North American Green Sturgeon Southern DPS*

The North American Green Sturgeon Southern DPS consists of coastal and Central Valley populations south of the Eel River, with the only known spawning population in the Sacramento River. In designating critical habitat for the North American Green Sturgeon Southern DPS, NMFS (74 FR 52345) identified PCEs as essential to the conservation of this species in freshwater riverine systems, estuarine areas, and nearshore marine waters. The PCEs for each area largely overlap and include the following items:

- **Food Resources.** Abundant prey items for larval, juvenile, subadult, and adult life stages.
- **Substrate Type or Size (i.e., structural features of substrates).** Substrates suitable for egg deposition and development (e.g., bedrock sills and shelves, cobble and gravel, or hard clean sand, with interstices or irregular surfaces to “collect” eggs and provide protection from predators, and free of excessive silt and debris that could smother eggs during incubation), larval development (e.g., substrates with interstices or voids providing refuge from predators and from high-flow conditions), and subadults and adults (e.g., substrates for holding and spawning).

- **Water Flow.** A flow regime (i.e., the magnitude, frequency, duration, seasonality, and rate-of-change of fresh water discharge over time) necessary for normal behavior, growth, and survival of all life stages.
- **Water Quality.** Water quality, including temperature, salinity, oxygen content, and other chemical characteristics, necessary for normal behavior, growth, and viability of all life stages.
- **Migratory Corridor.** A migratory pathway necessary for the safe and timely passage of Southern DPS fish within riverine habitats and between riverine and estuarine habitats (e.g., an unobstructed river or dammed river that still allows for safe and timely passage).
- **Water Depth.** Deep (greater than 5 meters [m]) holding pools for both upstream and downstream holding of adult or subadult fish, with adequate water quality and flow to maintain the physiological needs of the holding adult or subadult fish.
- **Sediment Quality.** Sediment quality (i.e., chemical characteristics) necessary for normal behavior, growth, and viability of all life stages.

Critical habitat in freshwater riverine habitats includes the stream channels in the designated stream reaches with the lateral extent defined by the ordinary high-water line. The ordinary high-water line on nontidal rivers is defined as “the line on the shore established by the fluctuations of water and indicated by physical characteristics such as a clear, natural line impressed on the bank; shelving; changes in the character of soil; destruction of terrestrial vegetation; the presence of litter and debris, or other appropriate means that consider the characteristics of the surrounding areas” (33 Code of Federal Regulations 329.11(a)(1)).

Within the study area, critical habitat includes the Sacramento River from the I-Street Bridge upstream to Keswick Dam, including areas in the Yolo Bypass and the Sutter Bypass and the lower American River from the confluence with the Sacramento River upstream to the State Route 160 bridge over the American River; the lower Feather River from the confluence with the Sacramento River upstream to the Fish Barrier Dam; and the lower Yuba River from the confluence with the Feather River upstream to Daguerre Dam. Critical habitat also includes all waterways of the Delta up to the elevation of mean higher high water except for certain excluded areas and all tidally influenced areas of San Francisco Bay, San Pablo Bay, and Suisun Bay up to the elevation of mean higher high water (NMFS 2009b).

O.2.2.8 *Delta Smelt*

In designating critical habitat for Delta Smelt (59 FR 65256), USFWS identified the following PCEs essential to the conservation of the species:

- suitable substrate for spawning;
- water of suitable quality and depth to support survival and reproduction (e.g., temperature, turbidity, lack of contaminants);
- sufficient Delta flow to facilitate spawning migrations and transport of larval Delta Smelt to appropriate rearing habitats; and
- salinity, which influences the extent and location of the low salinity zone where Delta Smelt rear. The location of the low salinity zone (or X2) is described in terms of the average distance of the two practical salinity units isohaline from the Golden Gate Bridge.

Critical habitat for Delta Smelt includes all water and submerged lands below ordinary high water and the entire water column bounded by and contained in Suisun Bay (including the contiguous Grizzly and Honker Bays); the length of Goodyear, Suisun, Cutoff, First Mallard (Spring Branch), and Montezuma Sloughs; and the existing contiguous waters contained in the legal Delta (as defined in Section 12220 of the California Water Code) (USFWS 1994).

O.2.2.9 *Eulachon Southern DPS*

In designating critical habitat for Eulachon, NMFS (76 FR 65323) identified the following physical or biological features essential to the conservation of the Eulachon Southern DPS reflect key life history phases of Eulachon: (1) freshwater spawning and incubation sites with water flow, quality, and temperature conditions and substrate supporting spawning and incubation, and with migratory access for adults and juveniles; (2) freshwater and estuarine migration corridors associated with spawning and incubation sites that are free of obstruction and with water flow, quality, and temperature conditions supporting larval and adult mobility, and with abundant prey items supporting larval feeding after the yolk sac is depleted; and (3) nearshore and offshore marine foraging habitat with water quality and available prey, supporting juveniles and adult survival.

Within the study area, critical habitat for Eulachon includes the Klamath River from the mouth upstream to the confluence with Omogar Creek. The critical habitat designation specifically excludes all lands of the Yurok Tribe and Reshigini Rancheria, based upon a determination that the benefits of exclusion outweigh the benefits of designation (NMFS 2011a). Exclusion of these areas will not result in the extinction of the Southern DPS because the overall percentage of critical habitat on Indian lands is so small (approximately 5% of the total are designated), and it is likely that Eulachon production on these lands represents a small percent of the total annual production for the DPS (NMFS 2011a, 2011b).

O.2.3 Trinity River

The Trinity River region includes Trinity Lake and Lewiston Reservoir, the Trinity River down to the Klamath River, and the lower Klamath River from the confluence with the Trinity River to the Pacific Ocean. The Trinity River flows through Trinity and Humboldt Counties and through the Hoopa Indian Reservation. The lower Klamath River flows through Humboldt and Del Norte Counties and through the Hoopa, Yurok, and Resighini Indian reservations. Lewiston Reservoir is directly downstream of Trinity Lake; the two reservoirs were built in the 1960s as part of the CVP to divert water from the Trinity River to the Sacramento River. Flows in the Trinity River are regulated by water releases from these two reservoirs. Downstream of Lewiston Lake, the Trinity River flows for 112 miles, receiving water from several tributaries, including the North Fork Trinity River, the South Fork Trinity River, and New River, before entering the Klamath River. Flows in these tributaries are not affected by CVP operations.

The lower Klamath River flows approximately 43 miles from the confluence with the Trinity River before entering the Pacific Ocean. There are no dams on the lower Klamath River downstream of the confluence with the Trinity River. The lower 5 miles of the Klamath River are within the Klamath River Estuary, which is generally influenced by tidal fluctuations, with salt water occurring up to 4 miles from the mouth of the Klamath River, especially when high tides correspond with low summer and fall flow conditions.

O.2.3.1 *Trinity Lake and Lewiston Reservoir*

Trinity Lake lies upstream of Trinity Dam. It is a relatively deep-water reservoir with oligotrophic conditions based on low levels of nutrients (e.g., phosphates, nitrogen, and organic matter) and consequently low productivity (USFWS et al. 2004). Trinity Lake supports several fisheries that provide substantial recreational fishing opportunities, including a trophy Smallmouth Bass fishery, in addition to Largemouth Bass, Rainbow and Brown Trout, and Kokanee Salmon (landlocked Sockeye Salmon). Other native fish species that occur in Trinity Lake include Speckled Dace, Klamath Smallscale Sucker, and Coast Range Sculpin. Trinity Lake also includes other nonnative fish species such as Green Sunfish and Brown Bullhead.

Directly downstream of Trinity Lake is Lewiston Reservoir which is a re-regulating reservoir for Trinity Lake. Lewiston Reservoir receives cold water released from the bottom of Trinity Lake, and the water surface elevation remains relatively constant throughout the year. Lewiston Reservoir also supports recreational fisheries for Rainbow, Brown, and Brook Trout along with Kokanee Salmon. Other species found in Lewiston Reservoir include native Pacific Lamprey, Speckled Dace, Klamath Smallscale Sucker, Coast Range Sculpin, along with nonnative Smallmouth Bass (USFWS et al. 2004)

O.2.3.2 *Trinity River from Lewiston Reservoir to Klamath River*

Lewiston Dam is the dam farthest downstream on the Trinity River. Flows in the Trinity River downstream of Lewiston Dam are heavily influenced by releases from Lewiston Reservoir and Trinity Lake. This section of the mainstem Trinity River and its tributaries support several native anadromous fish species including Spring-Run and Fall-Run Chinook Salmon, Coho Salmon, Steelhead, Green Sturgeon, White Sturgeon, and Pacific Lamprey, as well as a recreational American Shad fishery.

Construction of dams on the Trinity River has substantially altered hydrology and geomorphology of the system. Historically, flows within the Trinity River were extremely variable. Changes to the Trinity River hydrology due to CVP operations have altered flows and reduced sediment input to downstream locations, which affects the quantity and quality of aquatic habitat. Furthermore, these changes have hindered important fluvial processes that support riparian habitat and river channel dynamics. The reduction in high flow events, which historically would have led to river channel meander and scouring of riparian vegetation within the active floodplain, has allowed for vegetation to encroach on areas along the active river channel, creating a more stable berm and reducing the potential for channel movement. The resulting narrow, high channel acts as a natural levee that isolates the channel from the floodplain, prevents recruitment of young trees and shrubs, and lowers the potential for mature woody vegetation to become established along the active river channel. These alterations have led to a reduction in channel complexity and aquatic habitat for several fish species in the mainstem Trinity River downstream of Lewiston Dam.

Several management components have been established to mitigate for effects of the dams built on the Trinity River and to restore fish populations to near pre-dam conditions. These management components are included in the Trinity River Restoration Program (TRRP), which focuses on the 40-mile section of the Trinity River from Lewiston Dam to the confluence with the North Fork Trinity River (TRRP 2014). The TRRP includes instream flow management, mechanical channel rehabilitation, fine and coarse sediment management, watershed restoration, infrastructure improvement, and adaptive environmental assessment and monitoring (NCRWQCB and Reclamation 2009; USFWS et al. 1999; TRPP 2014). Under the TRRP, channel rehabilitation efforts have been implemented to increase fish habitat complexity for various life stages of anadromous salmonids and reestablish floodplain connectivity by removing riparian berms that confine the river and fluvial processes. Sediment management has focused on decreasing fine sediment inputs and increasing coarse sediment at specific locations to support spawning and other aquatic life stages. Over 75 projects have been completed under the TRRP since 2008, with more planned for the future.

O.2.3.3 *Fish in the Trinity River*

The following focal fish species that occur in the Trinity River are considered in this EIS:

- Coho Salmon
- Chinook Salmon (Spring-Run and Fall-Run)
- Steelhead (Winter-Run and Summer-Run)
- Green Sturgeon
- White Sturgeon
- Pacific Lamprey
- American Shad

O.2.3.3.1 Coho Salmon

Coho Salmon exhibit a 3-year life cycle in the Trinity River during which they spend the first year in freshwater before migrating out to the ocean, where they spend the next 2 years maturing, and then return to their natal stream to spawn and die. This strategy makes Coho Salmon especially dependent on freshwater conditions because juveniles remain in the river year-round. Adult Coho Salmon typically enter the Trinity River between August and January. The timing of Coho Salmon river entry is influenced by several factors, including genetics, stage of maturity, river discharge, and access past the river mouth. Coho Salmon spawning occurs mostly in November and December. Spawning occurs in the mainstem Trinity River and its tributaries, with peak Coho Salmon spawning activities in the mainstem Trinity River occurring between Lewiston Dam and the North Fork Trinity River. Spawning is concentrated in riffles or in gravel deposits at the downstream end of pools with suitable water depth, velocity, and substrate size.

Coho Salmon were not likely the dominant species of Salmon in the Trinity River before dam construction. They were, however, found throughout the Trinity Basin ranging as far upstream as Stuarts Fork above Trinity Dam. Approximately 109 miles of Coho Salmon habitat in the Trinity River became inaccessible after Lewiston Dam was built. To mitigate for the loss of upstream habitat, the Trinity River Salmon and Steelhead Hatchery (Trinity River Hatchery) was constructed near Lewiston Dam and produces Coho Salmon with an annual production goal of 500,000 yearling fish (CHSRG 2012). Today, wild Coho Salmon are not abundant in the Trinity River, and most of the Coho Salmon that return to the river are of hatchery origin. NMFS (2012) considers this proportion of hatchery fish in the population a high-level risk factor for the continued existence of Coho Salmon in the Trinity River basin. NMFS, Reclamation, and CDFW are working to develop a Hatchery and Genetics Management Plan to mitigate the adverse effects of the hatchery program on production of wild Coho Salmon in the Trinity River (NMFS et al. 2017; Reclamation and CDFW 2017).

Coho Salmon run-size estimates have ranged from 852 fish in 1994 to 59,079 fish in 1987. In 2013, an estimated 21,906 adult Coho Salmon migrated into the Trinity River basin upstream of Willow Creek about 88 miles downstream of Lewiston Dam. Of these, 6,631 entered Trinity River Hatchery, while the remaining 15,275 fish were estimated to have spawned in the river (CDFW 2014a). Available spawning habitat for Coho Salmon downstream of Lewiston Dam is thought to be near carrying capacity (NMFS 2014b).

Several interrelated factors affect Coho Salmon abundance and distribution in the Trinity River. These include water temperature, water flow, habitat suitability, habitat availability, hatcheries, predation, competition, disease, ocean conditions, and harvest. Current CVP operations primarily affect water temperature, water flow, and habitat suitability in the Trinity River. Climate change also affects water temperature, water flow, and habitat suitability in the Trinity River.

Habitat for Coho Salmon in the Trinity River has changed since flow regulation; the encroachment of riparian vegetation is restricting channel movement and limiting fry rearing habitat (Trush et al. 2000). According to the TRRP, higher peak flows are needed to restore attributes of a more alluvial river, such as alternate bar features and more off-channel habitats. These flows are projected in the TRRP to provide better rearing habitat for Coho Salmon than the dense riparian vegetation currently present. Physical habitat manipulations described above have improved juvenile rearing in selected sites along the river.

O.2.3.3.2 Spring-Run Chinook Salmon

Adult Spring-Run Chinook Salmon typically enter the Trinity River from April through September; by the end of July, most fish have arrived at the mouth of the North Fork Trinity. Spawning is concentrated in the reaches immediately downstream of Lewiston Dam to the mouth of the North Fork Trinity River. After entering fresh water, Spring-Run Chinook Salmon remain in deep pools until the onset of the spawning season, which usually peaks in October but typically ranges from the third week of September through November. In the Trinity River, Spring-Run Chinook Salmon fry emerge from the gravel beginning in December, and emergence can last into mid-April. Juvenile Spring-Run Chinook Salmon typically out-migrate after a year of growth in the Trinity River. Peak out-migration occurs in May and June, based on monitoring in the lower Trinity River near the town of Willow Creek.

Historically, Spring-Run Chinook Salmon were likely the most abundant salmonid species in the Trinity River (Snyder 1931; LaFaunce 1967). Spring-Run Chinook Salmon historically spawned in the Trinity River and several of its tributaries upstream of Lewiston Dam (e.g., East Fork Trinity River, Stuart Fork, Coffee Creek, Hayfork Creek [Gibbs 1956; Campbell and Moyle 1991]). The completion of dams on the Trinity River in the 1960s blocked access to 59 miles of habitat, most of which was considered prime spawning and nursery habitat (Moffett and Smith 1950).

The current Spring-Run Chinook Salmon population for the Klamath and Trinity River basins is estimated to be 10% of historical levels (Myers et al. 1998). Williams et al. (2011) concluded that although abundance is low compared with historical abundance, the current Spring-Run Chinook Salmon population (which includes hatchery fish) appears to have been fairly stable for the past 30 years. The estimated average run size for Spring-Run Chinook Salmon in the Trinity River from 1991 through 2017 is 14,472, with approximately 59% of the run composed of hatchery-origin fish (Kier et al. 2018). Since 2012, Spring-Run Chinook estimates for the Trinity River have been consistently less than 10,000 fish, with more than half of the fish being of hatchery origin (Kier et al. 2018).

O.2.3.3.3 Fall-Run Chinook Salmon

Adult Fall-Run Chinook Salmon typically enter the Trinity River from August through December. Spawning activity usually occurs between October and December, with peak spawning activity occurring in November. Spawning activity typically begins just downstream of Lewiston Dam and then extends farther downstream as the spawning season progresses. Adult Fall-Run Chinook Salmon spawn throughout the mainstem Trinity River from Lewiston Dam to the Hoopa Valley (Myers et al. 1998). Similar to Spring-Run Chinook Salmon, emergence of Fall-Run Chinook Salmon fry begins in December and continues into mid-April. Juvenile Fall-Run Chinook Salmon typically spend a few months rearing in the Trinity River before they out-migrate. Near Lewiston Dam, out-migration occurs from March through May, with peak out-migration occurring in early May, while out-migration in the river farther downstream peaks in May and June.

The estimated average run size for Fall-Run Chinook Salmon in the Trinity River from 1991 through 2017 is 37,094, making it the most abundant salmonid species currently in the Trinity River. Fall-Run Chinook Salmon are nearly equally represented by wild and hatchery fish, with an average of 49% of the fish estimated to be of hatchery origin for the period of 1991 to 2017 (Kier et al. 2018). Overall, the population of Fall-Run Chinook Salmon in the Trinity River is highly variable, with estimated returns ranging from a high of 105,725 (1995) fish to a low of 6,196 fish (2017) during the period of 1991 to 2017.

O.2.3.3.4 Steelhead

Steelhead in the Trinity River exhibit two primary life history strategies: a Summer-Run, which matures after entering freshwater, and a Winter-Run, which matures in the ocean. The ocean maturing strategy is often further divided into a third group for Fall-Run Steelhead, based upon the timing of the adult migration. Adult Summer-Run Steelhead enter the Trinity River from May through October and over-summer in deep pools within the mainstem or upper reaches of cool tributaries until they reach sexual maturity (Busby et al. 1996). Adult Fall-Run Steelhead enter the Klamath River basin in September and October (Hill 2010) and spawn from January through April. Adult Winter-Run Steelhead begin their upstream migration in the Klamath River from November through March (USFWS 1997). Winter-Run Steelhead primarily spawn in the Trinity River from January through April (USFWS 1997), with peak spawning in February and March (NRC 2004).

Steelhead fry emerge in the spring, and juveniles remain in freshwater for up to 3 years. The majority of Steelhead (86%) that return to the Klamath River basin are estimated to spend 2 years in freshwater before outmigrating to the ocean (Hopelain 1998), although Summer-Run Steelhead may begin their out-migration at an earlier age (Scheiff et al. 2001; Pinnix and Quinn 2009; Pinnix et al. 2013). The average length of Steelhead smolts from the Trinity River when they enter the ocean is 200 milimeters (mm) (Hodge et al. 2016). Juvenile Steelhead may out-migrate from the tributaries at age 0+ or 1+ and then rear in the mainstem or in nonnatal tributaries (particularly during periods of poor water quality) for another year or two before migrating out to the ocean. Out-migration on the Trinity River lasts from spring through fall and there are three peak juvenile-out-migration periods: March, May/June, and October/November (USFWS et al. 2004).

Summer-Run Steelhead were likely common in the snowmelt-fed upper mainstem Trinity River in the 1940s (Moffett and Smith 1950). An estimated 8,000 adult Summer-Run Steelhead occurred on average in the Trinity River upstream of Lewiston Dam prior to its construction. Suitable habitat conditions are available downstream of Lewiston Dam and in some of the larger tributaries to the Trinity River (e.g., the north and south forks of the Trinity River, New River, and Canyon Creek [BLM 1995]). Summer-Run Steelhead observations in Trinity River and its tributaries have ranged from 20 to 1,037 adults (USFWS et al. 2004).

The mean estimated run size for adult Fall-Run Steelhead in the Trinity River above Willow Creek is 14,470 fish, based on surveys conducted between 1980 and 2017. Run-size estimates during this period have ranged from 2,972 in 1998 to 53,885 in 2007. While the proportion of wild fish to hatchery fish varies between year, hatchery fish made up a majority (>50%) of the Steelhead run observed since 1980 (Kier et al. 2018).

O.2.3.3.5 Green Sturgeon

Green Sturgeon data from the Trinity River are limited, so most information on life history characteristics for Green Sturgeon in the Trinity River is based on data from the Klamath River. Green Sturgeon are long-lived fish with an expected life span of at least 50 years. They reach maturity around age 16 and typically spawn once every 4 years (Klimley et al. 2007). Surveys of adult Green Sturgeon in the Klamath River found fish ranging in age from 16 to 40 years (Van Eenennaam et al. 2006). Adult migration occurs from February through July, with most spawning taking place from the middle of April to the middle of June (NRC 2004). Green Sturgeon are known to spawn in the lower section of mainstem Trinity River from the confluence with the Klamath River upstream approximately 43 miles to Gray’s Falls near Burnt Ranch.

After spawning, most Green Sturgeon hold in mainstem pools until the onset of fall rainstorms and increased river flow, when they move downstream and leave the river system (Benson et al. 2007). Around 25% of Green Sturgeon migrate directly back to the ocean after spawning (Benson et al. 2007). Juvenile Green Sturgeon likely begin to out-migrate from the Trinity River during their first summer, based on observations near Willow Creek. After moving downstream, juvenile Green Sturgeon may rear in larger river sections, such as the lower Klamath River, or in the Klamath River estuary for another year or two before they migrate to Pacific Ocean (NRC 2004; FERC 2007a; CALFED Bay-Delta Program 2007).

O.2.3.3.6 White Sturgeon

White Sturgeon are uncommon in the Klamath and Trinity Rivers (NRC 2004). Although historically there may have been small spawning runs in these rivers, there are no recent reports of White Sturgeon spawning in this system. Currently almost all Sturgeon found in the Klamath River basin above the estuary are Green Sturgeon (Moyle 2002).

O.2.3.3.7 Pacific Lamprey

Pacific Lamprey are an anadromous species that is important to local tribes and supports a subsistence fishery on the lower Trinity River. Adult Pacific Lamprey may begin their upstream migration during all months of the year, but peak upstream migration typically occurs from December through June (Larson and Belchik 1998; Petersen Lewis 2009). After entering fresh water, Pacific Lamprey hold through summer and most of the winter before reaching sextual maturity. Pacific Lamprey undergo a secondary migration in the late winter or early spring from holding areas to spawning grounds; spawning occurs during the spring (Robinson and Bayer 2005; Clemens et al. 2012; Lampman 2011). Therefore, adult Pacific Lamprey can be found in the Trinity River throughout the year. Ammocoetes (the larval stage of lamprey) rear within fine substrates in depositional areas and remain in the Trinity River and tributaries for up to 7 years before outmigrating to the ocean (Moyle 2002; Reclamation and Trinity County 2006).

Limited data are available on the distribution and abundance of Pacific Lamprey in the Trinity River. They are expected to have a distribution similar to anadromous salmonids that use the mainstem Trinity River and accessible reaches of larger tributaries. Pacific Lamprey abundance in the Trinity River is expected to be declining based on information from tribal fishermen who catch lamprey in the lower Klamath River (Petersen Lewis 2009). Parallels in the lifecycle of Pacific Lamprey make them susceptible to many of the same factors as Salmon and Steelhead. Reduced access to historical spawning and rearing habitats in the Trinity River above Lewiston Dam, degraded spawning and rearing habitat resulting from operations of dams and water diversions, impacts from historic mining practices, and predation by nonnative invasive species (e.g., Brown Trout) have likely contributed to adverse effects on the Trinity River Pacific Lamprey population.

O.2.3.3.8 American Shad

American Shad are a nonnative anadromous fish species that has become established in the Klamath and Trinity Rivers. Adult fish leave the ocean in late spring or early summer to spawn in freshwater. American Shad spawn shortly after entering freshwater. American Shad are primarily found in the lower Klamath River but may occur in the lower sections of the Trinity River up Willow Creek, based on capture of juveniles during salmonid outmigrant monitoring (Scheiff et al. 2001; Pinnix and Quinn 2009; Pinnix et al. 2013).

O.2.3.4 *Hatcheries on the Trinity River*

The Trinity River Hatchery was established immediately downstream of Lewiston Dam to mitigate for the loss of salmonid production upstream of the Lewiston and Trinity Dams (Reclamation 2008). The hatchery is funded by Reclamation and operated by CDFW to produce Coho Salmon, Spring-Run and Fall-Run Chinook Salmon, and Steelhead. The hatchery releases approximately 500,000 yearling Coho Salmon annually from March 15 to May 15. Currently, all Coho Salmon are produced from endemic Coho Salmon broodstock. All juvenile Chinook Salmon and Steelhead are produced from in-river broodstock. The hatchery has a goal of releasing 1 million subyearling Spring-Run Chinook Salmon in June and 400,000 yearlings in October, while the goal for Fall-Run Chinook Salmon is to release 2 million sub-yearlings in June and 900,000 yearlings in October. The goal for Steelhead is to release 800,000 Steelhead smolts (approximately 6 inches) from March 15 to May 1.

O.2.3.5 *Lower Klamath River from Trinity River to Pacific Ocean*

The lower Klamath River flows for approximately 43 miles from the confluence with the Trinity River near Weitchpec to the Pacific Ocean. The Trinity River is the largest tributary of the Klamath River and provides a substantial amount of flow to the lower Klamath River. Salmonids primarily use this section of the Klamath River as a migration corridor to access most spawning and rearing habitat located upstream of the confluence with the Trinity River or in other large tributaries (e.g., Blue Creek) that enter the lower Klamath River.

O.2.3.5.1 Fish in the Lower Klamath River

Focal fish species that occur in the lower Klamath River include all those described in the Trinity River above, as well as Eulachon.

Eulachon

Eulachon are an anadromous smelt species that were important to local tribes and once supported a subsistence fishery on the lower Klamath River. The spawning migration period for adult Eulachon in the Klamath River begins in December and continues until May, with peak migration occurring in March and April (YTFP 1998; Larson and Belchik 1998). Eulachon can become sexually mature at 2 years but spawning typically occurs at ages 3, 4, or 5 (Scott and Crossman 1973). Spawning occurs in the lower reaches of rivers and tributaries. Eulachon are broadcast spawners and usually die after spawning.

Athough specific spawning areas are unknown, adult Eulachon are generally observed only in the lower 24 miles (40 kilometers [km]) of the Klamath River, except during rare years when they are sometimes observed as high as Pecwan Creek and even Weitchpec (YTFP 1998). Eulachon eggs hatch in 20 to 40 days depending on water temperature, with cooler temperatures leading to longer hatch times. Once they hatch, larval Eulachon are carried out to the ocean by river currents (Scott and Crossman 1973).

Historically, Eulachon were abundant in the lower Klamath River, based on accounts from Yurok Tribal elders. Noticeable runs of Eulachon were observed by Tribal fishers in 1988 and 1989, and a Eulachon was incidentally captured at the mouth of the Klamath River in 1996 (Larson and Belchik 1998). More recently, Eulachon were documented in the Klamath River during the spawning seasons of 2011–2014, with abundance peaking in 2013–2015 return years (NMFS 2016d).

O.2.4 Sacramento River

Aquatic resources in the Sacramento River are affected by the habitat along the river and along the tributaries that connect to the river. Habitat along the river ranges from artificial structures used for water supply and flood management to open spaces that provide more natural types of habitat. The flow regime of the Sacramento River is managed for water supply and flood management, as described in Appendix H, *Water Supply Technical Appendix*. The following discussion focuses on the fish in the Sacramento River and aquatic habitat conditions.

O.2.4.1 *Upper Sacramento River from Keswick Dam to the Delta*

The upper Sacramento River extends from Keswick Dam and Reservoir, the afterbay for Lake Shasta, for approximately 240 miles to the Delta. The Sacramento River is the largest river in California. The river and its tributaries provide spawning, rearing, and migratory habitat for four races of Chinook Salmon, Steelhead, and two species of Sturgeon. Winter-Run and Spring-Run Chinook Salmon are federally and state-listed species and Central Valley Steelhead and Green Sturgeon are federally listed.

O.2.4.2 *Fish in the Sacramento River*

The analysis is focused on the following species:

- Chinook Salmon (Winter-Run, Spring-Run, and Fall- /Late Fall-Run)
- Steelhead
- Green Sturgeon
- White Sturgeon
- Sacramento Splittail
- Pacific Lamprey
- Striped Bass
- American Shad

O.2.4.2.1 <u>Winter-Run Chinook Salmon</u>

Adult Winter-Run Chinook Salmon return to fresh water during winter but delay spawning until spring and summer. Adults enter fresh water in an immature reproductive state, similar to Spring-Run Chinook, but Winter-Run Chinook Salmon move upstream much more quickly and then hold in the cool waters downstream of Keswick Dam for an extended period before spawning. Juveniles spend about 5 to 9 months in the river and estuary systems before entering the ocean. This life-history pattern differentiates the Winter-Run Chinook Salmon from other Sacramento River Chinook Salmon runs and from all other populations within the range of Chinook Salmon (CDFG 1985, 1998b).

Access to approximately 58% of the original Winter-Run Chinook Salmon habitat has been blocked by dam construction (Reclamation 2008a). The remaining accessible habitat occurs in the Sacramento River downstream of Keswick Dam and in Battle Creek. The number of Winter-Run Chinook Salmon in Battle Creek is unknown, but if they do occur, they are scarce (Reclamation and SWRCB 2003). The Battle Creek Salmon and Steelhead Restoration Program recently released 200,000 juvenile Winter-Run Chinook Salmon to the creek in 2018 (NMFS 2018a).

Escapement data indicate that the Winter-Run Chinook Salmon population declined from its levels in the 1970s to relatively low levels through the 1980s and 1990s, with a moderate, 6-year rebound in the early 2000s (CDFW 2018a).

Adult Winter-Run Chinook Salmon migrate upstream past the location of the Red Bluff Diversion Dam (RBDD) beginning in mid-December and continuing into early August. Most of the run passes RBDD between January and May, with the peak in mid-March (CDFG 1985). Winter-Run Chinook Salmon spawn only in the Sacramento River, almost exclusively above RBDD, with the majority spawning upstream of the Clear Creek confluence, based on CDFW aerial redd survey data (see Table 3 in Appendix A *Components for the Reinitiation of Consultation on Long-Term Operations).* Aerial redd surveys have indicated that the Winter-Run Chinook Salmon spawning distribution has shifted upstream since gravel was installed in the upper river near Keswick Dam; a high proportion of Winter-Run Chinook Salmon spawn on the recently placed gravel (USFWS and Reclamation 2008). Spawning occurs May through August, with the peak in June and July. High water temperatures during spawning and incubation of eggs and alevins has been a major stressor in recent years (NMFS 2017a; Martin 2017, Anderson 2018).

Fry emergence occurs primarily from mid-June through mid-October and fry disperse to areas downstream for rearing. Juvenile migration past RBDD may begin in late July, peaks in the fall, and can continue until mid-March in drier years (Vogel and Marine 1991). The majority of the juveniles emigrate past RBDD, as fry and rear in the river downstream of RBDD (Martin et al. 2001) before emigrating to the Delta, primarily during December through April. The juveniles usually migrate past Knight’s Landing once flows at Wilkins Slough rise to about 14,000 cfs. Most juvenile Winter-Run Chinook Salmon emigrate past Chipps Island by the end of March (del Rosario et al. 2013).

O.2.4.2.2 Spring-Run Chinook Salmon

Historically, Spring-Run Chinook Salmon in the Sacramento River basin were found in the upper and middle reaches (1,000 to 6,000 feet) of the American, Yuba, Feather, Sacramento, McCloud and Pit Rivers, as well as smaller tributaries of the upper Sacramento River downstream of present-day Shasta Dam (NMFS 2009a). Estimates indicate that 82% of the approximately 2,000 miles of salmon spawning and rearing habitat available in the mid-1800s are unavailable or inaccessible today (Yoshiyama et al. 1996). Naturally spawning populations of Spring-Run Chinook Salmon currently are restricted to accessible reaches of the upper Sacramento River, Antelope Creek, Battle Creek, Beegum Creek, Big Chico Creek, Butte Creek, Clear Creek, Deer Creek, Feather River, Mill Creek, and the Yuba River (CDFG 1998). Most of these reaches are outside the project area; however, all Spring-Run Chinook Salmon migratory life stages pass through the action area.

Spring-Run Chinook Salmon abundance in the Sacramento River mainstem has apparently declined sharply through time, with escapement estimates ranging from approximately 5,000 to 23,000 fish in the

1980s, 100 to 4,100 fish in the 1990s, and 0 to 600 fish between 2000 and 2017 (CDFW 2018a). However, the criteria for run classification at RBDD have changed, so no conclusions can be reached about changes in the number of Spring-Run Chinook Salmon in the Sacramento River. Chinook Salmon expressing spring-run timing do spawn in the mainstem Sacramento River between RBDD and Keswick Dam from August through October (NMFS 2009a). As described above for Winter-Run Chinook Salmon, high water temperature during spawning and egg/alevin incubation is potentially a major stressor for Spring-Run spawning in the Sacramento River. The river currently serves primarily as a migratory corridor for the adult and juvenile life stages of Spring-Run Chinook Salmon from the river's tributaries.

In fresh water, juvenile Spring-Run Chinook Salmon rear in natal tributaries, the Sacramento River mainstem, and nonnatal tributaries to the Sacramento River (CDFG 1998). Emigration timing is highly variable, as the juveniles may migrate downstream as YOY or as yearlings. The emigration period for Spring-Run Chinook Salmon extends from November to early May, with up to 69% of the YOY fish emigrating through the lower Sacramento River and Delta during this period (CDFG 1998). Peak movement of juvenile Spring-Run Chinook Salmon in the Sacramento River at Knights Landing occurs in December and again in March and April (Snider and Titus 1998, 2000b, 2000c, 2000d; Vincik et al. 2006; Roberts 2007). Migratory cues, such as increased flows, increasing turbidity from runoff, changes in day length, or intraspecific competition from other fish in their natal streams, may spur emigration of juveniles from the upper Sacramento River basin when they have reached the appropriate stage of maturation (NMFS 2009a). Spring-Run Chinook Salmon juveniles that remain in the Sacramento River over summer are confined to approximately 100 miles of the upper mainstem, where cool water temperatures are maintained by dam releases.

O.2.4.2.3 Fall- /Late Fall-Run Chinook Salmon

The Fall-Run Chinook Salmon is an ocean-maturing type of salmon adapted for spawning in lowland reaches of big rivers, including the mainstem Sacramento River; the Late Fall-Run Chinook Salmon is mostly a stream-maturing type (Moyle 2002). Similar to Spring-Run, adult Late Fall-Run Chinook Salmon typically hold in the river for 1 to 3 months before spawning, while Fall-Run Chinook Salmon generally spawn shortly after entering fresh water. Fall-Run Chinook Salmon migrate upstream past RBDD on the Sacramento River between July and December, typically spawning in upstream reaches from October through March. Late Fall-Run Chinook Salmon migrate upstream past RBDD from August to March and spawn from January to April (NMFS 2009a; TCCA 2008). The majority of young Fall-Run Chinook Salmon migrate to the ocean during the first few months following emergence, although some may remain in fresh water and migrate as yearlings. Late Fall-Run Chinook Salmon juveniles typically enter the ocean after 7 to 13 months of rearing in fresh water, at 150- to 170 mm in fork length, considerably larger and older than Fall-Run Chinook Salmon (Moyle 2002).

The primary spawning area used by Fall-Run and Late Fall-Run Chinook Salmon in the Sacramento River is the area from Keswick Dam downstream to RBDD. Spawning densities for all of the Chinook Salmon runs are highest in this reach, but Fall-Run Chinook Salmon generally spawn further downstream in the reach than the other Chinook Salmon runs (USFWS 2003a).

Annual Fall-Run and Late Fall-Run Chinook Salmon escapement to the Sacramento River and its tributaries has generally been declining in the last decade, following peaks in the late 1990s to early 2000s (CDFW 2018a).

O.2.4.2.4 Steelhead

Steelhead are broadly divided into two life history types, Summer-Run Steelhead and Winter-Run Steelhead, based on their state of sexual maturity at the time of river entry. Only Winter-Run Steelhead are currently found in Central Valley rivers and streams. Historically, Central Valley Steelhead were distributed from the upper Sacramento and Pit river systems (upper Sacramento, McCloud, Pit and Fall Rivers) south to the Kings River (and possibly Kern river system in wet years) (McEwan 2001). Presently, Central Valley Steelhead are found in the Sacramento River downstream of Keswick Dam, in major tributary rivers and creeks in the Sacramento River watershed, and in major tributaries of the San Joaquin River (Stanislaus, Tuolumne, Merced Rivers) and Delta (Calaveras River). The populations in the Feather and American Rivers are supported primarily by the Feather and Nimbus hatcheries. Other major Steelhead populations in the Sacramento River watershed are found in Battle, Mill, Deer, Clear and Butte Creeks.

Adult Steelhead migrate upstream past the Fremont Weir between August and March, primarily from August through October; they migrate upstream past RBDD during all months of the year, but primarily during September and October (NMFS 2009a). The primary spawning area used by Steelhead in the Sacramento River is the area from Keswick Dam downstream to RBDD. Unlike Pacific Salmon, Steelhead may live to spawn more than once and generally rear in freshwater streams for 2 to 4 years before outmigrating to the ocean. Both spawning areas and migratory corridors are used by juvenile Steelhead for rearing prior to out-migration. The Sacramento River functions primarily as a migration channel, although some rearing habitat remains in areas with setback levees (primarily upstream of Colusa) and flood bypasses (e.g., Yolo Bypass) (NMFS 2009a).

Recent Steelhead monitoring data are scarce for the upper portion of the Sacramento River system. Hallock (1989) reported that Steelhead had declined drastically in the Sacramento River upstream of the Feather River confluence. In the 1950s, the average estimated spawning population size upstream of the Feather River confluence was 20,540 fish (McEwan and Jackson 1996). In 1991–1992, the annual run size for the total Sacramento River system was likely fewer than 10,000 adult fish (McEwan and Jackson 1996). From 1967 to 1993, the estimated number of Steelhead passing the Red Bluff Pumping Plant ranged from a low of 470 to a high of 19,615 (CHSRG 2012). Steelhead escapement surveys at the site of RBDD ended in 1993.

O.2.4.2.5 Green Sturgeon

The Sacramento River provides habitat for Green Sturgeon spawning, adult holding, foraging, and juvenile rearing. Sturgeon spawn in deep pools (averaging about 28 feet deep) (NMFS 2018b). Suitable spawning temperatures and spawning substrate exist for Green Sturgeon in the Sacramento River upstream and downstream of RBDD (Reclamation 2008a). Although the upstream extent of historical Green Sturgeon spawning in the Sacramento River is unknown, the observed distribution of Sturgeon eggs, larvae, and juveniles indicates that spawning occurs from Hamilton City to as far upstream as Inks Creek confluence and possibly up to the Cow Creek confluence (Brown 2007; Poytress et al. 2013). Adult Green Sturgeon that migrate upstream in April, May, and June are completely blocked by the Anderson-Cottonwood Irrigation District (ACID) diversion dam (NMFS 2009b), rendering approximately 3 miles of spawning habitat upstream of the diversion dam inaccessible. Based on the distribution of Sturgeon eggs, larvae, and juveniles in the Sacramento River, California Department of Fish and Game (now known as the California Department of Fish and Wildlife [CDFW](2002) indicated that Green Sturgeon spawn in late spring and early summer, although they periodically spawn in late summer and fall (as late as October) (Heublein et al. 2009, 2017b; NMFS 2018b). Green Sturgeon eggs are believed generally to hatch about a week after fertilization (Heublein et al. 2017b).

Green Sturgeon from the Sacramento River are genetically distinct from their northern counterparts, indicating a spawning fidelity to their natal rivers (Israel et al. 2004), even though individuals can range widely (Lindley et al. 2008). Larval Green Sturgeon have been regularly captured during their dispersal stage at about 2 weeks of age (24 to 34 mm fork length) in rotary screw traps at RBDD (CDFG 2002a) and at about 3 weeks old when captured at the Glenn-Colusa Irrigation District (GCID) intake (Van Eenennaam et al. 2001).

Young Green Sturgeon appear to rear for the first 1 to 2 months in the Sacramento River between Keswick Dam and Hamilton City (CDFG 2002a). Rearing habitat condition and function may be affected by variation in annual and seasonal river flow and temperatures.

Empirical estimates of Green Sturgeon abundance are not available for the Sacramento River population or any West Coast population (Reclamation 2008a), and the current population status is unknown (Beamesderfer et al. 2007; Adams et al. 2007). A genetic analysis of Green Sturgeon larvae captured in the Sacramento River resulted in an estimate of the number of adult spawning pairs upstream of RBDD ranging from 32 to 124 between 2002 and 2006 (Israel 2006). NMFS (2009b) noted that, similar to Winter-Run Chinook Salmon, the restriction of spawning habitat for Green Sturgeon to only one reach of the Sacramento River increases the vulnerability of this spawning population to catastrophic events, which is one of the primary reasons that the Southern DPS of Green Sturgeon was federally listed as a threatened species in 2006. However, there is evidence that Green Sturgeon may also spawn in the Feather River, although perhaps irregularly (Seesholtz et al. 2014).

O.2.4.2.6 White Sturgeon

In California, White Sturgeon are most abundant within the Delta region, but the population spawns mainly in the Sacramento River; a small part of the population is also thought to spawn in the Feather River (Moyle 2002). In addition to spawning, White Sturgeon larval rearing occurs in the Sacramento River (Moyle 2002; Israel et al. 2008). White Sturgeon are found in the Sacramento River primarily downstream of RBDD (TCCA 2008), with most spawning between Knights Landing and Colusa (Schaffter 1997).

The population status of White Sturgeon in the Sacramento River is unclear. Overall, limited information on trends in adult and juvenile abundance in the Delta population suggests that numbers are declining (Reis-Santos et al. 2008). Adults ready for spawning generally move into the lower reaches of the Sacramento River during winter prior to spawning, and then migrate upstream in response to higher flows and spawn from February to early June (Schaffter 1997; McCabe and Tracy 1994). Most spawning in the Sacramento River occurs in April and May (Kohlhorst 1976). YOY White Sturgeon make an active downstream migration that disperses them widely to rearing habitat throughout the lower Sacramento River and Delta (McCabe and Tracy 1994; Israel et al. 2008). Statistical analysis has demonstrated a positive relationship between Delta outflow and recruitment of White Sturgeon year classes (Kohlhorst et al. 1991).

O.2.4.2.7 Sacramento Splittail

Historically, Sacramento Splittail were widespread in the Sacramento River from Redding to the Delta (Rutter 1908, as cited in Moyle et al. 2004). This distribution has become somewhat reduced in recent years (Sommer et al. 1997, 2007b). During drier years there is evidence that spawning occurs farther upstream (Feyrer et al. 2005). Adult Splittail migrate upstream in the lower Sacramento River to above the mouth of the Feather River and into the Sutter and Yolo Bypasses (Sommer et al. 1997; Feyrer et al. 2005; Sommer et al. 2007b). Each year, mainly during the spring spawning season, a small number of individuals have been documented at the Red Bluff Pumping Plant and the entrance to the GCID intake (Moyle et al. 2004).

Nonreproductive adult Splittail are most abundant in moderately shallow, brackish areas in the Delta and Suisun Bay, but can also be found in freshwater areas with tidal or riverine flow (Moyle et al. 2004). Adults typically migrate upstream from brackish areas in January and February and spawn in fresh water on inundated floodplains in March and April (Moyle et al. 2004; Sommer et al. 2007b). In the Sacramento drainage, the most important spawning areas appear to be the Yolo and Sutter Bypasses; however, some spawning occurs almost every year along inundated river edges and backwaters created by small increases in flow. Splittail spawn in the Sacramento River from Colusa to Knights Landing in most years (Feyrer et al. 2005).

Most juvenile Sacramento Splittail move from upstream areas downstream into the Delta from April through August (Meng and Moyle 1995; Sommer et al. 2007b). The production of YOY Sacramento Splittail is largely influenced by extent and duration of inundation of floodplain spawning habitats, with abundance spiking following wet years and declining after dry years (Sommer et al. 1997; Moyle et al. 2004; Feyrer et al. 2006). Other factors that may affect the Sacramento Splittail adult population include pumping at the CVP and SWP south Delta export facilities, flood control operations and infrastructure, entrainment by irrigation diversions, recreational fishing, changed estuarine hydraulics, pollutants, and nonnative species (Moyle et al. 2004; Sommer et al. 2007b).

O.2.4.2.8 <u>Pacific Lamprey</u>

Pacific Lampreys are anadromous, rearing in fresh water before emigrating to the ocean, where they grow to full size prior to returning to their natal streams to spawn. Data from mid-water trawls in Suisun Bay and the lower Sacramento River indicate that adults likely migrate into the Sacramento River and tributaries from late fall (November) through early-summer (June) (Hanni et al. 2006). Adult Pacific Lampreys have been observed at the GCID diversion from December through July and nearly all year at RBDD (Hanni et al. 2006). Hannon and Deason (2008) documented Pacific Lampreys spawning in the American River between early January and late May, with peak spawning typically in early April. Spawning in the Sacramento River is expected to occur during a similar timeframe. Pacific Lamprey ammocoetes (larval form) rear in parts of the Sacramento River for all or part of their 5- to 7-year freshwater residence. Data from rotary screw trapping at sites on the mainstem Sacramento River indicate that emigration of Pacific Lamprey peaks from early winter through early summer, but some emigration is observed year-round at both the RBDD and the GCID diversion dam (Hanni et al. 2006).

O.2.4.2.9 <u>Striped Bass</u>

Striped Bass are anadromous; adult Striped Bass are distributed mainly in the lower bays and ocean during summer, and in the Delta during fall and winter. Spawning takes place in spring from April to mid-June (Leet et al. 2001), at which time Striped Bass swim upstream to spawning grounds. Striped Bass are not believed to spawn or rear in the Sacramento River upstream of RBDD (TCCA 2008). Most Striped Bass spawning in the Sacramento River occurs in the lower river between Colusa and the confluence of the Sacramento and Feather Rivers (Moyle 2002). About one-half to two-thirds of Striped Bass spawn in the Sacramento River and the remainder spawn in the Delta (Leet et al. 2001). After spawning, most adult Striped Bass move downstream into brackish and salt water for summer and fall.

Eggs are free-floating and negatively buoyant, hatching as they drift downstream. The larvae occur in shallow and open waters of the lower reaches of the Sacramento and San Joaquin Rivers, the Delta, Suisun Bay, Montezuma Slough, and Carquinez Strait. The Sacramento River functions primarily as a migration corridor for both adults and drifting eggs and larvae.

O.2.4.3 *Aquatic Habitat*

The mainstem Sacramento River provides habitat for native and introduced (nonnative) fish and other aquatic species. The diversity of aquatic habitats ranges from fast-water riffles and glides in the upper reaches to tidally influenced slow-water pools and glides in the lower reaches (Vogel 2011).

A few miles downstream of Keswick Dam, the river enters the valley and the floodplain broadens. Historically, this area had wide expanses of riparian forests, but the riparian zone now has a great deal of urban encroachment. In the middle Sacramento River between Red Bluff and Chico Landing, the mainstem channel is flanked by broad floodplains (TNC 2007a). In the lower reaches downstream of Verona, much of the Sacramento River is constrained by levees. Dredging, dams, levee construction, urban encroachment, and other human activities in the Sacramento River have modified aquatic habitat, altered sediment dynamics, simplified stream bank and riparian habitat, reduced floodplain connectivity, and modified hydrology (NMFS 2009a). However, some complex floodplain habitats remain in the system such as reaches with setback levees and the Yolo and Sutter Bypasses.

O.2.4.3.1 Holding Habitat

An abundance of deep, cold-water pools in the mainstem Sacramento River provide habitat for holding adult anadromous salmonids during all months of the year (Vogel 2011). Green Sturgeon also use deep pools for holding and spawning, but can tolerate warmer water temperatures than Salmon, so can hold farther downstream.

O.2.4.3.2 Spawning Habitat

Spawning habitat on the Sacramento River is affected by lack of sediment and flow patterns as determined by the operations of the CVP and local water diverters.

Water Temperatures

Water temperatures in the upper Sacramento River are influenced by the timing, volume, and temperature of water releases from Shasta and Keswick Dams, and are currently managed according to SWRCB Water Rights Orders 90-05 and 91-01. The orders require Reclamation to operate Keswick and Shasta Dams and the Spring Creek Power Plant to meet a daily average water temperature of 56°F as far downstream in the Sacramento River as practicable during periods when higher temperatures would be harmful to Winter-Run Chinook Salmon. Under the orders, the water temperature compliance point may be modified to an upstream location when the objective cannot be met at Red Bluff Pumping Plant. A Temperature Control Device (TCD) on Shasta Dam allows Reclamation to control the temperature of the water released from the dam. Water temperature directly affects many metabolic functions of fish and affects the availability of dissolved oxygen, which is required for respiration. In recent years, elevated water temperatures have resulted in high mortalities of Winter-Run eggs and alevin (cite), and may have adversely affected other Salmon runs and other fish species present in the Sacramento River during summer. Drought conditions make efforts to maintain suitable water temperatures in the upper Sacramento River more difficult because reduced storage in Lake Shasta results in a smaller coldwater pool.

Sediment Conditions

Shasta and Keswick Dams substantially influence sediment transport in the upper Sacramento River because they block sediment that would normally be transported downstream (TNC 2007a; DWR 1985). The result has been a net loss of coarse sediment, including gravel particle sizes suitable for salmon spawning, in the Sacramento River downstream of Keswick Dam (Reclamation 2013). To address the issue of spawning gravel loss downstream of Keswick Dam, Reclamation has placed approximately 5,000 tons of washed spawning gravel into the Sacramento River downstream of Keswick about every other year since 1997 (Reclamation 2010a).

Spawning Habitat Availability

The suitability of physical habitat for salmonid spawning (i.e., not including water quality parameters such as temperature and dissolved oxygen) is largely of function of the availability of clean, coarse gravel for constructing redds, favorable depths, and suitable flow velocities. Instream flow potentially affects all three of these habitat characteristics, and therefore, often affects the availability of suitable habitat. The availability of suitable habitat as a function of flow is determined from field surveys of the fishes' spawning habitat selections (Habitat Suitability Criteria), the distribution of suitable spawning gravels, and hydraulic models that simulate site-specific effects of river flow on depth and flow velocity.

Most Winter-Run Chinook Salmon spawn in the uppermost reach of the Sacramento River, from Keswick Dam to the confluence with Clear Creek (see Table 3 in Appendix A *Components for the Reinitiation of Consultation on Long-Term Operations*). Operations of Shasta and Keswick Dams generally determine flow in this area and therefore largely determine spawning habitat availability. However, spawning habitat availability in this reach is also affected by the seasonal ACID diversion dam, which involves placement of flashboards in the river between April and May. When the ACID dam is installed in the river, spawning habitat availability upstream of the Cow Creek confluence is lower than when the dam is removed for flows less than about 10,000 cfs, but is higher at higher flows (USFWS 2003a).

Like Winter-Run Chinook Salmon, the spawning distributions of Spring-Run, Fall-Run, and Late Fall-Run Chinook Salmon populations that spawn in the Sacramento River are primarily upstream of RBDD, with Fall-Run spawning the farthest downstream, including about 15% of redds downstream of the RBDD, Spring-Run spawning locations generally between those of Winter-Run and Fall-Run Chinook Salmon, and Late Fall-Run spawning distribution most similar to that of Winter-Run Chinook Salmon (NMFS 2017b). The spawning substrate, depth, and flow velocity requirements of the four Chinook Salmon runs are generally similar, so differences in spawning habitat availability among the runs are most strongly related to differences in their spawning distributions and in the prevailing flow levels during the time of year that they spawn.

Variations in flow also have major effects on spawning habitat. Reductions in flow following spawning may result in dewatering of the redds and mortality of incubating eggs and alevins (USFWS 2006). Large increases in flow may result in scouring of river bed sediments, including any redds present, or entombment in deposited sediments.

The spawning distribution of Steelhead in the upper Sacramento is poorly known, but the suitability of spawning habitat is largely determined by the same physical habitat and water quality parameters that affect the Chinook Salmon runs, although preferred depths, flow velocities, and spawning substrates are somewhat different than those for Chinook Salmon. As for the Salmon runs, the availability of suitable spawning habitat for Steelhead is strongly affected by instream flow (USFWS 2011c, 2011d).

O.2.4.3.3 Rearing Habitat

Rearing habitat suitability for juvenile (including fry) salmonids is generally related to flow much as described above for spawning habitat suitability, although the physical habitat characteristics estimated for rearing also include cover, and the Habitat Suitability Criteria (HSC) for depth and flow velocity differ from those for spawning (USFWS 2005).

Inundated floodplains typically provide large areas of suitable rearing habitat for juvenile salmonids (Sommer 2001 – *Fisheries article*). In the Sacramento River between Red Bluff and Chico Landing, the mainstem channel is flanked by broad floodplains. Ongoing sediment deposition in these areas provides evidence of continued inundation of floodplains in this reach (DWR 1994). Between Chico Landing and Colusa, the Sacramento River is bounded by levees that provide flood protection for cities and agricultural areas. However, the levees in this portion of the Sacramento River are, for the most part, set back from the mainstem channel such that flooding can be significant within the river corridor (TNC 2007b).

Vogel (2011) suggested that the mainstem Sacramento River may not provide adequate rearing areas for fry-stage anadromous salmonids, as evidenced by rapid displacement of fry from upstream to downstream areas and into nonnatal tributaries during increased flow events. Underwater observations of salmon fry in the mainstem Sacramento River suggest that optimal habitats for rearing may be limited at higher flows (Vogel 2011).

O.2.4.3.4 Fish Passage and Entrainment

Historically, anadromous salmonids had access to a minimum of approximately 493 miles of habitat in the Sacramento River (Yoshiyama et al. 1996). After completion of Shasta Dam in 1945, access to approximately 207 miles was blocked. Keswick Dam, just downstream of Shasta Dam, is now the upstream extent of available habitat for anadromous fish in the Sacramento River.

Until recently, three large-scale, upper Sacramento River diversions, the ACID and GCID intakes and RBDD, were of particular concern as potential passage or entrainment problems for Chinook Salmon, Steelhead, Sturgeon, and other migratory fish species (NRC 2012; NMFS 2009a; McEwan and Jackson 1996). Recently, the RBDD was eliminated, the GCID fish screens were installed, and fish passage at the ACID intake was improved (NRC 2012). At the ACID intake, new fish ladders and fish screens were installed around the diversion and began operating in the summer 2001 diversion period. However, adult Green Sturgeon that migrate upstream in April, May, and June continue to be completely blocked by the ACID intake (NMFS 2009a), rendering approximately 3 miles of spawning habitat upstream of the diversion dam inaccessible. Adult Green Sturgeon that pass upstream of the intake before April are delayed for 6 months until the flashboards are pulled before they can return downstream to the ocean. Newly emerged Green Sturgeon larvae that hatch upstream of the ACID intake must hold for 6 months upstream of the dam, or pass over it and be subjected to higher velocities and turbulent flow below the intake (NMFS 2009a).

Numerous other diversions are located on the Sacramento River. Herren and Kawasaki (2001) documented up to 431 diversions from the Sacramento River between Shasta Dam and the city of Sacramento. Hanson (2001) studied juvenile Chinook Salmon entrainment at unscreened diversions at the Princeton Pumping Plant and documented the entrainment of approximately 0.05% of juvenile Chinook Salmon passing the diversion. Similar to the results of Hanson (2001), Vogel (2013) found that entrainment of juvenile Salmon in 12 unscreened diversions was low relative to other fish species. Mussen et al. (2014) examined the risk to Green Sturgeon from unscreened water diversions and found that juvenile Green Sturgeon entrainment susceptibility (in a laboratory setting) was high relative to that estimated for Chinook Salmon, suggesting that unscreened diversions could be a contributing mortality source for threatened Southern DPS Green Sturgeon. Reclamation is currently coordinating with USFWS to support improvements at other fish screens.

Potential barriers to migration for adult Green Sturgeon into the upper reaches of the Sacramento River include structures such as the ACID intake, Sacramento River Deep Water Ship Channel locks, Fremont Weir, Sutter Bypass, and DCC gates on the Sacramento River (70 FR 17386). A set of locks at the upstream end of the Sacramento River Deep Water Ship Channel, where it connects to the Sacramento River, "blocks the migration of all fish from the deep-water ship channel back to the Sacramento River" (DWR 2005).

O.2.4.3.5 Hatcheries

The Livingston Stone NFH, located at the foot of Shasta Dam, is a conservation hatchery that has been producing and releasing juvenile Winter-Run Chinook Salmon since 1998. There is growing concern about the potential genetic effects that may result from the use of a conventional hatchery program to supplement Winter-Run Chinook Salmon populations. To maintain a low risk of compromised genetic fitness, Lindley et al. (2007) recommend that no more than 5% of the naturally spawning population should be composed of hatchery fish. Since 2001, more than 5% of the Winter-Run Chinook Salmon run has been composed of hatchery-origin fish, and in 2005, the contribution of hatchery fish was more than 18% (Lindley et al. 2007).

The Livingston Stone NFH minimizes hatchery affects in the population by preferentially collecting wild adult Winter-Run Chinook Salmon for brood stock (USFWS 2011b). Up to 15% of the estimated run size for Winter-Run Chinook Salmon run may be collected for brood stock use (up to a maximum of 120 natural-origin Winter-Run Chinook Salmon per brood year). Although there is no adult production goal, Livingston Stone NFH releases up to 250,000 Winter-Run Chinook Salmon a year in late January or early February. Winter-Run Chinook Salmon are released at the pre-smolt stage and are intended to rear in the freshwater environment prior to smoltification. The pre-smolts are released into the Sacramento River at Caldwell Park in Redding, about 10 miles downstream of the hatchery. All juvenile Winter-Run Chinook Salmon produced at Livingston Stone NFH are adipose fin-clipped and coded wire-tagged (CHSRG 2012). As previously noted, 200,000 juvenile Winter-Run Chinook Salmon from Livingston Stone NFH were released into Battle Creek in 2018.

O.1.1.1.1 Disease

Several endemic salmonid-specific pathogens occur in the Sacramento River: *Ceratonova shasta* (salmonid ceratomyxosis), *Parvicapsula minibicornis*, *Flavobacterium columnare* (columnaris), Infectious Hematopoietic Necrosis (IHN) virus, *Renibacterium salmoninarum* (bacterial kidney disease), *Flavobacterium psychrophilum* (cold-water disease), *Ichthyophthirius multifiliis* (white spot disease or Ich), and *Aeromonas salmonicida* (Furunculosis) (DWR 2004; Foott 2014). Of these, salmonid *Ceratonova shasta* and *Parvicapsula minibicornis* are of most concern for fisheries management in the region (Foott 2014; Foott et al. 2017). The Coleman National Fish Hatchery on Battle Creek employs best management practices and protocols to minimize the spread of diseases to Battle Creek and the Sacramento River (Cramer Fish Sciences 2016).

Salmonid ceratomyxosis is endemic to the Sacramento River Basin. While native fish have developed some resistance to the disease, mortality in all ages of anadromous and resident salmonids still occurs. Steelhead appear to be particularly susceptible to the disease, compared to Chinook (DWR 2004c). Fish can become infected at temperatures as low as 39°F; however, mortality predominantly occurs at water temperatures exceeding 50°F (Bartholomew 2012).

The risk of infection in the Sacramento River Basin to salmonid ceratomyxosis is highest when the fish remain for an extended period in an infectious zone, an area with a high concentration of infectious pathogen(s) (Foott et al. 2017; PFMC 2018). An infectious zone may develop when the following factors coincide: low flow velocity and volume (especially in proximity to spawning areas) and water temperatures above 54°F–59°F (Ray and Bartholomew 2013; Foott et al. 2017; PFMC 2018). Therefore, risk of infection increases when river flow decreases and water temperature increases.

O.2.4.3.6 Predation

On the mainstem Sacramento River, high rates of predation have been known to occur at the diversion facilities and areas where rock revetment has replaced natural river bank vegetation (NMFS 2009a). Chinook Salmon fry, juveniles, and smolts are more susceptible to predation at these locations because Sacramento Pikeminnow and Striped Bass congregate in areas that provide predator refuge (Williams 2006; Tucker et al. 2003).

O.2.4.4 *Battle Creek*

Battle Creek is a tributary that enters the Sacramento River about 20 miles southeast of Redding. The cold, spring-fed waters of Battle Creek historically supported large runs of Chinook Salmon and Steelhead. Diversion dams constructed in the early 1900s for hydroelectric power production reduced instream flow and blocked anadromous salmonids from accessing habitat in large portions of the north and south forks of Battle Creek.

Coleman NFH, located on Battle Creek, was established in 1942 by Reclamation to partially mitigate habitat and fish losses from historical spawning areas caused by construction of two CVP features, Shasta and Keswick Dams. The hatchery is funded by Reclamation and operated by USFWS. The Steelhead program at the hatchery was initiated in 1947 to mitigate losses resulting from the CVP (USFWS 2012). The weir at the hatchery is a barrier to anadromous fish passage, as are various Pacific Gas and Electric Company (PG&E) dams (e.g., Wildcat) located on Battle Creek (Yoshiyama et al. 1996). Yoshiyama et al. (1996) reported that the Coleman South Fork Diversion Dam is the first impassible barrier on Battle Creek.

Beginning in 1995, planning was initiated to restore naturally spawning anadromous fish populations in Battle Creek, and construction began in 2010 on the Battle Creek Salmon and Steelhead Restoration Project (Reclamation 2014a). When complete, the restoration project will restore ecological processes along 42 miles of Battle Creek and 6 miles of tributaries while minimizing reductions to hydroelectric power generation, although five dams are decommissioned (Wildcat, Coleman, South, Lower Ripley, and Soap Creek Feeder Diversion Dams). New fish screens and fish ladders that meet NMFS and CDFW criteria will be constructed at three diversion dams (North Battle Creek Feeder, Eagle Canyon, and Inskip Diversion Dams). Connectors are proposed that prevent the discharge of North Fork Battle Creek water to South Fork Battle Creek and the mixing of flow sources. Higher minimum flow requirements will increase instream flows, subsequently cooling water temperatures, increasing stream area, and providing reliable passage conditions for adult salmonids in downstream reaches. The project will result in 42 miles of newly accessible anadromous fish habitat and improved water quality for the Coleman NFH. As noted above, 200,000 juvenile Winter-Run Chinook Salmon from Livingston Stone NFH were released into Battle Creek in 2018.

O.2.5 Clear Creek

The action area includes all reaches of Clear Creek accessible to anadromous fish from its confluence with the Sacramento River to Whiskeytown Dam. Beginning in 1995, the Central Valley Project Improvement Act (CVPIA) and later the CALFED Bay-Delta Program have conducted salmonid habitat and flow restoration in Clear Creek and re-established Central Valley Spring-Run Chinook Salmon (*Oncorhynchus tshawytscha*) and California Central Valley (Central Valley) Steelhead (*O. mykiss*). The Clear Creek Technical Team was established in 1996 to facilitate implementation of these CVPIA and CALFED restoration actions.

In 2009, National Oceanic and Atmospheric Administration's NMFS issued a Coordinated Long-Term Operations biological opinion (BO). Under this BO, Reasonable and Prudent Alternative (RPA) actions included flow and temperature management on Clear Creek.

Since being established, the Clear Creek Restoration Program (CCRP) identified and implemented a variety of actions to improve Salmon and Steelhead habitat and the ecosystem on which these species depend. Past and continued actions include increased minimum flows, summer temperature control through flow management, removal of a low-head dam, large-scale stream and floodplain restoration, gravel augmentation, spring and early summer pulse flows, and erosion control.

Priority restoration actions for Clear Creek include (NMFS 2014a) the following:

- Develop a new spawning gravel budget and implement a long-term gravel augmentation plan in Clear Creek, including acquisition of long-term gravel.
- Operate the Clear Creek segregation weir to create reproductive isolation between Fall-Run Chinook Salmon and Spring-Run Chinook Salmon.
- Manage releases from Whiskeytown Dam with instream flow schedules and criteria to provide suitable water temperatures for all life stages, reduce stranding and isolation, protect incubating eggs from being dewatered, and promote habitat quality and availability.
- Develop water temperature models to improve Clear Creek water temperature management.
- Adaptively manage Whiskeytown Reservoir releases and water temperatures to evaluate whether anadromy can be increased without causing adverse impacts to other species.
- Implement channel maintenance flows in Clear Creek called for in the CVP/SWP biological opinion.

O.2.5.1 *Fish in Clear Creek*

The analysis is focused on the following species:

ESA-listed Central Valley Spring-Run Chinook Salmon

- Unlisted Fall- and Late Fall-Run Chinook Salmon
- ESA-listed California Central Valley (CCV) Steelhead
- California species of special concern, Pacific Lamprey

O.2.5.1.1 Central Valley Spring-Run Chinook Salmon

Clear Creek supports a population of Central Valley Spring-Run Chinook Salmon. Between 2000 and 2017, adult returns have ranged from 0 in 2001 to 659 in 2013 (Figure O.2-1).

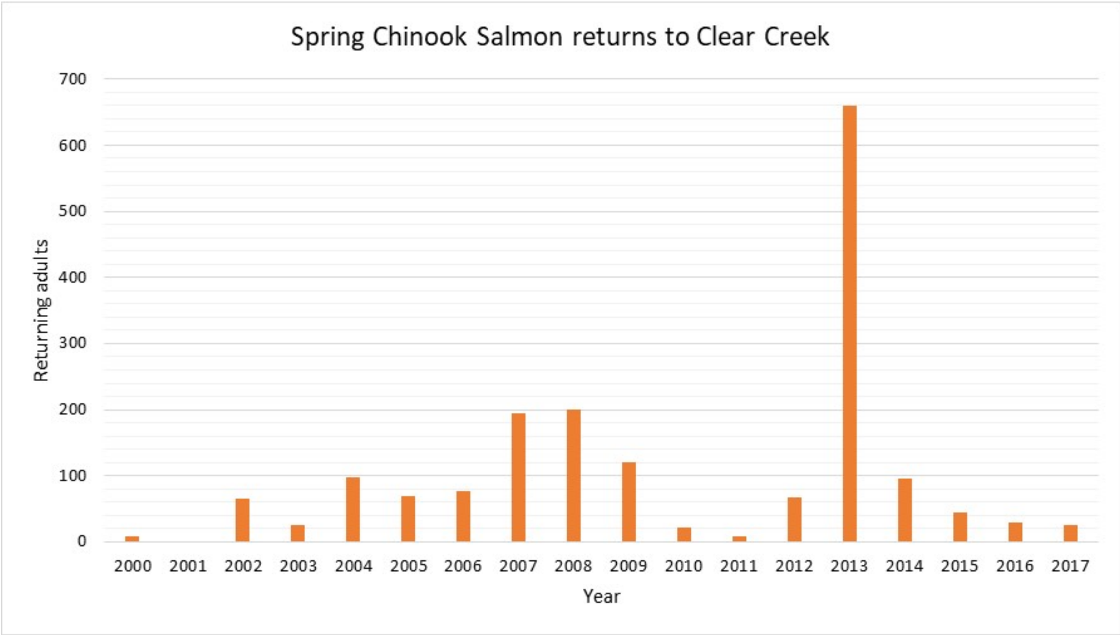


Figure O.2-1. Spring-Run Chinook Salmon Returns 2000 to 2017

Source: TNC 2018.

The removal of the McCormick-Saeltzer Dam in 2000 opened nearly 12 miles of access to areas just downstream of Whiskeytown Dam for a total of 18 miles for Central Valley Spring-Run Chinook Salmon (and Central Valley Steelhead) habitat. Adult Central Valley Spring-Run Chinook Salmon migrate upstream beginning early June in lower Clear Creek, throughout the action area, to the uppermost reaches to spawn beginning early September and continuing through early to mid-October. Since 2003, the USFWS has installed a temporary picket weir from late August through early November to allow Spring-Run Chinook Salmon a spatial separation from Fall-Run Chinook Salmon, which otherwise have an overlap in spawning timing (NMFS 2014c). Overlapping spawning timing could result in hybridization between spring and fall runs.

Water temperature criteria (maximum mean daily 56°F) in Clear Creek are set to be protective during spawning and incubation (September 15 to October 31). In years with warm, dry falls, these targets have occasionally not been met, as the Whiskeytown Reservoir begins to run out of coldwater pool. One such year was 2018, but criteria were met for all but 4 days during the spawning period (CCTT 2018).

The majority (95% in 2011) of juvenile Chinook Salmon out-migrate as fry, generally under 40 mm fork length (Schraml et al. 2018). Most of the migration occurs from November to February, with a peak in December (in 2011, out-migration peaked in mid- to late December) (Schraml et al. 2018).

O.2.5.1.2 Fall- /Late Fall-Run Chinook Salmon

Beginning in 1995, restoration actions in Clear Creek have had a clear effect on Fall-Run Chinook Salmon populations. The combined actions have contributed to a near four-fold increase in escapement of Fall-Run Chinook Salmon to Clear Creek (population estimates average 1,749 from 1967 to 1991 and 7,333 from 1992 to 2017) (CCTT 2018).

Adult returns of Fall-Run and Late Fall-Run Chinook Salmon from 2000 to 2017 are illustrated in Figures O.2-2 and O.2-3 (note Y-axes are on different scales).

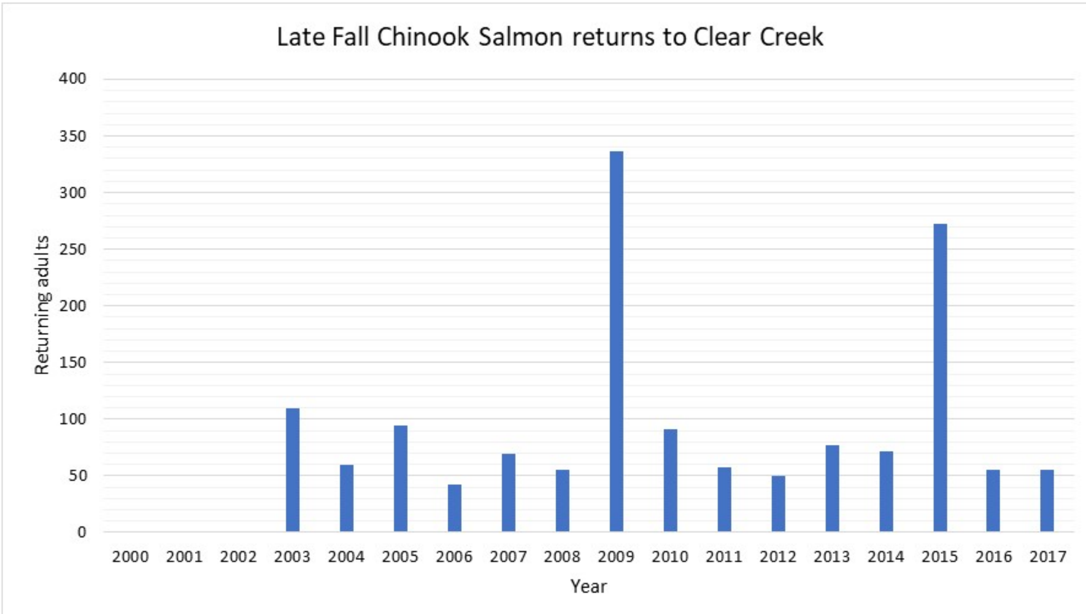


Figure O.2-2. Late Fall-Run Chinook Salmon Returns 2000 to 2017

(Source: https://www.casalmon.org/salmon-snapshots/history/clear-creek population data courtesy of CDFW, NMFS, and other federal, state and local agencies, watershed groups and conservation organizations.)

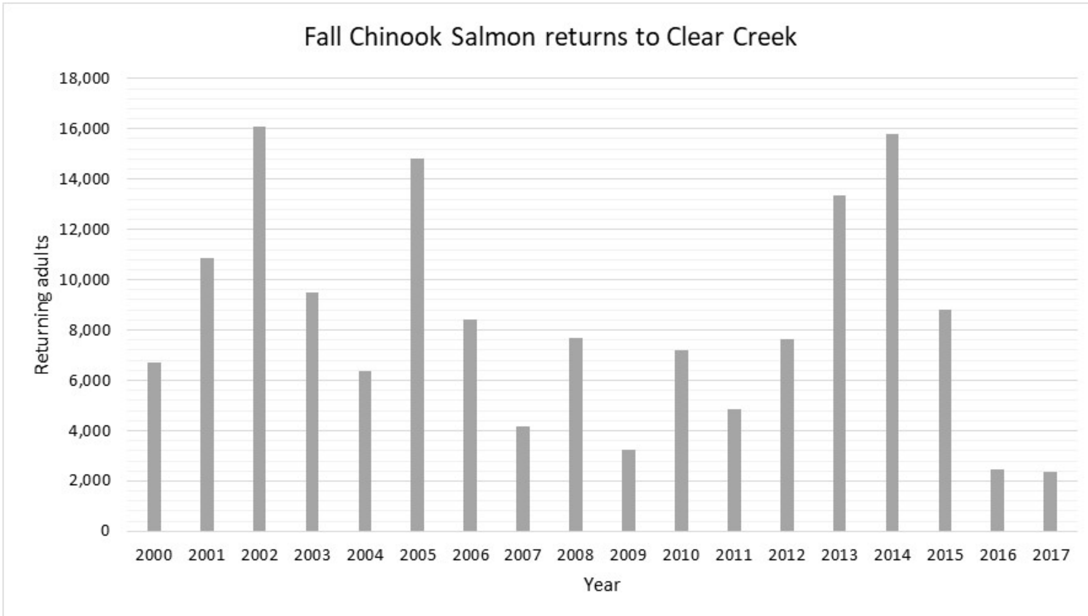


Figure O.2-3. Fall-Run Chinook Salmon Returns 2000 to 2017

(Source: https://www.casalmon.org/salmon-snapshots/history/clear-creek population data courtesy of CDFW, NMFS, and other federal, state and local agencies, watershed groups and conservation organizations.)

For Late Fall-Run Chinook Salmon generally (not just those in Clear Creek), peak spawning time is typically from October to November, but can continue through December and into January. Juveniles typically emerge from the gravel in December through March and rear in fresh water for 1 to 7 months (Moyle et al. 2015).

Based on carcass surveys and juvenile out-migration trapping, Fall Chinook Salmon typically spawn in Clear Creek from late September through early December, and peak emigration of juveniles occurs in January and February (Earley et al. 2013).

Fall- and Late Fall-Run Chinook Salmon generally out-migrate as age-0 fish, although some (8.3% in 2011) Late Fall-Run Chinook Salmon juveniles out-migrate in their second year. Out-migration is generally from April to June for Late Fall-Run and November to May for Fall-Run Chinook Salmon. During the most recent year for which there are records (2011), the peak out-migration for Fall-Run was in late December and the Late Fall-Run peak out-migration was from mid-April to mid-May (Schraml et al. 2018).

O.2.5.1.3 Steelhead and Rainbow Trout

Both Steelhead and non-anadromous Rainbow Trout (*O. mykiss*) occur in Clear Creek. Adult Central Valley Steelhead populations in Clear Creek have been relatively stable between 2003 and 2011, with redd counts ranging from 42 to 409, with an average of 176 (Giovanetti et al. 2013; Provins et al. 2019). In 2012, the majority of the *O. mykiss* redds (70%) were identified in the lower alluvial reach between the Gorge Cascade at river mile (RM) 6.5 and the lower extent of the survey at RM 1.7. Twenty-six percent of redds were detected in a half-mile stretch of habitat referred to as Renshaw Riffle (RM 5.1–5.6). Sixteen percent of the total *O. mykiss* redds were located in the upper alluvial reach between the Whiskeytown Dam (RM 18.1) and the Need Camp Bridge (RM 16.2). The remaining 26 *O. mykiss* redds (14%) were identified in the 9.7 river miles between these two alluvial reaches (Provins et al. 2019).

Adult Central Valley Steelhead spawn in Clear Creek from early December to mid-March. Steelhead rear in Clear Creek year-round, and out-migration can occur in any month, although peak out-migration in 2011 was from February to June (Schraml et al. 2018).

O.2.5.1.4 Pacific Lamprey

There are no data on Pacific Lamprey spawning specific to Clear Creek, but they are assumed to occur throughout the accessible portion of Clear Creek downstream of Whiskeytown Dam. Pacific Lamprey are known to spawn and rear in Clear Creek because ammocoetes have been routinely collected in the screw trap at RM 1.7. During the 2011 collection season, a total of 320 lamprey ammocoetes were collected throughout the sampling season, with peaks in December 2010 and June 2011. In addition, 220 Pacific Lamprey transformers were collected throughout the sampling season but with peak passage in December 2010 (Schraml et al. 2018). Presumably, lamprey numbers are reduced from historical abundance due to the same factors that have reduced anadromous salmonid numbers (e.g., blocked passage, habitat alteration, etc.).

Lamprey life cycles in Clear Creek are assumed to follow those elsewhere in California. Adult Pacific Lampreys are thought to remain in the ocean for approximately 18 to 40 months before returning to fresh water as sexually immature adults, typically from late winter to early summer. The adults then typically hold for a year in fresh water before spawning.

Pacific Lamprey usually spawn from March through July, depending on water temperatures and local conditions such as seasonal flow regimes. The adults construct redds similar to Steelhead redds, and eggs incubate for 11 to 30 days, depending on the water temperature, prior to hatching. Hatched embryos remain in the gravel for up to one more month as gill slits develop. The ammocoetes then spend 5 to 7 years in soft sediments as filter feeders (Calfish species account, https://www.calfish.org/fisheriesmanagement/speciespages/pacificlamprey.aspx).

O.2.5.2 *Fish in Whiskeytown Reservoir*

Whiskeytown Reservoir and some tributaries have been stocked by CDFW with Rainbow Trout, Brown Trout, and Kokanee Salmon. Other introduced species include Largemouth Bass, Smallmouth Bass, Spotted Bass, Bluegill, Black Crappie, Brown Trout, Brook Trout, Channel Catfish, and Brown Bullhead. Whiskeytown Reservoir also contains native fish species including Sacramento Pikeminnow, Hardhead, Riffle Sculpin, Western Sucker, and Rainbow Trout (NPS 1999).

Two California Species of Special Concern occur above Whiskeytown Dam:

- Hardhead (Mylopharodon conocephalus)
- Central California Roach (Lavinia symmetricus symmetricus)

Both species are cyprinids (members of the minnow family) and are classified as Species of Moderate Concern. California classifies Species of Concern into four categories: Extinct, Critical Concern, High Concern, and Moderate Concern. Moderate Concern indicates that the species have declining, fragmented, and/or small populations that are possibly subject to rapid status change and that need management actions to prevent increased conservation concern (Moyle et al. 2015).

Hardhead are present in Whiskeytown Reservoir and several of its tributaries. Central California Roach have been documented in three tributary streams but are not found in Whiskeytown Reservoir.

Although there are federal ESA-listed Spring-Run Chinook Salmon, Fall- /Late Fall-Run Chinook Salmon, California Central Valley Steelhead, and Pacific Lamprey (USFWS Species of Concern) in Clear Creek below Whiskeytown Dam, there are no federally listed fish species in Whiskeytown Reservoir. Whiskeytown Dam does not have upstream fish passage facilities.

O.2.5.2.1 Hardhead

Hardhead is a large minnow species, reaching lengths up to 60 centimeters (cm) (Moyle et al. 2015). They are widely distributed in streams at low to middle elevations in the Sacramento–San Joaquin and Russian River drainages. They prefer pools and runs with deep (>80 cm), clear water, slow (20 centimeters per second (cm/sec) to 40 cm/sec) velocities, and sand-gravel-boulder substrates (Moyle et al. 2015). Although spawning has not been directly observed, it is presumed that they spawn in sand or gravel in riffles, runs, or heads of pools (Moyle et al. 2015). Spawning occurs in April and May and is usually complete by July, except at the highest elevations.

The largest threats to Hardhead appear to be a combination of habitat loss and predation by introduced centrarchid fish species. Hardhead prefer large to medium cool to warm streams, most of which have largely been altered in California by dams and diversions (Moyle 2002). Thus, their natural habitats are increasingly rare. Where Hardhead do occur in reservoirs, their populations are often detrimentally affected by nonnative piscine predators (Moyle 2002). Moyle (2002) stated that Hardhead are “largely absent from reservoirs that undergo strong annual variations in water level” but did not suggest specific causes for this absence.

In 2004 and 2005, Hardhead were found at only 2 of 31 sampling locations upstream of Whiskeytown Dam (both in the mainstem Clear Creek) (Wulff et al. 2012). Hardhead are also found in Whiskeytown Reservoir (NPS 1999).

O.2.5.2.2 Central California Roach

The Central California Roach is a small (usually less than 10 cm total length), stout-bodied minnow that occurs in tributaries to the Sacramento and San Joaquin Rivers and tributaries to San Francisco Bay. Their historic distribution in the upper Sacramento River basin is poorly understood, but their upstream range limit is thought to have been Pit River Falls (Moyle et al. 2015).

Central California Roach are found in small, high gradient, often intermittent tributaries but appear to be poorly adapted to lakes and reservoirs. Where dams have been constructed on Central Valley streams, Central California Roach persist only in small tributaries to the resultant reservoirs (Moyle et al. 2015). Their absence from reservoirs is likely due both to habitat alteration and to the presence of introduced predatory fish species.

The general range-wide observation that Central California Roach are confined to headwater streams in impounded systems is reinforced locally by fish surveys of streams tributary to Whiskeytown Reservoir (Wulff et al. 2012). In 2004 and 2005, Central California Roach were found in 3 of 11 surveyed streams upstream of Whiskeytown Dam. Central California Roach were confined to Clear Creek and its tributary Cline Gulch upstream of the Carr Powerhouse and Grizzly Gulch upstream of Whiskeytown Lake. They were also found in Paige-Boulder Creek, a tributary of Clear Creek downstream of Whiskeytown Dam. Where found, Central California Roach could be locally abundant, second only in abundance to Riffle Sculpin and, in some locations, Sacramento Sucker (Wulff et al. 2012).

O.2.5.3 *Aquatic Habitat*

Existing fish habitat has been negatively affected by Whiskeytown Dam, Saeltzer Dam, placer and dredger gold mining, in-stream aggregate mining, road-related erosion, and decades of fire suppression (BLM and NPS 2008).

Reclamation and USFWS began implementing the CVPIA Fish Restoration Program in 1995 by increasing stream flows. CVPIA removed Saeltzer Dam in 2000, which has led to the re-establishment of populations of threatened Spring-Run Chinook Salmon and Steelhead. To combat the elimination of gravel recruitment from upstream of Whiskeytown Dam, spawning gravels have been added to Clear Creek downstream of Whiskeytown Dam every year since 2002. The gravel injection augmentation program on Clear Creek continues to enhance the spawning habitat available to Central Valley Fall- and Spring-Run Chinook Salmon and Central Valley Steelhead. (BLM and NPS 2008). During the most recent year, 10,000 tons of gravel were injected in July and August 2018 at 5 sites in Clear Creek (CCTT 2018).

O.2.5.3.1 Spawning Habitat

All coarse and fine sediment from the upper watershed is now trapped by the reservoir behind Whiskeytown Dam. The resulting coarse sediment deficit and reduction in fisheries habitat quality in lower Clear Creek has been well documented (BLM and NPS 2008). Effects of reduced sediment supply include: riffle coarsening, fossilization of alluvial features, loss of fine sediments available for overbank deposition and riparian regeneration, and a reduction in the amount and quality of spawning gravels available for anadromous salmonids.

The gravel augmentation program has recreated significant spawning habitat and is assessed by direct observation of the habitat used by Central Valley Spring-Run Chinook Salmon and Central Valley Steelhead for spawning. The proportional use of injected gravels vs. native gravels has steadily increased, and by 2017 over 80% of the Central Valley Steelhead and nearly 70% of the Spring Chinook Salmon that spawned in Clear Creek spawned on gravel that had been injected into the system (CCTT 2018).

Chinook Salmon and Steelhead populations in Clear Creek are faring relatively well when compared to other Central Valley populations. Anadromous fish escapement, redd counts, and carcass indices in Clear Creek have either increased, remained stable, or decreased significantly less than their Central Valley counterparts in the years after implementation of habitat improvements; however, spawning habitat continues to limit anadromous fish production in Clear Creek (NMFS 2014a)

An instream flow study in 2007 found that the optimum spawning depths for Spring-Run Chinook Salmon were 6.0 to 6.2 feet, while optimum velocities were 2.9 to 3.1 feet per second (ft/sec), and optimum substrates were 2 to 4 inches. The optimum spawning depths for Steelhead/Rainbow Trout were, 1.4 to 1.5 feet, while optimum velocities were 1.6 to 1.7 ft/sec, and optimum substrates were 1 to 2 inches. The flow with the maximum habitat varied by stream segment and ranged from 650 to 900 cfs for Spring-Run Chinook Salmon and 350 to 600 cfs for Steelhead/Rainbow Trout.

The amount of spawning habitat currently available is more than adequate to support the target population levels of Spring-Run Chinook Salmon and Steelhead in Clear Creek. In contrast, the amount of spawning habitat present in Clear Creek is less than the amount of spawning habitat needed to support 7,920 adult Fall-Run Chinook Salmon (the target population level) in Clear Creek (USFWS 2015).

O.2.5.3.2 Rearing Habitat

USFWS (2015) compared the total amount of rearing habitat available for Spring-Run Chinook Salmon and Steelhead to the amount of rearing habitat needed to support an annual escapement of 833 adults for each species (the target populations for Clear Creek). For Fall-Run Chinook Salmon, available habitat was compared to the amount of habitat needed to support an average escapement of 7,920. At all modeled flows, habitat availability is greater than the current habitat needs for all life stages (including spawning) of Central Valley Steelhead and Central Valley Spring-Run Chinook Salmon (USFWS 2015).

The amount of rearing habitat for the various species and life stages in Clear Creek is highly related to flow (discharge). In general, the instream flow study found that fry and juvenile rearing habitat for all species and life stages peaked at flows higher than are typically provided by Whiskeytown Dam (USFWS 2013, 2015); however, rearing habitat is currently more than adequate at all modeled flows to support the target populations of Central Valley Spring-Run Chinook and Central Valley Steelhead. It was therefore determined that instream flow needs for physical habitat should be based on Fall-Run Chinook Salmon due to its much higher population levels. The USFWS found that no flow between 50 cfs and 900 cfs would meet the habitat needs for any of the three life stages of Fall-Run Chinook Salmon. For example, a 200 cfs flow would meet approximately 70% of the spawning need, 40% of the juvenile rearing need, and 30% of the fry rearing need. The authors stated that adaptive management of the flow regime and habitat restoration coupled with long-term monitoring should be an effective strategy to address species recovery.

O.2.5.3.3 Fish Passage

Whiskeytown Dam blocks access to 25 miles of historical Spring-Run Chinook Salmon and Steelhead spawning and rearing habitat. Prior to 2000, the McCormick-Saeltzer Dam was a barrier to upstream migration for anadromous salmonids. Its removal opened an additional 12 miles of habitat for anadromous fish. The McCormick-Saeltzer Dam removal contributed to the reestablishment of Spring-Run Chinook Salmon and Steelhead in Clear Creek. After the removal of the dam, a berm of cleaned spawning gravel was constructed downstream from the dam site to retain additional sediment. Although armored with rocks, this berm was expected to wash out in winter flows. Instead, it created a new barrier to Spring-Run Chinook. Consequently, the California Department of Water Resources (DWR) removed the armoring and disbursed the berm in 2001.

O.2.6 Feather River

The Feather River contributes approximately 25% of the total flow in the Sacramento River (FERC 2007b). The lower Feather River consists of the stretch between the Fish Barrier Dam, near Oroville, and its confluence with the Sacramento River, near Verona (FERC 2007b). This summary describes the area from the Oroville Complex (FERC Project No. 2100) project boundary downstream to its confluence with the Sacramento River, but includes conditions within, or upstream of the Oroville Complex project area for context.

O.2.6.1 *Fish in the Feather River*

The Fish Barrier Dam on the Feather River restricts the distribution of the approximately 44 anadromous and resident (both native and introduced) fish species potentially occurring in the lower Feather River to the 67 miles between the dam and the confluence with the Sacramento River (FERC 2007b).

The analysis is focused on the following species:

- Chinook Salmon (Winter-Run and Spring-Run)

- Steelhead
- Green Sturgeon

O.2.6.1.1 Winter-Run Chinook Salmon

Although Sacramento River Winter-Run Chinook Salmon predominantly spawn and rear in the Sacramento River, the species ventures into the lower Feather River to rear (Phillis et al. 2018). Phillis et al. (2018) found isotope data that demonstrated 44 to 65% of surviving Winter-Run Chinook adults reared in nonnatal habitats, such as the Feather River. Fry disperse from mid-June through mid-October to areas downstream for rearing (Vogel and Marine 1991), and juvenile occupancy in the greater Sacramento River and estuary system is expected to last between 5 and 9 months prior to entering the ocean (CDFG 1985, 1998). Although there is potential for this ESU to occur in the Feather River, the Feather River is not contained within the species' Critical Habitat (58 FR 33212–33219).

O.2.6.1.2 Spring-Run Chinook Salmon

In the Sacramento River basin, Central Valley Spring-Run Chinook Salmon were historically found in the upper and middle reaches of the American, Yuba, Feather, Sacramento, McCloud, and Pit Rivers, as well as smaller tributaries of the upper Sacramento River downstream of present-day Shasta Dam (NMFS 2009). An independent Spring-Run Chinook Salmon population historically occurred in the lower Feather River downstream of the Oroville Dam (Lindley et al. 2004). Following the construction of the Oroville Complex, the number of naturally spawning Spring-Run Chinook Salmon in the Feather River has been periodically estimated between 2,908 in 1964 to 2 fish in 1978. However, the genetic integrity of this population is questionable because of the significant temporal and spatial overlap between spawning populations of Spring-Run and Fall-Run Chinook Salmon (Good et al. 2005). NMFS (2012) found that the overlap in spawning between Spring-Run and Fall-Run Chinook Salmon may have led to some hybridization between the ESUs in the lower Feather River. Additionally, production of hatchery-raised Chinook prior to 2005 may have contributed to the hybridization of Spring-Run and Fall-Run Chinook Salmon. Subsequently, any remnant independent Spring-Run Chinook population cannot be accurately estimated.

Of the estimated 2,000 miles of salmon spawning and rearing habitat available in the mid-1800s, only approximately 360 miles remain accessible (Yoshiyama et al. 1996). Based on current spawning and rearing habitat estimates, the Feather River contains approximately 18% of the spawning and rearing habitat available for the Central Valley Spring-Run Chinook Salmon population.

The Central Valley Spring-Run Chinook Salmon population currently consists of individuals naturally spawned in the Sacramento River and its tributaries, including the lower Feather River; however, the majority of individuals in the Feather River are raised in the Feather River Fish Hatchery (NMFS 2016a). Mature Spring-Run Chinook Salmon typically begin their migration from the ocean to freshwater estuaries in late January and early February (CDFG 1998). They complete their adjustment to freshwater and begin their upstream migration into rivers in mid-April, moving into spawning tributaries, such as the Feather River, in mid-June (Lindley et al. 2004). Spring-Run Chinook adults hold in cool pools and spawn around September and October, depending on water temperatures (NMFS 2012). Fry typically emerge between November and March (Moyle 2002) into calm, shallow waters with fine substrates and cover, such as woody material, undercut banks, and overhanging vegetation (Healey 1991). The emigration period for Spring-Run Chinook Salmon juveniles can extend from November to early May (CDFG 1998, as cited in NMFS 2009), depending on a variety of environmental factors (NMFS 2009).

O.2.6.1.3 Steelhead

California Central Valley Steelhead DPS immigrate into the Feather River between July and March, and redd construction occurs from late December to March, peaking in late January (FERC 2007b; McEwan 2001). Spawning in the Feather River primarily occurs within the Oroville Complex Project Boundary within the low-flow channel between the Fish Barrier Dam near the hatchery and the Thermalito Afterbay Outlet, although a small amount of spawning occurs downstream of the Thermalito Afterbay Outlet (FERC 2007b). Nearly half of all observed redds were constructed in the uppermost mile of the low-flow channel (FERC 2007b). Fry begin to emigrate in February, soon after emerging, with the majority emigrating between March and mid-April. Most juveniles emigrate by September; however, a small portion of juveniles that do not emigrate rear in the river for up to 1 year, most often in secondary channels of the low-flow channel (FERC 2007b).

O.2.6.1.4 Green Sturgeon

The southern DPS North American Green Sturgeon are thought to have historically spawned in the Sacramento, Feather, and San Joaquin Rivers (Adams et al. 2007). Green Sturgeon are long-lived, reach maturity around 15 years old, and usually spawn every 3 to 4 years (NMFS 2015). Adults enter San Francisco Bay around late winter through early spring and generally migrate to spawning areas from late February through April. Spawning mainly occurs April through late July, with some occurring in late summer and early fall (Heublein et al. 2017a). A significant portion of the spawning habitat was lost with the construction of Oroville Dam (FERC 2007b; Yoshiyama et al. 2001; Schick et al. 2005). While regular occurrence of Green Sturgeon has been verified in the Sacramento River, only intermittent observations have been reported in the lower Feather River at the Thermalito Afterbay Outlet (Beamesderfer et al. 2007; Seesholtz and Manuel 2012). After hatching, larvae possess limited swimming ability and generally seek refuge in low-velocity and complex habitats, such as large cobble substrate (Kynard et al. 2005). While little is known about Green Sturgeon rearing, it is likely that juveniles rear near spawning habitat for a few months or more before migrating to the Delta (Heublein et al. 2017b).

O.2.6.2 *Aquatic Habitat*

The lower Feather River contained at least 71 miles of suitable spawning habitat for Winter-Run and Spring-Run Chinook Salmon, Steelhead, and Green Sturgeon prior to the installation of the Oroville Complex on the Feather River (Yoshiyama et al. 2001; Schick et al. 2005). Extensive mining, irrigation, and other dams significantly reduced the amount of suitable habitat for these species (Yoshiyama et al. 2001). Currently, most spawning for these fishes is concentrated in the uppermost 3 miles of accessible habitat downstream of the Feather River Fish Hatchery (FERC 2007b). As a result, spawning is concentrated at unnaturally high levels directly downstream of Oroville Dam and the Fish Barrier Dam in the low-flow channel.

The lower Feather River is almost entirely contained within a series of levees. Streamflow is regulated by the Oroville Complex (composed of the Oroville Dam, Thermalito Diversion Dam, and Thermalito Afterbay Outlet), and releases from the Oroville Complex are planned weekly to accommodate water deliveries, Sacramento Valley in-basin demands such as Delta requirements, instream flow requirements in the Feather River, and minimum flood management space requirements. The lower Feather River's modified flow regime has reduced the frequency of channel forming flows, which, along with levees, has reduced the lateral movement of the Feather River and resulted in a more channelized river with reduced sinuosity.

Natural channel processes have also been affected by flow fluctuations, including the interruption of the downstream movement of gravel and wood, lateral river movement forming side channels, and a reduction in the frequency of inundated flood plains. An estimated 97% of the sediment from the upstream watershed has been trapped behind Oroville Dam, only allowing the discharge of fine sediment into the lower Feather River (FERC 2007b). As a result, optimum habitat features such as gravel and large woody materials from upstream reaches are now limited in the lower Feather River, and the median gravel diameter (D50) in the low-flow channel may generally be too large for successful redd construction by native salmonids (FERC 2007b). However, the lower Feather River watershed encompasses approximately 803 square miles, with approximately 190 miles of major streams and 695 miles of minor streams, which contribute to the sediment load of the lower Feather River. FERC (2007b) noted that the suitability of gravel sizes for spawning Chinook Salmon increased with distance downstream of Oroville Dam.

California Department of Water Resources (DWR) currently operates the Oroville Complex consistent with the applicable NMFS and USFWS BOs. When Lake Oroville surface elevation is greater than 773 feet, minimum instream flow releases downstream of the Thermalito Afterbay Outlet range from 1,000 to 1,700 cfs, depending on water year type and season.

Feather River flows show a consistent pattern of increased winter and spring runoff and decreased summer and fall flows across all water year types. Mean daily flow in the Feather River ranged from approximately 2,000 cfs in critically dry years to 18,000 cfs in wet years prior to the completion of Oroville Dam (Oroville gage 1906–1965), and from approximately 1,000 cfs during critically dry years to 12,000 cfs during wet years after the completion of the Oroville Dam (Gridley gage 1969–2012) (Figure O.2-4) (NMFS 2016a).

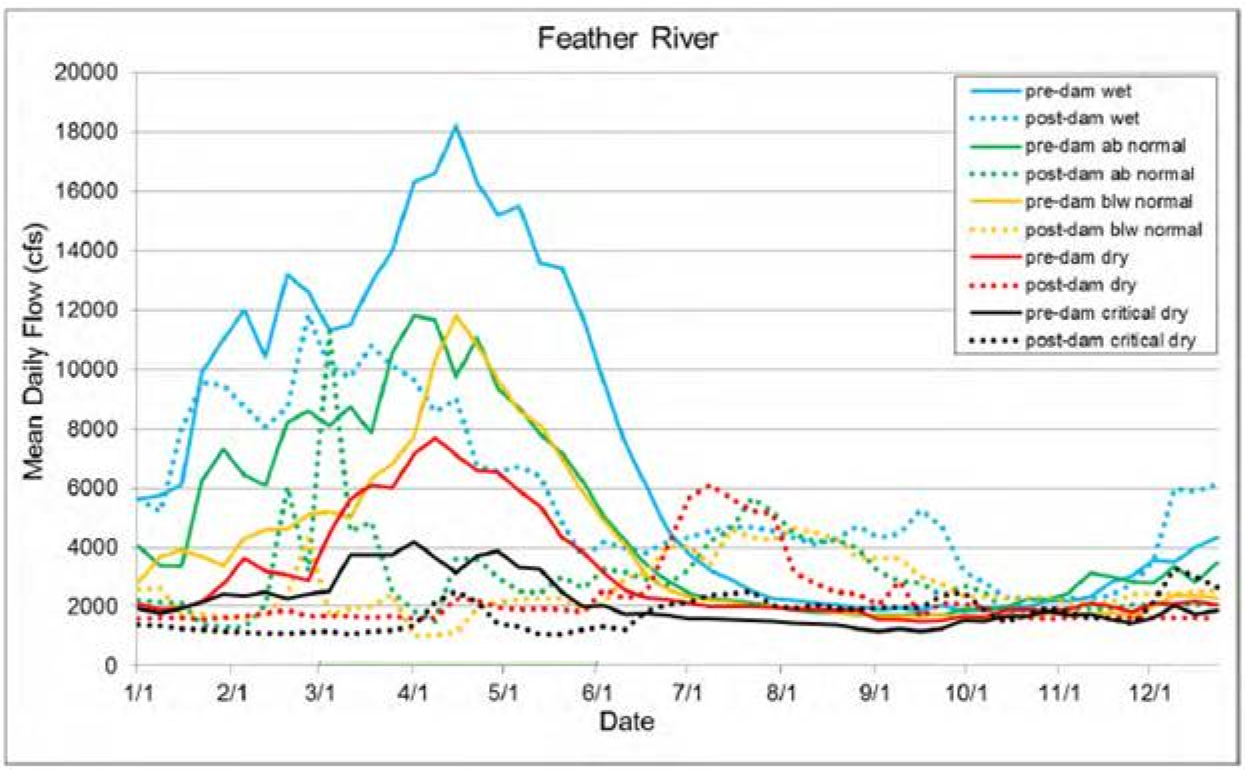


Figure O.2-4. Mean Daily Flow During all Water Year Types in the Feather River During Pre-Dam Years (Oroville Gage 1906–1965) and Post-Dam Years (Gridley gage 1969–2012; NMFS 2016a)

Modeling and surveys have been conducted to inform management decisions by identifying optimum water flow for native salmonids. According to DWR (2002) optimum Chinook Salmon flow suitability for spawning is about 800 to 825 cfs in the low-flow channels and 1,200 cfs in high-flow channels. Steelhead appeared to have no optimum flow for spawning in the low-flow channel; however, optimum flow was just under 1,000 cfs in the high-flow channel (DWR 2004a).

O.2.6.2.1 Fish Passage

The Oroville Complex facilities (i.e., the Oroville Dam, Thermalito Diversion Dam, and Fish Barrier Dam) currently block the upstream migration of anadromous fish from historically available spawning areas in the Feather River and have altered flow regimes as part of ongoing operations, which affects upstream and downstream migration passage in downstream reaches. The loss of spawning habitat and altered passage conditions downstream of the dams have resulted in hybridization of Spring-Run and Fall-Run Chinook Salmon populations and have decreased population sizes.

In addition to the Oroville Complex, three other potential/partial upstream migration barriers exist in the lower Feather River during low-flow or high-flow conditions (approximately 2,074 cfs or 9,998 cfs, respectively). These are Shanghai Bench, the Sunset Pumps Diversion Dam, and Steep Riffle (FERC 2007b). Shanghai Bench is a natural partial barrier located downstream of the Yuba River confluence consisting of a short drop under low-flow conditions and side channel that may lack attraction flows under low-flow conditions. The Sunset Pumps Diversion Dam is a rock weir structure approximately 27 miles downstream of the Fish Barrier Dam that may impede or delay passage under certain flow conditions. Steep Riffle is located approximately 2 miles upstream of the Thermalito Afterbay Outlet but is generally considered passable under both low and high flows (Beamesderfer et al. 2004).

O.2.6.2.2 Hatcheries

The Feather River Fish Hatchery is part of the SWP Oroville Complex. The hatchery is operated as part of a mitigation measure established to address anadromous fish decline as a result of loss of habitat upstream of Oroville Dam (NMFS 2009). This facility produces Fall-Run Chinook Salmon, Spring-Run Chinook Salmon, and Steelhead and is the sole contributor of hatchery-raised Spring-Run Chinook Salmon found within the Central Valley (CHSRG 2012). The hatchery-raised Spring-Run Chinook Salmon are included in the federal designation of Central Valley Spring-Run Chinook Salmon ESU (70 FR 37160).

The initial Chinook Salmon production protocols separated returning Spring-Run and Fall-Run Chinook Salmon based solely on the run periods, which resulted in considerable mixing of Spring-Run and Fall-Run Chinook Salmon stocks due to the overlap in spawning periods (DWR 2009a; NMFS 2012). In 2005, the Feather River Fish Hatchery changed their methodology to prevent any further mixing; only fish entering the hatchery prior to July 1 receive an external tag. These are the only fish used as Spring-Run Chinook Salmon broodstock (CHSRG 2012; DWR 2009a). Additionally, all hatchery-raised Spring-Run Chinook Salmon are now adipose fin-clipped, coded wire-tagged (CHSRG 2012), and thermally otolith-marked with race and brood year specific details (DWR 2009a). The juvenile hatchery production goal is two million smolts during April or May. Returning hatchery-produced Spring-Run Chinook Salmon are intended to spawn and integrate with the natural population in the lower Feather River, although there are no specific goals for the number of adult Spring-Run Chinook Salmon.

The Steelhead program at the Feather River Hatchery traps marked hatchery-origin and unmarked natural-origin Steelhead to artificially produce Steelhead for later release. However, few unmarked fish are trapped annually, and only fish returning to the Feather River basin are used for broodstock. There are no specific goals for the quantity of adults produced by this program; however, there is an annual production goal of 450,000 yearlings released in January or February. All Feather River Hatchery Steelhead have their adipose fin clipped prior to release to distinguish them from the naturally spawned population (CHSRG 2012).

The Feather River Fish Hatchery utilizes an ultraviolet treatment system, conducts periodic testing, uses prescribed therapeutic treatments, and has modified the stocking practices of Lake Oroville to successfully manage disease (DWR 2004b).

O.2.6.2.3 Disease

Several endemic salmonid-specific pathogens and diseases occur in the Feather River basin: *Ceratomyxa shasta* (salmonid ceratomyxosis), *Flavobacterium columnare* (columnaris), Infectious Hematopoietic Necrosis (IHN) virus, *Renibacterium salmoninarum* (bacterial kidney disease), and *Flavobacterium psychrophilum* (cold-water disease) (DWR 2004b). Each of these diseases has been shown to infect stocked and native salmonids in the Feather River (FERC 2007b). Of these, salmonid ceratomyxosis and IHN are of most concern for fisheries management in the region because of the associated fish mortality rates at the hatchery (DWR 2004b).

Salmonid ceratomyxosis is endemic to the Feather River basin. While native fish have developed some resistance to the disease, mortality in all ages of anadromous and resident salmonids still occurs. Steelhead appear to be particularly susceptible to the disease, compared to Chinook Salmon (DWR 2004b). Fish can become infected at temperatures as low as 39°F; however, mortality predominantly occurs at water temperatures exceeding 50°F (Bartholomew 2012). While whirling disease has been found in upstream tributaries of the Feather River, it has not been detected downstream of Oroville Dam (DWR 2004b).

The Feather River Fish Hatchery experienced severe IHN outbreaks in 2000 and 2001. The University of California at Davis and USFWS have indicated that although there were no clinical signs of disease, 28% and 18% of adult salmonids returning to the Yuba and Feather Rivers, respectively, carried IHN (Brown et al. 2004). Survivors of IHN can become carriers, and the disease can be spread via contaminated water or contact with carriers, making IHN particularly difficult to control.

Feather River Fish Hatchery employs best management practices and protocols to avoid the spread of diseases. By installing an ultraviolet treatment system, modifying the stocking of Lake Oroville, conducting periodic testing, and using prescribed therapeutic treatments, the hatchery has been successful in adaptively managing disease concerns as they arise (DWR 2004b).

O.2.6.2.4 Predation

Sufficient information is not available to estimate the current rate of predation on juvenile salmonids in the lower Feather River. As reported by FERC (2007), the Fish Barrier Dam concentrates most anadromous salmonid spawning within the low-flow channel. Reported counts of known predators on juvenile anadromous salmonids in the low-flow channel were low. However, significant numbers of predators reportedly do exist throughout the lower Feather River and have been known to congregate at passage impediments, such as the Sunset Pumps Diversion Dam (Seesholtz et al. 2004; Windell et al. 2017). Passage impediments increase the risk of predation by providing habitat for predator fishes that feed on out-migrating juvenile salmonids that become disoriented in the turbulent water below the dam, and by increasing the exposure to predation by delaying passage.

O.2.6.3 *Yuba River*

Portions of the Yuba River watershed along the North Yuba River between New Bullards Bar Reservoir and Englebright Lake and along the lower Yuba River between Englebright Lake and the Feather River could be affected by operation of the Lower Yuba River Accord (DWR et al. 2007).

Fish species found in the New Bullards Bar Reservoir include Rainbow Trout, Brown Trout, Kokanee Salmon, Bass, Bluegill, Crappie, and Bullhead (DWR et al. 2007). A similar mix of species is found in Englebright Reservoir. Fall-Run and Spring-Run Chinook Salmon and Steelhead occur in the Yuba River downstream of Englebright Dam (YCWA 2009). Sacramento Splittail have been documented only in the lower Feather River and not in the Yuba River. Low numbers of Green Sturgeon and White Sturgeon occasionally range into the Yuba River (Beamesderfer et al. 2004). Other species found in the lower Yuba River include American Shad, Smallmouth Bass, and Striped Bass (DWR et al. 2007).

O.2.6.4 *Bear River*

The Bear River flows into the Feather River downstream of the confluence of the Feather and Yuba Rivers. The Bear River has several reservoirs: Nevada Irrigation District's Rollins Reservoir and Combie Reservoir along the upper and middle reaches of the Bear River, and South Sutter Water District's Camp Far West Reservoir along the lower reach of the Bear River (FERC 2013; NID 2005).

Fall-Run and Spring-Run Chinook Salmon and Steelhead occur in the Bear River (YCWA 2009). Sacramento Splittail have been documented only in the lower Feather River and not in the Bear River. Low numbers of Green Sturgeon and White Sturgeon occasionally range into the Bear River (Beamesderfer et al. 2004). Rollins Reservoir is currently managed as a put-and-take fishery for Rainbow and Brown Trout. Kokanee Salmon reproduce naturally in the lake. Gill net surveys from 1970 to 1983 documented numerous other species including Bass, Catfish, Sunfish, Golden Shiner, Tui Chub, Pond Smelt, Crappie, and Bluegill (CDFG 1974–1983, in NID 2008). Native fishes found in Combie Reservoir may include Sacramento Pikeminnow, Sacramento Sucker, Hardhead, Tui Chub, Hitch, and Inland Silverside. Nonnative fishes likely include Bluegill, Green Sunfish, Largemouth Bass, Spotted Bass, Smallmouth Bass, Common Carp, Golden Shiner, Threadfin Shad, Black Crappie, Brown Bullhead, White Catfish, Channel Catfish, Western Mosquitofish, and stocked Rainbow Trout (NID 2009).

O.2.7 American River

The American River watershed encompasses approximately 2,100 square miles (Reclamation et al. 2006). The three forks of the American River (north, middle, and south forks) converge upstream of Folsom Dam, with the combined flow moving through Lake Natoma and the lower American River for about 23 miles before entering the Sacramento River.

Water surface elevations vary annually as a result of seasonal inflow and water release and are generally the least variable during spring and most variable during summer (USACE et al. 2012). Thermal stratification of the reservoir generally begins during April and usually persists throughout summer until November, when cooler temperatures, winter rains, and high inflows create mixing and result in "turnover" (Reclamation 2005; USACE et al. 2012). During summer, a thermocline develops that separates the epilimnion (i.e., upper layer of warm water) and the hypolimnion (i.e., lower layer of cooler water). This thermal stratification and segregation of habitats allow for both cold-water and warm-water species to coexist in Folsom Reservoir (USACE et al. 2012). Warm-water fish species include native Hardhead, California Roach, Sacramento Pikeminnow, and Sacramento Sucker, as well as nonnative Largemouth Bass, Smallmouth Bass, Spotted Bass, Sunfish, Black Crappie, and White Crappie

(Reclamation 2007). Cold-water fish species include native Rainbow Trout and planted Chinook and Kokanee Salmon, as well as nonnative Brown Trout (Reclamation 2007).

Nimbus Dam creates Lake Natoma, which serves as a regulating afterbay to the Folsom power plant, maintaining more uniform flows in the lower American River. Lake Natoma is a shallow reservoir with an average depth of about 16 feet (Reclamation 2005). Surface water elevations in Lake Natoma may fluctuate between 4 and 7 feet daily (USACE et al. 2012). Lake Natoma has relatively low productivity as a fishery due to the effects of wide water temperature variability associated with the lake's fluctuating elevation. Reclamation (2007) reports that fish species found in Lake Natoma are generally the same as those in Folsom Lake. Although CDFW annually stocks Lake Natoma with hatchery Rainbow Trout, conditions in Lake Natoma are more favorable for warm-water fish species (Reclamation 2007).

O.2.7.1 *Water Operations Management*

O.2.7.1.1 Flow

Reclamation operates the CVP American River Division for flood control, M&I and agricultural water supplies, hydroelectric power generation, fish and wildlife protection, recreation, and Delta water quality. Facilities include the Folsom Dam, Folsom Reservoir (977 thousand acre-feet [TAF] capacity), power plant, urban water supply temperature control device, and the Joint Federal Project auxiliary spillway as well as the Nimbus Dam, Lake Natoma, Nimbus Power Plant, and Folsom South Canal. Folsom Reservoir is the main storage and flood control reservoir on the American River. Numerous other smaller reservoirs in the upper basin provide hydroelectric generation and water supply without specific flood control responsibilities. The total upstream reservoir storage above Folsom Reservoir is approximately 820 TAF, and these reservoirs are operated primarily for hydropower production. Ninety percent of this upstream storage is contained by five reservoirs: French Meadows (136 TAF); Hell Hole (208 TAF); Loon Lake (76 TAF); Union Valley (271 TAF); and Ice House (46 TAF). Reclamation coordinates with the operators of these reservoirs to aid in planning for Folsom Reservoir operations. Releases from Folsom Dam are re-regulated approximately 7 miles downstream by Nimbus Dam. Nimbus Dam creates Lake Natoma, which serves as a forebay for diversions to the Folsom South Canal. Releases from Nimbus Dam to the American River pass through the Nimbus Power Plant, or the spillway gates, at flows in excess of 5,000 cfs. Because Folsom Reservoir is the closest reservoir to the Delta, releases from Folsom can more quickly address Delta water quality requirements under D-1641.

Reclamation, operating under the SWRCB Decision 893 (D-893) adopted in 1958, allows flows at the mouth of the American River to fall as low as 250 cfs from January through mid-September, with a minimum of 500 cfs required between September 15 and December 31. The D-893 decision is out of touch with modern biological, socioeconomic, and institutional conditions. For instance, it doesn't address the requirements of the CVPIA, the 1995 Bay-Delta Plan, or biological opinions issued to protect Central Valley Steelhead. Reclamation and the SWRCB and many stakeholders (Water Forum) agreed that D-893 did not provide sufficient protections for Central Valley Steelhead in the lower American River. Recently, Reclamation has operated the Folsom/Nimbus complex to more modern protective requirements and habitat management plans by providing flows that far exceed those required in D-893.

Current flow operations are according to the Minimum Flow Requirements (MFR) established in the 2006 Water Forum Lower American River Flow Management Standard (Water Forum 2006). The MFR establishes minimum flows, as measured by the total release at Nimbus Dam, which vary throughout the year in response to the hydrology of the Sacramento and American River basins. The October 1 through December 31 MFR range between 800 and 2,000 cfs. The January 1 through Labor Day MFR range between 800 and 1,750 cfs. The post Labor Day through September MFR range between 800 and 1,500 cfs. As a general rule, the MFR must equal or exceed 800 cfs year round. Narrowly defined exceptions to this rule allow Nimbus releases to drop below 800 cfs to avoid depletion of water storage in Folsom Reservoir when dry or critical hydrologic conditions are forecasted to occur. These narrowly defined exceptions to the MFR are an important component of the 2006 Flow Management Standard.

O.2.7.1.2 Temperature

Water temperatures in the lower American River are influenced by the timing, volume, and temperature of water releases from Folsom and Nimbus Dams, and are currently managed according to the Water Temperature Objectives established in the 2006 Flow Management Standard. The Water Temperature Objectives comply with the targets identified in the NMFS BO (2004) for the Long-Term Central Valley Project (CVP) and State Water Project (SWP) Operations and Criteria Plan (OCAP), which are intended to minimize water temperature effects on Central Valley Steelhead, including the lower American River. Under the primary Water Temperature Objective, Reclamation operates the Folsom/Nimbus Dam complex and the water temperature control shutters at Folsom Dam are used to maintain a daily average water temperature of 65°F or lower at Watt Avenue Bridge from May 15 through October 31. Subsequent objectives provide measures minimizing temperature effects if the primary objective cannot be achieve. The Water Temperature Objectives are achieved according to an annual Temperature Plan, which is prepared in accordance with the Water Temperature Objectives and is designed to minimize water temperature effects on Central Valley Steelhead and provide for Chinook Salmon spawning in the fall.

O.2.7.2 *Lower American River between Lake Natoma and the Sacramento River*

The lower American River extends approximately 23 miles from Nimbus Dam downstream to the confluence with the Sacramento River. Access to the upper reaches of the river by anadromous fish is blocked at Nimbus Dam.

O.2.7.2.1 Fish in the Lower American River

The lower American River system supports numerous resident native and introduced species as well as several anadromous species.

The analysis is focused on the following species:

- Fall-Run Chinook Salmon
- Steelhead
- White Sturgeon
- Sacramento Splittail
- Pacific Lamprey
- Striped Bass
- American Shad

Fall-Run Chinook Salmon

Historically, the American River supported Fall-Run and perhaps Late Fall-Run Chinook Salmon (Williams 2001). Both natural-origin and hatchery-produced Chinook Salmon spawn in the lower American River. Analysis by PSFMC and CDFW (2018) indicated that the most recently available constant fractional marking results from 2013 show approximately 86% of the Fall-Run Chinook Salmon spawners in the American River returning to the hatchery are hatchery-origin. In addition, 71% of Fall-Run Chinook salmon counted at the Hatchery Weir are of hatchery origin and 65% of carcass were also identified as of hatchery origin.

Adult Fall-Run Chinook Salmon enter the lower American River from about mid-September through January, with peak migration from approximately mid-October through December (Williams 2001). Spawning occurs from about mid-October through early February, with peak spawning from mid-October through December. Chinook Salmon spawning occurs within an 18-mile stretch from Paradise Beach to Nimbus Dam; however, most spawning occurs in the uppermost 3 miles (CDFG 2012a). Chinook Salmon egg and alevin incubation occurs in the lower American River from about mid-October through April. There is high variability from year to year; however, most incubation occurs from about mid-October through February. Chinook Salmon fry emergence occurs from January through mid-April, and juvenile rearing extends from January to about mid-July (Williams 2001). Most Chinook Salmon out-migrate from the lower American River as fry between December and July; out-migration peaks in February to March (Snider and Titus 2002; PSMFC 2014).

Steelhead

Natural spawning by Steelhead in the American River occurs (Hannon and Deason 2008), but the population is supported primarily by the Nimbus Fish Hatchery. The total estimated Steelhead return to the river (spawning naturally and in the hatchery) has ranged from 946 to 3,426 fish, averaging 2,184 fish per year from 2002 to 2010 (CHSRG 2012). Steelhead spawning surveys have shown approximately 300 Steelhead spawning in the river each year (Hannon and Deason 2008). Lindley et al. (2007) classifies the listed (i.e., naturally spawning) population of American River Steelhead at a high risk of extinction because it is reportedly mostly composed of Steelhead originating from Nimbus Fish Hatchery. NMFS views the American River population as important to the survival and recovery of the species (NMFS 2009a).

Nielsen et al. (2005) found Steelhead in the American River to be genetically different from other Central Valley stocks. Eel River Steelhead were used to found the Nimbus Hatchery stock, and Steelhead from the American River (collected from both the Nimbus Fish Hatchery and the American River) are genetically more similar to Eel River Steelhead than other Central Valley Steelhead stocks. Based on studies by Hallock et al. (1961), Staley (1976), and Neilsen et al. (2005), Lee and Chilton (2007) reported that American River Winter-Run Steelhead are genetically and phenotypically different, and demonstrate a later upstream migration period than Central Valley Steelhead. Zimmerman et al. (2008) also noted that there remains a strong resident component (i.e., fish that do not migrate to the ocean) of the *O. mykiss* population that interacts with and produces anadromous individuals. Steelhead and Rainbow Trout are the same species and when juveniles of the species are found in fresh water, it is unclear if they will exhibit an anadromous (Steelhead) or resident (Rainbow Trout) life history strategy. Thus, they are often collectively referred to as *O. mykiss* at this stage to indicate this uncertainty.

Adult Steelhead enter the American River from November through April with a peak occurring from December through March (SWRI 2001). Steelhead have been trapped at Nimbus Fish Hatchery as early as the first week of October. Results of a spawning survey conducted from 2001 through 2007 indicate that Steelhead spawning occurs in the lower American River from late December through early April, with the peak occurring in late February to early March (Hannon and Deason 2008). Spawning density is highest in the upper 7 miles of the river, but spawning occurs as far downstream as Paradise Beach. About 90% of spawning occurs upstream of the Watt Avenue Bridge (Hannon and Deason 2008).

Embryo incubation begins with the onset of spawning in late December and generally extends through May, although incubation can occur into June in some years (SWRI 2001). Steelhead embryo and alevin mortality associated with high flows in the American River has not been documented, but flows high enough to mobilize spawning gravels do occur during the spawning and embryo incubation periods (i.e., late December through early April) (NMFS 2009a).

Juvenile *O. mykiss* have been documented year-round throughout the lower American River, with rearing generally upstream of spawning areas. Juveniles reportedly can rear in the lower American River for a year or more before outmigrating as smolts from January through June (Snider and Titus 2000a; SWRI 2001). However, Snider and Titus (2002) reported only one yearling Steelhead capture, and PSMFC (2014) reported capturing primarily YOY fry and parr. Peak out-migration occurs from March through May (McEwan and Jackson 1996; SWRI 2001; PSMFC 2014).

Rearing habitat for juvenile Steelhead in the lower American River occurs throughout the upper reaches downstream to Paradise Beach. In summer, juveniles occur in most major riffle areas, with the highest concentrations near the higher density spawning areas (Reclamation 2008a). The number of juveniles in the American River decreases throughout summer (Reclamation 2008a). Warm water temperatures stress juvenile Steelhead rearing in the American River, particularly during summer and early fall (LARTF 2002; Water Forum 2005c; NMFS 2014c). However, laboratory studies suggest that American River Steelhead may be more tolerant of high temperatures than Steelhead from regions farther north (Myrick and Cech 2004).

Pacific Lamprey

The Pacific Lamprey inhabits accessible reaches of the American River. Information on the status of Pacific Lamprey in the American River is limited, but the loss of historical habitat and apparent population declines throughout California indicate populations are greatly decreased compared to historical levels (Moyle et al. 2009).

Hannon and Deason (2008) documented Pacific Lamprey spawning in the American River between early January and late May, with peak spawning typically occurring in early April. Pacific Lamprey ammocoetes rear in the American River for all or part of their 5- to 7-year freshwater residence. Data from rotary screw trapping in the nearby Feather River suggest that out-migration of Pacific Lamprey generally occurs from early winter through early summer (Hanni et al. 2006), although some out-migration likely occurs year-round, as observed at sites on the mainstem Sacramento River (Hanni et al. 2006) and in other river systems (Moyle 2002).

Because of the parallels in their life cycles, particularly spawning, lampreys may be affected by many of the same factors as Salmon and Steelhead. Little information is available on factors influencing Pacific Lamprey populations in the American River, but the dams likely play an important role. Moyle et al. (2009) suggested that in addition to blocking upstream migration, dams may disrupt upstream sediment inputs required to maintain habitat for ammocoetes and subject ammocoetes to rapid decreases in stream flow. Moyle et al. (2009) also indicated that ramping rates sufficient to protect salmonids may not be adequate to prevent the stranding of ammocoetes and metamorphosing individuals, which are vulnerable to desiccation and avian predation. Additionally, commercial harvest of lampreys on the American River (presumably for bait) may reduce spawning success in some years (Hannon and Deason 2008).

Sacramento Splittail

Splittail likely spawn in the lower reaches of the American River (Sommer et al. 2008; Moyle et al. 2004). During wet years, upstream migration is more directed and fish tend to swim farther upstream (Moyle 2002), thus more individuals are expected to use the American River in wet years. Although juvenile Splittail are known to rear in upstream areas for a year or more (Baxter 1999), most move to the Delta after only a few weeks of rearing on floodplain habitat (Reclamation 2008a). Most juveniles move downstream into the Delta from April to August (Meng and Moyle 1995). The primary factor potentially limiting the American River population of Sacramento Splittail is availability of inundated floodplains for spawning and rearing habitats (Moyle et al. 2004).

White Sturgeon

Limited quantitative information is available on the distribution and status of White Sturgeon in the American River; however, small numbers of adults apparently use the American River, as evidenced by Sturgeon report cards submitted to CDFW by anglers in recent years (e.g., CDFG 2012b).

Striped Bass

Striped Bass are found in the American River throughout the year, with the greatest abundance in summer (SWRI 2001). Although the occurrence of spawning in the American River is uncertain, the river is believed to serve as a nursery area for YOY and subadult Striped Bass (SWRI 2001). Striped Bass are distributed from the confluence with the Sacramento River to Nimbus Dam (Moyle 2002), and they provide a locally important sportfishing resource.

American Shad

Adult American Shad ascend the lower American River to spawn during the late spring. During this period, they provide an important sport fishery. The shortage of adequate attraction flows in major tributaries such as the American River may be contributing to declines in the population (Moyle 2002).

O.2.7.2.2 Aquatic Habitat

Since 1955, Nimbus Dam has blocked upstream passage by anadromous fish and restricted available habitat in the lower American River to the approximately 23 river miles between the dam and the confluence with the Sacramento River. Additionally, Folsom Dam has blocked the downstream transport of sediment that contributes to the formation and maintenance of habitat for aquatic species.

In 2008, Reclamation, in coordination with USFWS and the Sacramento Water Forum, began implementation of salmonid habitat improvement in the lower American River. An estimated 5,000 cubic yards of gravel and cobble were placed just upstream of Nimbus Fish Hatchery in 2008, followed by an estimated 7,000 cubic yards adjacent to the Nimbus Fish Hatchery in fall 2009. In September 2010, approximately 11,688 cubic yards (approximately 16,200 tons) of gravel and cobble were placed at Sailor Bar to enhance spawning habitat for Chinook Salmon and Steelhead in the lower American River (Merz et al. 2012). Additionally, the 2010 augmentation site contained a constructed cobble island and “scallops” in the substrate designed to add habitat heterogeneity to the main channel and rearing habitat for juvenile Chinook Salmon and Steelhead. Additionally, approximately 5,500 tons of cleaned cobble were placed downstream of the 2010 augmentation site. The specific purpose of this placement was to divert flow into an adjacent, perched side channel, thereby preventing the dewatering of salmonid redds in a historically important spawning and rearing area during low-flow conditions.

During higher flows, channel geomorphology in the lower American River is characterized by bar complexes and side channel areas, which may become limited at lower flows (NMFS 2009a). Spawning bed materials in the lower American River may begin to mobilize at flows of 30,000 cfs, with more substantial mobilization at flows of 50,000 cfs or greater (Reclamation 2008a). At 115,000 cfs (the highest flow modeled), particles up to 70 mm median diameter would be moved in the high-density spawning areas around Sailor Bar and Sunrise Avenue. Flood frequency analysis for the American River at the Fair Oaks gage shows that, on average, flood control releases exceed 30,000 cfs about once every 4 years and exceed 50,000 cfs about once every 5 years (Reclamation 2008a).

In 2008, Reclamation began implementing floodplain and spawning habitat restoration projects in the American River to assist in meeting the requirements of the 1992 CVPIA, Section 3406 (b)(13). The side channel at Upper Sunrise was identified as a suitable site for Steelhead spawning habitat restoration. In 2008, the CVPIA (b)(13) program cut and widened the side channel so that it inundated at a greater range of flows. The project reduced Steelhead stranding, but also inadvertently reduced Chinook Salmon and Steelhead spawning and rearing habitat (AFRP 2012). Consequently, the main channel was filled at the head-cut to create greater head pressure, thereby allowing flow once again through the side channel. Monitoring at the Upper Sunrise project revealed immediate response from Chinook Salmon and Steelhead moving up into the side channel to spawn after completion of the project. Spawning and rearing habitat enhancement projects occurred each year from 2008 through 2014 in the reach from Nimbus Dam down to River Bend Park. These annual projects are planned to continue.

O.2.7.2.3 Fish Passage

Including the mainstem, north, middle, and south forks, more than 125 miles of riverine habitat historically were available for anadromous salmonids in the American River watershed (Yoshiyama et al. 1996). Access to the upper reaches of the river has been blocked by a series of impassable dams, including Old Folsom Dam, first constructed in the American River between 1895 and 1939.

Reclamation operates a fish diversion weir approximately 0.25 mile downstream of Nimbus Dam, which functions to divert adult Steelhead and Chinook Salmon into Nimbus Fish Hatchery. The weir is annually installed during September prior to the arrival of Fall-Run Chinook Salmon and Steelhead and is removed at the conclusion of Fall-Run Chinook Salmon immigration in early January (Reclamation and CDFG 2011). Some Steelhead may be trapped prior to weir removal, but they are returned to the river. A new fish passageway is being implemented in the Nimbus Dam stilling basin, commonly referred to as Nimbus Shoals. The passageway will replace the existing fish diversion weir with a new flume and fish ladder that will connect to the existing fish ladder near Nimbus Fish Hatchery.

O.2.7.2.4 Hatcheries

CDFW operates the Nimbus Salmon and Steelhead Hatchery and American River Trout Hatchery, located immediately downstream from Nimbus Dam. Facilities associated with Nimbus Fish Hatchery include a fish weir, fish ladder, gathering and handling tanks, hatchery-specific buildings, and rearing ponds. Nimbus Fish Hatchery was constructed primarily to mitigate the loss of spawning habitat for Chinook Salmon and Central Valley Steelhead (regardless of unintended genetic differences, discussed earlier) that were blocked by the construction of Nimbus Dam (Reclamation and CDFG 2011); it does not address lost habitat upstream from Folsom Dam (CHSRG 2012). The hatchery operations include the trapping, artificial spawning, rearing, and release of Steelhead and Fall- /Late Fall-Run Chinook Salmon. Propagation programs for American River Winter-Run Steelhead and Central Valley Fall- /Late Fall-Run Chinook Salmon are operated by CDFW under contract with Reclamation (Lee and Chilton 2007). The Nimbus Fish Hatchery Winter-Run Steelhead Program is an isolated-harvest program (i.e., it does not include natural-origin Steelhead in the broodstock) designed and implemented to artificially spawn the adipose fin-clipped adult Steelhead that seasonally enter the trapping facilities (CHSRG 2012). These fin-clipped fish are not part of the Central Valley Steelhead DPS. The Nimbus Fish Hatchery Winter-Run Steelhead Program propagates fish for recreational fishing opportunities and harvest (CHSRG 2012).

Steelhead have been trapped at Nimbus Fish Hatchery as early as the first week of October; however, since 2000, the ladder has been opened in early November. Trapping of Steelhead has continued to occur as late as the second week of March. Presently, Winter-Run Steelhead are trapped at Nimbus Fish Hatchery, and artificially spawned adults are marked with an adipose fin clip (CHSRG 2012). Unmarked Steelhead adults are not retained at Nimbus Fish Hatchery for use in the annual broodstock and are released back to the river (CHSRG 2012). In addition, marked or unmarked *O. mykiss* that are less than 16 inches long may be resident hatchery-origin trout and are returned to the river (CHSRG 2012).

On average, the program has raised and released approximately 422,000 yearling Steelhead since brood year 1999 (CHSRG 2012). Since 1998, all Steelhead/Rainbow Trout produced in Nimbus Fish Hatchery have been marked with an adipose fin-clip to aid in subsequently identifying hatchery-origin fish.

Juvenile Steelhead yearlings are not held past March 30 because of increasing hatchery water temperatures and to encourage out-migration during spring. If releases occur during periods of low flows in the Sacramento River and possibly the American River, some released fish migrate back to Nimbus Fish Hatchery and may take up residency rather than migrating downstream (Lee and Chilton 2007). Additionally, juvenile fish are released in February and early March to coincide with SWRCB D-1641 closures of the DCC gates from February 1 through May 20 to reduce straying into the Delta. Reclamation determines the exact timing and duration of the gate closures after discussion with USFWS, CDFW, and NMFS.

Reclamation is implementing a genetic screening study of Nimbus Fish Hatchery Steelhead. Reclamation, in contract with NMFS, is conducting a parental-based tagging study of American River Steelhead and continuing a study to determine a more genetically appropriate stock.

CDFW releases all hatchery-produced Steelhead juveniles into the American River at boat ramps on the American River or at the confluence of the Sacramento and American Rivers and releases all unclipped Steelhead adults returning to Nimbus Fish Hatchery into the lower American River via the river return tube that is just downstream of the fish ladder. In accordance with California law, the current protocol of Nimbus Fish Hatchery is to destroy all surplus eggs to prevent inter-basin transfer of eggs or juveniles to other hatcheries or waters.

The goal of the Nimbus Fish Hatchery Integrated Fall- /Late Fall-Run Chinook Salmon Program is to release 4 million smolts. Each fall, Nimbus Hatchery staff collect approximately 10,000 adult Fall-Run Chinook Salmon, with an annual goal of harvesting 8,000,000 eggs and releasing the 4,000,000 smolts. All adult Fall-Run Chinook Salmon collected at the hatchery are euthanized, and no trapped salmon are returned to the American River (Reclamation 2008a).

O.2.7.2.5 Disease

The occurrence of a bacterial-caused inflammation of the anal vent (commonly referred to as “rosy anus”) of Steelhead in the lower American River has been reported by CDFW to be associated with relatively warm water temperatures (Water Forum 2005b). Anal vent inflammation of Steelhead in the lower American River was observed in 2004 during periods when water temperatures were measured between 65°F and 68°F (Water Forum 2005a, 2005b). The Water Forum (2005b) suggested that, in addition to possible diminished immune system responses and incidences of diseases associated with elevated water temperatures, disease transmission may be exacerbated by crowding under conditions when water flows are reduced.

O.2.7.2.6 Predation

Two factors, reduced cold-water storage in Folsom Reservoir and using Folsom Reservoir to meet Delta water quality objectives and demands, influence habitat conditions in the lower American River for warm-water predator species that feed on juvenile salmonids and potentially alter predation pressure (Water Forum 2005b). Additionally, isolation of redds in side channels resulting from fluctuations in Folsom Reservoir releases may increase predation of emergent fry (Water Forum 2005b).

O.2.8 Stanislaus River

O.2.8.1 *Water Operations Management*

O.2.8.1.1 Flow

Reclamation operates the CVP East Side Division for flood control, agricultural water supplies, hydroelectric power generation, fish and wildlife protection, and recreation. In the Stanislaus River watershed, Reclamation owns and operates New Melones Dam and Reservoir (2.4 MAF capacity). The Tri-Dam Project, a partnership between the Oakdale Irrigation District (OID) and South San Joaquin Irrigation District (SSJID), consists of Donnells and Beardsley Dams, located upstream of New Melones Reservoir on the Middle Fork Stanislaus River, and Tulloch Dam and Powerplant, located approximately 6 miles downstream of New Melones Dam on the mainstem Stanislaus River. Releases from Donnells and Beardsley Dams affect inflows to New Melones Reservoir. The main water diversion point on the Stanislaus River is Goodwin Dam, located approximately 2 miles downstream of Tulloch Dam. OID and SSJID manage the Tulloch and Goodwin Dam infrastructure through separate agreements with both Reclamation and Reclamation’s CVP water service contractors (Stockton East Water District and the Central San Joaquin Water Conservation District) to meet Reclamation’s Stanislaus River objectives, CVP contractor deliveries, and deliveries to the OID and SSJID service areas.

The Stanislaus River watershed has annual obligations that exceed the average annual runoff in a given year due to a number of factors, including SWRCB water rights decisions D-1641, D-1422 and D-1616, the 1987 CDFG (now CDFW) agreement, CVPIA objectives, the 2009 BO, the 1988 Agreement and Stipulation with OID and SSJID, riparian water right diverters, and CVP water delivery contracts.

Over the past decade, Reclamation has worked with Stanislaus River water users and related agencies in developing a revised operating plan for New Melones Reservoir that addresses multiple objectives, including a more predictable and sustainable operation, minimizing low storage conditions in successive drought years, and providing flows to support listed species and critical habitat. These efforts have allowed multiple agencies and to provide input on potential solutions.

As described in *Appendix 2-E – Stanislaus River Minimum Flows for Fish Needs* of the 2011 NMFS RPA (NMFS 2011c), Reclamation is required to operate releases from the East Side Division reservoirs according to the New Melones year-type specific minimum flow schedules. Tables XO.2-2 through O.2-5 indicate the specific minimum flow schedule that Reclamation currently operates for the East Side Division reservoir. The flow is based on releases measured at Goodwin Dam. However, the flow schedule does not preclude Reclamation from making higher releases for fishery benefits or other operational criteria.

In the 2011 amendment to the NMFS RPA, NMFS clarified that the timing, magnitude, and duration of the flows indicated in Tables O.2-2 through O.2-5 are intended to provide certain hydrologic features at certain times of year to benefit Central Valley Steelhead. Based upon the advice of the Stanislaus Operations Group and the occurrence from NMFS, flows may be implemented with minor modifications to the timing, magnitude, and/or duration, as long as NMFS concurs that the rationale for the shift in timing, magnitude, and/or duration is deemed to be consistent with the intent of the action.

The flow schedule provided by NMFS in 2011, included the following components:

- Minimum base flows based on Instream Flow Incremental Methodology (Aceituno 1993) to optimize available Central Valley Steelhead habitat for adult migration, spawning, and juvenile rearing. These base flows are scaled to water year type as defined by the New Melones water supply parameter, with lowest flows in critically dry years and highest flows in wet years.
- Fall pulse flow to improve in-stream conditions sufficiently to attract Central Valley Steelhead to the Stanislaus River.
- Winter instability flows to simulate natural variability in the winter hydrograph and to enhance access to varied rearing habitats.
- Channel forming and maintenance flows in the 3,000 to 5,000 cfs range in above normal and wet years to maintain spawning and rearing habitat quality. These flows are scheduled to occur after March 1 to protect incubating eggs and are intended to work synergistically with providing out-migration flow cues and late spring flows. These flows are high intensity, but limited in duration to avoid potential seepage issues that have been alleged under extended periods of flow greater than 1,500 cfs. These flows provide flow cues downstream for incoming adults, as well as some remedial effect on the low dissolved oxygen conditions that develop in the Stockton Deep Water Ship Channel. In addition to benefitting Steelhead, this action also produces ancillary benefits to EFH for pacific salmonids (i.e., Fall-Run Chinook Salmon).

Table O.2-2. Stanislaus River Minimum Fish Flow Schedule during Critically Dry Water Year Types

OCT	CFS	NOV	CFS	DEC	CFS	JAN	CFS	FEB	CFS	MAR	CFS
1	200	1	200	1	200	1	200	1	200	1	200
2	200	2	200	2	200	2	200	2	200	2	200
3	200	3	200	3	200	3	400	3	200	3	200
4	200	4	200	4	200	4	400	4	200	4	200
5	200	5	200	5	200	5	200	5	400	5	200
6	200	6	200	6	200	6	200	6	400	6	200
7	200	7	200	7	200	7	200	7	200	7	200
8	200	8	200	8	200	8	200	8	200	8	200
9	200	9	200	9	200	9	200	9	200	9	200
10	200	10	200	10	200	10	200	10	200	10	200
11	200	11	200	11	200	11	200	11	200	11	200
12	200	12	200	12	200	12	200	12	200	12	200
13	200	13	200	13	200	13	200	13	200	13	200
14	200	14	200	14	200	14	200	14	200	14	200
15	500	15	200	15	200	15	200	15	200	15	200
16	750	16	200	16	200	16	200	16	200	16	200
17	1000	17	200	17	200	17	200	17	200	17	200
18	1250	18	200	18	200	18	200	18	200	18	200
19	1250	19	200	19	200	19	200	19	200	19	200
20	1250	20	200	20	200	20	200	20	200	20	200
21	1250	21	200	21	200	21	200	21	200	21	200
22	1250	22	200	22	200	22	200	22	200	22	200
23	1250	23	200	23	200	23	200	23	200	23	200
24	1250	24	200	24	200	24	200	24	200	24	200
25	1250	25	200	25	200	25	200	25	200	25	200
26	1000	26	200	26	200	26	200	26	200	26	200
27	750	27	200	27	200	27	200	27	200	27	200
28	500	28	200	28	200	28	200	28	200	28	200
29	200	29	200	29	200	29	200			29	200
30	200	30	200	30	200	30	200			30	200
31	200			31	200	31	200			31	200
APR	**CFS**	**MAY**	**CFS**	**JUN**	**CFS**	**JUL**	**CFS**	**AUG**	**CFS**	**SEP**	**CFS**
1	200	1	725	1	150	1	150	1	150	1	150
2	200	2	725	2	150	2	150	2	150	2	150
3	200	3	725	3	150	3	150	3	150	3	150
4	200	4	725	4	150	4	150	4	150	4	150
5	200	5	725	5	150	5	150	5	150	5	150
6	200	6	725	6	150	6	150	6	150	6	150
7	200	7	725	7	150	7	150	7	150	7	150
8	200	8	725	8	150	8	150	8	150	8	150

OCT	CFS	NOV	CFS	DEC	CFS	JAN	CFS	FEB	CFS	MAR	CFS
9	200	9	725	9	150	9	150	9	150	9	150
10	200	10	725	10	150	10	150	10	150	10	150
11	200	11	725	11	150	11	150	11	150	11	150
12	200	12	725	12	150	12	150	12	150	12	150
13	200	13	550	13	150	13	150	13	150	13	150
14	200	14	450	14	150	14	150	14	150	14	150
15	350	15	300	15	150	15	150	15	150	15	150
16	500	16	150	16	150	16	150	16	150	16	150
17	725	17	150	17	150	17	150	17	150	17	150
18	725	18	150	18	150	18	150	18	150	18	150
19	725	19	150	19	150	19	150	19	150	19	150
20	725	20	150	20	150	20	150	20	150	20	150
21	725	21	150	21	150	21	150	21	150	21	150
22	725	22	150	22	150	22	150	22	150	22	150
23	725	23	150	23	150	23	150	23	150	23	150
24	725	24	150	24	150	24	150	24	150	24	150
25	725	25	150	25	150	25	150	25	150	25	150
26	725	26	150	26	150	26	150	26	150	26	150
27	725	27	150	27	150	27	150	27	150	27	150
28	725	28	150	28	150	28	150	28	150	28	150
29	725	29	150	29	150	29	150	29	150	29	150
30	725	30	150	30	150	30	150	30	150	30	150
		31	150			31	150	31	150		

Table O.2-3. Stanislaus River Minimum Fish Flow Schedule during Dry Water Year Types

OCT	CFS	NOV	CFS	DEC	CFS	JAN	CFS	FEB	CFS	MAR	CFS
1	200	1	200	1	200	1	200	1	200	1	200
2	200	2	200	2	200	2	200	2	200	2	200
3	200	3	200	3	200	3	400	3	200	3	200
4	200	4	200	4	200	4	400	4	200	4	200
5	200	5	200	5	200	5	400	5	400	5	200
6	200	6	200	6	200	6	200	6	400	6	200
7	200	7	200	7	200	7	200	7	400	7	200
8	200	8	200	8	200	8	200	8	200	8	200
9	200	9	200	9	200	9	200	9	200	9	200
10	200	10	200	10	200	10	200	10	200	10	200
11	200	11	200	11	200	11	200	11	200	11	200
12	200	12	200	12	200	12	200	12	200	12	200
13	200	13	200	13	200	13	200	13	200	13	200
14	200	14	200	14	200	14	200	14	200	14	200
15	500	15	200	15	200	15	200	15	200	15	200
16	750	16	200	16	200	16	200	16	200	16	200
17	1000	17	200	17	200	17	200	17	200	17	200
18	1250	18	200	18	200	18	200	18	200	18	200
19	1250	19	200	19	200	19	200	19	200	19	200
20	1250	20	200	20	200	20	200	20	200	20	200
21	1500	21	200	21	200	21	200	21	200	21	200
22	1500	22	200	22	200	22	200	22	200	22	200
23	1500	23	200	23	200	23	200	23	200	23	200
24	1250	24	200	24	200	24	200	24	200	24	200
25	1250	25	200	25	200	25	200	25	200	25	200
26	1250	26	200	26	200	26	200	26	200	26	200
27	1000	27	200	27	200	27	200	27	200	27	200
28	750	28	200	28	200	28	200	28	200	28	200
29	500	29	200	29	200	29	200			29	200
30	200	30	200	30	200	30	200			30	200
31	200			31	200	31	200			31	200
APR	**CFS**	**MAY**	**CFS**	**JUN**	**CFS**	**JUL**	**CFS**	**AUG**	**CFS**	**SEP**	**CFS**
1	200	1	1000	1	200	1	200	1	200	1	200
2	200	2	1000	2	200	2	200	2	200	2	200
3	200	3	1000	3	200	3	200	3	200	3	200
4	200	4	1000	4	200	4	200	4	200	4	200
5	200	5	1000	5	200	5	200	5	200	5	200
6	200	6	1000	6	200	6	200	6	200	6	200
7	200	7	1000	7	200	7	200	7	200	7	200
8	350	8	1000	8	200	8	200	8	200	8	200

OCT	CFS	NOV	CFS	DEC	CFS	JAN	CFS	FEB	CFS	MAR	CFS
9	500	9	1000	9	200	9	200	9	200	9	200
10	750	10	1000	10	200	10	200	10	200	10	200
11	1000	11	1000	11	200	11	200	11	200	11	200
12	1000	12	1000	12	200	12	200	12	200	12	200
13	1000	13	1000	13	200	13	200	13	200	13	200
14	1000	14	1000	14	200	14	200	14	200	14	200
15	1000	15	1000	15	200	15	200	15	200	15	200
16	1000	16	800	16	200	16	200	16	200	16	200
17	1000	17	600	17	200	17	200	17	200	17	200
18	1000	18	450	18	200	18	200	18	200	18	200
19	1000	19	300	19	200	19	200	19	200	19	200
20	1000	20	200	20	200	20	200	20	200	20	200
21	1000	21	200	21	200	21	200	21	200	21	200
22	1000	22	200	22	200	22	200	22	200	22	200
23	1000	23	200	23	200	23	200	23	200	23	200
24	1000	24	200	24	200	24	200	24	200	24	200
25	1000	25	200	25	200	25	200	25	200	25	200
26	1000	26	200	26	200	26	200	26	200	26	200
27	1000	27	200	27	200	27	200	27	200	27	200
28	1000	28	200	28	200	28	200	28	200	28	200
29	1000	29	200	29	200	29	200	29	200	29	200
30	1000	30	200	30	200	30	200	30	200	30	200
		31	200			31	200	31	200		

Table O.2-4. Stanislaus River Minimum Fish Flow Schedule during Below Normal Water Year Types

OCT	CFS	NOV	CFS	DEC	CFS	JAN	CFS	FEB	CFS	MAR	CFS
1	250	1	200	1	200	1	200	1	200	1	200
2	250	2	200	2	200	2	200	2	200	2	200
3	250	3	200	3	200	3	400	3	200	3	200
4	250	4	200	4	200	4	400	4	200	4	200
5	250	5	200	5	200	5	400	5	400	5	200
6	250	6	200	6	200	6	400	6	400	6	200
7	250	7	200	7	200	7	200	7	400	7	200
8	250	8	200	8	200	8	200	8	400	8	200
9	250	9	200	9	200	9	200	9	200	9	200
10	250	10	200	10	200	10	200	10	200	10	200
11	250	11	200	11	200	11	200	11	200	11	200
12	250	12	200	12	200	12	200	12	200	12	200
13	250	13	200	13	200	13	200	13	200	13	200
14	250	14	200	14	200	14	200	14	200	14	200
15	500	15	200	15	200	15	200	15	200	15	200
16	750	16	200	16	200	16	200	16	200	16	200
17	1000	17	200	17	200	17	200	17	200	17	200
18	1250	18	200	18	200	18	200	18	200	18	200
19	1500	19	200	19	200	19	200	19	200	19	200
20	1500	20	200	20	200	20	200	20	200	20	200
21	1500	21	200	21	200	21	200	21	200	21	200
22	1500	22	200	22	200	22	200	22	200	22	200
23	1500	23	200	23	200	23	200	23	200	23	200
24	1500	24	200	24	200	24	200	24	200	24	200
25	1500	25	200	25	200	25	200	25	200	25	200
26	1500	26	200	26	200	26	200	26	200	26	200
27	1500	27	200	27	200	27	200	27	200	27	200
28	1250	28	200	28	200	28	200	28	200	28	200
29	1000	29	200	29	200	29	200			29	200
30	750	30	200	30	200	30	200			30	200
31	500			31	200	31	200			31	200
APR	**CFS**	**MAY**	**CFS**	**JUN**	**CFS**	**JUL**	**CFS**	**AUG**	**CFS**	**SEP**	**CFS**
1	400	1	1500	1	900	1	250	1	250	1	250
2	750	2	1500	2	600	2	250	2	250	2	250
3	1000	3	1500	3	600	3	250	3	250	3	250
4	1250	4	1500	4	600	4	250	4	250	4	250
5	1500	5	1500	5	600	5	250	5	250	5	250
6	1700	6	1500	6	600	6	250	6	250	6	250
7	2000	7	1500	7	450	7	250	7	250	7	250

OCT	CFS	NOV	CFS	DEC	CFS	JAN	CFS	FEB	CFS	MAR	CFS
8	2000	8	1500	8	450	8	250	8	250	8	250
9	2000	9	1500	9	450	9	250	9	250	9	250
10	2000	10	1500	10	450	10	250	10	250	10	250
11	1500	11	1500	11	300	11	250	11	250	11	250
12	1500	12	1500	12	300	12	250	12	250	12	250
13	1500	13	1500	13	300	13	250	13	250	13	250
14	1500	14	1250	14	300	14	250	14	250	14	250
15	1500	15	1250	15	250	15	250	15	250	15	250
16	1500	16	1250	16	250	16	250	16	250	16	250
17	1500	17	1250	17	250	17	250	17	250	17	250
18	1500	18	1250	18	250	18	250	18	250	18	250
19	2000	19	1250	19	250	19	250	19	250	19	250
20	2000	20	1000	20	250	20	250	20	250	20	250
21	2000	21	1000	21	250	21	250	21	250	21	250
22	2000	22	1000	22	250	22	250	22	250	22	250
23	1500	23	1000	23	250	23	250	23	250	23	250
24	1500	24	1000	24	250	24	250	24	250	24	250
25	1500	25	1000	25	250	25	250	25	250	25	250
26	1500	26	1000	26	250	26	250	26	250	26	250
27	1500	27	900	27	250	27	250	27	250	27	250
28	1500	28	900	28	250	28	250	28	250	28	250
29	1500	29	900	29	250	29	250	29	250	29	250
30	1500	30	900	30	250	30	250	30	250	30	250
		31	900			31	250	31	250		

Table O.2-5. Stanislaus River Minimum Fish Flow Schedule during Wet Water Year Types

OCT	CFS	NOV	CFS	DEC	CFS	JAN	CFS	FEB	CFS	MAR	CFS
1	400	1	300	1	300	1	300	1	300	1	600
2	400	2	300	2	300	2	300	2	300	2	1200
3	400	3	300	3	300	3	600	3	300	3	2400
4	400	4	300	4	300	4	600	4	300	4	5000
5	400	5	300	5	300	5	600	5	600	5	5000
6	400	6	300	6	300	6	600	6	600	6	5000
7	400	7	300	7	300	7	600	7	600	7	5000
8	400	8	300	8	300	8	600	8	600	8	4500
9	400	9	300	9	300	9	300	9	600	9	2400
10	400	10	300	10	300	10	300	10	600	10	1200
11	400	11	300	11	300	11	300	11	300	11	800
12	400	12	300	12	300	12	300	12	300	12	800
13	400	13	300	13	300	13	300	13	300	13	800
14	400	14	300	14	300	14	300	14	300	14	800
15	500	15	300	15	300	15	300	15	300	15	800
16	750	16	300	16	300	16	300	16	300	16	800
17	1000	17	300	17	300	17	300	17	300	17	800
18	1250	18	300	18	300	18	300	18	300	18	800
19	1500	19	300	19	300	19	300	19	300	19	800
20	1500	20	300	20	300	20	300	20	300	20	1200
21	1500	21	300	21	300	21	300	21	300	21	1200
22	1500	22	300	22	300	22	300	22	300	22	1200
23	1500	23	300	23	300	23	300	23	300	23	1200
24	1500	24	300	24	300	24	300	24	300	24	1200
25	1500	25	300	25	300	25	300	25	300	25	800
26	1500	26	300	26	300	26	300	26	300	26	800
27	1500	27	300	27	300	27	300	27	300	27	800
28	1250	28	300	28	300	28	300	28	300	28	800
29	1000	29	300	29	300	29	300			29	800
30	750	30	300	30	300	30	300			30	800
31	500			31	300	31	300			31	800
APR	**CFS**	**MAY**	**CFS**	**JUN**	**CFS**	**JUL**	**CFS**	**AUG**	**CFS**	**SEP**	**CFS**
1	800	1	4800	1	1200	1	800	1	400	1	400
2	800	2	4800	2	1200	2	500	2	400	2	400
3	1200	3	4500	3	1200	3	500	3	400	3	400
4	2400	4	4500	4	1200	4	500	4	400	4	400
5	5000	5	4500	5	1200	5	500	5	400	5	400
6	5000	6	2400	6	1200	6	500	6	400	6	400
7	5000	7	1200	7	1200	7	400	7	400	7	400
8	4500	8	800	8	1200	8	400	8	400	8	400

OCT	CFS	NOV	CFS	DEC	CFS	JAN	CFS	FEB	CFS	MAR	CFS
9	3500	9	800	9	1200	9	400	9	400	9	400
10	2400	10	800	10	1200	10	400	10	400	10	400
11	1200	11	800	11	1200	11	400	11	400	11	400
12	800	12	800	12	1200	12	400	12	400	12	400
13	800	13	800	13	1200	13	400	13	400	13	400
14	800	14	800	14	1200	14	400	14	400	14	400
15	800	15	800	15	1200	15	400	15	400	15	400
16	800	16	800	16	1200	16	400	16	400	16	400
17	800	17	800	17	1200	17	400	17	400	17	400
18	800	18	1500	18	1200	18	400	18	400	18	400
19	800	19	1500	19	1000	19	400	19	400	19	400
20	800	20	1500	20	1000	20	400	20	400	20	400
21	800	21	2500	21	1000	21	400	21	400	21	400
22	800	22	2500	22	1000	22	400	22	400	22	400
23	800	23	2500	23	1000	23	400	23	400	23	400
24	800	24	2500	24	1000	24	400	24	400	24	400
25	800	25	2500	25	1000	25	400	25	400	25	400
26	800	26	1500	26	1000	26	400	26	400	26	400
27	800	27	1500	27	1000	27	400	27	400	27	400
28	800	28	1500	28	800	28	400	28	400	28	400
29	1200	29	1500	29	800	29	400	29	400	29	400
30	2400	30	1500	30	800	30	400	30	400	30	400
		31	1500			31	400	31	400		

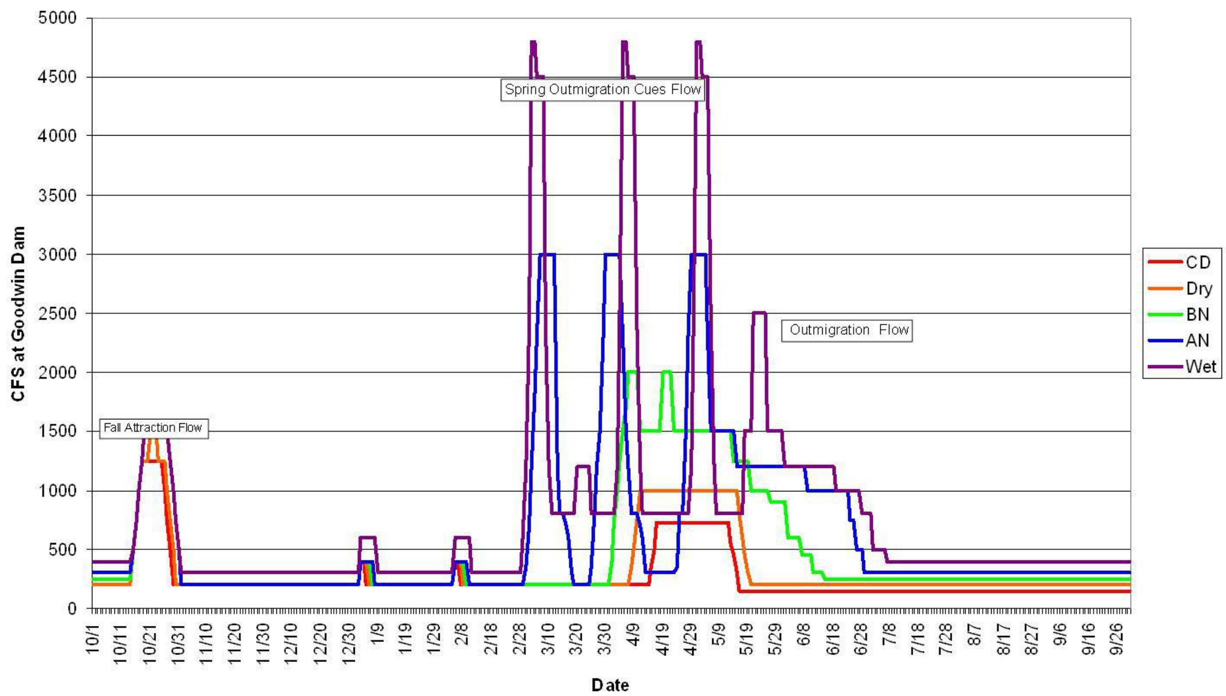


Figure O.2-5. Depicts Minimum Stanislaus River In-Stream Flow Schedule for Central Valley Steelhead as Measured at Goodwin Dam

O.2.8.1.2 Temperature

The 2009 NMFS RPA required Reclamation to manage cold water supply within New Melones Reservoir and make cold water releases from New Melones Reservoir to provide suitable temperatures for all life stages of Central Valley Steelhead in the Stanislaus River downstream of Goodwin Dam. The following table provides the criterion and temperature compliance location, duration, and life stage of Central Valley Steelhead benefiting from the operation. NMFS expected Reclamation to measure temperature compliance based on a 7-day average daily maximum temperature.

The temperature compliance schedule provides an operational framework to minimize temperature-related effects of operations in the reaches of the river most used by Central Valley Steelhead on a year-round basis. The temperature criteria for adult Central Valley Steelhead migration in the river were included, as NMFS expected that fall attraction flows would improve downstream temperature conditions necessary for adult migration.[2]

[2] https://www.westcoast.fisheries.noaa.gov/publications/Central_Valley/Water%20Operations/Operations,%20Criteria%20and%20Plan/nmfs_biological_and_conference_opinion_on_the_long-term_operations_of_the_cvp_and_swp.pdf, accessed February 18, 2019

Table O.2-6. Criterion and Temperature Compliance Location

Criterion and Temperature Compliance Location	Duration	Steelhead Life Stage Benefit
Temperature below 56°F at Orange Blossom Bridge	October 1–December 31	Adult migration
Temperature below 52°F at Knights Ferry and 57°F at Orange Blossom Bridge	January 1–May 31	Smoltification
Temperature Below 55°F at Orange Blossom Bridge	January 1–May 31	Spawning and incubation
Temperature below 65°F at Orange Blossom Bridge	June 1–September 30	Juvenile rearing

However, in April 2011, NMFS provided amendments to the NMFS OCAP RPA, indicating that the NMFS provided more flexibility to the Stanislaus Operation Group to adjust the timing and shape of various pulse flows within the Stanislaus River (NFMS 2011c).

Based on the flow schedule depicted in Appendix 2-E, NMFS indicated that the temperature criteria of RPA Action III.1.2 can generally be met. NMFS expected that salmon mortality may be about 2% higher in critically dry years, but is reduced by about 1% in all other year types under the RPA.

O.2.8.1.3 Dissolved Oxygen

Current operations are required to meet a year-round dissolved oxygen minimum of 7 mg/L, from June 1 to September 30 in the Stanislaus River at Ripon to protect salmon, steelhead, and trout in the river (CDFW 2018b). Under existing conditions, it is challenging to maintain dissolved oxygen concentrations above 7 mg/L during drought conditions, and based on recent studies, does not appear to be warranted to protect salmonds in the river (Kennedy and Cannon 2005, Kennedy 2008).

O.2.8.2 Fish in the Stanislaus River

Steelhead and Fall-Run Chinook Salmon currently occur in the lower Stanislaus River. Historically, Spring-Run Chinook Salmon were believed to be the primary Salmon run in the Stanislaus River. Native Spring-Run Chinook Salmon have been extirpated from all tributaries in the San Joaquin River basin, which represents a large portion of their historic range and abundance (NMFS 2014c). Other anadromous fish species that occur in the lower Stanislaus River include Striped Bass, American Shad, and an unidentified species of lamprey (SRFG 2003).

The analysis is focused on the following species:

- Fall-Run Chinook Salmon
- Steelhead
- Pacific Lamprey
- Striped Bass
- American Shad

O.2.8.2.1 Fall-Run Chinook Salmon

Data collected by private fishery consultants, nonprofit organizations, and CDFW demonstrate the majority of Fall-Run Chinook Salmon adults migrate upstream from late September through December with peak migration from late October through early November. Most Chinook Salmon spawning occurs between Riverbank (RM 33) and Goodwin Dam (RM 58.4) (Reclamation 2012b). Based on redd surveys conducted by FISHBIO, peak spawning typically occurs in November with roughly 7% of spawning occurring prior to November 1, and 2% prior to October 15. The few redds created during late September and early October are typically in the reach just below Goodwin Dam. By late October, the amount of spawning in downstream locations increases as water temperatures decrease, and the median redd location is typically around Knights Ferry (SWRCB 2015).

In 2010, over 20% of the Fall-Run Chinook Salmon observed passing the Stanislaus River weir had adipose fin clips, indicating the presence of a Coded Wire Tag (CWT) in their snout. Since there is no hatchery on the Stanislaus River and no hatchery releases into this tributary have occurred since 2006, it is apparent that straying from other rivers is occurring (FISHBIO 2010b).

Rotary screw trap data indicate that about 99% of salmon juveniles migrate out of the Stanislaus River from January through May (SRFG 2004). Fry migration generally occurs from January through March, followed by smolt migration from April through May (Reclamation 2012b). Watry et al. (2012) found that in both 2010 and 2011, peak passage during the pre-smolt period generally corresponded with flow pulses. Zeug et al. (2014) examined 14 years of rotary screw trap data on the lower Stanislaus River and found a strong positive response in survival, the proportion of pre-smolt migrants and the size of smolts when cumulative flow and flow variance were greater. From the data, they concluded that periods of high discharge in combination with high discharge variance are important for successful emigration as well as migrant size and the maintenance of diverse migration strategies.

Mesick (2001) surmised that when water exports are high relative to San Joaquin River flows, little, if any, San Joaquin River water reaches San Francisco Bay, where it may be needed to help attract the Salmon back to the Stanislaus River. During mid-October from 1987 through 1989, when export rates exceeded 400% of Vernalis flows, Mesick (2001) found that straying rates ranged between 11 and 17%. In contrast, straying rates were estimated to be less than 3% when Delta export rates were less than about 300% of San Joaquin River flow at Vernalis during mid-October.

One of the limiting factors appears to be the high rates of mortality for juveniles migrating through dredged channels in the Stanislaus River and Delta, particularly the Stockton Deep Water Ship Channel (Newcomb and Pierce 2010). Pickard et al. (1982) reported that the survival of juvenile fish in the ship channel is highest during flood flows or when a barrier is placed at the head of the Old River that more than doubles the flow in the ship channel. The Stanislaus River Fish Group (SRFG) (2004) noted that escapement is also directly correlated with springtime flows, when each brood migrates downstream as smolts. However, the cause of the mortality in the ship channel has not been studied. It is possible that mortality results from the combined effects of warm water temperatures, low dissolved oxygen concentrations, ammonia toxicity, and predation.

As discussed earlier, dredging for gravel and gold, regulated flows, and the diking of floodplains for agriculture have substantially limited the availability of spawning and rearing habitat for Fall-Run Chinook Salmon. Reclamation has conducted spawning gravel augmentation to improve spawning and rearing habitats in the reach between Goodwin Dam and Knights Ferry most years since 1999. The dredged areas also contain an abundance of large predatory fish, although SRFG concluded that there is uncertainty about whether predation is a substantial source of mortality for juvenile salmon.

SRFG also concluded that water diversions for urban and agricultural use in all three San Joaquin River tributaries, which reduce flows and potentially result in unsuitably warm water temperatures during spring and fall, affect Fall-Run Chinook Salmon juvenile rearing and adult and juvenile migration in the lower San Joaquin River and Delta.

O.2.8.2.2 Steelhead

Steelhead were thought to be extirpated from the San Joaquin River system (NMFS 2009a). However, monitoring has detected small self-sustaining (i.e., of natural origin, not of hatchery origin) populations of Steelhead in the Stanislaus River and other streams previously thought to be devoid of Steelhead (SRFG 2003; McEwan 2001). There is a catch-and-release Steelhead fishery in the lower Stanislaus River between January 1 and October 15. Surveys of *O. mykiss* (resident Rainbow Trout and the anadromous Steelhead) abundance and distribution conducted annually since 2009 have documented a relatively stable population. River-wide abundance estimates from 2009 to 2014 have averaged just over 20,220 (all life stages combined) and have never been estimated to be less than about 14,000 (2009). The highest densities and abundances of *O. mykiss* are consistently found in Goodwin Canyon. Key factors that may contribute to higher than average abundances in the Stanislaus River (relative to other San Joaquin River tributaries) include high gradient reaches that are typically associated with more fast-water habitats, particularly in Goodwin Canyon (SWRCB 2015).

Historically, the distribution of Steelhead extended into the headwaters of the Stanislaus River (Yoshiyama et al. 1996). Steelhead currently can migrate more than 58 miles up the Stanislaus River to the base of Goodwin Dam. In the Stanislaus River, there is little data regarding the migration patterns of adult Steelhead since adults generally migrate during periods when river flows and turbidity are high, making fish difficult to observe with standard adult monitoring techniques. Stanislaus River weir data indicate that Steelhead migrate upstream, through the south Delta and lower San Joaquin River, between September and March (Reclamation 2014b). High Delta export rates relative to San Joaquin River flows at Vernalis, when adults are migrating through the Delta (presumably December through May), may result in adults straying to the Sacramento River basin.

It is believed that Steelhead spawn primarily between December and March in the Stanislaus River. Although few Steelhead spawning surveys have been conducted in the Stanislaus River, spawning *O. mykiss* were documented between Goodwin Dam and Horseshoe Bar in a 2014 spawning survey (Reclamation and DWR 2015). The spawning adults require holding and feeding habitat with cover adjacent to suitable spawning habitat. These habitat features are relatively rare in the lower Stanislaus River because of in-river gravel mining and the scouring of gravel from riffles in Goodwin Canyon.

Juvenile Steelhead rear in the Stanislaus River for at least 1 year, and usually 2 years, before migrating to the ocean. As a result, flow, water temperature, and dissolved oxygen concentration in the reach between Goodwin Dam and the Orange Blossom Bridge (their primary rearing habitat) are critical during summer (Reclamation 2012b).

Small numbers of Steelhead smolts have been captured in rotary screw traps at Caswell State Park and near Oakdale (FISHBIO 2007; Watry et al. 2007, 2012), and data indicate that Steelhead out-migrate primarily from February through May. Rotary screw traps are generally not considered efficient at catching fish as large as Steelhead smolts, and the number captured is too small to estimate capture efficiency, so no Steelhead smolt out-migration population estimate has been calculated. The capture of these fish in downstream migrant traps and the advanced smolting characteristics exhibited by many of the fish indicate that some Steelhead/Rainbow juveniles might migrate to the ocean in spring. However, it is not known whether the parents of these fish were anadromous or fluvial (i.e., migrate within fresh water). Resident populations of Steelhead/Rainbow Trout in large streams are typically fluvial, and migratory juveniles look much like smolts.

O.2.8.2.3 Pacific Lamprey

The Pacific Lamprey is a widely distributed anadromous species that inhabits accessible reaches of the Stanislaus River (SRFG 2003). Limited information on Pacific Lamprey status in the Stanislaus River exists, but the species has experienced loss of access to historical habitat and apparent population declines throughout California and the Sacramento and San Joaquin River basins (Moyle et al. 2009). Little information is available on factors influencing Pacific Lamprey populations in the Stanislaus River, but they are likely affected by many of the same factors as Salmon and Steelhead because of parallels in their life cycles.

Ocean stage adults likely migrate into the Stanislaus River in spring and early summer, where they hold for approximately 1 year before spawning (Hanni et al. 2006). Hannon and Deason (2008) have documented Pacific Lampreys spawning in the American River from between early January and late May, with peak spawning typically in early April. Spawning time is presumably similar in the Stanislaus River. Pacific Lamprey ammocoetes are expected to rear in the Stanislaus River for all or part of their 5- to 7-year freshwater residence. Data from rotary screw trapping in the nearby Mokelumne and Tuolumne Rivers suggest that out-migration of Pacific Lamprey generally occurs from early winter through early summer (Hanni et al. 2006). Catches of juvenile Pacific Lampreys in trawl surveys of the mainstem San Joaquin River, near the mouth of the Stanislaus River at Mossdale, occurred during winter and spring. Some out-migration likely occurs year-round, as observed at sites on the mainstem Sacramento River (Hanni et al. 2006). Significant numbers of lampreys of unknown species and unspecified life stage have been captured during rotary screw trapping on the Stanislaus River at Oakdale (FISHBIO 2007) and Caswell (Watry et al. 2007).

O.2.8.2.4 Striped Bass

Striped Bass occur in the Stanislaus River, and they support a sport fishery when adult fish migrate upstream to spawn. Striped Bass have been observed at Lovers Leap and at Knights Ferry from May through the end of June. These adult fish were observed in all habitats (USFWS 2002; Kennedy and Cannon 2005). The distribution of Striped Bass in the Stanislaus River is thought to be limited to downstream of the historic Knights Ferry Bridge due to a set of falls about 3 feet tall in the area (USFWS 2002).

O.2.8.2.5 American Shad

American Shad migrate up the Stanislaus River to spawn in the late spring and support a sport fishery during that period. American Shad have been observed on occasion from June through July at Lovers Leap (USFWS 2002; Kennedy and Cannon 2005). American Shad were found primarily in the faster habitats and were observed in schools of 20 or more (USFWS 2002).

O.2.8.2.6 Aquatic Habitat

Schneider et al. (2003) conducted hydrologic analysis of the Stanislaus River and found that New Melones Dam (built in 1979) and more than 30 smaller dams cumulatively impound 240% of average annual unimpaired runoff. Schneider et al. (2003) concluded that this has reduced winter floods and spring snow melt runoff, and increased summer base flows to supply irrigation demand. As a result, the frequency and extent of overbank flooding has been reduced. Based on historical data and field measurements, Schneider et al. (2003) suggested that the channel had incised approximately 1 to 3 feet since dam construction, and that the discharge needed for overbank flows has approximately doubled.

With respect to the related need for geomorphic flows, Kondolf et al. (2001) estimated bedload mobilization flows in the Stanislaus River to be around 5,000 to 8,000 cfs to mobilize the median particle size of the channel bed material. Flows necessary to mobilize the bed material increased downstream from a minimal 280 cfs where gravel had been recently added near Goodwin Dam to about 5,800 cfs at Oakdale Recreation Area (Reclamation 2008a). Before construction of New Melones Dam, a bed-mobilizing flow of 5,000 to 8,000 cfs was equivalent to a 1.5- to 1.8-year return interval flow. Following construction of the dam, 5,000 cfs represents approximately a 5-year return interval flow, and 8,000 cfs exceeds all flows within the 21-year study period, 1979 to 1999 (maximum flow was 7,350 cfs on January 3, 1997). The probability of occurrence for a daily average flow exceeding 5,330 cfs (the pre-dam bankfull discharge) is 0.01 per year.

Low dissolved oxygen levels have been measured in the San Joaquin River, in particular in the Deep Water Ship Channel from the Port of Stockton seven miles downstream to Turner Cut (Lee and Jones-Lee 2003). These conditions are the result of increased residence time of water combined with high oxygen demand in the anthropogenically modified channel, which leads to dissolved oxygen depletion, particularly near the sediment-water interface (SJTA 2012). Despite these conditions, adult Salmon and Steelhead migration does not appear to be adversely affected (Pyper et al. 2006). However, during the 1960s, Hallock et al. (1970) found that adult radio-tagged Chinook Salmon delayed their upstream migration whenever dissolved oxygen concentrations were less than 5 milligrams per liter (mg/L) at Stockton. SWRCB D-1422 requires water to be released from New Melones Reservoir to maintain dissolved oxygen standards in the Stanislaus River, as described in Chapter 6, Surface Water Quality. It has been shown that low dissolved oxygen conditions in the San Joaquin River can be ameliorated somewhat through installation of the Head of the Old River Barrier, which increases San Joaquin River flows (SJTA 2012).

O.2.8.2.7 Spawning and Rearing Habitat

Upstream dams have suppressed channel-forming flows that replenish spawning beds in the Stanislaus River (Kondolf et al. 1996). The physical presence of the dams impedes normal sediment transportation processes. Kondolf (et al. 2001) identified levels of sediment depletion at 20,000 cubic yards per year as a result of a variety of factors, including mining and geomorphic processes associated with past and ongoing dam operations. In 2011, 5,000 tons of gravel were placed in Goodwin Canyon downstream of Goodwin Dam, of which about 70% was transported into nearby downstream areas during high flows (SOG 2012).

Extensive instream gravel mining removed large quantities of spawning habitat from the Stanislaus River (Kondolf et al. 2001). Gravel mining also has resulted in instream mine pits that occur in the primary salmonid spawning areas, including a large, approximately 1-mile-long pit called the Oakdale Recreation Pond. Instream mine pits trap bedload sediment, store large volumes of sand and silt, and pass “sediment-starved” water downstream, where it typically erodes the channel bed and banks to regain its sediment load (Kondolf et al. 2001). Reclamation restores and replenishes spawning gravel and rearing habitat lost from the construction and operation of dams in the Stanislaus River to restore spawning habitat and remediate sediment related loss of geomorphic function, such as channel incision.

O.2.8.2.8 Floodplain Habitat

Kondolf et al. (2001) identified that floodplain terraces and point bars inundated before operation of New Melones Reservoir have become fossilized with fine material and thick riparian vegetation that is never rejuvenated by scouring flows. Channel forming flows in the 8,000-cfs range have occurred only twice since New Melones Reservoir began operation operation in 1979.

Based on historical data and field measurements, Schneider et al. (2003) suggested that the channel incised approximately 1 to 3 feet since dam construction, and that the discharge needed for overbank flows has approximately doubled. Without inundation, the floodplains cannot provide terrestrial food for juvenile Salmon or organic matter that helps produce more food within the river. Increased flows required for inundation also have had the effect of further isolating floodplains from the channel, leading to the loss of floodplain habitats.

In 2011, a habitat restoration project to increase spawning habitat also restored 640 feet of remnant side channel habitat, allowing water to flow at the current 1.5-year return interval (575 cfs), in addition to three cross channels designed to inundate at higher flows (SOG 2011).

O.2.8.2.9 Fish Passage and Entrainment

Constructed in 1913, Goodwin Dam was probably the first permanent barrier to significantly affect anadromous fish access to upstream habitat in the Stanislaus River. Goodwin Dam had a fishway, but Chinook Salmon could seldom pass it, and other salmonids may have been similarly affected. Yoshiyama et al. (1996) estimated that historically Chinook Salmon and other salmonids had access to 113 miles of habitat, compared with 58 miles under current conditions.

There are numerous small, unscreened diversions on the lower Stanislaus River (Herren and Kawasaki 2001). The effects of these diversions on fish is not clear; however, in tracking the fate of 49 radio-tagged fish, S.P. Cramer and Associates (1998) did not detect any entrainment at several moderately sized unscreened pumps in the lower Stanislaus River.

O.2.8.2.10 Predation

Areas of the Stanislaus River, including spawning riffles in the active channel, were mined for gravel and gold primarily between 1940 and 1970. The mined areas consist of long, deep ditches and large ponds that provide habitat for predators, such as Striped Bass, Sacramento Pikeminnow, Largemouth Bass, and Smallmouth Bass (Mesick 2002). Studies by S.P. Cramer and Associates (1998) documented predation on juvenile salmonids by Bass in the Tuolumne and Stanislaus Rivers. However, in its review of information, SRFG (2004) concluded that the available studies and observations suggest that fish predators in the Stanislaus River may be limited to adult Sacramento Pikeminnow and Riffle Sculpin feeding on newly emerged fry, whereas Smallmouth Bass, Largemouth Bass, and possibly American Shad probably feed on relatively few parr that remain in the river during late spring and summer when water temperatures are high.

It is possible that predation is high for juveniles rearing in the Deep-Water Ship Channel in the Delta as observed by Pickard et al. (1982). Predation rates on hatchery-reared juveniles and tagged juveniles may be higher than those for naturally produced fish. TID/MID (1992, 2013), and TRTAC et al. (2006), have documented predation on salmonids by nonnative predatory fishes in the Tuolumne River, primarily in run-of-river gravel mining ponds and dredged areas. Sonke and Fuller (2012) reported the number of juvenile Chinook Salmon passing the rotary screw traps at Waterford (2006 to 2012) and Grayson (1995 to 2012) on the Tuolumne River. FISHBIO (2013a) calculated the potential consumption of juvenile

Chinook Salmon by predators in the reach between the Waterford and Grayson rotary screw traps in 2012 and found that consumption of juvenile Chinook Salmon in this reach could equal or exceed the number passing the Waterford trap. Based on their consumption calculations and the difference in estimated numbers of juvenile Chinook Salmon passing the Waterford and Grayson rotary screw traps, FISHBIO (2013c) concluded that it is plausible that the majority of juvenile Chinook Salmon losses in this reach are due to predation. NMFS (2009a) noted that losses on the Stanislaus River have not been similarly quantified, but predation on Fall-Run Chinook Salmon smolts and Steelhead by Striped Bass and Largemouth Bass has been documented.

O.2.9 San Joaquin River

Since the construction of Friant Dam, significant changes in physical (fluvial geomorphic) processes and substantial reductions in streamflows in the San Joaquin River have occurred, resulting in large-scale alterations to the river channel and associated aquatic, riparian, and floodplain habitats. Throughout the area, there are physical barriers, reaches with poor water quality or no surface flow, and false migration pathways that have reduced habitat connectivity for anadromous and resident native fishes (Reclamation and DWR 2011). As a result, there has been a general decline in both the abundance and distribution of native fishes, with several species extirpated from the system (Moyle 2002).

Moyle (2002) reported that of the 21 native fish species historically present in the San Joaquin River, at least 8 are now uncommon, rare, or extinct. The deep-bodied fish assemblage (e.g., Sacramento Splittail, Sacramento Blackfish) has been replaced by nonnative species like Carp and Catfish.

The San Joaquin River from the Stanislaus River to the Delta is dominated by nonnative species such as Largemouth Bass, Inland Silverside, Carp, and several species of Sunfish and Catfish (Moyle 2002). Anadromous species include Fall-Run Chinook Salmon, Steelhead, Striped Bass, American Shad, White Sturgeon, and several species of Lamprey (Reclamation et al. 2003). The Fall-Run Chinook Salmon population is supported in part by hatchery stock in the Merced River. Spawning by anadromous salmonids in the San Joaquin River basin occurs only in the tributaries to the San Joaquin River, including the Merced, Tuolumne, and Stanislaus Rivers (Brown and Moyle 1993). Spring-Run Chinook Salmon no longer exist in the San Joaquin River, but are targeted for restoration in this system under Reclamation's San Joaquin River Restoration Program. In early 2015, the program experimentally released juvenile Spring-Run Chinook Salmon into the San Joaquin River near the Merced River. Surviving adults may return to the San Joaquin River as early as spring 2017. Because of the uncertainty of future restoration success and the current lack of natural presence in the San Joaquin River, Spring-Run Chinook Salmon is not included in the analysis of San Joaquin River fish.

O.2.9.1 *Water Operations Management*

O.2.9.2 *Flow*

Reclamation operates the Friant Division for flood control, irrigation, M&I, and fish and wildlife purposes. Facilities include Friant Dam, Millerton Reservoir, and the Friant-Kern and Madera Canals. Friant Dam provides flood control on the San Joaquin River, provides downstream releases to meet senior water rights requirements above Gravelly Ford, provides Restoration Flow releases under Title X of Public Law 111-11, and provides conservation storage as well as diversion into Madera and Friant-Kern Canals for water supply. Water is delivered to about a million acres of agricultural land in Fresno, Kern, Madera, and Tulare Counties in the San Joaquin Valley via the Friant-Kern Canal south into Tulare Lake Basin and via the Madera Canal northerly to Madera Irrigation District and Chowchilla Water Districts. A minimum of 5 cfs is required to pass the last holding contract diversion located about 40 miles downstream of Friant Dam near Gravelly Ford.

The San Joaquin River Restoration Program implements the San Joaquin River Restoration Settlement Act in Title X of Public Law 111-11. USFWS and NMFS issued programmatic biological opinions in 2012 that included project-level consultation for San Joaquin River Restoration Program flow releases. Programmatic ESA coverage is provided for flow releases up to a certain level, recapture of those flows in the lower San Joaquin River and the Delta, and all physical restoration and water management actions listed in the Settlement.

The Stipulation of Settlement of *Natural Resources Defence Council, et al. v. Rogers, et al.* (No. CIV-S-88-1658-LKK/GGH), is based on two goals—the Restoration Goal and the Water Management Goal. To achieve the Restoration Goal, the Settlement calls for, among other things, releases of water from Friant Dam to the confluence of the Merced River (referred to as Restoration Flows) according to the hydrographs in Settlement Exhibit B. To achieve the Water Management Goal, the Settlement calls for the development and implementation of a plan for recirculation, recapture, reuse, exchange or transfer of Restoration Flows for the purpose of reducing or avoiding impacts on water deliveries to all of the Friant Contractors caused by Restoration Flows. Recapture of Restoration Flows may occur upstream of a capacity restricted reach, or downstream of the Merced River confluence. Recapture can occur at Banta-Carbona, Patterson, or West Stanislaus Irrigation District facilities, or at the Jones or Banks Pumping Plants. Recapture of Restoration Flows in the Sacramento–San Joaquin Delta under this proposed action would average 65 TAF, ranging from approximately 25 TAF to 78 TAF depending on the water year type.

O.2.9.3 *Temperature*

Restoration flows are determined through review of the Restoration Allocation and Default Flow schedule as determined under the settlement. The flow schedule is determined from a series of pre-set schedules based on water year type and atmospheric conditions. Other factors in consideration include water allocations, unreleased volumes of restoration flows, flow targets set at Gravelly Ford, remaining flexible flow volumes and general operational constraints. Specific temperature targets were not identified in determining ongoing flow management. While specific temperatures to manage to were not identified, flow schedules based on water year types are created by considering a number of factors including temperature. As a result, prescribed flow schedules indirectly manage for temperature within available resources.

O.2.9.4 *Fish in the San Joaquin River*

The analysis is focused on the following species:

- Fall-Run Chinook Salmon
- Steelhead
- White Sturgeon
- Sacramento Splittail
- Pacific Lamprey
- Striped Bass
- American Shad

O.2.9.4.1 Fall-Run Chinook Salmon

Fall-Run Chinook Salmon are present in the San Joaquin River and its major tributaries upstream to and including the Merced River. Spawning and rearing occur in the major tributaries (Merced, Tuolumne, and Stanislaus Rivers) downstream of the mainstem dams. Weir counts in the Stanislaus River suggest that adult Fall-Run Chinook Salmon in the San Joaquin River basin typically migrate into the upper rivers between late September and mid-November and spawn shortly thereafter (Pyper et al. 2006; Anderson et al. 2007; FISHBIO 2010a, 2011).

The San Joaquin River downstream of the Stanislaus River primarily provides upstream passage for adult Fall-Run Chinook Salmon and downstream passage for juveniles and smolts as they out-migrate from the tributary spawning and rearing areas to the Delta and the Pacific Ocean. The juvenile Fall-Run Chinook Salmon out-migration in the San Joaquin River basin typically occurs during winter and spring, primarily from January through May. The out-migration consists primarily of fry in winter and smolts in spring (FISHBIO 2007, 2013b). Trawl sampling in the lower San Joaquin River from Mossdale to the Head of Old River (the Mossdale Trawl) captures Chinook Salmon from February into July, with peak catches generally during April and May (Speegle et al. 2013).

O.2.9.4.2 Steelhead

Steelhead were historically present in the San Joaquin River, though data on their population levels are lacking (McEwan 2001). The current Steelhead population in the San Joaquin River is substantially reduced compared with historical levels, although resident Rainbow Trout occur throughout the major San Joaquin River tributaries. Additionally, small populations of Steelhead persist in the lower San Joaquin River and tributaries (e.g., Stanislaus, Tuolumne, and possibly the Merced Rivers) (Zimmerman et al. 2009; McEwan 2001). Steelhead/Rainbow Trout of anadromous parentage occur at low numbers in all three major San Joaquin River tributaries. These tributaries have a higher percentage of resident Rainbow Trout compared to the Sacramento River and its tributaries (Zimmerman et al. 2009).

Presence of Steelhead smolts from the San Joaquin River basin is estimated annually by CDFW based on the Mossdale Trawl (SJRGA 2011). The sampling trawls capture Steelhead smolts, although usually in small numbers. One Steelhead smolt was captured and returned to the river during the 2009 sampling period (SJRGA 2010), and three Steelhead were captured and returned in both 2010 and 2011 (Speegle et al. 2013).

O.2.9.4.3 Sacramento Splittail

Historically, Sacramento Splittail were widespread in the San Joaquin River and found upstream to Tulare and Buena Vista lakes, where they were harvested by native peoples (Moyle et al. 2004). Today, Sacramento Splittail likely ascend the San Joaquin River to Salt Slough during wet years (Baxter 1999). During dry years, Sacramento Splittail are uncommon in the San Joaquin River downstream of the Tuolumne River (Moyle et al. 2004). Most spawning takes place in the flood bypasses, along the lower reaches of the Sacramento and San Joaquin Rivers and major tributaries, and lower Cosumnes River and similar areas in the western Delta.

Most juveniles apparently move downstream into the Delta from April to August (Meng and Moyle 1995). The population of Sacramento Splittail is largely influenced by extent and period of inundation of floodplain spawning habitats, with abundance spiking following wet years and declining after dry years (Moyle et al. 2004). Other factors that may influence the San Joaquin River portion of the Sacramento

Splittail population include flood control, entrainment by diversion, recreational fishing, pollutants, and nonnative species (Moyle et al. 2004).

O.2.9.4.4 Pacific Lamprey

The Pacific Lamprey is a widely distributed anadromous species found in accessible reaches of the San Joaquin River and many of its tributaries.

Data from mid-water trawls in the lower San Joaquin River near Mossdale indicate that adults likely migrate into the San Joaquin River in spring and early summer (Hanni et al. 2006). In other large river systems, the initial adult migration from the ocean generally stops in summer, and Pacific Lampreys hold until the following winter or spring before undergoing a secondary migration to spawning grounds (Robinson and Bayer 2005; Clemens et al. 2012). Midwater trawl surveys in the San Joaquin River suggest that peak ammocoete out-migration occurs in January and February (Hanni et al. 2006).

Little information is available on factors influencing Pacific Lamprey in the San Joaquin River, but they are likely affected by many of the same factors as Salmon and Steelhead because of parallels in their life cycles. Lack of access to historical spawning habitats because of the mainstem dams and other migration barriers, modification of spawning and rearing habitats, altered hydrology, entrainment by water diversions, and predation by nonnative invasive species such as Striped Bass all likely influence Pacific Lamprey in the San Joaquin River and tributaries.

O.2.9.4.5 Striped Bass

Striped Bass are regularly found in San Joaquin River tributaries, including in lower mainstem deep pools of the Stanislaus and Tuolumne Rivers (e.g., Anderson et al. 2007). Ainsley et al. (2013) reported that Striped Bass were collected at two locations between the Head of the Old River and the mouth of the Stanislaus River on the mainstem San Joaquin River in May.

O.2.9.4.6 American Shad

Little is known about American Shad populations inhabiting the San Joaquin River. American Shad may spawn in the San Joaquin River system, but their abundance is unknown. Sport fishing for American Shad occurs seasonally in the San Joaquin River.

O.2.9.4.7 Sturgeon

Little is known about White Sturgeon populations inhabiting the San Joaquin River. Spawning-stage adults generally move into the lower reaches of rivers during winter prior to spawning, then migrate upstream to spawn in response to higher flows (Schaffter 1997; McCabe and Tracy 1994). Based on tag returns from White Sturgeon tagged in the Sacramento–San Joaquin Delta and recovered by anglers, Kohlhorst et al. (1991) estimated that over 10 times as many White Sturgeon spawn in the Sacramento River as in the San Joaquin River.

CDFW fisheries catch information for the San Joaquin River obtained from fishery report cards (CDFG 2008b, 2009b, 2010, 2011, 2012b; CDFW 2013, 2014) documented that anglers upstream of State Route 140 caught between 8 and 25 mature White Sturgeon annually between 2007 and 2013. Below State Route 140 downstream to Stockton, anglers caught between 2 and 35 mature White Sturgeon annually over the same time period; most of the White Sturgeon caught were released.

White Sturgeon spawning in the San Joaquin River was documented for the first time in 2011 and confirmed in 2012. Viable White Sturgeon eggs were collected in 2011 at one sampling location downstream of Laird Park (Gruber et al. 2012) and in 2012 at four sampling locations generally between Laird Park and the Stanislaus River confluence (Jackson and Van Eenennaam 2013). Although the majority of Sturgeon likely spawn in the Sacramento River, the results of these surveys confirm that White Sturgeon do spawn in the San Joaquin River in both wet- and dry-year conditions and may be an important source of production for the White Sturgeon population in the Sacramento–San Joaquin River system.

Green Sturgeon are also present in the San Joaquin River, but at considerably lower numbers than White Sturgeon. Between 2007 and 2012, anglers reported catching six Green Sturgeon in the San Joaquin River (Jackson and Van Eenennaam 2013). Although the reported presence of Green Sturgeon in the San Joaquin River coincides with the spawning migration period of Green Sturgeon within the Sacramento River, no evidence of spawning has been detected (Jackson and Van Eenennaam 2013).

O.2.9.5 *Aquatic Habitat*

Aquatic habitat conditions vary spatially and temporally throughout the lower San Joaquin River because of differences in habitat availability and connectivity, water quantity and quality (including water temperature), and channel morphology.

Downstream of the Stanislaus River confluence, the San Joaquin River is more sinuous than upstream reaches and contains oxbows, side channels, and remnant channels. It conveys the combined flows of the major tributaries, including the Merced, Tuolumne, Stanislaus, and Calaveras Rivers. Flood control levees closely border much of the river but are set back in places, creating some off-channel aquatic habitat areas when inundated (Reclamation and DWR 2011). The channel gradient in this portion of the San Joaquin River is low, and the lack of gravel or coarser substrate precludes spawning by salmonids.

O.2.9.6 *Fish Passage*

In the reach of the river downstream of the confluence of the Stanislaus River, fish encounter passage challenges associated with water diversions, and adult Salmon migrating upstream from the Delta also may encounter prohibitively high stream temperatures that delay migration until temperatures decline (McBain and Trush 2002). Installation of seasonal barriers in the Delta also can impair fish passage.

O.2.9.7 *Hatcheries*

No hatcheries in the San Joaquin River basin are affected by CVP or SWP operations. The Merced River Hatchery, located on the Merced River, is operated by CDFW to supplement the Fall-Run Chinook Salmon population. It is not included in the CVP or SWP service areas. As part of the San Joaquin River Restoration Program, CDFW has begun operation of a conservation hatchery downstream of Friant Dam to produce Spring-Run Chinook Salmon (Reclamation and DWR 2010).

O.2.9.8 *Predation*

Recent studies of predation in the San Joaquin River are limited to the major tributaries, where Largemouth and Smallmouth Bass have been identified as the most important predators of juvenile Chinook Salmon (McBain and Trush and Stillwater Sciences 2006). Striped Bass, Channel Catfish, and White Catfish have also been identified as important Salmon predators in the San Joaquin River (Hayes et al. 2017).

O.2.9.9 *New Melones Reservoir, Tulloch Reservoir, and Goodwin Dam*

The north, middle, and south forks of the Stanislaus River converge upstream of the CVP New Melones Reservoir. Water from New Melones Reservoir flows into Tulloch Reservoir (Reclamation 2010b). Downstream of Tulloch Reservoir, the Stanislaus River flows through the reservoir formed by Goodwin Dam and then approximately 40 miles to the confluence with the San Joaquin River.

New Melones Reservoir is approximately 60 miles upstream from the confluence of the Stanislaus and San Joaquin Rivers and is operated by Reclamation. New Melones Reservoir is an artificial environment and does not support a naturally evolved aquatic community. Most of the species in the reservoir were introduced, although a few native species may still be present. From a fisheries perspective, recreational fishing is the most important use of New Melones Reservoir. Fish species in New Melones Reservoir include Rainbow Trout, Brown Trout, Largemouth Bass, Sunfishes such as Black Crappie and Bluegill, and three species of Catfish (Reclamation 2010b). Rainbow Trout, Brown Trout, and large Channel Catfish are generally restricted to colder, deeper water during summer, when New Melones Reservoir has two distinct thermal layers of water, although large Brown Trout and Channel Catfish are found in shallow water near steep banks at night when they ascend to feed.

Tulloch Reservoir is operated as an afterbay for the New Melones Reservoir and is subject to fluctuating water levels that occur on a daily and seasonal basis. Tulloch Reservoir stratifies weakly during summer and contains a reserve of relatively cold, well-oxygenated water that is released downstream. Tulloch Reservoir supports both warm and cold freshwater habitat. Goodwin Power (2013) reported that CDFW captured 15 species in Tulloch Reservoir from 1969 through 1998. Five dominant species made up almost 80% of the catch: White Catfish (31%), Bluegill (20%), Sacramento Sucker (11%), Smallmouth Bass (10%), and Black Crappie (7%). Of these, only the Sacramento Sucker is native. Other native species in the catch were Sacramento Hitch, Hardhead, Sacramento Pikeminnow, and Rainbow Trout (now stocked). Other nonnative fish found in Tulloch reservoir include Largemouth Bass and Threadfin Shad (CDFG 2002b).

Little information exists regarding aquatic resources in the reservoir formed by Goodwin Dam. It is assumed that fish assemblies are similar to those described for Tulloch Reservoir.

O.2.10 Bay-Delta

Ecologically, the Delta consists of three major landscapes and geographic regions: (1) the north Delta freshwater flood basins composed primarily of freshwater inflow from the Sacramento River system; (2) the south Delta distributary channels composed of predominantly San Joaquin River system inflow; and (3) the central Delta tidal islands landscape wherein the Sacramento, San Joaquin, and east side tributary flows converge and tidal influences from San Francisco Bay are greater.

O.2.10.1 *Fish in the Delta*

The Delta provides unique and, in some places, highly productive habitats for a variety of fish species, including euryhaline and oligohaline resident species and anadromous species. For anadromous species, the Delta is used by adult fish during upstream migration and by rearing juvenile fish that are feeding and growing as they migrate downstream to the ocean. Conditions in the Delta influence the abundance and productivity of all fish populations that use the system. Fish communities currently in the Delta include a mix of native species, some with low abundance, and a variety of introduced fish, some with high abundance (Matern et al. 2002; Feyrer and Healey 2003; Nobriga et al. 2005; Brown and May 2006; Moyle and Bennett 2008; Grimaldo et al. 2012).

The analysis is focused on the following species:

- Chinook Salmon (Winter-Run, Spring-Run, and Fall- /Late Fall-Run)
- Steelhead
- Green Sturgeon
- White Sturgeon
- Sacramento Splittail
- Pacific Lamprey
- Striped Bass
- American Shad
- Delta Smelt
- Longfin Smelt
- Sacramento Splittail

The Interagency Ecological Program (IEP) has been monitoring fish populations in the San Francisco Estuary for decades. Survey methods have included beach seining, midwater trawls, Kodiak trawls, otter trawls, and other methods (Honey et al. 2004) to sample the pelagic fish assemblage throughout the estuary. Three of the most prominent resident pelagic fishes captured in the surveys (Delta Smelt, Longfin Smelt, and Striped Bass) have shown substantial long-term population declines (Kimmerer et al. 2000; Bennett 2005; Rosenfield and Baxter 2007). Reductions in pelagic fish abundance since 2002 have been recognized as a serious water and fish management issue and have become known as the Pelagic Organism Decline (POD) (Sommer et al. 2007a).

In response to the POD, IEP formed a study team in 2005 to evaluate the potential causes of the decline. Since completion of the first set of studies in late 2005, alternative models have been developed based on the available data and at professional judgment of the POD-Modeling Team regarding the extent to which individual drivers are likely to affect each species-life stage. The nine drivers identified (Baxter et al. 2010) were: (1) mismatch of larvae and food; (2) reduced habitat space; (3) adverse water movement/transport; (4) entrainment; (5) toxic effects on fish; (6) toxic effects on fish food items; (7) harmful Microcystis aeruginosa blooms; (8) *Potamocorbula amurensis* effects on food availability; and (9) disease and parasites.

An overall negative trend in habitat quality has occurred for Delta Smelt and Striped Bass (and potentially other fish species) as measured by water quality attributes and midwater trawl catch data since 1967, with Delta Smelt and Striped Bass experiencing the most apparent declines in abundance, distribution, and a related index of environmental quality (Feyrer et al. 2007, 2010). More specifically, the position of X2 and water clarity may be important factors influencing the quality of habitat for these species (Mac Nally et al. 2010). Other factors, such as the introduction of nonnative clam species, also contribute to reducing habitat quality. Pelagic habitat suitability in the San Francisco Estuary has been characterized by changes in X2 (Feyrer et al. 2007, 2010). The abundance of several taxa increases in years when flows into the estuary are high and X2 is pushed seaward (Jassby et al. 1995; Kimmerer 2002a, 2002b), implying that the quantity or suitability of estuarine habitat increases when outflows are high. Recent analyses by Kimmerer et al. (2009) indicated that neither changes in area or volume of low salinity water (habitat) account for this relationship, except for striped bass and American shad. This suggests that X2 is indexing other environmental variables or processes rather than simple extent of habitat (Baxter et al. 2010).

O.2.10.1.1 Winter-Run Chinook Salmon

Winter-Run Chinook Salmon use the Delta for upstream migration as adults and for downstream migration and rearing as juveniles (del Rosario et al. 2013). Adults migrate through the Delta during winter and into late spring (May/June) enroute to their spawning grounds in the mainstem Sacramento River downstream of Keswick Dam (USFWS 2001, 2003b). Adults are believed to primarily use the mainstem Sacramento River for passage through the Delta (NMFS 2009a). After entry into the Delta, juvenile Winter-Run Chinook Salmon remain and rear in the Delta until they are 5 to 10 months of age (based on scale analysis) (Fisher 1994; Myers et al. 1998). Although the duration of residence in the Delta is not precisely known, del Rosario et al. (2013) suggested that it can be up to several months. Winter-Run Chinook Salmon juveniles have been documented in the north Delta (e.g., Sacramento River, Steamboat Slough, Sutter Slough, Miner Slough, Yolo Bypass, and Cache Slough complex); the central Delta (e.g., Georgiana Slough, DCC, Snodgrass Slough, and Mokelumne River complex below Dead Horse Island); south Delta channels, including Old and Middle Rivers, and the joining waterways between Old and Middle Rivers (e.g., Victoria Canal, Woodward Canal, and Connection Slough); and the western central Delta, including the mainstem channels of the Sacramento and San Joaquin Rivers and Threemile Slough (NMFS 2009a).

Sampling at Chipps Island in the western Delta suggests that Winter-Run Chinook Salmon exit the Delta as early as December and as late as May, with a peak in March (Brandes and McLain 2001; del Rosario et al. 2013). The peak timing of the out-migration of juvenile Winter-Run Chinook Salmon through the Delta is corroborated by recoveries of Winter-Run-sized juvenile Chinook Salmon from the SWP Skinner Delta Fish Protection Facility and the CVP Tracy Fish Collection Facility (TFCF) in the south Delta (NMFS 2009a).

O.2.10.1.2 Spring-Run Chinook Salmon

The Delta is an important migratory route for all remaining populations of Spring-Run Chinook Salmon. Like all salmonids migrating up through the Delta, adult Spring-Run Chinook Salmon must navigate the many channels and avoid direct sources of mortality (e.g., fishing and predation), but also must minimize exposure to sources of nonlethal stress (e.g., high temperatures) that can contribute to prespawn mortality in adult salmonids (Budy et al. 2002; Naughton et al. 2005; Cooke et al. 2006; NMFS 2009a). Habitat degradation in the Delta caused by factors such as channelization and changes in water quality can present challenges for outmigrating juveniles. Additionally, outmigrating juveniles are subjected to predation and entrainment in the project export facilities and smaller diversions (NMFS 2009a). Further detail is provided later in this section.

Spring-Run Chinook Salmon returning to spawn in the Sacramento River system enter the San Francisco Estuary from the ocean in January to late February and move through the Delta prior to entering the Sacramento River. Several populations of Spring-Run Chinook Salmon occur in the Sacramento River basin, but historical populations that occurred in the San Joaquin River and tributaries have been extirpated. The Sacramento River channel is the main Spring-Run Chinook Salmon migration route through the Delta. However, adult Spring-Run Chinook Salmon may stray into the San Joaquin River side of the Delta in response to water from the Sacramento River basin flowing into the interconnecting waterways that join the San Joaquin River channel through the DCC, Georgiana Slough, and Threemile Slough. Closure of the DCC radial gates is intended to minimize straying, but some southward net flow still occurs naturally in Georgiana and Threemile sloughs.

Juvenile Spring-Run Chinook Salmon show two distinct out-migration patterns in the Central Valley: outmigrating to the Delta and ocean during their first year of life as YOY, or holding over in their natal streams and outmigrating the following fall/winter as yearlings. Peak movement of juvenile Spring-Run Chinook Salmon in the Sacramento River at Knights Landing generally occurs in December, and again in March. However, juveniles also have been observed migrating between November and the end of May (Snider and Titus 1998, 2000b, 2000c, 2000d; Vincik et al. 2006; Roberts 2007).

YOY Spring-Run Chinook Salmon presence in the Delta peaks during April and May, as suggested by the recoveries of Chinook Salmon in the CVP and SWP salvage operations and the Chipps Island trawls of a size consistent with the predicted size of Spring-Run fish at that time of year. However, it is difficult to distinguish the YOY Spring-Run Chinook Salmon out-migration from that of the Fall-Run due to the similarity in their spawning and emergence times and size. Together, these two runs generate an extended pulse of Chinook Salmon smolts outmigrating through the Delta throughout spring, frequently lasting into June. Spring-Run Chinook Salmon juveniles also overlap spatially with juvenile Winter-Run Chinook Salmon in the Delta (NMFS 2009a). Typically, juvenile Spring-Run Chinook Salmon are not found in the channels of the eastern side of the Delta or the mainstem of the San Joaquin River upstream of Columbia and Turner Cuts.

O.2.10.1.3 Fall- /Late Fall-Run Chinook Salmon

Central Valley Fall-Run and Late Fall-Run Chinook Salmon pass through the Delta as adults migrating upstream and juveniles outmigrating downstream. Adult Fall-Run and Late Fall-Run Chinook Salmon migrating through the Delta must navigate the many channels and avoid direct sources of mortality and minimize exposure to sources of nonlethal stress. Additionally, outmigrating juveniles are subject to predation and entrainment in the project export facilities and smaller diversions.

Adult Fall-Run Chinook Salmon migrate through the Delta and into Central Valley rivers from June through December. Adult Late Fall-Run Chinook Salmon migrate through the Delta and into the Sacramento River from October through April. Adult Central Valley Fall-Run and Late Fall-Run Chinook Salmon migrating into the Sacramento River and its tributaries primarily use the western and northern portions of the Delta, whereas adults entering the San Joaquin River system to spawn use the western, central, and southern Delta as a migration pathway.

Most Fall-Run Chinook Salmon fry rear in fresh water from December through June, with out-migration as smolts occurring primarily from January through June. In general, Fall-Run Chinook Salmon fry abundance in the Delta increases following high winter flows. Smolts that arrive in the estuary after rearing upstream migrate quickly through the Delta and Suisun and San Pablo Bays. A small number of juvenile Fall-Run Chinook Salmon spend over a year in fresh water and out-migrate as yearling smolts the following November through April. Late Fall-Run fry rear in fresh water from April through the following April and out-migrate as smolts from October through February (Snider and Titus 2000b). Juvenile Chinook Salmon were found to spend about 40 days migrating through the Delta to the mouth of San Francisco Bay (MacFarlane and Norton 2002).

Results of mark-recapture studies conducted using juvenile Chinook Salmon released into both the Sacramento and San Joaquin Rivers have shown high mortality during passage downstream through the rivers and Delta (Brandes and McLain 2001; Newman and Rice 2002; Buchanan et al. 2013). Juvenile Salmon migrating from the San Joaquin River generally experience greater mortality than fish outmigrating from the Sacramento River. In years when spring flows are reduced and water temperatures are increased, mortality is typically higher in both rivers. Closing the DCC gates and installation of the Head of Old River Barrier to reduce the movement of juvenile Salmon into the south Delta from the Sacramento and San Joaquin Rivers, respectively, may contribute to improved survival of outmigrating juvenile Chinook Salmon from these watersheds.

Although not directly comparable to these previous CWT studies in the San Joaquin River, Buchanan et al. (2013, 2015) found that survival of acoustically tagged hatchery-origin (Feather River) juvenile Chinook Salmon was either not statistically different between routes (2009) or was higher through the south Delta via the Old River route than via the San Joaquin River (2010). Additionally, most fish in the Old River that survived to the end of the Delta had been salvaged from the federal water export facility on the Old River and trucked around the remainder of the Delta (Buchanan et al. 2013; SJRGA 2013). Buchanan et al. 2013 indicated that the differences in their results compared to past CWT studies may reflect that an alternative non-physical barrier was being used during their investigation to examine its ability to keep fish out of the Old River instead of the Head of Old River Barrier, which is a physical barrier that reduces not only the number of fish, but also the majority of flows, from entering the Old River. Nonphysical barriers may deprive smolts routed to the San Joaquin River of the increased flows needed for improved survival and may have created habitat for increased predation at the site (Buchanan et al. 2013).

Juvenile Fall-Run and Late Fall-Run Chinook Salmon migrating through the Delta toward the Pacific Ocean use the Delta, Suisun Marsh, and the Yolo Bypass for rearing to varying degrees, depending on their life stage (fry versus juvenile), size, river flows, and time of year. Movement of juvenile Chinook Salmon in the estuarine environment is driven by the interaction between tidally influenced saltwater intrusion through San Francisco Bay and freshwater outflow from the Sacramento and San Joaquin Rivers (Healey 1991).

In the Delta, tidal and floodplain habitat areas provide important rearing habitat for foraging juvenile salmonids, including Fall-Run Chinook Salmon. Studies have shown that juvenile Salmon may spend 2 to 3 months rearing in these habitat areas, and losses resulting from land reclamation and levee construction are considered to be major stressors (Williams 2010). The channeled, leveed, and riprapped river reaches and sloughs common in the Delta typically have low habitat diversity and complexity, have low abundance of food organisms, and offer little protection from predation by fish and birds.

O.2.10.1.4 Steelhead

Upstream migration of Steelhead begins with estuarine entry from the ocean as early as July and continues through February or March in most years (McEwan and Jackson 1996; NMFS 2009a). Populations of Steelhead occur primarily within the watersheds of the Sacramento River basin, although not exclusively. Steelhead can spawn more than once, with postspawn adults (typically females) potentially moving back downstream through the Delta after completion of spawning in their natal streams.

Upstream migrating adult Steelhead enter the Sacramento River and San Joaquin River basins through their respective mainstem river channels. Steelhead entering the Mokelumne River system (including dry Creek and the Cosumnes River) and the Calaveras River system to spawn are likely to move up the mainstem San Joaquin River channel before branching off into the channels of their natal rivers, although some may detour through the South Delta waterways and enter the San Joaquin River through the Head of Old River.

Steelhead entering the San Joaquin River basin appear to have a later spawning run, with adults entering the system starting in late October through December, indicating that migration up through the Delta may begin a few weeks earlier. During fall, warm water temperatures in the south Delta waterways and water quality impairment because of low dissolved oxygen at Stockton have been suggested as potential barriers to upstream migration (NMFS 2009a). Reduced water temperatures, as well as rainfall runoff and flood control release flows, provide the stimulus to adult Steelhead holding in the Delta to move upriver toward their spawning reaches in the San Joaquin River tributaries. Adult Steelhead may continue entering the San Joaquin River basin through winter.

Juvenile Steelhead can be found in all waterways of the Delta, but particularly in the main channels leading from their natal river systems (NMFS 2009a). Juvenile Steelhead are recovered in trawls from October through July at Chipps Island and at Mossdale. Chipps Island catch data indicate there is a difference in the out-migration timing between wild and hatchery-reared Steelhead smolts from the Sacramento and eastside tributaries. Hatchery fish are typically recovered at Chipps Island from January through March, with a peak in February and March corresponding to the schedule of hatchery releases of Steelhead smolts from the Central Valley hatcheries (Nobriga and Cadrett 2001; Reclamation 2008a). The timing of wild (unmarked) Steelhead out-migration is more spread out, and based on salvage records at the CVP and SWP fish collection facilities, out-migration occurs over approximately 6 months with the highest levels of recovery in February through June (Aasen 2011, 2012). Steelhead are salvaged annually at the project export facilities (e.g., 4,631 fish were salvaged in 2010, and 1,648 in 2011) (Aasen 2011, 2012).

Outmigrating Steelhead smolts enter the Delta primarily from the Sacramento or San Joaquin Rivers. Mokelumne River Steelhead smolts can either follow the north or south branches of the Mokelumne River through the central Delta before entering the San Joaquin River, although some fish may enter farther upstream if they diverge from the south branch of the Mokelumne River into Little Potato Slough. Calaveras River Steelhead smolts enter the San Joaquin River downstream of the Port of Stockton. Although Steelhead have been routinely documented by CDFW in trawls at Mossdale since 1988 (SJRGA 2011), it is unknown whether successful out-migration occurs outside the seasonal installation of the barrier at the Head of Old River (between April 15 and May 15 in most years). Prior to the installation of the Head of Old River barrier, Steelhead smolts exiting the San Joaquin River basin could follow one of two routes to the ocean, either staying in the mainstem San Joaquin River through the central Delta, or entering the Head of Old River and migrating through the south Delta and its associated network of channels and waterways.

O.2.10.1.5 Green Sturgeon

Green Sturgeon reach maturity around 14 to 16 years of age and can live to be 70 years old, returning to their natal rivers every 3 to 5 years for spawning (Van Eenennaam et al. 2005). Adult Green Sturgeon move through the Delta from February through April, arriving at holding and spawning locations the upper Sacramento River between April and June (Heublein 2006; Kelly et al. 2007). Following their initial spawning run upriver, adults may hold for a few weeks to months in the upper river before moving back downstream in fall (Vogel 2008; Heublein et al. 2009), or they may migrate immediately back downstream through the Delta. Radio-tagged adult Green Sturgeon have been tracked moving downstream past Knights Landing during summer and fall, typically in association with pulses of flow in the river (Heublein et al. 2009), similar to behavior exhibited by adult Green Sturgeon on the Rogue River and Klamath River systems (Erickson et al. 2002; Benson et al. 2007).

Similar to other estuaries along the west coast of North America, adult and subadult Green Sturgeon frequently congregate in the San Francisco Estuary during summer and fall (Lindley et al. 2008). Specifically, adults and subadults may reside for extended periods in the central Delta as well as in Suisun and San Pablo Bays, presumably for feeding, because bays and estuaries are preferred feeding habitat rich in benthic invertebrates (e.g., amphipods, bivalves, and insect larvae). In part because of their bottom-oriented feeding habits, Sturgeon are at risk of harmful accumulations of toxic pollutants in their tissues, especially pesticides such as pyrethroids and heavy metals such as selenium and mercury (Israel and Klimley 2008; Stewart et al. 2004).

Juvenile Green Sturgeon and White Sturgeon are periodically (although rarely) collected from the lower San Joaquin River at south Delta water diversion facilities and other sites (NMFS 2009a; Aasen 2011, 2012). Green Sturgeon are salvaged from the south Delta Project diversion facilities and are generally juveniles greater than 10 months but less than 3 years old (Reclamation 2008a). NMFS (2005b) suggested that the high percentage of San Joaquin River flows contributing to the TFCF could mean that some entrained Green Sturgeon originated in the San Joaquin River basin. Jackson (2013) reported spawning by White Sturgeon in the San Joaquin River, and anglers have reported catching a few Green Sturgeon in recent years in the San Joaquin River (CDFG 2012b).

After hatching, larvae and juveniles migrate downstream toward the Delta. Juveniles are believed to use the Delta for rearing for the first 1 to 3 years of their lives before moving out to the ocean and are likely to be found in the main channels of the Delta and the larger interconnecting sloughs and waterways, especially within the central Delta and Suisun Bay/Marsh. Project operations at the DCC have the potential to reroute Green Sturgeon as they out-migrate through the lower Sacramento River to the Delta (Israel and Klimley 2008; Vogel 2011). When the DCC is open, there is no passage delay for adults, but juveniles could be diverted from the Sacramento River into the interior Delta. This has been shown to reduce the survival of juvenile Chinook Salmon (Brandes and McLain 2001; Newman and Brandes 2010; Perry et al. 2012), but it is unknown whether it has similar effects on Green Sturgeon.

O.2.10.1.6 White Sturgeon

White Sturgeon are similar to Green Sturgeon in terms of their biology and life history. Like Green Sturgeon and other Sturgeon species, White Sturgeon are late-maturing and infrequent spawners, which makes them vulnerable to overexploitation and other sources of adult mortality. White Sturgeon are believed to be most abundant within the Bay-Delta region (Moyle 2002). Both nonspawning adults and juveniles can be found throughout the Delta year-round (Radtke 1966; Kohlhorst et al. 1991; Moyle 2002; DWR et al. 2013). When not undergoing spawning or ocean migrations, adults and subadults are usually most abundant in brackish portions of the Bay-Delta (Kohlhorst et al. 1991). The population status of White Sturgeon in the Delta is unclear, but it is not presently listed. Overall, information on trends in adults and juveniles suggests that numbers are declining (Moyle 2002; NMFS 2009a).

The Delta population of White Sturgeon spawns mainly in the Sacramento and Feather Rivers, with occasional spawning in the San Joaquin River (Moyle 2002; Jackson 2013). Spawning-stage adults generally move into the lower reaches of rivers during winter prior to spawning and migrate upstream in response to higher flows to spawn from February to early June (McCabe and Tracy 1994; Schaffter 1997).

After absorbing yolk sacs and initiating feeding, YOY White Sturgeon make an active downstream migration that disperses them widely to rearing habitat throughout the lower rivers and the Delta (McCabe and Tracy 1994). White Sturgeon larvae have been observed to be flushed farther downstream in the Delta and Suisun Bay in high outflow years, but are restricted to more interior locations in low outflow years (Stevens and Miller 1970).

Salinity tolerance increases with increasing age and size (McEnroe and Cech 1985), allowing White Sturgeon to access a broader range of habitat in the San Francisco Estuary (Israel et al. 2008). During dry years, White Sturgeon have been observed following brackish waters farther upstream, while the opposite occurs in wet years (Kohlhorst et al. 1991). Adult White Sturgeon tend to concentrate in deeper areas and tidal channels with soft bottoms, especially during low tides, and typically move into intertidal or shallow subtidal areas to feed during high tides (Moyle 2002). These shallow water habitats provide opportunities for feeding on benthic organisms, such as opossum shrimp, amphipods, and even invasive overbite clams, and small fishes (Israel et al. 2008; Kogut 2008). White Sturgeon also have been found in tidal habitats of medium-sized tributary streams to the San Francisco Estuary, such as Coyote Creek and Guadalupe River in the south bay and Napa and Petaluma Rivers and Sonoma Creek in the north bay (Leidy 2007).

Numerous factors likely affect the White Sturgeon population in the Delta, similar to those for Green Sturgeon. Survival during early life history stages may be adversely affected by insufficient flows, lack of rearing habitat, predation, warm water temperatures, decreased dissolved oxygen, chemical toxicants in the water, and entrainment at diversions (Cech et al. 1984; Israel et al. 2008). Historical habitats, including shallow intertidal feeding habitats, have been lost in the Delta because of channelization. Over-exploitation by recreational fishing and poaching also likely has been an important factor adversely affecting numbers of adult Sturgeon (Moyle 2002), although new regulations were implemented in 2007 by CDFW to reduce harvest. Like Green Sturgeon, there are substantial passage problems for White Sturgeon such as the Fremont Weir (Sommer et al. 2014).

O.2.10.1.7 Delta Smelt

Delta Smelt are endemic to the Delta and Suisun Marsh (Moyle et al. 1992; Bennett 2005). Declines in the Delta Smelt population led to their listing under the ESA as threatened in 1993 (USFWS 2008a). Delta Smelt are one of four pelagic fish species (including Longfin Smelt, Threadfin Shad, and juvenile Striped Bass) documented to be in decline based on fall midwater trawl abundance indices (Sommer et al. 2007a). The causes of the declines have been extensively studied and are thought to include a combination of factors, such as decreased habitat quantity and quality, increased mortality rates, and reduced food availability (Feyrer et al. 2007; Sommer et al. 2007a; Moyle and Bennett 2008; Baxter et al. 2010; Mac Nally et al. 2010; Maunder and Deriso 2011; Rose et al. 2013a, 2013b; Sommer and Mejia 2013). Two statistical analyses that used similar data but different statistical methods (Mac Nally et al. 2010; Thomson et al. 2010), examined the dynamics of the four fish species. Both analyses identified several covariates that were related to abundance of the fish, but they could not resolve the cause of the recent declines. The analysis of model results and data for 1995 to 2005 conducted by Rose et al. (2013a) indicated that it has been difficult to ascribe the Delta Smelt's decline to a single cause, either over the long term or as part of the 2002 decline.

The status of the Delta Smelt is uncertain, as indices of Delta Smelt abundance have continued to decline and the number of fish collected in sampling programs, such as the trawl surveys conducted by IEP, have dropped even lower in recent years. Figure O.2-6 presents the FMWT abundance indices for Delta Smelt from 1967 to 2018 (CDFW 2019). No Delta Smelt were collected in this survey in 2018; the 2018 Delta Smelt index was 0, making it the lowest in FMWT history (CDFW 2019). Results for Delta Smelt from other surveys (spring Kodiak trawl and summer townet survey) were also low in 2018, with the 20-mm survey index being unable to be calculated because of low catch (Tempel 2018).

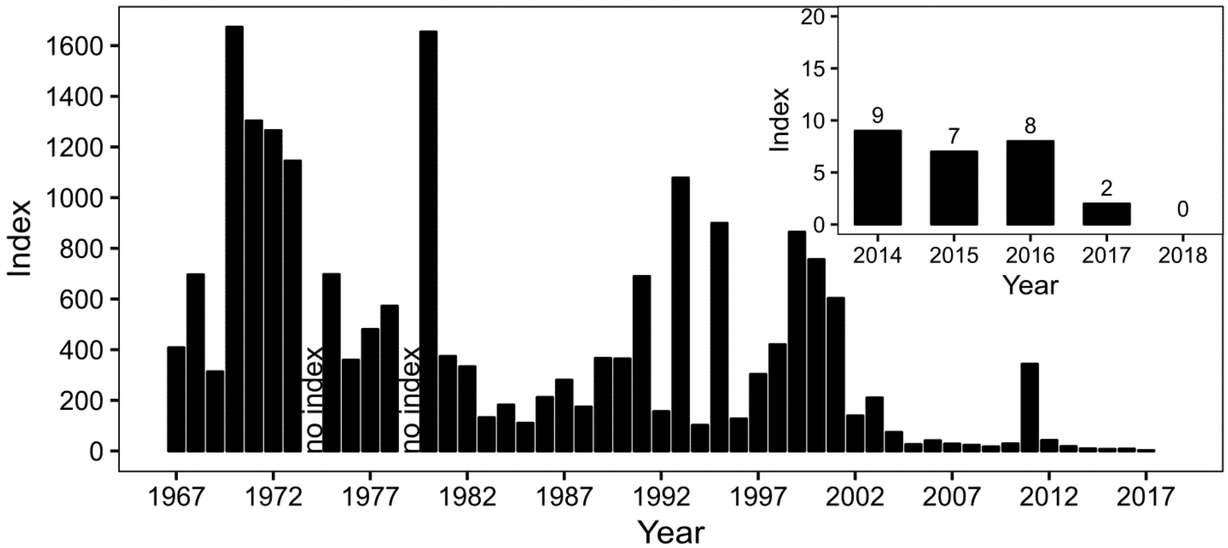


Figure O.2-6 Fall Midwater Trawl Abundance Indices for Delta Smelt from 1967 to 2018

Source: CDFW 2019.

Studies conducted to synthesize available information about Delta Smelt indicate that Delta Smelt have been documented throughout their geographic range during much of the year (Merz et al. 2011; Sommer and Mejia 2013; Brown et al. 2014). Studies indicate that in fall, prior to spawning, Delta Smelt are found in the Delta, Suisun and San Pablo Bays, the Sacramento River and San Joaquin River confluence, Cache Slough, and the lower Sacramento River (Murphy and Hamilton 2013). By spring, they move to freshwater areas of the Delta region, including the Sacramento River and San Joaquin River confluence, the upper Sacramento River, and Cache Slough (Brown et al. 2014; Murphy and Hamilton 2013). There is also a freshwater resident life history type (Bush 2017), occurring primarily in the Cache Slough region year-round (Sommer et al. 2011).

Sommer et al. (2011) described that during winter, adult Delta Smelt initiate upstream spawning migrations in association with “first flush” freshets. Others report this seasonal change as a multi-directional and more circumscribed dispersal movement to freshwater areas throughout the Delta region (Murphy and Hamilton 2013). After arriving in freshwater staging habitats, adult Delta Smelt hold until spawning commences during favorable water temperatures in the late winter-spring (Bennett 2005; Grimaldo et al. 2009; Sommer et al. 2011). Delta Smelt spawn over a wide area throughout much of the Delta, including some areas downstream and upstream as conditions allow. Although the specific substrates or habitats used for spawning by Delta Smelt are not known, spawning habitat preferences of closely related species (Bennett 2005) suggest that spawning may occur in shallow areas over sandy substrates. The nonpelagic habitats used by larval Delta Smelt before they move into the pelagic areas also are not known (Swanson et al. 1998; Sommer et al. 2011).

During and after larval rearing in fresh water, many young Delta Smelt move with river and tidal currents to remain in favorable rearing habitats, often moving increasingly into the low salinity zone to avoid seasonally warm and highly transparent waters that typify many areas in the central Delta (Nobriga et al. 2008). Bennett and Burau (2015) showed that during winter, Delta Smelt aggregate near frontal zones at the shoal-channel interface moving laterally into the shoals on ebb tides and back into the channel on flood tides. They suggest that this migration strategy can minimize the energy spent swimming against strong river and tidal currents, as well as predation risks by remaining in turbid water.

During summer and fall, many juvenile Delta Smelt continue to grow and rear in the low salinity zone until maturing the following winter (Bennett 2005). Some Delta Smelt also rear in upstream areas such as the Cache Slough complex and Sacramento Deep Water Ship Channel, depending on habitat conditions (Sommer and Mejia 2013).

During summer and fall, the distribution of juvenile Delta Smelt rearing is influenced by the position of the low salinity zone (as indexed by the position of X2), although their distribution can also be influenced by temperature and turbidity (Bennett 2005; Feyrer et al. 2007, 2010; Kimmerer et al. 2009; Sommer and Mejia 2013). The geographical position of the low salinity zone varies primarily as a function of freshwater outflow; thus, X2 typically lies farther east in summer and fall during low outflow conditions and drier water years and farther west during high outflow conditions (Jassby et al. 1995).

Higher outflow causes X2 and the low salinity zone to more frequently overlap with the Suisun Bay/Marsh region, which is broader and shallower and typically has greater turbidity than the mainstem Sacramento and San Joaquin Rivers. The overlap of the low salinity zone (or X2) with the Suisun Bay/Marsh results in a dramatic increase in the habitat index (Feyrer et al. 2010); however others (e.g., Manly et al. 2015) have questioned the use by Feyrer et al. (2010) of outflow and X2 location as an indicator of Delta Smelt habitat because other factors may be influencing survival.

In addition to salinity, turbidity is an important factor associated with habitat use; Delta Smelt show a strong preference for higher turbidity water (Feyrer et al. 2007, 2010; Sommer and Mejia 2013) and turbidity may be a key habitat feature and cue initiating the Delta Smelt spawning migration (Bennett and Burau 2015). Turbidity has decreased in recent decades within the Delta (Kimmerer 2004; Schoellhamer 2011), which has likely contributed to declines in environmental quality of Delta Smelt habitat (Feyrer et al. 2007, 2010). Higher turbidities are believed to allow Delta Smelt to hide from open-water predators, such as Striped Bass (Gregory and Levings 1998; Nobriga et al. 2005), and contribute to feeding success (Lindberg et al. 2000; IEP 2015).

Water temperature is another important environmental factor that affects Delta Smelt habitat and population dynamics (Sommer and Mejia 2013). A longer period of optimal water temperatures in cooler years increases the number of spawning events and cohorts produced (Bennett 2005). During rearing, summer water temperatures also have been shown to be an important predictor of Delta Smelt occurrence, based on multi-decadal analyses of summer tow net survey data (Nobriga et al. 2008).

The quality and availability of food also have important effects on the abundance and distribution of Delta Smelt (Sommer and Mejia 2013; Kimmerer 2008). Delta Smelt feed primarily on zooplankton, and Nobriga (2002) showed that Delta Smelt larvae with food in their guts typically co-occurred with higher calanoid copepod densities. Food quality and availability have varied substantially, largely because of the history of nonnative species introduction into the San Francisco Estuary (Baxter et al. 2008; Winder and Jassby 2011). The decline of zooplankton in the western Delta has been hypothesized to be related to several factors, including increased ammonium concentrations from wastewater effluent and agricultural runoff (Wilkerson et al. 2006; Dugdale et al. 2007; Miller et al. 2012; Glibert 2010; Glibert et al. 2011, 2014).

In 2011 and 2012, an unanticipated change in water management operations led to relatively large phytoplankton blooms in the western Delta, including in the Sacramento River near Rio Vista. Historically, rice fields along the Colusa Basin Drain are flooded in fall to decompose the rice stubble, and the water is released through the Knights Landing Outfall gates into the Sacramento River. In 2011 and 2012, construction at the outfall gates required the water to be diverted into the Yolo Bypass, resulting in higher than normal flows. These events temporarily resulted in a fall pulse flow in the Yolo

Bypass that increased the volume of flow by more than 300 to 900% (Frantzich 2014). Concurrently, a substantial increase in nutrients, phytoplankton, and zooplankton was observed in the Yolo Bypass and Cache Slough. In 2013, the fall pulse flow of rice drainage water did not occur in the Yolo Bypass, and nutrient concentrations did not increase. These nutrient inputs, when they occur, and corresponding increases in phytoplankton and zooplankton production, could contribute to improved foraging opportunities for Delta Smelt.

Results in prior years indicate that entrainment and salvage-related mortality of Delta Smelt associated with water pumping and CVP/SWP exports from the Delta occur primarily from December to July (Kimmerer 2008; Grimaldo et al. 2009; Baxter et al. 2010). Entrainment occurs when migrating and spawning adult Delta Smelt and their larvae overlap in time and space with reverse (southward, or upstream) flows in the Old and Middle River channels (Kimmerer 2008; Grimaldo et al. 2009; Baxter et al. 2010).

In January 2015, the IEP Management Analysis and Synthesis Team (MAST) published a report to provide an assessment and conceptual model of factors affecting Delta Smelt throughout its life cycle. One focus of the report was an evaluation of a notable increase in abundance of all Delta Smelt life stages in 2011, which indicated that the Delta Smelt population could potentially rebound when conditions are favorable for spawning, growth, and survival.

The IEP MAST updated conceptual model described the habitat conditions and ecosystem drivers affecting each Delta Smelt life stage, across seasons and how the seasonal effects contributed to the annual success of the species. The conclusions of the report highlighted some key points about Delta Smelt and their habitat, using 2011 as the example year in relation other a prior wet year (2006) and two drier years (2005 and 2010). In summary, the report concluded that Delta Smelt likely benefitted from the following favorable habitat conditions in 2011:

1. Adults and larvae benefitted from high winter 2010 and spring 2011 outflows, which reduced entrainment risk and possibly improved other habitat conditions, prolonged cool spring water temperatures, and possibly good food availability in late spring.
2. Juvenile Delta Smelt benefitted from cool water temperatures in late spring and early summer as well as from relatively good food availability and low levels of harmful Microcystis.
3. Subadults benefitted from good food availability and from favorable habitat conditions in the large low salinity zone, located more toward Suisun Bay in 2010.

O.2.10.1.8 Longfin Smelt

Longfin Smelt populations occur along the Pacific Coast of North America, and the San Francisco Estuary represents the southernmost population. Longfin Smelt generally occur in the Delta; Suisun, San Pablo, and San Francisco Bays; and the Gulf of the Farallones, just outside San Francisco Bay. Longfin Smelt are not a focus of any specific RPA actions. However, RPA actions that benefit Delta Smelt, salmonids, and Sturgeon, including increasing Delta outflow, have the potential to benefit other fish, including Longfin Smelt, given their similar habitat requirements and trophic feeding levels.

Longfin Smelt are anadromous and spawn in fresh or low salinity water in the Bay-Delta (Grimaldo et al. 2017), generally at 2 years of age (Moyle 2002). They migrate upstream to spawn during late fall through winter, with most spawning from November through April (CDFG 2009a). Previous studies suggested that spawning in the Sacramento River occurs from just downstream of the confluence of the Sacramento and San Joaquin Rivers upstream to about Rio Vista and that spawning on the San Joaquin River extends from the confluence upstream to about Medford Island (Moyle 2002); more recent studies suggest hatching and early rearing occurs in a much broader region and higher salinity (2–12 ppt) than previously recognized (Grimaldo et al. 2017). Spawning likely also occurs in Suisun Marsh and the Napa River (CDFG 2009a).

Longfin Smelt larvae are most abundant in the water column usually from January through April (Reclamation 2008a). As previously noted, larval Longfin Smelt rear in low salinity to brackish water (2–12 ppt; Grimaldo et al. 2017). Larger Longfin Smelt feed primarily on opossum shrimps and other invertebrates (Feyrer et al. 2003). Copepods and other crustaceans also can be important food items, especially for smaller fish (Reclamation 2008a).

Longfin Smelt in the San Francisco Estuary are broadly distributed in both time and space, and interannual distribution patterns are relatively consistent (Rosenfield and Baxter 2007). Seasonal patterns in abundance and occurrence in the nearshore ocean suggest that the population is at least partially anadromous (Rosenfield and Baxter 2007; Garwood 2017), and the detection of Longfin Smelt within the estuary throughout the year suggests that, similar to Striped Bass, anadromy is one of several life history strategies or contingents in this population.

The relative population size of Longfin Smelt in the San Francisco Estuary is measured by indices of abundance generated from different sampling programs. The abundance of age 0 and older fish is best indexed by the Fall Midwater Trawl and Bay Study, while the abundance of larvae and young juveniles is best indexed by the 20-mm survey. The relationship between these indices and actual population sizes is unknown. Although the Fall Midwater Trawl data suggest a sharp decline in Longfin Smelt abundance during the last decade, some of that decline might be attributable to a downstream movement in the longfin distribution into regions better covered by the Bay Study fish survey. The Bay Study uses two types of trawls, an otter trawl and a midwater trawl. The Longfin Smelt abundance index created from the Fall Midwater Trawl is consistent with the trend in the Bay Study midwater trawl but not the Bay Study otter trawl. In addition, there have been an increasing proportion of false zeros in the survey data where the Bay Study midwater trawl failed to detect any Longfin Smelt when they were detected in the otter trawl.

The abundance of Longfin Smelt in the estuary has fluctuated over time but has exhibited statistically significant step-declines around 1989 to 1991 and in 2004 (Thomson et al. 2010). A synthesis of prior studies conducted by USFWS in its 12-Month Finding on a Petition to List the San Francisco Bay-Delta Population of the Longfin Smelt as Endangered or Threatened (USFWS 2012) reported that increased Delta outflow in winter and spring is the largest factor possibly affecting Longfin Smelt abundance. The trend in Longfin Smelt abundance from 1967 through 2013 is presented on Figure O.2-7.

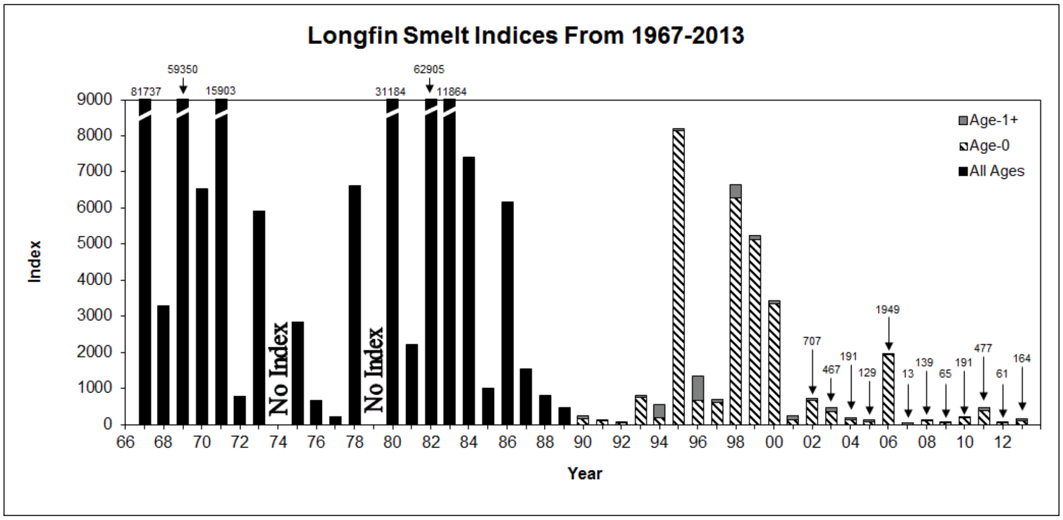


Figure O.2-7 Fall Midwater Trawl Abundance Indices for Longfin Smelt from 1967 to 2013

Source: CDFW 2014b.

Habitat for Longfin Smelt is open water, largely away from shorelines and vegetated inshore areas except perhaps during spawning. This includes all of the large embayments in the estuary and the deeper areas of many of the larger channels in the western Delta; habitat suitability in these areas for Longfin Smelt can be strongly influenced by variation in freshwater flow (Jassby et al. 1995; Bennett and Moyle 1996; Kimmerer 2004; Kimmerer et al. 2009).

Water exports and inadvertent entrainment at the SWP and CVP export facilities are anthropogenic sources of mortality for Longfin Smelt. The export facilities are known to entrain most species of fish in the Delta (Brown et al. 1996). Longfin Smelt entrainment mainly occurs from December to May, with peak adult entrainment from December to February (Grimaldo et al. 2009). In water year 2011, Aasen (2012) reported four adult Longfin Smelt were salvaged at the project export facilities, compared with much higher numbers in the early 2000s and late 1980s. The entrainment of Longfin Smelt in recent years has been reduced likely because of changes in export operations and a decline in abundance.

O.2.10.1.9 Sacramento Splittail

Sacramento Splittail are found primarily in marshes, turbid sloughs, and slow-moving river reaches throughout the Delta subregion (Sommer et al. 1997, 2008). Sacramento Splittail are most abundant in moderately shallow, brackish tidal sloughs and adjacent open-water areas, but they also can be found in freshwater areas with tidal or riverine flow (Moyle et al. 2004).

Adult Sacramento Splittail typically migrate upstream from brackish areas in January and February and spawn in fresh water, particularly on inundated floodplains when they are available, in March and April (Sommer et al. 1997; Moyle et al. 2004; Sommer et al. 2008). A substantial amount of Splittail spawning occurs in the Yolo and Sutter Bypasses and the Cosumnes River area of the Delta (Moyle et al. 2004). Spawning also can occur in the San Joaquin River during high-flow events (Sommer et al. 1997, 2008). However, not all adults migrate significant distances to spawn, as evidenced by spawning in the Napa and Petaluma Rivers (Feyrer et al. 2005).

Although juvenile Sacramento Splittail are known to rear in upstream areas for a year or more (Baxter 1999), most move to the Delta after only a few weeks or months of rearing in floodplain habitats along the rivers (Feyrer et al. 2006). Juveniles move downstream into the Delta from April to August (Meng and Moyle 1995; Feyrer et al. 2005). Sacramento Splittail recruitment is largely limited by extent and period of inundation of floodplain spawning habitats, with abundance observed to spike following wet years and dip after dry years (Moyle et al. 2004). However, the 5- to 7-year life span buffers the adult population abundance (Sommer et al. 1997; Moyle et al. 2004). Other factors that may adversely affect the Splittail population in the Delta include entrainment, predation, changed estuarine hydraulics, nonnative species (Moyle et al. 2004), pollutants (Greenfield et al. 2008), and limited food.

O.2.10.1.10 American Shad

American Shad is a recreationally important anadromous species introduced into the Sacramento–San Joaquin River basin in the 1870s (Moyle 2002). American Shad spend most of their adult life at sea and may make extensive migrations along the coast. American Shad become sexually mature while in the ocean and migrate through the Delta to spawning areas in the Sacramento, Feather, American, and Yuba Rivers. Some spawning also takes place in the lower San Joaquin, Mokelumne, and Stanislaus Rivers (USFWS 1995). The spawning migration may begin as early as February, but most adults migrate into the Delta in March and early April (Skinner 1962). Migrating adults generally take 2 to 3 months to pass through the Sacramento–San Joaquin estuary (Painter et al. 1979).

Fertilized eggs are slightly negatively buoyant, are not adhesive, and drift in the current. Newly hatched larvae are found downstream of spawning areas and can be rapidly transported downstream by river currents because of their small size. Juvenile Shad rear in the Sacramento River below Knights Landing, the Feather River below Yuba City, and the Delta; rearing also takes place in the Mokelumne River near the DCC to the San Joaquin River. No rearing occurs in the American and Yuba Rivers (Painter et al. 1979). Some juvenile Shad may rear in the Delta for up to a year before outmigrating to the ocean (USFWS 1995). Out-migration from the Delta begins in late June and continues through November (Painter et al. 1979).

Juvenile American Shad are frequently encountered in the Delta during the FMWT Survey and in fish salvage monitoring at the south Delta SWP and CVP fish facilities (DWR et al. 2013). American Shad use of the Delta has been observed to vary with salinity (e.g., X2 position) and outflows (Kimmerer 2002).

American Shad are entrained at the TFCF (Bowen et al. 1998) and in the Clifton Court Forebay, mostly during May through December when young American Shad migrate downstream. The American Shad population in the Sacramento–San Joaquin River basin has declined since the late 1970s, most likely because of increased diversion of water from rivers and the Delta, combined with changing ocean conditions, and possibly pesticides (Moyle 2002). Salvage of American Shad at project export facilities in water year 2011 represented nearly 659,000 fish (Aasen 2012), with similar but slightly lower salvage in 2010 (545,125 fish) (Aasen 2011).

O.2.10.1.11 Striped Bass

Striped Bass is a recreationally important anadromous species introduced into the Sacramento–San Joaquin River basin between 1879 and 1882 (Moyle 2002). Despite their nonnative status and piscivorous feeding habits, Striped Bass are considered important because they are a major game fish in the Delta. Striped Bass use the Delta as a migratory route and for rearing and seasonal foraging. Striped Bass spend the majority of their lives in salt water, returning to fresh water to spawn. When not migrating for spawning, adult Striped Bass in the Bay-Delta are found in San Pablo Bay, San Francisco Bay, and the Pacific Ocean (Moyle 2002). Adult Striped Bass spend about 6 to 9 months of the year in San Francisco and San Pablo Bays (Hassler 1988). Striped Bass also use deeper areas of many of the larger channels in the Delta, in addition to large embayments such as Suisun Bay.

Spawning occurs in spring, primarily in the Sacramento River between Sacramento and Colusa and in the San Joaquin River between Antioch and Venice Island (Farley 1966). Eggs are free-floating and negatively buoyant and hatch as they drift downstream, with larvae occurring in shallow and open waters of the lower reaches of the Sacramento and San Joaquin Rivers, the Delta, Suisun Bay, Montezuma Slough, and Carquinez Strait. According to Hassler (1988), the distribution of larvae in the estuary depends on river flow. In low-flow years, all Striped Bass eggs and larvae are found in the Delta, while in high-flow years, the majority of eggs and larvae are transported downstream into Suisun Bay.

YOY Striped Bass distribute themselves in accordance with the estuarine salinity gradient (Kimmerer 2002; Feyrer et al. 2007), indicating that salinity is a major factor affecting their habitat use and geographic distributions. Kimmerer (2002) found that distributions of fish species, including Striped Bass, substantially overlapped with the low salinity zone. Older Striped Bass are increasingly flexible about their distribution relative to salinity (Moyle 2002).

The entrainment of Striped Bass has been observed at the project export facilities, including Clifton Court Forebay (Stevens et al. 1985; Bowen et al. 1998; Aasen 2012). In water year 2011, salvage of Striped Bass at export facilities (approximately 550,000 fish) continued a generally low trend observed since the mid-1990s. Prior to 1995, annual Striped Bass salvage was generally above 1 million fish (Aasen 2012). DWR et al. (2013) reported that Striped Bass longer than 24 mm were effectively screened at TFCF and bypassed the pumps. However, planktonic eggs, larvae, and juveniles smaller than 24 mm in length received no protection from entrainment.

Striped Bass, primarily YOY, are one of the pelagic fish of the upper estuary that have shown substantial variability in their populations, with evidence of long-term declines (Kimmerer et al. 2000; Sommer et al. 2007a). As discussed earlier for Delta Smelt, a substantial portion of the abundance patterns has been associated with variation of outflow in the estuary (Jassby et al. 1995; Kimmerer et al. 2001; Loboschefsky et al. 2012), although this is disputed by some stakeholders (Bourez 2011). However, surveys showed that population levels for YOY Striped Bass began to decline sharply around 1987 and 2002 (Thomson et al. 2010), despite relatively moderate hydrology, which typically supports at least modest fish production (Sommer et al. 2007a). Moyle (2002) cites causes of decline in Striped Bass to include climatic factors, entrainment at project export facilities in the south Delta, other diversions, pollutants, reduced estuarine productivity, invasions by alien species, and human exploitation. Kimmerer et al. (2000, 2001) attribute the decline in juvenile YOY Striped Bass to declining carrying capacity, likely related to food limitation. Loboschefsky et al. (2012) showed that there had been no long-term decline for age 1 and older Striped Bass as of 2004.

O.2.10.1.12 Pacific Lamprey

The Pacific Lamprey is a widely distributed species that uses the Delta for upstream migration as adults, for downstream migration as juveniles, and for rearing as ammocoetes (Hanni et al. 2006; Moyle et al. 2009). Pacific Lampreys are present in the north, central, and south Delta, and ammocoetes are present year-round in all of the regions (DWR et al. 2013). Limited information on status of Pacific Lamprey in the Delta exists, but the number of Lampreys inhabiting the Delta is likely greatly suppressed compared with historical levels, as suggested by the loss of access to historical habitat and apparent population declines throughout California and the Sacramento–San Joaquin River basin (Moyle et al. 2009).

Limited data indicate most adult Pacific Lamprey migrate though the Delta enroute to upstream holding and spawning grounds in the early spring through early summer (Hanni et al. 2006). As documented in other large river systems, it is likely that some adult migration through the Delta occurs from late fall and winter through summer and possibly over an even broader period (Robinson and Bayer 2005; Hanni et al. 2006; Moyle et al. 2009; Clemens et al. 2012; Lampman 2011). Data from the FMWT Survey in the lower Sacramento and San Joaquin Rivers and Suisun Bay suggest that peak out-migration of Pacific Lamprey through the Delta coincides with high-flow events from fall through spring (Hanni et al. 2006). Some out-migration likely occurs year-round, as observed at sites farther upstream (Hanni et al. 2006) and in other river systems (Moyle 2002). Some Pacific Lamprey ammocoetes likely spend part of their extended (5 to 7 years) freshwater residence rearing in the Delta, particularly in the upstream, freshwater portions (DWR et al. 2013).

O.2.10.2 *Aquatic Habitat*

Flow management in the Delta has created stress on aquatic resources by (1) changing aspects of the historical flow regime (timing, magnitude, duration) that supported life history traits of native species; (2) limiting access to or quality of habitat; (3) contributing to conditions better suited to invasive, nonnative species (reduced spring flows, increased summer inflows and exports, and low and less-variable interior Delta salinity [Moyle and Bennett 2008]); and (4) causing reverse flows in channels leading to project export facilities that can entrain fish (Mount et al. 2012). Native species of the Delta are adapted to and depend on variable flow conditions at multiple scales as influenced by the region's dramatic seasonal and interannual climatic variation. In particular, most native fishes evolved reproductive or out-migration timing associated with historical peak flows during spring (Moyle 2002).

Water temperatures in the Delta follow a seasonal pattern of winter cold-water conditions and summer warm-water conditions, largely because of the region's Mediterranean climate, with alternating cool-wet and hot-dry seasons. Currently in the Delta, the most significant changes in water temperatures have been in the form of increased summer water temperatures over large areas of the Delta because of high summer ambient air temperatures, the increased temperature of river inflows, and to a lesser extent, reduced quantities of freshwater inflow and modified tidal and groundwater hydraulics (Kimmerer 2004; Mount et al. 2012; NRC 2012; Wagner et al. 2011). Water temperatures in summer now approach or exceed the upper thermal tolerances (e.g., 20 to 25° Centigrade [C]) for cold-water fish species such as salmonids and Delta-dependent species such as Delta Smelt. This is especially true in parts of the south Delta and San Joaquin River, potentially restricting the distribution of these species and precluding previously important rearing areas (NRC 2012).

Landscape-scale changes resulting from flood management infrastructure, along with flow modification, have eliminated most of the historical hydrologic connectivity of floodplains and aquatic ecosystems in the Delta and its tributaries, thereby degrading and diminishing Delta habitat for native plant and animal communities (Mount et al. 2012). The large reduction of hydrologic variability and landscape complexity, coupled with degradation of water quality, has supported invasive aquatic species that have further degraded conditions for native species. Due to the combination of these factors, the Delta appears to have undergone an ecological regime shift unfavorable to many native species (Moyle and Bennett 2008; Baxter et al. 2010). The major species influenced by current Delta hydrology include Delta Smelt, Longfin Smelt, Sacramento Splittail, White Sturgeon, juvenile Chinook Salmon, and Striped Bass (Jassby et al. 1995; Kimmerer 2002; Rosenfield and Baxter 2007; Kimmerer et al. 2009; Fish 2010; Perry et al. 2012; Thomson et al. 2010; Feyrer et al. 2010; Loboschefsky et al. 2012; Mount et al. 2012).

Salinity is a critical factor influencing plant and animal communities in the Delta. Although estuarine fish species are generally tolerant of a range of salinity, this varies by species and lifestage. Some species can be highly sensitive to excessively low or high salinity during physiologically vulnerable periods, such as reproductive and early life history stages. Although the Delta is tidally influenced, most of the Delta is fresh water year-round, due to inflows from rivers. The south Delta can have low salinity because of agricultural return water. The tidally influenced low salinity zone can move upstream into the central Delta.

An important measure of the spatial geography of salinity in the western Delta is X2. The X2 has also been correlated with the amount of suitable habitat for Delta Smelt in fall (Feyrer et al. 2007, 2010; USFWS 2008a). It also helps define the extent of habitat available for oligohaline pelagic organisms and their prey. An analysis of historical monitoring data by Feyrer et al. (2007) revealed that the abiotic habitat of Delta Smelt can be defined as a specific envelope of salinity and turbidity that changes over the course of the species' life cycle. Project operations and other potential factors (e.g., lower outflows) have tended to shift the X2 position in fall farther upstream out of the wide expanse of Suisun Bay into the much narrower channels near the confluence of the Sacramento and San Joaquin Rivers (near Collinsville), reducing the spatial extent of low salinity habitat important for relevant species such as Delta Smelt (USFWS 2008a, 2011a; Kimmerer et al. 2009; Baxter et al. 2010). However, there is emerging information suggesting that a comparison of the Delta outflow during pre-project and post-project time periods do not support the conclusion that project operations have significantly moved X2 more easterly in September and October compared to pre-project conditions and project operations have only potentially affected X2 location in November (Hutton et al. 2015).

O.2.10.2.1 Nutrients and Food Web Support

Nutrients are essential components of terrestrial and aquatic environments because they provide a resource base for primary producers. Typically, in freshwater aquatic environments, phosphorous is the primary limiting macronutrient, whereas in marine aquatic environments, nitrogen tends to be limiting. A balanced range of abundant nutrients provides optimal conditions for maximum primary production, a robust food web, and productive fish populations. However, changes in nutrient loadings and forms, excessive amounts of nutrients, and altered nutrient ratios can lead to eutrophication and a suite of problems in aquatic ecosystems, such as low dissolved oxygen concentrations, un-ionized ammonia, excessive growth of toxic forms of cyanobacteria, and changes in components of the food web. Nutrient concentrations in the Delta have been well studied (Jassby et al. 2002; Kimmerer 2004; Van Nieuwenhuyse 2007; Glibert 2010; Glibert et al. 2011, 2014).

Estuaries are commonly characterized as highly productive nursery areas for numerous aquatic organisms. Nixon (1988) noted that there is a broad continuum of primary productivity levels in different estuaries, which in turn affects fish production and abundance. Compared to other estuaries, pelagic primary productivity in the upper San Francisco Estuary is relatively poor, and a relatively low fish yield is expected (Wilkerson et al. 2006). In the Delta and Suisun Marsh, this appears to result from turbidity, clam grazing (Jassby et al. 2002), and nitrogen and phosphorus dynamics (Wilkerson et al. 2006; Van Nieuwenhuyse 2007; Glibert 2010; Glibert et al. 2014).

There has been a significant long-term decline in phytoplankton biomass (chlorophyll a) and primary productivity to low levels in the Suisun Bay region and the Delta (Jassby et al. 2002). Shifts in nutrient concentrations such as high levels of ammonium and nitrogen to phosphorus ratio may contribute to the phytoplankton reduction and to changes in algal species composition in the San Francisco Estuary (Wilkerson et al. 2006; Dugdale et al. 2007; Lehman et al. 2005, 2008b, 2010; Glibert 2010; Glibert et al. 2014). Low and declining primary productivity in the estuary may be contributing to the long-term pattern of relatively low and declining biomass of pelagic fishes (Jassby et al. 2002).

The introductions of two clams from Asia have led to major alterations in the food web in the Delta. *Potamocorbula* is most abundant in the brackish and saline water of Suisun Bay and the western Delta, and *Corbicula* is most abundant in the fresh water of the central Delta. These filter feeders significantly reduce the phytoplankton and zooplankton concentrations in the water column, reducing food availability for native fishes, such as Delta Smelt and young Chinook Salmon (Feyrer et al. 2007; Kimmerer 2002).

Additionally, introduction of the clams led to the decline of native copepods of higher food quality and the establishment of poorer quality nonnative copepods. More recently, the cyclopoid copepod, *Limnoithona*, has rapidly become the most abundant copepod in the Delta since its introduction in 1993 (Hennessy and Enderlein 2013). This species is hypothesized to be a low-quality food source and intraguild predator of native and nonnative calanoid copepods (CRA 2005). The clam *Potamocorbula* also has been implicated in the reduction of the native opossum shrimp, a preferred food of Delta native fishes such as Sacramento Splittail and Longfin Smelt (Feyrer et al. 2003). Reductions in food availability and food quality have led to lower fish foraging efficiency and reduced growth rates (Moyle 2002).

Studies on food quality have been relatively limited in the San Francisco Estuary, with even less information on long-term trends. Nonetheless, several studies have documented or suggested the food limitations for aquatic species in the estuary, including zooplankton (Mueller-Solger et al. 2002; Kimmerer et al. 2005), Delta Smelt (Bennett 2005; Bennett et al. 2008), Chinook Salmon (Sommer et al. 2001), Sacramento Splittail (Greenfield et al. 2008), Striped Bass (Loboschefsky et al. 2012), and Largemouth Bass (Nobriga 2009).

O.2.10.2.2 Turbidity

Turbidity is an important water quality component in the Delta that affects physical habitat through sedimentation and food web dynamics by means of attenuation of light in the water column. Light attenuation, in turn, affects the extent of the photic zone where primary production can occur and the ability of predators to locate prey and for prey to escape predation.

Turbidity has been declining in the Delta, as indicated by sediment data collected by the U.S. Geological Survey since the 1950s (Wright and Schoellhamer 2004), with important implications for food web dynamics and predation. Higher water clarity is at least partially caused by increased water filtration and plankton grazing by highly abundant overbite clams (*Potamocorbula amurensis*) and other benthic organisms (Kimmerer 2004; Greene et al. 2011). High nutrient loads, coupled with reduced sediment loads and higher water clarity, could contribute to plankton and algal blooms and overall increased eutrophic conditions in some areas (Kimmerer 2004).

The first high-flow events of winter create turbid conditions in the Delta, which can be drawn into the south Delta during reverse flow conditions in the Old and Middle Rivers. Delta Smelt may follow turbid waters into the southern Delta, increasing their proximity to project export facilities and, therefore, their entrainment risk (USFWS 2008a).

O.2.10.2.3 Contaminants

Contaminants can change ecosystem functions and productivity through numerous pathways. Trends in contaminant loadings and their ecosystem effects are not well understood. Efforts are underway to evaluate direct and indirect toxic effects on the POD fishes of manmade contaminants and natural toxins associated with blooms of *Microcystis aeruginosa*, a cyanobacterium or blue-green alga that releases a potent toxin known as microcystin. Toxic microcystins cause food web impacts at multiple trophic levels, and histopathological studies of fish liver tissue suggest that fish exposed to elevated concentrations of microcystins have developed liver damage and tumors (Lehman et al. 2005, 2008b, 2010).

There are longstanding concerns related to mercury and selenium in the Sacramento and San Joaquin watersheds, the Delta, and San Francisco Bay (see Chapter 6, Surface Water Quality, for additional detail on these constituents). Additional study is needed to avoid increases in mercury exposure resulting from tidal wetlands restoration; methylmercury is produced at a relatively high rate in wetlands and newly flooded aquatic habitats (Davis et al. 2003). Methylmercury increases in concentration at each level in the food chain and can cause concern for people and birds that eat piscivorous fish (Bass) and Sturgeon, as described in Chapter 6, Surface Water Quality. It has not been shown to be a direct problem for fish in the Delta, but studies of other fish summarized by Alpers et al. (2008) indicate that mercury in fish has been linked to hormonal and reproductive effects, liver necrosis, and altered behavior in fish. With regard to selenium, benthic foragers like diving ducks, Sturgeon, and Sacramento Splittail have the greatest risk of selenium toxicity; the invasion of the nonnative bivalves (e.g., *P. amurensis*) has resulted in increased bioavailability of selenium to benthivores in San Francisco Bay (Linville et al. 2002).

Baxter et al. (2008) prepared a 2007 synthesis of results as part of a POD Progress Report, including a summary of prior studies of contaminants in the Delta. The summary included studies that suggested that phytoplankton growth rates may be inhibited by localized high concentrations of herbicides (Edmunds et al. 1999). Toxicity to invertebrates has been noted in water and sediments from the Delta and associated watersheds (Kuivila and Foe 1995; Weston et al. 2004). The 2004 Weston study of sediment toxicity recommended additional study of the effects of the pyrethroid insecticides on benthic organisms. Undiluted drainwater from agricultural drains in the San Joaquin River watershed can be acutely toxic (quickly lethal) to fish (Chinook Salmon and Striped Bass) and have chronic effects on growth, likely because of high concentrations of major ions (e.g., sodium and sulfates) and trace elements (e.g., chromium, mercury, and selenium) (Saiki et al. 1992).

O.2.10.2.4 Fish Passage and Entrainment

The Delta presents a challenge for anadromous and resident fish during upstream and downstream migration, with its complex network of channels, low eastern and southern tributary inflows, and reverse currents created by pumping for water exports. These complex conditions can lead to straying, extended exposure to predators, and entrainment during out-migration. Tidal elevations, salinity, turbidity, in-flow, meteorological conditions, season, habitat conditions, and project exports all have the potential to influence fish movement, currents, and ultimately the level of entrainment and fish passage success and survival, which is the subject of extensive research and adaptive management efforts (IRP 2010, 2011). Michel et al. (Michel 2010; Michel et al. 2015) used acoustic telemetry to examine survival of Late Fall-Run Chinook Salmon smolts outmigrating from the Sacramento River through the Delta and San Francisco Estuary. Survival was lowest in the freshwater portion (Delta) and the brackish portion of the estuary relative to survival in the riverine portion of the migration route.

North Delta Fish Passage and Entrainment

In the north Delta, migrating fish have multiple potential pathways as they move upstream into the Sacramento or Mokelumne river systems. Marston et al. (2012) studied stray rates for in-migrating San Joaquin River basin adult Salmon that stray into the Sacramento River basin. Results indicated that it was unclear whether reduced San Joaquin River pulse flows or elevated exports caused increased stray rates. The DCC, when open, can divert fish as they out-migrate along this route. The opening of the DCC when Salmon are returning to spawn to the Mokelumne and Cosumnes Rivers is believed to lead to increased straying of these fish into the American and Sacramento Rivers because of confusion over olfactory cues.

Experimental DCC closures have been scheduled during the Fall-Run Chinook Salmon migration season for selected days, coupled with pulsed flow releases from reservoirs on the Mokelumne River, in an attempt to reduce straying rates of returning adults. These closures have corresponded with reduced recoveries of Mokelumne River hatchery fish in the American River system and increased returns to the Mokelumne River hatchery (EBMUD 2012).

Outmigrating juvenile fish moving down the mainstem Sacramento River also can enter the DCC when the gates are open and travel through the Delta via the Mokelumne and San Joaquin River channels. In the case of juvenile salmonids, this shifted route from the north Delta to the central Delta increases their mortality rate (Kjelson and Brandes 1989; Brandes and McLain 2001; Newman and Brandes 2010; Perry et al. 2010, 2012). Steel et al. (2012) found that the best predictor of which route was selected was the ratio of mean water velocity between the two routes. Salmon migration studies show losses of approximately 65% for groups of outmigrating fish that are diverted from the mainstem Sacramento River into the waterways of the central and southern Delta (Brandes and McLain 2001; Vogel 2004, 2008; Perry and Skalski 2008). Perry and Skalski (2008) found that, by closing the DCC gates, total through-Delta survival of marked fish to Chipps Island increased by nearly 50% for fish moving downstream in the Sacramento River system. Closing the DCC gates appears to redirect the migratory path of outmigrating fish into Sutter and Steamboat sloughs and away from Georgiana Slough, resulting in higher survival rates. Species that may be affected include juvenile Green Sturgeon, Steelhead, and Winter-Run and Spring-Run Chinook Salmon (NMFS 2009a).

However, analysis by Perry et al. (2015) suggests that the mechanisms governing route selection are more complex. Their analysis revealed the strong influence of tidal forcing on the probability of fish entrainment into the interior Delta. The probability of entrainment into both Georgiana Slough and the Delta Cross Channel was highest during reverse-flow flood tides, and the probability of fish remaining in the Sacramento River was near zero during flow reversals (Perry et al. 2015). The magnitude and duration of reverse flows at this river junction decrease as inflow of the Sacramento River increases. Consequently, reduced Sacramento River inflow increases the frequency of reverse flows at this junction, thereby increasing the proportion of fish that are entrained into the interior Delta, where mortality is high (Perry 2010).

Fish passage in the north Delta also can be affected by water quality. Water quality in the mainstem Sacramento River and its distributary sloughs can be poor at times during summer, creating conditions that may stress migrating fish or even impede migration. These conditions include dissolved oxygen, water temperatures, and, for some species, salinity (e.g., Delta Smelt). For adult Chinook Salmon, dissolved oxygen concentration less than 3 to 5 mg/L can impede migration (Hallock et al. 1970), as can mean daily water temperatures of 70°F to 73°F depending on whether water temperatures are rising or falling (Strange 2010). Dissolved oxygen levels are generally >5 mg/L throughout the Delta, but water temperatures can exceed these thresholds during summer and fall.

The SWP Barker Slough Pumping Plant, located on a tributary to Cache Slough, may cause larval fish entrainment. The intake is equipped with a positive barrier fish screen to prevent fish at least 25 mm in size from being entrained. CDFW has monitored entrainment of larval Delta Smelt less than 20 mm at Barker Slough since 1995. When the presence of Delta Smelt larvae is indicated, pumping rates from Barker Slough are reduced to a 5-day running average rate of 65 cfs, not to exceed a 75-cfs daily average for any day, for a minimum of 5 days and until monitoring shows no Delta Smelt are present.

Central and South Delta Fish Passage and Entrainment

Diversion facilities in the south Delta include the CVP and SWP export facilities; local agency intakes, including Contra Costa Water District intakes; and agricultural intakes. Contra Costa Water District intakes, including the CVP Contra Costa Canal Rock Slough Intake, have fish screens; however, most of the remaining intakes do not include fish screens. Water flow patterns in the south Delta are influenced by the water diversion actions and operations of the south Delta seasonal temporary barriers and tides and river inflows to the Delta (Kimmerer and Nobriga 2008). Delta diversions can create reverse flows, drawing fish toward project facilities if they are within the footprint of altered hydrology (Arthur et al. 1996; Kimmerer 2008; Grimaldo et al. 2009). While swimming through southern Delta channels, fish can be subjected to stress from poor water quality (seasonally high temperatures, low dissolved oxygen, high water transparency, and *Microcystis* blooms) and slow water velocities in lake-like habitats. Any of these factors can cause elevated mortality rates by weakening or disorienting the fish and increasing their vulnerability to predators (Vogel 2011).

Cunningham et al. (2015) found a negative influence of the export/inflow ratio on the survival of Fall-Run Chinook Salmon populations and a negative influence of increased total Delta exports on the survival of Spring-Run Chinook populations. An increase in total exports of 1 standard deviation from the 1967 to 2010 average was predicted to result in a 68.1% reduction in the survival of Deer, Mill, and Butte Creek Spring-Run Chinook Salmon. Similarly, an increase in the ratio of Delta water exports to Delta inflow of 1 standard deviation was expected to reduce survival of the four Fall-Run populations by 57.8% (Cunningham et al. 2015). Although a mechanistic explanation for the reduction in survival remains elusive, "*direct entrainment mortality seems an unlikely mechanism given the success of reclamation and transport procedures, even given increased predation potential at the release site. Changes to water routing may provide a more reasonable explanation for the estimated survival influence of Delta water exports*" (Cunningham et al. 2015). Although not directly comparable, this contrasts with the results of Zeug and Cavallo (2012), who found there was little evidence that large-scale water exports or inflows influenced CWT recovery rates in the ocean from 1993 to 2003.

Delaney et al. (2014) reported on a mark-recapture experiment examining the survival and movement patterns of acoustically tagged juvenile Steelhead emigrating through the central and southern Delta. Their results indicated that most tagged Steelhead remained in the mainstem San Joaquin River (77.6%); however, approximately one quarter (22.4%) of them entered Turner Cut. Route-specific survival probability for tagged Steelhead using the Turner Cut route was 27.0%. The survival probability for tagged Steelhead using the Mainstem route was 56.7% (Delaney et al. 2014). Travel times for tagged Steelhead also differed between these two routes, with Steelhead using the mainstem route reaching Chipps Island significantly sooner than those that used the Turner Cut route. Travel time was not significantly affected by the limited OMR flow treatments examined in their study. While not significant, there was some evidence that fish movement toward each export facility could be influenced by relative flow entering the export facility (Delaney et al. 2014).

Water from the San Joaquin River mainly moves downstream through the Head of Old River and through the channels of Old and Middle Rivers and Grant Line and Fabian-Bell canals toward the south Delta intake facilities. Conversely, when water to the north of the diversion points for the two facilities moves southward (upstream), the net flow is negative (toward) the pumps. When the temporary barriers are installed from April through November, internal reverse circulation is created within the channels isolated by the barriers from other portions of the south Delta. These conditions are most pronounced during late spring through fall when San Joaquin River inflows are low and water diversion rates are typically high. Drier hydrologic years also reduce the frequency of net downstream flows in the south Delta and mainstem San Joaquin River.

A portion of fish that enter the CVP Jones Pumping Plant approach channel and the SWP Clifton Court Forebay are salvaged at screening and fish salvage facilities, transported downstream by trucks, and released. NMFS (2009a) estimates that the direct loss of fish from the screening and salvage process is in the range of 65 to 83.5% for fish from the point they enter Clifton Court Forebay or encounter the trash racks at the CVP facilities. Additionally, mark-recapture experiments indicate that most fish are probably subject to predation prior to reaching the fish salvage facilities (e.g., in Clifton Court Forebay) (Gingras 1997; Clark et al. 2009; Castillo et al. 2012). Aquatic organisms (e.g., phytoplankton and zooplankton) that serve as food for fish also are entrained and removed from the Delta (Jassby et al. 2002; Kimmerer et al. 2008; Brown et al. 1996). Fish entrainment and salvage are particular concerns during dry years when the distributions of young Striped Bass, Delta Smelt, Longfin Smelt, and other migratory fish species shift closer to the project facilities (Stevens et al. 1985; Sommer et al. 1997).

Salvage estimates reflect the number of fish entrained by project exports, but these numbers alone do not account for other sources of mortality related to the export facilities. These numbers do not include prescreen losses that occur in the waterways leading to the diversion facilities, which may in some cases reduce the number of salvageable fish (Gingras 1997; Clark et al. 2009; Castillo et al. 2012). For Delta Smelt, prescreen losses appear to be where most mortality occurs (Castillo et al. 2012). In addition, actual salvage numbers do not include the entrainment of fish larvae, which cannot be collected by the fish screens. The number of fish salvaged also does not include losses of fish that pass through the louvers intended to guide fish into the fish collection facilities or the losses during collection, handling, transport, and release back into the Delta.

The life stage of the fish at which entrainment occurs may be important for population dynamics (IRP 2011). For example, winter entrainment of Delta Smelt and Longfin Smelt may correspond to migration and spawning of adult fish, and spring and summer exports may overlap with development of larvae and juveniles. The loss of prespawning adults and all their potential progeny may have greater consequences than entrainment of the same number of larvae or juvenile fish. Entrainment risk for fish tends to increase with increased reverse flows in Old and Middle Rivers (Kimmerer 2008; Grimaldo et al. 2009).

Research has shown that upriver movements of adult Delta Smelt are achieved through a form of tidal rectification or active tidal transport by using lateral movement to shallow edges of channels on ebb tides to maintain their position (Bennett and Burau 2015). Turbidity gradients could be involved in the lateral positioning of Delta Smelt within the channels, but large-scale turbidity pulses through the system may not be necessary to trigger upriver migrations of Delta Smelt if they are already occupying sufficiently turbid water (IRP 2011). The new understanding of potential tidal and turbidity effects on Delta Smelt behavior may have important implications for the Delta Smelt monitoring programs that are the basis for biological triggers for RPA Actions 1 and 2 by understanding the catch efficiency of mid-water trawl data in relation to the lateral positioning of Delta Smelt within channels.

There are more than 2,200 diversions in the Delta (Herren and Kawasaki 2001). These irrigation diversion pipes are shore-based, typically small (30 to 60 cm pipe diameter), and operated via pumps or gravity flow, and most lack fish screens. These diversions increase total fish entrainment and losses and alter local fish movement patterns (Kimmerer and Nobriga 2008). Delta Smelt have been found in samples of Delta irrigation diversions, as well as larger wetland management diversions downstream. However, Nobriga et al. (2004) found that the low and inconsistent entrainment of Delta Smelt measured in the study reflected habitat use by Delta Smelt and relatively small hydrodynamic influence of the diversion.

O.2.10.2.5 Disease

Preliminary results of several histopathological studies have found evidence of significant disease in Delta fish species (Reclamation 2008a). For example, massive intestinal infections with an unidentified myxosporean were found in Yellowfin Goby collected from Suisun Marsh (Baxa et al. 2013). Studies by Bennett (2005) and Bennett et al. (2008) show that exposure to toxic chemicals may cause liver abnormalities and cancerous cells in Delta Smelt, and stressful summer conditions, warm water, and lack of food may result in liver glycogen depletion and liver damage. Studies of Sacramento Splittail suggest that liver abnormalities in this species are more linked to health and nutritional status than to pollutant exposure (Greenfield et al. 2008).

Additionally, preliminary evidence suggests that contaminants and disease may impair Striped Bass. Studies by Lehman et al. (2010) suggest that the liver tissue and health of Striped Bass and Mississippi Silverside were adversely affected by tumors, particularly at sampling stations where concentrations of tumor-promoting microcystins were elevated. Exposure of Sacramento Splittail and Threadfin Shad to microcystins in experimental diets resulted in severe liver damage; Shad also exhibited ovarian necrosis, indicating impairment of health and reproductive potential (Acuna et al. 2012).

In contrast, histopathological and viral evaluation of juvenile Longfin Smelt and Threadfin Shad collected in 2006 indicated no histological abnormalities and no evidence of viral infections or high parasite loads (Foott et al. 2006). Parasites were noted in Threadfin Shad gills at a high frequency, but the infections were not considered severe. Thus, both Longfin Smelt and Threadfin Shad were considered healthy in 2006 (a high-flow year). Adult Delta Smelt collected from the Delta during winter 2005 also were considered healthy, showing little histopathological evidence for starvation or disease (Reclamation 2008a). However, there was some evidence of low frequency endocrine disruption. In 2005, 9 of 144 (6%) adult Delta Smelt males were intersex, having immature oocytes in their testes (Reclamation 2008a).

O.2.10.2.6 Nonnative Invasive Species

Nonnative invasive species influence the Delta ecosystem by increasing competition and predation on native species, reducing habitat quality (as result of invasive aquatic macrophyte growth), and reducing food supplies by altering the aquatic food web. Not all nonnative species are considered invasive.[3] Some introduced species have minimal ability to spread or increase in abundance. Others have commercial or recreational value (e.g., Striped Bass, American Shad, and Largemouth Bass).

Many nonnative fishes have been introduced into the Delta for sport fishing (game fish such as Striped Bass, Largemouth Bass, Smallmouth Bass, Bluegill, and other Sunfish), as forage for game fish (Threadfin Shad, Golden Shiner, and Fathead Minnow), for vector control (Inland Silverside, Western Mosquitofish), for human food use (Common Carp, Brown Bullhead, and White Catfish), and from accidental releases (Yellowfin Goby, Shimofuri Goby, and Shokihaze Goby) (Moyle 2002). Introduced fish may compete with native fish for resources and, in some cases, prey on native species.

Because of invasive species and other environmental stressors, native fishes have declined in abundance throughout the region during the period of monitoring (Matern et al. 2002; Brown and Michniuk 2007;

[3] DFG (2008) defines *invasive species* as "species that establish and reproduce rapidly outside of their native range and may threaten the diversity or abundance of native species through competition for resources, predation, parasitism, hybridization with native populations, introduction of pathogens, or physical or chemical alteration of the invaded habitat."

Sommer et al. 2007a; Mount et al. 2012). Habitat degradation, changes in hydrology and water quality, and stabilization of natural environmental variability are all factors that generally favor nonnative, invasive species (Mount et al. 2012; Moyle et al. 2012).

O.2.10.2.7 Predation

Predation is an important factor that influences the behavior, distribution, and abundance of prey species in aquatic communities to varying degrees. Predation can have differing effects on a population of fish depending on the size or age selectivity, mode of capture, mortality rates, and other factors. Predation is a part of every food web, and native Delta fishes were part of the historical Delta food web. Because of the magnitude of change in the Delta from historical times and the introduction of nonnative predators, it is logical to conclude that predation may have increased in importance as a mortality factor for Delta fishes, with some observers suggesting that it is likely the primary source of mortality for juvenile salmonids in the Delta (Vogel 2011). Predation occurs by fish, birds, and mammals, including sea lions. The alternatives considered in this EIS are not anticipated to modify predatory actions of birds and mammals on the focal species. Therefore, the predation discussion is focused on fish predators.

A panel of experts convened to review data on predation in the Delta and draw preliminary conclusions on the effects of predation on salmonids. The panel acknowledged that the system supports large populations of fish predators that consume juvenile salmonids (Grossman et al. 2013). However, the panel concluded that because of extensive flow modification, altered habitat conditions, native and nonnative fish and avian predators, temperature and dissolved oxygen limitations, and the overall reduction in Salmon population size, it was unclear what proportion of the juvenile salmonid mortality could be attributed to predation. The panel further indicated that predation, while the proximate cause of mortality, may be influenced by a combination of other stressors that make fish more vulnerable to predation.

Striped Bass, White Catfish, Channel Catfish Largemouth Bass and other centrarchids, and Silversides are among the introduced, nonnative species that are notable predators of smaller-bodied fish species and juveniles of larger species in the Delta. Along with Largemouth Bass, Striped Bass, White Catfish, Channel Catfish are believed to be major predators on larger-bodied fish in the Delta. In open-water habitats, Striped Bass are most likely the primary predator of juvenile and adult Delta Smelt (DWR et al. 2013) and can be an important open-water predator on juvenile salmonids (Johnston and Kumagai 2012). Native Sacramento Pikeminnow may also prey on juvenile salmonids and other fishes. Limited sampling of smaller pikeminnows did not find evidence of salmonids in the foregut of Sacramento Pikeminnow (Nobriga and Feyrer 2007), but this does not mean that Sacramento Pikeminnow do not prey on salmonids in the Delta.

Largemouth Bass abundance has increased in the Delta over the past few decades (Brown and Michniuk 2007). Although Largemouth Bass are not pelagic, their presence at the boundary between the littoral and pelagic zones makes it probable that they opportunistically consume pelagic fishes. The increase in salvage of Largemouth Bass occurred during the time period when Brazilian waterweed was expanding its range in the Delta (Brown and Michniuk 2007). The beds of Brazilian waterweed provide good habitat for Largemouth Bass and other species of centrarchids. Largemouth Bass have a much more limited distribution in the estuary than Striped Bass, but a higher per-capita impact on small fishes (Nobriga and Feyrer 2007). Increases in Largemouth Bass may have had a particularly important effect on Threadfin Shad and Striped Bass, whose earlier life stages occur in littoral habitat (Grimaldo et al. 2004; Nobriga and Feyrer 2007).

Invasive Mississippi Silversides are another potentially important predator of larval and pelagic fishes in the Delta. This introduced species was not believed to be an important predator on Delta Smelt, but studies using DNA techniques detected the presence of Delta Smelt in the guts of 41% of Mississippi Silversides sampled in mid-channel trawls (Baerwald et al. 2012). This finding may suggest that predation impacts could be significant, given the increasing numbers of Mississippi Silversides in the Delta.

Predation of fish in the Delta is known to occur in specific areas, for example at channel junctions and areas that constrict flow or confuse migrating fish and provide cover for predatory fish (Vogel 2011). Sabal (2014) found similar results at Woodbridge Dam on the Mokelumne River where the dam was associated with increased Striped Bass per capita Salmon consumption and attracted larger numbers of Striped Bass, decreasing migrating juvenile Salmon survival by 10 to 29%. CDFG (1992) identified subadult Striped Bass as the major predatory fish in Clifton Court Forebay. In 1993, for example, Striped Bass made up 96% of the predators removed (Vogel 2011). Cavallo et al. (2012) studied tagged Salmon smolts to test the effects of predator removal on outmigrating juvenile Chinook Salmon in the south Delta. Their results suggested that predator abundance and migration rates strongly influenced survival of Salmon smolts. Exposure time to predators has been found to be important for influencing survival of outmigrating Salmon in other studies in the Delta (Perry et al. 2012).

O.2.10.2.8 Aquatic Macrophytes

Aquatic macrophytes are an important component of the biotic community of Delta wetlands and can provide habitat for aquatic species, serve as food, produce detritus, and influence water quality through nutrient cycling and dissolved oxygen fluctuations. Whipple et al. (2012) described likely historical conditions in the Delta, which have been modified extensively, with major impacts on the aquatic macrophyte community composition and distribution. The primary change has been a shift from a high percentage of emergent aquatic macrophyte wetlands to open water and hardened channels.

The introduction of two nonnative invasive aquatic plants, water hyacinth and Brazilian waterweed, has reduced habitat quantity and value for many native fishes. Water hyacinth forms floating mats that greatly reduce light penetration into the water column, which can significantly reduce primary productivity and available food for fish in the underlying water column. Brazilian waterweed grows along the margins of channels in dense stands that prohibit access by native juvenile fish to shallow water habitat. Additionally, the thick cover of these two invasive plants provides excellent habitat for nonnative ambush predators, such as Bass, which prey on native fish species. Studies indicate low abundance of native fish, such as Delta Smelt, Chinook Salmon, and Sacramento Splittail, in areas of the Delta where submerged aquatic vegetation infestations are thick (Grimaldo et al. 2004, 2012; Nobriga et al. 2005).

Invasive aquatic macrophytes are still equilibrating within the Delta and resulting habitat changes are ongoing, with negative impacts on habitats and food webs of native fish species (Toft et al. 2003; Grimaldo et al. 2009). Concerns about invasive aquatic macrophytes are centered on their ability to form large, dense growth that can clog waterways, block fish passage, increase water clarity, provide cover for predatory fish, and cause high biological oxygen demand.

O.2.10.3 *Yolo Bypass*

The Yolo Bypass conveys flood flows from the Sacramento Valley, including the Sacramento River, Feather River, American River, Sutter Bypass, and west side streams

The Yolo Bypass provides habitat for a wide variety of fish and aquatic species, including temporary migration corridors and juvenile rearing habitat for anadromous salmonids and other native and anadromous fishes. Species captured as adults and subsequently collected as YOY suggest that the Yolo

Bypass provides spawning habitat for these species, including Sacramento Splittail, American Shad, Striped Bass, Threadfin Shad, Largemouth Bass and Carp (Harrell and Sommer 2003; Sommer et al. 2014). The Yolo Bypass lacks suitable gravel substrate that would support salmon spawning.

O.2.10.3.1 Aquatic Habitat

Aquatic habitats in the Yolo Basin include stream and slough channels for fish migration, and when flooded, seasonal spawning habitat and productive rearing habitat (Sommer et al. 2001; CALFED 2000a, 2000b). During years when the Yolo Bypass is flooded, it serves as an important migratory route for juvenile Chinook Salmon and other native migratory and anadromous fishes moving downstream. During these times, it provides juvenile anadromous salmonids an alternative migration corridor to the lower Sacramento River (Sommer et al. 2003) and, sometimes, better rearing conditions than the adjacent Sacramento River channel (Sommer et al. 2001, 2005). When the floodplain is activated, juvenile Salmon can rear for weeks to months in the Yolo Bypass floodplain before migrating to the estuary (Sommer et al. 2001a). Research on the Yolo Bypass has found that juvenile Salmon grow substantially faster in the Yolo Bypass floodplain than in the adjacent Sacramento River, primarily because of greater availability of invertebrate prey in the floodplain (Sommer et al. 2001, 2005). When not flooded, the lower Yolo Bypass provides tidal habitat for young fish that enter from the lower Sacramento River via Cache Slough Complex (McLain and Castillo; DWR, unpublished data).

Sommer et al. (1997) demonstrated that the Yolo Bypass is one of the single most important habitats for Sacramento Splittail. Because the Yolo Bypass is dry during summer and fall, nonnative species (e.g., predatory fishes) generally are not present year-round except in perennial water sources (Sommer et al. 2003). In addition to providing important fish habitat, seasonal inundation of the Yolo Bypass supplies phytoplankton and detritus that may benefit aquatic organisms downstream in the brackish portion of the San Francisco Estuary (Sommer et al. 2004; Lehman et al. 2008a).

O.2.10.3.2 Fish Passage

The Fremont Weir is a major impediment to fish passage and a source of migratory delay and loss of adult Chinook Salmon, Steelhead, and Sturgeon (NMFS 2009a; Sommer et al. 2014). A new fish passage facility has been installed in Fremont Weir to facilitate passage of adult salmonids and sturgeon and became operational in 2018. On going evaluations are being performed to determine its effectiveness. Some adult Winter-Run, Spring-Run, and Fall-Run Chinook Salmon and White Sturgeon migrate into Yolo Bypass when there is no flow into the floodplain via the Fremont Weir. Therefore, these fish are often unable to reach upstream spawning habitat in the Sacramento River and its tributaries (Harrell and Sommer 2003; Sommer et al. 2014). Other structures in the Yolo Bypass, such as the Toe Drain, Lisbon Weir, and irrigation dams in the northern end of the Tule Canal, also may impede upstream passage of adult anadromous fish (NMFS 2009a).

Fish are also attracted into the bypass during periods when water is not flowing over the Fremont Weir. Fyke trap monitoring by DWR has shown that adult Salmon and Steelhead migrate up the Toe Drain in autumn and winter regardless of whether the Fremont Weir spills (Harrell and Sommer 2003; Sommer et al. 2014). The Toe Drain does not extend to the Fremont Weir because the channel is blocked by roads or other higher ground at several locations. Sturgeon and salmonids attracted by high flows into the basin become concentrated behind the Fremont Weir, where they are subject to heavy legal and illegal fishing pressure.

Stranding of juvenile salmonids and Sturgeon has been reported in the Yolo Bypass in scoured areas behind the weir and in other areas as floodwaters recede (NMFS 2009a; Sommer et al. 2005). However, Sommer et al. (2005) found most juvenile Salmon out-migrated off the floodplain as it drained.

O.2.10.4 *Suisun Marsh*

Suisun Bay and Marsh are ecologically linked with the central Delta, although with different tidal and salinity conditions than found upstream. Suisun Bay and Marsh are the largest expanse of remaining tidal marsh habitat within the greater Bay-Delta ecosystem and include Honker, Suisun, and Grizzly Bays; Montezuma and Suisun Sloughs; and numerous other smaller channels and sloughs.

O.2.10.4.1 Aquatic Habitat

Suisun Marsh is a brackish-water marsh bordering the northern edge of Suisun Bay. Most of its marsh area consists of diked wetlands managed for waterfowl, with the rest of the acreage consisting of tidally influenced sloughs (Suisun Ecological Workgroup 2001). The central latitudinal location of Suisun Marsh within the San Francisco Estuary makes it an important rearing area for euryhaline freshwater, estuarine, and marine fishes. Many fish species that migrate or use Delta habitats also are found in the waters of Suisun Bay. Tides reach Suisun Bay and Marsh through the Carquinez Strait, and most freshwater flows enter at the southeast border of Suisun Marsh at the confluence of the Sacramento and San Joaquin Rivers. The mixing of freshwater outflows from the Central Valley with saline tidal water in Suisun Bay and Suisun Marsh results in brackish water with strong salinity gradients, complex patterns of flow interactions, and generally the highest biomass productivity in the entire estuary (Siegel et al. 2010).

Although the fish assemblages in Suisun Bay and Marsh can differ substantially from the fish assemblages in the Delta, all the species that use the Delta also use Suisun Bay and Marsh.

Flow, turbidity, and salinity are important factors influencing the location and abundance of zooplankton and small prey organisms used by Delta species (Kimmerer et al. 1998). The location where net current flowing inland along the bottom reverses direction and sinking particles are trapped in suspension is associated with higher turbidity known as the estuarine turbidity maximum. Burau et al. (2000) reports that the estuarine turbidity maximum occurs near the Benicia Bridge and in Suisun Bay near Garnet Point on Ryer Island. Zooplanktonic organisms maintain position in this region of historically high productivity in the estuary through vertical movements (Kimmerer et al. 1998).

Salinity in the Suisun Bay and Marsh system is a major water quality characteristic that strongly influences physical and ecological processes. Fish species native to Suisun Marsh require low salinities during the spawning and rearing periods (Suisun Ecological Workgroup 2001; Kimmerer 2004; Feyrer et al. 2007, 2010; Nobriga et al. 2008). The Suisun Bay and Marsh usually contain both the maximum estuarine salinity gradient and the low salinity zone. The overall estuarine salinity gradient trends from west (higher) to east (lower) in Suisun Bay and Marsh. The location of the low salinity zone gradient and X2 can be influenced by outflow. Suisun Marsh also exhibits a persistent north-south salinity gradient. Despite low and seasonal flows, the surrounding watersheds have a significant water freshening effect because of the long residence times of freshwater discharges from the upper sloughs and wastewater effluent.

The Suisun Bay and Marsh system contains a wide variety of habitats such as marsh plains, tidal creeks, sloughs, channels, cuts, mudflats, and bays. These features and the complex hydrodynamics and water quality of the system have historically fostered significant biodiversity within Suisun tidal aquatic habitats, but, like the Delta, these habitats also have been significantly altered and degraded by human activities over the decades.

Categories of tidal aquatic habitat were identified as part of the Suisun Marsh Plan development process and were defined using physical boundaries; habitats include bays, major sloughs, minor sloughs, and the intertidal mudflats in those areas (Engle et al. 2010). These tidal habitats total approximately 26,000 acres, with the various embayments totaling about 22,350 acres. Tidal slough habitat is composed of major and minor sloughs, with major sloughs of Suisun Marsh having a combined acreage of about 2,200 acres consisting of both shallow and deep channels. Minor sloughs are made up of shallow channel habitat and have a combined acreage of about 1,100 acres. Habitats in Suisun Marsh bays and sloughs support a diverse assemblage of aquatic species that typically use open-water tidal areas for breeding, foraging, rearing, or migrating.

O.2.10.4.2 Fish Entrainment

Several facilities have been constructed by DWR and Reclamation to provide lower-salinity water to managed wetlands in the Suisun Marsh, including the Roaring River Distribution System, Morrow Island Distribution System, and Goodyear Slough Outfall. Other facilities constructed under the Suisun Marsh Preservation Agreement that could entrain fish include the Lower Joice Island and Cygnus Drain diversions.

The intake to the Roaring River Distribution System is screened to prevent entrainment of fish larger than approximately 1 inch (approximately 25 mm). DWR monitored fish entrainment from September 2004 to June 2006 at the Morrow Island Distribution System to evaluate entrainment losses at the facility. Monitoring took place over several months under various operational configurations and focused on Delta Smelt and salmonids. Over 20 species were identified during the sampling, but only 2 Fall-Run-sized Chinook Salmon (at the South Intake in 2006) and no Delta Smelt from entrained water were caught (Reclamation 2008a). The Goodyear Slough Outfall system is open for free fish movement except near the outfall when flap gates are closed during flood tides (Reclamation 2008a). Conical fish screen have been installed on the Lower Joice Island diversion on Montezuma Slough.

O.2.10.5 *San Francisco Bay Area*

Fish and aquatic habitat resources in the San Francisco Bay Area include habitat through San Francisco Bay.

The San Francisco Bay Area also includes fish habitat within reservoirs that store CVP and SWP water. CVP and SWP water supplies are stored in Contra Loma and San Justo Reservoirs; the SWP Bethany Reservoir and Lake Del Valle; the Contra Costa Water District Los Vaqueros Reservoir; and the East Bay Municipal Utility District (EBMUD) Upper San Leandro, San Pablo, Briones, and Lafayette Reservoirs and Lake Chabot. Many of these reservoirs also store water from local and regional water supplies. CVP and SWP water is generally not stored in reservoirs within Santa Clara County (SCVWD 2010).

O.2.10.6 *Contra Loma Reservoir*

The Contra Loma Reservoir is a CVP facility in Contra Costa County that provides offstream storage along the Contra Costa Canal. The 80-acre reservoir is part of 661-acre Contra Loma Regional Park and Antioch Community Park (Reclamation 2014c). There are currently 20 known fish species, including 8 species of game fish, in Contra Loma Reservoir. The East Bay Parks and Recreation District and CDFW stock Rainbow Trout and Channel Catfish in the reservoir. The reservoir also supports self-sustaining populations of Largemouth Bass, Crappie, Redear Sunfish, and Bluegill, which are also popular with anglers (Reclamation 2014c). Other species found include White Catfish, Threadfin Shad, Bigscale Logperch, Common Carp, Sacramento Blackfish, Warmouth, Green Sunfish, Goldfish, Prickly Sculpin, and Inland Silversides (Reclamation 2014c).

Some of the fish species present have been introduced from the Delta via the Contra Costa Canal. Recently, the Rock Slough Fish Screen at the head of Contra Costa Canal was constructed to prevent the entrainment of federally protected species such as Delta Smelt at the Rock Slough Intake of the Contra Costa Canal. The screen also minimizes fish entrainment and significantly reduces the potential for fish introductions into Contra Loma Reservoir from the Contra Costa Canal (Reclamation 2014c).

O.2.10.7 *San Justo Reservoir*

The San Justo Reservoir is a CVP facility in San Benito County that provides offstream storage as part of the San Felipe Division. Other than stocked Rainbow Trout, all of the fish and other aquatic organisms that have been observed in San Justo Reservoir are nonnative species (SBCWD 2012).

O.2.10.8 *South Bay Aqueduct Reservoirs*

Bethany Reservoir, Patterson Reservoir, and Lake Del Valle are SWP facilities associated with the South Bay Aqueduct in Alameda County. At Bethany Reservoir, anglers catch five types of Bass (Spotted, White, Largemouth, Smallmouth, and Striped), Crappie, Catfish, and Trout (CSP 2013). Presumably, many of the same species would be found in Patterson Reservoir. Lake Del Valle is stocked regularly with Trout and Catfish. Largemouth and Smallmouth Bass, Striped Bass, and panfish are also caught (EBPRD 2014).

O.2.10.9 *Los Vaqueros Reservoir*

Los Vaqueros Reservoir is a Contra Costa Water District offstream storage facility in Contra Costa County. Aquatic habitat quality for fish is low to moderate due to poorly developed cover vegetation along the shoreline. The reservoir has a robust recreational fish stocking program, primarily Rainbow Trout. Other fish introduced to the reservoir include Striped Bass, Largemouth Bass, Sunfish, Brown Bullhead, and Channel Catfish (Reclamation and CCWD 2011).

O.2.10.10 *East Bay Municipal Utility District Reservoirs*

The EBMUD reservoirs in Alameda and Contra Costa County used to store water within and near the EBMUD service area include Briones Reservoir, San Pablo Reservoir, Lafayette Reservoir, Upper San Leandro Reservoir, and Lake Chabot. Water stored in these reservoirs includes water from local watersheds, the Mokelumne River watershed, and CVP water supplies. San Pablo Reservoir is regularly stocked with Trout and Catfish (EBMUD 2014). Other species caught in the reservoir include Crappie, Largemouth Bass, Smallmouth Bass, Spotted Bass, and Carp (OEHHA 2009).

CDFW annually stocks Trout in Lafayette Reservoir. Other species found in the reservoir include Bluegill, Black Bass, Black Crappie, and several species of Catfish (Lafayette Chamber of Commerce 2014).

Lake Chabot is stocked with hatchery-raised Rainbow Trout and Channel Catfish by East Bay Parks and Recreation District and CDFW for recreational fishing. The lake also supports a popular nonnative, warm-water recreational fishery for Largemouth Bass, Bluegill, and Black Crappie. Some native trout escape from the Upper San Leandro Reservoir during spill events and likely end up in Lake Chabot (EBMUD 2013).

O.2.11 Nearshore Pacific Ocean on the California Coast

The anadromous fish species use the Pacific Ocean as part of their life cycles. In addition, the Pacific Ocean supports the Southern Resident Killer Whale, which relies upon Chinook Salmon (e.g., Fall-Run Chinook Salmon) for food.

O.2.11.1 *Pacific Ocean Habitat of the Killer Whale*

The Pacific Ocean along the coast of California is included in this description of the affected environment because of it provides habitat for the Southern Resident Killer Whale population. The effect of the action, however, is limited to changes in the number of Chinook Salmon produced in the Central Valley entering the Pacific Ocean, which contribute an important component of the Killer Whale diet.

Southern Resident Killer Whales are found primarily in the coastal waters offshore of British Columbia and Washington and Oregon in summer and fall (NMFS 2008). During winter, Killer Whales are sometimes found off the coast of central California and more frequently off the Washington coast (Hilborn et al. 2012).

The 2005 NMFS endangerment listing (70 FR 69903) for the Southern Resident Killer Whale distinct population segment lists several factors that may be limiting the recovery of Killer Whales, including the quantity and quality of prey, accumulation of toxic contaminants, and sound and vessel disturbance. In the Recovery Plan for Southern Resident Killer Whales (*Orcinus orca*), NMFS (2008) posits that reduced prey availability forces whales to spend more time foraging, which may lead to reduced reproductive rates and higher mortality rates. Reduced food availability may lead to mobilization of fat stores, which can release stored contaminants and adversely affect reproduction or immune function (NMFS 2008).

The Independent Science Panel reported that Southern Resident Killer Whales depend on Chinook Salmon as a critical food resource (Hilborn et al. 2012). Hanson et al. (2010) analyzed tissues from predation events and feces to confirm that Chinook Salmon were the most frequent prey item for Killer Whales in two regions of the whale’s summer range off the coast of British Columbia and Washington state, representing over 90% of the diet in July and August. Samples indicated that when Southern Residents are in inland waters from May to September, they consume Chinook Salmon stocks that originate from regions including the Fraser River, Puget Sound, the Central British Columbia Coast, West and East Vancouver Island, and Central Valley California (Hanson et al. 2010).

Significant changes in food availability for Killer Whales have occurred over the past 150 years, largely due to human impacts on prey species. Salmon abundance has been reduced over the entire range of the Southern Resident Killer Whales, from British Columbia to California. The Recovery Plan for Southern Resident Killer Whales (*Orcinus orca*) (NMFS 2008) indicates that wild Salmon have declined primarily due to degraded aquatic ecosystems, overharvesting, and production of fish in hatcheries. The recovery plan supports restoration efforts to rebuild depleted Salmon populations and other prey to ensure an adequate food base for Southern Resident Killer Whales.

Central Valley streams produce Chinook Salmon that contribute to the diet of Southern Resident Killer Whales. The number of Central Valley Chinook Salmon that annually enter the ocean and survive to a size susceptible to predation by Killer Whales is not known. However, estimates of total Chinook Salmon production produced by the Comprehensive Assessment and Monitoring Program, administered by USFWS and Reclamation, provide an approximation of the size of the ocean population of Central Valley Chinook Salmon potentially available to Killer Whales. Since 1992, total production of Fall-Run Chinook Salmon ranged from 53,129 in 2009 to 1,436,928 in 2002 (Table O.2-7). The term *total production* here represents the number of fish that returned from the ocean plus those that were taken as part of the commercial and sport fishery. It does not include natural mortality in the ocean, including Salmon taken by Killer Whales.

Table O.2-7 Total Production (Number of Individuals) of Central Valley Fall-Run Chinook Salmon in the Pacific Ocean and Ocean Harvest 1992–2011

Year	Total Production	Ocean Harvest
1992	333,087	203,318
1993	553,617	352,913
1994	711,654	449,060
1995	1,391,357	994,194
1996	891,739	471,865
1997	1,146,471	679,151
1998	557,433	263,935
1999	795,768	316,873
2000	1,156,596	571,829
2001	976,034	218,424
2002	1,436,928	418,785
2003	1,019,686	297,140
2004	977,463	500,929
2005	874,670	356,514
2006	453,274	110,540
2007	202,311	87,528
2008	71,870	0
2009	53,129	0
2010	208,050	13,851
2011	329,092	57,224

O.2.12 CVP and SWP Service Areas (south to Diamond Valley)

O.2.12.1 *San Luis Reservoir*

San Luis Reservoir is located at the base of the foothills on the west side of the San Joaquin Valley in Merced County. Water from the Delta is delivered to San Luis Reservoir via the California Aqueduct and Delta-Mendota Canal for storage.

San Luis Reservoir and O'Neill Forebay support several species of fish that have become established within the system, either by direct introduction or from the Delta system via pumping from the California Aqueduct and Delta-Mendota Canal. Striped Bass are the predominant species in San Luis Reservoir (DWR 1987) and support a recreational fishery. Other species include Sacramento Blackfish, American Shad, Threadfin Shad, Largemouth Bass, Kokanee Salmon, Green Sunfish, Bluegill, White Sturgeon, and White Crappie.

There are no sensitive fish species in the San Luis Reservoir except, possibly, individuals entrained by the CVP and SWP projects in the Delta. These individuals have already been lost to their populations, as they cannot return to the Delta once entrained. Potentially occurring fish species with special status that may have been imported from the Delta include Chinook Salmon, Delta Smelt, Hardhead, and Sacramento Splittail (Reclamation and CSP 2013).

O.2.12.2 *Central Coast*

The Central Coast includes portions of San Luis Obispo and Santa Barbara Counties served by the SWP. SWP water is delivered to southern Santa Barbara County communities through Cachuma Lake.

O.2.12.2.1 Cachuma Lake

Cachuma Lake is a facility owned and operated by Reclamation in Santa Barbara County. Cachuma Lake provides a variety of habitats for fish species, including deep-water areas, rocky drop-offs, shallow areas, and weed beds (wetland areas). Cachuma Lake and the upper Santa Ynez River are popular fishing areas that have been stocked with game fish by CDFW and the County of Santa Barbara. Native fish species in Cachuma Lake include Steelhead/Rainbow Trout, Armored Three-Spine Stickleback, and Prickly Sculpin. Key game fish include Largemouth Bass, Smallmouth Bass, Bluegill, Green Sunfish, Redear Sunfish, Black Crappie, and White Crappie. Other species that have been identified in the lake include Channel Catfish, Black Bullhead, Threadfin Shad, Goldfish, Carp, and Mosquitofish (Reclamation 2010c).

O.2.12.3 *Southern California*

Portions of Ventura, Los Angeles, Orange, San Diego, Riverside, and San Bernardino Counties are served by the SWP. There are six SWP reservoirs along the main canal, West Branch, and East Branch of the California Aqueduct and many other reservoirs owned and operated by regional and local agencies. The Metropolitan Water District of Southern California's Diamond Valley Lake and Lake Skinner primarily store water from the SWP. Other reservoirs store SWP water, including United Water Conservation District's Lake Piru; the city of Escondido's Dixon Lake; San Diego's San Vicente Reservoir and Lower Otay Reservoir; Helix Water District's Lake Jennings; and Sweetwater Authority's Sweetwater Reservoir.

O.2.12.3.1 State Water Project Reservoirs

The SWP reservoirs include Quail Lake, Pyramid Lake, and Castaic Lake in Los Angeles County; Silverwood Lake and Crafton Hills Reservoir in San Bernardino County; and Lake Perris in Riverside County.

Although small compared to nearby Pyramid and Castaic lakes, Quail Lake's 290 acres and 3 miles of shoreline offer shoreline fishing. Striped Bass, Channel Catfish, Blackfish, Tule Perch, Threadfin Shad, and Hitch have been found at Quail Lake (DWR 1997).

Pyramid Lake is in the Angeles and Los Padres National Forests, about 60 miles northwest of downtown Los Angeles. Largemouth Bass, Smallmouth Bass, and Striped Bass as well as Bluegill, Crappie, Brown Bullhead, Channel Catfish, and Trout are caught by anglers in Pyramid Lake (OEHHA 2013a). Rainbow Trout, Bluegill, Green Sunfish, Largemouth Bass, catfish, and Prickly Sculpin are found in Piru Creek below the dam (DWR 2004d).

Castaic Lake supports a warm-water fishery for Striped Bass and Largemouth Bass. Bluegill and assorted minnows provide a forage base for the Bass as well as being caught by anglers. CDFW maintains a Rainbow Trout fishery in Castaic Lake through stocking (DWR 2007).

Silverwood Lake is in the San Bernardino National Forest and surrounded by the Silverwood Lake State Recreation Area at the edge of the Mojave Desert and at the base of the San Bernardino Mountains. Common sport fish caught in Silverwood Lake include stocked Rainbow Trout, Largemouth Bass, Bluegill, Carp, Crappie, Catfish, and Striped Bass (CSP 2010; OEHHA 2013b). Other species found in the lake include Blackfish, Brown Bullhead, Tui Chub, and Tule Perch (OEHHA 2013b).

The Crafton Hills Reservoir area includes 4.5 acres of open water and 1.9 acres of open space. One fish species, Mosquitofish, was observed in the reservoir (DWR 2009b).

Lake Perris is located within the Lake Perris State Recreation Area, which provides extensive recreational opportunities. Lake Perris is stocked with Rainbow Trout and managed as a recreational fishery. Common fish species in the lake include Largemouth Bass, Channel Catfish, Bluegill, Spotted Bass, Flathead Catfish, Green Sunfish, Redear Sunfish, and Black Crappie (DWR 2010a). Other species found in the lake include Inland Silversides and Threadfin Shad (DWR 2007).

O.3 Evaluation of Alternatives

This section describes the technical background for the evaluation of environmental consequences associated with the Project alternatives and the No Action Alternative. This section also describes the results of the impact analysis for each Project alternative and the No Action Alternative.

O.3.1 Methods and Tools

The impact assessment considers changes in flows, temperature, and other habitat conditions related to changes in CVP and SWP operations under the alternatives as compared to the No Action Alternative. This section details methods and tools used to evaluate those effects.

The following model simulations were utilized to analyze and compare the No Action Alternative and action alternatives:

- CalSim II
- HEC5Q
- Reclamation Temperature Model
- DSM2
- Winter Run Chinook Temperature-Dependent Egg Mortality Models

Each of these model simulations is summarized below and are more fully described in Appendix F, Modeling.

O.3.1.1 *CalSim II*

Reclamation / DWR CalSim II planning model was used to simulate the coordinated operation of the CVP and SWP over a range of hydrologic conditions. CalSim II is a generalized reservoir-river basin simulation model that allows for specification and achievement of user-specified allocation targets, or goals (Draper et al. 2004). CalSim II represents the best available planning model for CVP and SWP system operations and has been used in previous system-wide evaluations of CVP and SWP operations (U.S. Bureau of Reclamation 2015).

O.3.1.2 *HEC5Q*

Over the past 15 years, various temperature models were developed to simulate temperature conditions on the rivers affected by CVP and SWP operations (SRWQM, San Joaquin River HEC5Q model) (Reclamation 2008). Recently, these models were compiled and updated into a single modeling package called in here as the HEC5Q model. Further updates were performed under the LTO EIS modeling that included improved meteorological data and subsequent validation of the Sacramento and American River models, implementation of the Folsom Temperature Control Devices and low-level outlet, implementation of the Trinity auxiliary outlet, improved temperature targeting for Shasta and Folsom Dams, as well as improved documentation and streamlining of the models as well as improved integration with the CalSim II model (U.S. Bureau of Reclamation 2015).

O.3.1.3 *Reclamation Temperature Model*

Reclamation Temperature Model includes reservoir and stream temperature models, which simulate monthly reservoir and stream temperatures used for evaluating the effects of CVP/SWP project operations on mean monthly water temperatures in the basin (Reclamatioin 2008). The model simulates temperatures in seven major reservoirs (Trinity, Whiskeytown, Shasta, Oroville, Folsom, New Melones and Tulloch), four downstream regulating reservoirs (Lewiston, Keswick, Goodwin and Natoma), and five main river systems (Trinity, Sacramento, Feather, American and Stanislaus). The river component of the Reclamation Temperature model calculates temperature changes in the regulating reservoirs, below the main reservoirs. With regulating reservoir release temperature as the initial river temperature, the river model computes temperatures at several locations along the rivers. The calculation points for river temperatures generally coincide with tributary inflow locations. The model is one-dimensional in the longitudinal direction and assumes fully mixed river cross sections. The effect of tributary inflow on river temperature is computed by mass balance calculation. The river temperature calculations are based on regulating reservoir release temperatures, river flows, and climatic data (U.S Bureau of Reclamation 2015).

O.3.1.4 *DSM2*

DSM2 is a one-dimensional hydrodynamic and water quality simulation model used to simulate hydrodynamics, water quality, and particle tracking in the Sacramento-San Joaquin Delta (DWR 2002). DSM2 represents the best available planning model for Delta tidal hydraulic and salinity modeling. It is appropriate for describing the existing conditions in the Delta, as well as performing simulations for the assessment of incremental environmental impacts caused by future facilities and operations (Reclamation 2015).

O.3.1.5 *Winter Run Chinook Temperature-Dependent Egg Mortality Models*

Two egg mortality estimation methods were used for evaluating Winter Run Chinook habitat on the Sacramento River downstream of Keswick Dam. Both models start by modeling a redd's lifetime by counting the days required to cross a known cumulative degree-days threshold, and both estimate mortality as a linear, increasing function of temperature past a known temperature threshold, but each uses a different set of assumptions to implement this conceptual model. The methods are applied to a set of simulated redds and the results are summarized on a seasonal level for comparison of mortality outcomes between HEC5Q model runs. The Martin model was developed for estimating temperature-dependent egg mortality in the field and fit its parameters to Sacramento River Winter run Chinook population data collected between 1996 and 2015 (Martin et al., 2017). The Anderson model uses field data from 2002 through 2015, a critical period just before hatching was found to provide the best fit (Anderson, 2018).

The methods utilized in the EIS analysis relied on quantitative results from the aforementioned modeling tools, in combination with qualitative analyses of potential effects to aquatic species' life stage transitions that are based on available species-specific conceptual models consistent with the analysis conducted in the associated Final Biological Assessment of the Reinitiation of Consultation on the Coordinated Long-Term Operation of the Central Valley Project and State Water Project (ROC LTO BA). The impact analysis considered the applicable species life stage in relation to the components of each alternative, including those associated with effects of construction (i.e., the analysis of potential effects from the physical act of constructing proposed components of the alternatives) and effects of operation. The latter considered flow-dependent actions, which analyzes the potential effects of factors such as south Delta export operations and reservoir storage/releases, and non-flow-dependent actions, which analyzes the potential effects of factors such as habitat restoration and the proposed Delta Fish Species Conservation Hatchery. Where applicable, the analysis distinguishes between site-specific (project-level) components and programmatic actions.

The effects analysis for each alternative and its associated components includes an analysis of effects to each species, which considers the exposure of each life stage to the component, largely based on species timing information. Consideration of exposure focuses on the extent to which a component overlaps in time and location with the life stage. Potential effects of exposure to the alternative/component on individuals of the species are then analyzed. This analysis is generally qualitative, although the potential effects of flow-dependent actions are informed to the extent possible by modeling of the various operational scenarios (previously described), and is related to the conceptual model for the life stage transition being analyzed.

O.3.2 No Action Alternative

Under the No Action Alternative, Reclamation would continue with current operations of the CVP, as described in Chapter 4, *Alternative Descriptions*. The proposed operational changes, habitat restoration, and facility improvements, as well as habitat restoration, facility improvements, or intervention measures, under Alternative 1 would not occur under the No Action Alternative.

O.3.2.1 *Trinity River*

O.3.2.1.1 <u>Seasonal Operations</u>

Seasonal operations for the Trinity River direct the amount and timing of water exports into the Sacramento basin. The 2000 Record of Decision (Trinity River ROD) limits transbasin diversions to 55% of annual inflow on a 10-year average basis to increase the cold-water pool within Trinity Reservoir and improve conditions for Coho and Chinook Salmon spawning in the Trinity River. Reclamation maintains at least 600 TAF in Trinity Reservoir, except during the 10% to 15% of water years when Shasta Reservoir is drawn down. End-of-water-year carryover in dry and critically dry water year types is addressed on a case-by-case basis to help conserve cold-water pools and meet water temperature objectives on the upper Sacramento and Trinity Rivers, as well as power production economics.

In general, habitat conditions in the Trinity River downstream of Lewiston Dam would be expected to improve with continued implementation of the Trinity River ROD under the No Action Alternative compared to current conditions.

The variable annual flow regime is expected to maintain habitat conditions through physical geomorphic processes (scour and deposition) and interact with previously implemented and future restoration actions, including physical habitat manipulation, removal of riparian berms, and creation of side channels. In addition, adaptive management is expected to improve the effectiveness of flow releases under the No Action Alternative compared to current conditions.

A review of 2005 to 2010 TRRP Phase 1 actions and the physical and biological response indicated that the program was largely successful and that a substantial amount was learned regarding meeting goals and objectives of the program (Buffington et al. 2014). The review also highlighted the importance of monitoring and adaptive management. However, the review also concluded that the Trinity River was less alluvial and less responsive than originally hypothesized, and therefore, the timescale for both geomorphic and fish population responses to restoration actions was greater than expected. In part, this was due to the low frequency of geomorphically effective flows during the implementation and monitoring period in addition to lingering effects of past land management such as mining terraces and legacy coarse bed materials. Adaptive management is expected to improve the effectiveness of flow releases at achieving physical (geomorphic) or biological (fish habitat) goals within the constraints of the annual flow volumes and peak flow magnitudes required by the Trinity River ROD.

Flows from seasonal operations would be expected to maintain habitat conditions through physical geomorphic processes (scour and deposition) and interact with previously implemented and future habitat restoration actions. In addition, adaptive management is expected to improve the effectiveness of using flow releases to achieve biological (fish habitat) goals under the No Action Alternative compared to current conditions

Potential changes to aquatic resources from variation in flow

The variable annual flow regime for the Trinity River is determined based on the current year's hydrology as of April 1 of each year, which defines the water year type (the five water year types are based on historical [1912–1991] percent exceedance: critically dry [>88%], dry [60% to 88%], normal [40% to 60%], wet [12% to 40%], and extremely wet [<12%]) and associated flow release volume (TAF), peak flow (cfs), and peak flow duration (days). Water volumes range from 369 TAF in critically dry years to 815 TAF in extremely wet years. The flow release schedule generally coincides with the natural spring snowmelt runoff period (April to July), which is an important flow component to anadromous fish life history and life-stage-specific habitat requirements.

Peak flow releases range from 1,500 cfs in critically dry years to 11,000 cfs in extremely wet years. Peak flows are intended to promote natural geomorphic processes of erosion and deposition, support channel maintenance, promote formation of alternate bar sequence, control riparian vegetation, maintain spawning habitat quality by periodically mobilizing deposits and removing fine sediments, and transport/deposit sands and fines. Flow-specific examples include: peak flows of 1,500 cfs intended to prevent seedling germination on lower bar surfaces to prevent riparian encroachment; peak flows of 3,000 cfs (dry years) intended to mobilize active channel alluvial features including pool tail deposits and spawning gravel deposits; peak flows of 6,000 cfs (normal years) intended to mobilize most active channel bed surfaces and deposit fine sediments on upper bar surfaces; peak flows of 8,500 cfs (wet years) intended to scour and redeposit alternate bar surfaces, scour riparian seedlings, and promote fine sediment deposition on floodplains; and peak flows of 11,000 cfs intended to maintain side channels and deposit fine sediments on lower terrace surfaces (USFWS 2000). In addition, peak flow releases are intended to interact with restoration projects to promote scour and deposition as well as to increase hydraulic and habitat complexity.

Minimum average monthly flows in the Trinity River under the No Action Alternative would coincide with fall spawning periods (October and November). Modeled average October flow under the No Action Alternative is 375 cfs for most water year types with the exception of critically dry water years, when the modeled average October flow is 342 cfs. Modeled average November flows range from to 678 cfs during above normal water years down to 275 cfs in critically dry years and would remain at 300 cfs in all other water year types.

Coho Salmon

Habitat conditions for Coho Salmon in the Trinity River are expected to improve under the No Action Alternative compared to current conditions. Under the No Action Alternative, Trinity River flow below Lewiston Dam would continue to be managed to improve habitat conditions for anadromous fish. Seasonal flow releases in addition to water-year-specific peak flows would continue to include natural hydrograph elements that provide access to life-stage-specific habitat attributes.

Seasonal operations in the Trinity River would be expected to maintain favorable habitat elements for Coho Salmon spawning, rearing, and juvenile out-migration under the No Action Alternative compared to current conditions. Under the No Action Alternative, Trinity River flow and water temperature below Lewiston Dam would continue to be managed to improve habitat conditions for anadromous fish. Monthly average flows are typically at or above 300 cfs to maximize physical habitat for Coho Salmon spawning in November and December when the majority of spawning occurs, except in critically dry years when average monthly flows in November are expected to be 275 cfs. While there is no difference in the implementation of seasonal operations in the Trinity River between the No Action Alternative and current conditions, the continued flow conditions are likely to continue to improve habitat conditions for Coho Salmon under the No Action Alternative compared to current conditions.

Chinook Salmon (Spring-Run and Fall-Run)

Habitat conditions for Chinook Salmon in the Trinity River are expected to improve under the No Action Alternative compared to current conditions. Under the No Action Alternative, Trinity River flow below Lewiston Dam would continue to be managed to improve habitat conditions for anadromous fish. Seasonal flow releases in addition to water-year-specific peak flows would continue to include natural hydrograph elements that provide access to life-stage specific habitat attributes.

Seasonal operations in the Trinity River are expected to maintain favorable habitat elements for Spring-Run and Fall-Run Chinook Salmon spawning, rearing, and juvenile out-migration under the No Action Alternative compared to current conditions. Under the No Action Alternative, Trinity River flow and water temperature below Lewiston Dam would continue to be managed to improve habitat conditions for anadromous fish. Monthly average flows typically range from 300 cfs to 373 cfs to maximize physical habitat for Chinook Salmon spawning from September to December, except in wet years when flows in December increase to 1,192 cfs, above normal water years when flows in November increase to 678 cfs and in December when flows increase to 652 cfs, and critically dry years when average monthly flows in November decrease to 275 cfs. While there is no difference in the implementation of seasonal operations in the Trinity River between the No Action Alternative and current conditions, the continued flow conditions are likely to continue to improve habitat conditions for Chinook Salmon under the No Action Alternative compared to current conditions.

Steelhead (Winter-Run and Summer-Run)

Habitat conditions for Steelhead in the Trinity River are expected to improve under the No Action Alternative compared to current conditions. Under the No Action Alternative, Trinity River flow below Lewiston Dam would continue to be managed to improve habitat conditions for anadromous fish. Seasonal flow releases in addition to water-year-specific peak flows would continue to include natural hydrograph elements that provide access to life-stage specific habitat attributes.

Seasonal operations in the Trinity River are expected to maintain favorable habitat elements for Steelhead spawning, rearing, and juvenile out-migration under the No Action Alternative compared to current conditions. Under the No Action Alternative, Trinity River flow and water temperature below Lewiston Dam would continue to be managed to improve habitat conditions for anadromous fish. Steelhead spawning occurs from January through April in the Trinity River when monthly average flows are often around 300 cfs to maximize physical habitat for Steelhead spawning. However, in wet water year types flows are above 300 cfs throughout the Steelhead spawning season.

Green Sturgeon

No difference in the potential effects on Green Sturgeon is expected between the No Action Alternative and current conditions. Green Sturgeon distribution in the Trinity River is likely limited to the lower approximately 70 river miles by Grays Falls (Benson et al. 2007). Natural hydrograph elements included in the variable annual flow regime are expected to provide life-stage-specific habitat elements that are beneficial to Green Sturgeon populations. However, no difference in the potential effects of these hydrograph elements is expected on Green Sturgeon populations between the No Action Alternative and current conditions.

White Sturgeon

No difference in the potential effects on White Sturgeon is expected between the No Action Alternative and current conditions. White Sturgeon are uncommon in the Trinity River, and their distribution is likely limited to the lowermost reaches. Moyle et al. (2015) indicate that the Trinity River is unlikely to support a white Sturgeon population, although individuals are periodically observed (e.g., Benson et al. 2007). While natural hydrograph elements are expected to provide beneficial habitat conditions for White Sturgeon, no difference in the effects of the variable annual flow regime are expected between the No Action Alternative and current conditions.

Pacific Lamprey

Habitat conditions for Pacific Lamprey in the Trinity River are expected to improve under the No Action Alternative compared to current conditions. Under the No Action Alternative, Trinity River flow below Lewiston Dam would continue to be managed to improve habitat conditions for anadromous fish. Seasonal flow releases in addition to water-year-specific peak flows would continue to include natural hydrograph elements that promote life-stage specific habitat attributes. Under the No Action Alternative, the variable annual flow regime including peak flows is expected to maintain favorable habitat elements for Pacific Lamprey spawning, rearing, and out-migration. While there is no difference in the implementation of the variable annual flow regime between the No Action Alternative and current conditions, the synergistic effect of these flows interacting with the channel’s morphological conditions and restoration actions into the future is expected to foster a dynamic river channel and floodplain system, which is likely to improve habitat conditions for Pacific Lamprey under the No Action Alternative compared to current conditions.

American Shad

No difference in the potential effects of flow on American Shad is expected between the No Action Alternative and current conditions. American Shad occur in the lowermost reaches of the Trinity River. While natural hydrograph elements are expected to provide beneficial habitat conditions for American shad, no difference in the effects of the variable annual flow regime are expected between the No Action Alternative and current conditions.

Potential changes to aquatic resources due to variation in temperature

O.3.2.1.2 <u>Trinity Lake</u>

Trinity Lake storage is operated to maintain cold water for downstream releases and water transfers to the Sacramento River basin. Under the No Action Alternative the modeled minimum storage in Trinity Lake ranges from approximately 1,000 TAF in wet water years to just under 600 TAF in critically dry water years, based on the 40-30-30 index. Minimum reservoir storage levels occur in the fall (October or November). The effects of changes in reservoir storage conditions as they relate to water temperature can be assessed by looking at temperatures in the Trinity River downstream of Trinity Dam. Modeled monthly average water temperatures downstream of Trinity Dam range from 43.9°F to 47.1°F (Figure O.3-1). Maximum modeled temperatures range from 47.3°F in March to 58.7°F in October (Figure O.3-2).

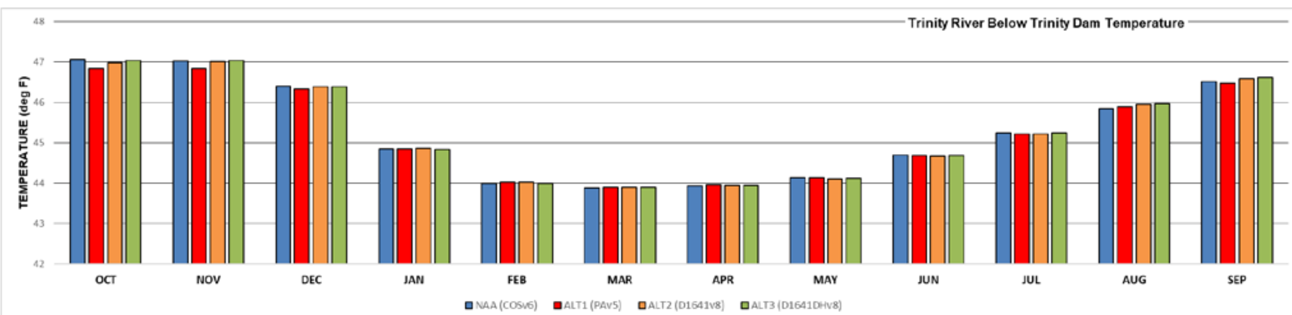


Figure O.3-1. Average Trinity River Water Temperatures below Trinity Dam for the Period October to September, Average of All Water Year Types

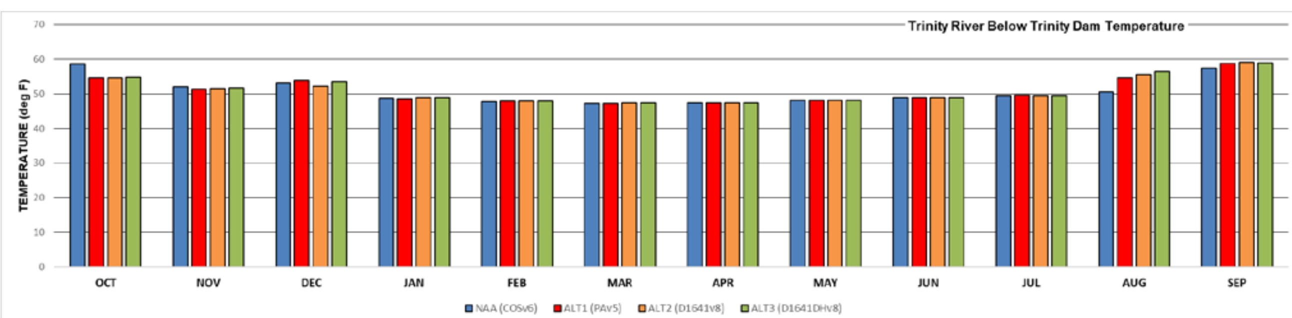


Figure O.3-2. Maximum Trinity River Water Temperatures below Trinity Dam for the Period October to September, Average of All Water Year Types

No focal fish species occur in Trinity Lake or in the Trinity River downstream of Trinity Dam. Effects of Trinity Reservoir operations on fish in the Trinity River downstream of Lewiston Dam are described below.

O.3.2.1.3 Trinity River Downstream of Lewiston Dam

Under the No Action Alternative, modeled average temperatures of water released into the Trinity River from Lewiston Dam range from 47.0°F to 52.0°F (Figure O.3-3). Modeled average temperatures are within the temperatures specified in the NCRWQCB (2018) objectives[4] for the Trinity River (Table O.3-11); however, modeled maximum temperatures would exceed the temperature objectives in July, September, and October (Figure O.3-4 and Table O.3-2). Water temperature objectives for the Trinity River are similar to the USEPA[5] (2003) suggested criteria for water temperature to support juvenile salmonid rearing (61°F) and salmonid spawning, egg incubation, and fry emergence (55°F). In the Trinity River juvenile salmonids are found in the river throughout the year while salmonid spawning generally lasts from September through April.

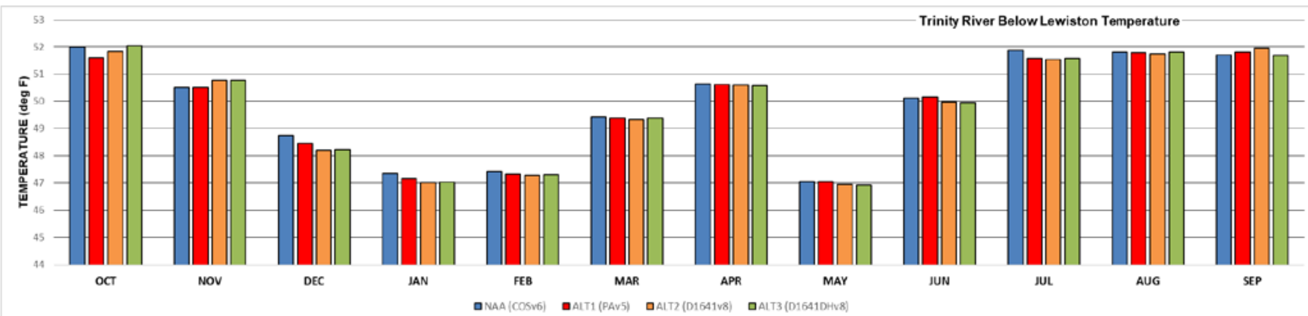


Figure O.3-3. Average Trinity River Water Temperatures below Lewiston Dam for the Period October to September, Average of All Water Year Types

Table O.3-1. Water Temperature Objectives for the First 40 Miles below Lewiston Dam

Location	Date	Daily Average Temperature Not to Exceed
Douglas City (RM 93.8)	July 1 through September 14	60°F
Douglas City (RM 93.8)	September 15 through September 30	56°F
North Fork Trinity River (RM 72.4)	October 1 through December 31	56°F

Source: NCRWQCB 2018: 3–13.

[4] The NCRWQCB (2018) uses the daily average as the metric for comparison of water temperature conditions against protective criteria for salmonid uses. While the HEC-5Q output used in this assessment is based on a monthly time step and does not provide daily water temperature predictions, maximum monthly water temperatures from HEC-5Q provide the closest available approximation to the values recommended by NCRWQCB (2018) and are therefore used herein to provide a coarse-level comparative analysis for each alternative.

[5] The USEPA (2003) recommends use of the maximum 7-day average of the daily maxima (7DADM) as the metric for comparison of water temperature conditions against protective criteria for salmonid uses. While the HEC-5Q output used in this assessment is based on a monthly time step and does not provide daily water temperature predictions, maximum monthly water temperatures from HEC-5Q provide the closest available approximation to the values recommended by USEPA (2003) and are therefore used herein to provide a coarse-level comparative analysis for each alternative.

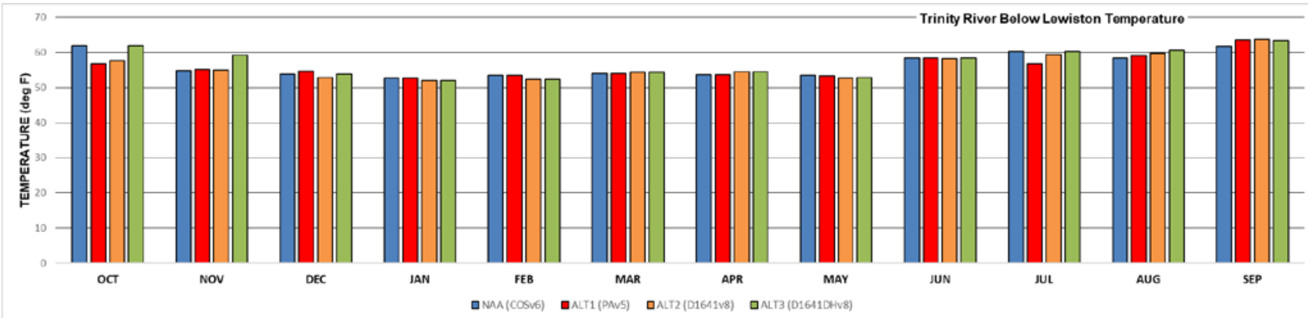


Figure O.3-4. Maximum Trinity River Water Temperatures below Lewiston Dam for the Period October to September, Average of All Water Year Types

Table O.3-2. Maximum Trinity River Water Temperatures below Trinity Dam for the Period October–September, Average of All Water Year Types (Differences >1°F Are Highlighted)

Alt	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
NAA	61.8	54.8	53.8	52.7	53.4	54.1	53.7	53.5	58.4	60.3	58.4	61.8
ALT 1	56.7	55.2	54.6	52.6	53.5	54.0	53.7	53.4	58.4	56.9	59.1	63.5
ALT 2	57.6	55.1	52.8	52.0	52.4	54.4	54.5	52.7	58.4	59.4	59.7	63.8
ALT 3	61.9	59.3	53.9	52.0	52.4	54.4	54.5	52.9	58.4	60.3	60.6	63.4

In a previous study that examined flow and water temperatures in the Trinity River, USFWS found that flows did not have a significant influence on water temperatures from mid-October through early April when cooler air temperatures help maintain cold water temperatures even if flow releases drop below 150 cfs (USFWS 1999: 192). Once tributary influence begins to decrease and meteorological conditions warm from May to mid-July, flow releases become more influential on downstream temperatures, particularly during hot and dry conditions. Maintaining a flow of 450 cfs during the summer and early fall was found to meet the water temperature objectives for the Trinity River when water released from Lewiston Dam was 53°F or less (USFWS 1999: 203). Modeled monthly flows in the Trinity River from July to October are typically equal to or greater than 450 cfs except in October when flows are reduced to maximize physical spawning habitat for salmonids.

Coho Salmon

Under the No Action Alternative, monthly average water temperatures meet the NCRWQCB (2018) objectives. The NCRWQCB (2018) uses the daily average as the metric for comparison of water temperature conditions against protective criteria for salmonid uses. While the HEC-5Q output used in this assessment is based on a monthly time step and does not provide daily water temperature predictions, maximum monthly water temperatures from HEC-5Q provide the closest available approximation to the values recommended by NCRWQCB (2018) and are therefore used herein to provide a coarse-level comparative analysis for each alternative. For the Trinity River (Table O.3-1); however, modeled maximum daily temperatures would exceed the temperature objectives in July, September, and October (Figure O.3-4 and Table O.3-2). Elevated temperatures in these months may affect juvenile Coho Salmon which rear in the Trinity River year-round. There would be no difference in the implementation of seasonal operations in the Trinity River between the No Action Alternative and current conditions. Therefore, continued implementation under the No Action Alternative would likely continue to benefit Coho Salmon by maintaining water temperature improvements seen under current conditions. While there would be no difference in the implementation of seasonal operations in the Trinity River between the No Action Alternative and current conditions, the continued temperature conditions are likely to continue to improve habitat conditions for Coho Salmon under the No Action Alternative compared to current conditions.

Chinook Salmon (Spring-Run and Fall-Run)

Under the No Action Alternative, monthly average water temperatures meet the NCRWQCB (2018) objectives or the Trinity River (Table 0.3-1); however, modeled maximum daily temperatures would exceed the temperature objectives in July, September, and October (Figure O.3-4 and Table O.3-2). Elevated temperatures in these months may affect juvenile Spring-Run Chinook Salmon which typically rear in freshwater for up to a year but are not expected to affect juvenile Fall-Run Chinook Salmon, which typically spend only a few months rearing in the Trinity River before they out-migrate. There would be no difference in the implementation of seasonal operations in the Trinity River between the No Action Alternative and current conditions. Therefore, continued implementation under the No Action Alternative would likely continue to benefit Chinook Salmon by maintaining water temperature improvements seen under current conditions.

Steelhead (Winter-Run and Summer-Run)

Under the No Action Alternative, monthly average water temperatures meet the NCRWQCB (2018) objectives for the Trinity River (Table O.3-1); however, modeled maximum daily temperatures would exceed the temperature objectives in July, September, and October (Figure O.3-4 and Table O.3-2). Elevated temperatures in these months may affect juvenile Steelhead, which rear year-round in the Trinity River for up to 3 years. There would be no difference in the implementation of seasonal operations in the Trinity River between the No Action Alternative and current conditions. Therefore, continued implementation under the No Action Alternative would likely continue to benefit Steelhead by maintaining water temperature improvements seen under current conditions. While there would be no difference in the implementation of seasonal operations in the Trinity River between the No Action Alternative and current conditions, the continued temperature conditions are likely to continue to improve habitat conditions for Steelhead under the No Action Alternative compared to current conditions.

Green Sturgeon

Model results indicate little variation in water temperature occurs under various flow releases within the lower 30 miles of the Trinity River (USFWS 1999: 201) where Green Sturgeon are primarily found. Since there would be no difference in the implementation of seasonal operations in the Trinity River between the No Action Alternative and current conditions and Green Sturgeon only occur in the lower 43 miles of the Trinity River where the influence of flow releases on temperature is limited, the implementation of seasonal operations in the Trinity River is likely to continue to support Green Sturgeon under the No Action Alternative compared to current conditions.

White Sturgeon

White Sturgeon are uncommon in the Trinity River, and their distribution is likely limited to the lowermost reaches. Moyle et al. (2015) indicate that the Trinity River is unlikely to support a White Sturgeon population, although individuals are periodically observed (e.g., Benson et al. 2007). Model results indicate little variation in water temperature occurs under various flow releases within the lower 30 miles of the Trinity River (USFWS 1999: 201), and flow releases are expected to have even less influence on water temperature in the lower Klamath River due the high volume of flow from the Klamath River mixing with water from the Trinity River. Due to their distribution being limited to the lower Trinity River and lower Klamath River, the implementation of seasonal operations in the Trinity River is not expected to alter conditions for White Sturgeon under the No Action Alternative compared to current conditions.

Pacific Lamprey

There would be no difference in the implementation of seasonal operations in the Trinity River between the No Action Alternative and current conditions. Therefore, continued implementation under the No Action Alternative would likely continue to benefit Pacific Lamprey by maintaining water temperature improvements seen under current conditions. While there would be no difference in the implementation of seasonal operations in the Trinity River between the No Action Alternative and current conditions, the continued temperature conditions are likely to continue to improve habitat conditions for Pacific Lamprey under the No Action Alternative compared to current conditions.

American Shad

No difference in the potential effects of water temperature on American Shad is expected between the No Action Alternative and current conditions.

Potential changes in fishery resources due to contributing factors not included in seasonal operations

In addition to potential effects of seasonal operations on fishery resources in the Trinity River, other potential factors that could influence future trends in anadromous fish populations in the Trinity River include future effects or continuing trends related to land use, water demand, human population growth, climate change, restoration actions, invasive or nonnative species, or fish population trends (effects from outside of the Trinity River). Of these, land use, climate change, restoration actions, nonnative species, and population trends (beyond the influence of seasonal operations) are the most likely to potentially affect future fishery resources in the Trinity River compared to current conditions.

Land use practices such as timber harvest, agriculture (including cannabis cultivation), and development, among others, may have a negative effect on anadromous fish populations in the Trinity River, with the greatest effects likely to be within tributary basins. These continuing disturbances are likely to represent a minor negative effect to future fishery resources in the Trinity River within the timeframe of this analysis (i.e., up to 2030).

Potential effects of climate change may influence future habitat conditions, however, the effects within this timeframe of this analysis (i.e., up to 2030) are likely to be minor. It is anticipated that climate change will increase the frequency of short-duration, high-magnitude rainfall events and reduce annual snowpack. It is also anticipated that annual variability in precipitation will increase, resulting in more extreme conditions (e.g., increased frequency and magnitude of flooding and drought). For unregulated rivers, reduced snowpack would shift the spring snowmelt runoff period earlier and reduce the magnitude and duration of these flows. For regulated rivers, earlier runoff and reduced snowpack could reduce reservoir storage going into summer. In combination, these factors could result in reduced flows and increased water temperatures during the summer and early fall.

Restoration actions intended to improve habitat conditions for anadromous fish are widespread. Restoration activities are occurring and ongoing on federal, state, local, tribal, and private lands within the Trinity River basin and are expected to improve habitat conditions for anadromous fish.

Nonnative Brown Trout in the Trinity River could have a negative effect on anadromous fish populations (particularly salmonids) resulting from predation on juveniles during rearing and out-migration. Studies indicate that Brown Trout can consume a substantial proportion of the juvenile salmonid outmigrants produced in the Trinity River upstream of the North Fork (Alvarez 2017).

Anadromous fish populations are influenced by habitat conditions throughout their life history. For Trinity River populations, this includes a substantial component outside the Trinity River basin, specifically the Klamath River, its estuary, and the marine environment. Conditions in the Klamath River are variable annually, with occasional high summer water temperatures and disease outbreaks known to be factors that affect salmonid populations. In addition, conditions in the marine environment are critical, and marine survival can vary widely from year to year.

Coho Salmon

Other potential effects that could influence future Trinity River Coho Salmon populations include land use, climate change, restoration actions, invasive species, and population trends. Land use and climate change may negatively affect habitat conditions for anadromous fish in the future; however, the effects leading up to 2030 are expected to be minimal compared to current conditions. Predation by nonnative Brown Trout on juvenile Coho Salmon could suppress juvenile production, but the magnitude of the potential effect is largely dependent on the abundance of large Brown Trout, and future Brown Trout population trends are uncertain. The effects of restoration actions in the Trinity River are expected to improve spawning and rearing habitat for Coho Salmon compared to current conditions. Habitat conditions in the marine environment are likely to affect Coho Salmon populations in the Trinity River; however, the possible trajectory of such an effect is unpredictable and could be positive/beneficial, negative/detrimental, or neutral. The potential changes in habitat conditions in the Klamath River are unlikely to affect Coho Salmon populations in the Trinity River compared to current conditions. Management actions to reduce water temperatures and control disease outbreaks in the lower Klamath River have been successful and are expected to continue into the future. In addition, Coho Salmon adult upstream migration typically occurs after the warmest periods when disease outbreaks are less likely.

Chinook Salmon (Spring-Run and Fall-Run)

Other potential effects that could influence future Trinity River Chinook Salmon populations include land use, climate change, restoration actions, invasive species, and population trends. Land use and climate change may negatively affect habitat conditions for anadromous fish in the future; however, the effects leading up to 2030 are expected to be relatively minor compared to current conditions. Predation by nonnative Brown Trout on juvenile Chinook Salmon could suppress juvenile production, but the magnitude of the potential effect is largely dependent on the abundance of large Brown Trout, and future Brown Trout population trends are uncertain. The effects of restoration actions in the Trinity River are expected to improve spawning and rearing habitat for Chinook Salmon compared to current conditions. Habitat conditions in the marine environment are likely to affect Chinook Salmon populations in the Trinity River; however, the possible trajectory of such an effect is unpredictable and could be positive/beneficial, negative/detrimental, or neutral. The potential changes in habitat conditions in the Klamath River are unlikely to affect Chinook Salmon populations in the Trinity River compared to current conditions. Management actions to reduce water temperatures and control disease outbreaks in the lower Klamath River have been successful and are expected to continue into the future.

Steelhead (Winter-Run and Summer-Run)

Other potential effects that could influence future Trinity River Steelhead populations include land use, climate change, restoration actions, invasive species, and population trends. Land use and climate change may negatively affect habitat conditions for anadromous fish in the future; however, the effects leading up to 2030 are expected to be relatively minor compared to current conditions. Predation by nonnative Brown Trout on juvenile Steelhead could suppress juvenile production, but the magnitude of the potential effect is largely dependent on the abundance of large Brown Trout, and future Brown Trout population trends are uncertain. The effects of restoration are expected to improve spawning and rearing habitat for Steelhead compared to current conditions. Habitat conditions in the marine environment are likely to affect Steelhead populations in the Trinity River; however, the possible trajectory of such an affect is unpredictable and could be positive/beneficial, negative/detrimental, or neutral. The potential changes in habitat conditions in the Klamath River are unlikely to affect Steelhead populations in the Trinity River compared to current conditions. Management actions to reduce water temperatures and control disease outbreaks in the lower Klamath River have been successful and are expected to continue into the future. In addition, Steelhead adult upstream migration typically occurs before (Summer-Run) or after (Winter-Run) the warmest periods when disease outbreaks are less likely.

Green Sturgeon

No difference in effects on Trinity River Green Sturgeon populations from contributing factors not included in the seasonal operations would be expected under No Action Alternative compared to current conditions.

White Sturgeon

No difference in effects on Trinity River White Sturgeon populations from contributing factors not included in seasonal operations would be expected under the No Action Alternative compared to current conditions.

Pacific Lamprey

No difference in effects on Trinity River Pacific Lamprey populations from contributing factors not included in seasonal operations would be expected under the No Action Alternative compared to current conditions.

American Shad

No difference in effects on Trinity River American Shad populations from contributing factors not included in seasonal operations would be expected under the No Action Alternative compared to current conditions.

O.3.2.1.4 Trinity River Record of Decision

The 2000 Trinity River Record of Decision (Trinity River ROD) is directed at restoring fish populations in the Trinity River that experienced significant declines after construction of the Trinity River Diversion (TRD) in the early 1960s (USDOI 2000). The Trinity River ROD documents actions intended to restore and maintain anadromous fishery resources in the Trinity River based on the best available scientific information, while continuing to provide water supplies for beneficial uses and power generation. Actions contained in the Trinity River ROD include:

- Variable annual instream flows for the Trinity River from the TRD based on forecasted hydrology for the Trinity River basin as of April 1 of each year, ranging from 369 TAF in critically dry years to 815 TAF in extremely wet years.

- Physical channel rehabilitation, including the removal of riparian berms and the establishment of side channel habitat.
- Sediment management, including the supplementation of spawning gravels below the TRD and reduction in fine sediments which degrade fish habitats.
- Watershed restoration efforts, addressing negative impacts which have resulted from land use practices in the basin.
- Infrastructure improvements or modifications, including rebuilding or fortifying bridges and addressing other structures affected by the peak instream flows provided by the Trinity River ROD.

Potential effects considered under the No Action Alternative include reasonably foreseeable consequences of actions implemented under the Trinity River ROD through 2030, whereas current conditions are defined as physical and biological conditions as they are today. In general, habitat conditions in the Trinity River are expected to improve with continued implementation of the Trinity River ROD under the No Action Alternative compared to current conditions.

The variable annual flow regime is expected to maintain habitat conditions through physical geomorphic processes (scour and deposition) and interact with previously implemented and future restoration actions. Habitat restoration including physical habitat manipulation, removal of riparian berms, and creation of side channels is expected to improve spawning and rearing habitat for anadromous fish in the mainstem Trinity River. In addition, adaptive management is expected to improve the effectiveness of flow releases and future habitat enhancements under the No Action Alternative compared to current conditions.

A review of 2005 to 2010 TRRP Phase 1 actions and the physical and biological response seen after about half of the channel restoration projects were built indicated that the program was largely successful and that a substantial amount was learned regarding meeting goals and objectives of the program (Buffington et al. 2014). The review also highlighted the importance of monitoring and adaptive management. However, the review also concluded that the Trinity River was less alluvial and less responsive than originally hypothesized, and therefore, the timescale for both geomorphic and fish population responses to restoration actions was greater than expected. In part, this was due to the low frequency of geomorphically effective flows during the implementation and monitoring period in addition to lingering effects of past land management such as mining terraces and legacy coarse bed materials. These findings indicate that benefits to anadromous fish populations from restoration actions will likely increase into the future as more in-channel restoration actions become geomorphically active and additional time is allowed for fish populations to respond. In addition, adaptive management is expected to improve the effectiveness of restoration actions implemented under the Trinity River ROD and may also improve the effectiveness of flow releases at achieving physical (geomorphic) or biological (fish habitat) goals within the constraints of the annual flow volumes and peak flow magnitudes required by the Trinity River ROD.

Potential effects of continued implementation of components of the Trinity River ROD on anadromous fish populations in the Trinity River are described in more detail below.

Potential changes to aquatic resources due to implementing variable annual flow regime under the Trinity River ROD

The variable annual flow regime for the Trinity River is determined based on the current year's hydrology as of April 1st of each year, which defines the water year type [5 types based on historic (1912–1991) percent exceedance—critically dry (>88%), dry (60% to 88%), normal (40% to 60%), wet (12% to 40%), and extremely wet (<12%)] and associated flow release volume (AF), peak flow (cfs), and peak flow duration (days) (USDOI 2000: 12). Water volumes range from 369 TAF in critically dry years to 815 TAF in extremely wet years. The flow release schedule generally coincides with the natural spring snowmelt runoff period (April to July), which is an important flow component to anadromous fish life history and life-stage-specific habitat requirements.

Peak flow releases range from 1,500 cfs in critically dry years to 11,000 cfs in extremely wet years. Peak flows are intended to promote natural geomorphic processes of erosion and deposition, support channel maintenance, promote formation of alternate bar sequence, control riparian vegetation, maintain spawning habitat quality by periodically mobilizing deposits and removing fine sediments, and transport/deposit sands and fines. Flow-specific examples include: peak flows of 1,500 cfs intended to prevent seedling germination on lower bar surfaces to prevent riparian encroachment; peak flows of 3,000 cfs (dry years) intended to mobilize active channel alluvial features including pool tail deposits and spawning gravel deposits; peak flows of 6,000 cfs (normal years) intended to mobilize most active channel bed surfaces and deposit fine sediments on upper bar surfaces; peak flows of 8,500 cfs (wet years) intended to scour and redeposit alternate bar surfaces, scour riparian seedlings, and promote fine sediment deposition on floodplains; and peak flows of 11,000 cfs intended to maintain side channels and deposit fine sediments on lower terrace surfaces (USFWS 2000). In addition, peak flow releases are intended to interact with restoration projects to promote scour and deposition as well as to increase hydraulic and habitat complexity.

Coho Salmon

Habitat conditions for Coho Salmon in the Trinity River are expected to improve under the No Action Alternative compared to current conditions. Under the No Action Alternative, Trinity River flow below Lewiston Dam would continue to be managed to improve habitat conditions for anadromous fish. Seasonal flow releases in addition to water-year-specific peak flows would continue to include natural hydrograph elements that provide access to life-stage specific habitat attributes.

Under the No Action Alternative, the variable annual flow regime including peak flows is expected to maintain favorable habitat elements for Coho Salmon spawning, rearing, and juvenile out-migration. Spawning habitat quality is expected to be maintained through periodic scour and redeposition of spawning gravel deposits, which is intended to improve incubation conditions and egg-to-emergence survival by reducing fine sediment in spawning gravels. The flow regime included in the Trinity River ROD is intended to provide juvenile Coho Salmon access to a diversity of habitats throughout the year as they grow. Relatively high flows in the spring are intended to mimic the natural snowmelt runoff hydrograph and provide access to low-velocity floodplain habitat for Coho Salmon fry and early juvenile rearing and to promote juvenile (smolt) out-migration. While there is no difference in the implementation of the variable annual flow regime between the No Action Alternative and current conditions, the synergistic effect of these flows interacting with the channel's morphological conditions and restoration actions into the future is expected to foster a dynamic river channel and floodplain system, which is likely to improve habitat conditions for Coho Salmon under the No Action Alternative compared to current conditions.

Chinook Salmon (Spring-Run and Fall-Run)

Habitat conditions for Chinook Salmon in the Trinity River are expected to improve under the No Action Alternative compared to current conditions. Under the No Action Alternative, Trinity River flow below Lewiston Dam would continue to be managed to improve habitat conditions for anadromous fish. Seasonal flow releases in addition to water-year-specific peak flows would continue to include natural hydrograph elements that provide access to life-stage specific habitat attributes.

Under the No Action Alternative, the variable annual flow regime including peak flows is expected to maintain favorable habitat elements for Chinook Salmon spawning, rearing, and juvenile out-migration. Spawning habitat quality is expected to be maintained through periodic scour and redeposition of spawning gravel deposits, which is intended to improve incubation conditions and egg-to-emergence survival by reducing fine sediment in spawning gravels. The flow regime included in the Trinity River ROD is intended to provide juvenile Chinook Salmon access to a diversity of habitats throughout the year as they grow. Relatively high flows in the spring are intended to mimic the natural snowmelt runoff hydrograph and provide access to low-velocity floodplain habitat for Chinook Salmon fry and early juvenile rearing and to promote juvenile (smolt) out-migration. While there is no difference in the implementation of the variable annual flow regime between the No Action Alternative and current conditions, the synergistic effect of these flows interacting with the channel's morphological conditions and restoration actions into the future is expected to foster a dynamic river channel and floodplain system, which is likely to improve habitat conditions for Chinook Salmon under the No Action Alternative compared to current conditions.

Steelhead (Winter-Run and Summer-Run)

Habitat conditions for Steelhead in the Trinity River are expected to improve under the No Action Alternative compared to current conditions. Under the No Action Alternative, Trinity River flow below Lewiston Dam would continue to be managed to improve habitat conditions for anadromous fish. Seasonal flow releases in addition to water-year-specific peak flows would continue to include natural hydrograph elements that provide access to life-stage specific habitat attributes.

Under the No Action Alternative, the variable annual flow regime including peak flows is expected to maintain favorable habitat elements for Steelhead spawning, rearing, and juvenile out-migration. Spawning habitat quality is expected to be maintained through periodic scour and redeposition of spawning gravel deposits, which is intended to improve incubation conditions and egg-to-emergence survival by reducing fine sediment in spawning gravels. The flow regime included in the Trinity River ROD is intended to provide juvenile Steelhead access to a diversity of habitats throughout the year as they grow. This is particularly important for Steelhead that may rear for 3 years or more in freshwater prior to smolt out-migration. Relatively high flows in the spring are intended to mimic the natural snowmelt runoff hydrograph and provide access to low-velocity floodplain habitat for Steelhead fry and to promote smolt out-migration. While there is no difference in the implementation of the variable annual flow regime between the No Action Alternative and current conditions, the synergistic effect of these flows interacting with the channel's morphological conditions and restoration actions into the future is expected to foster a dynamic river channel and floodplain system, which is likely to improve habitat conditions for Steelhead under the No Action Alternative compared to current conditions.

Green Sturgeon

No difference in potential effects on Green Sturgeon is expected between the No Action Alternative and current conditions. Green Sturgeon distribution in the Trinity River is likely limited to the lower approximately 70 river miles by Grays Falls (Benson et al. 2007). Natural hydrograph elements included in the variable annual flow regime are expected to provide life-stage-specific habitat elements that are beneficial to Green Sturgeon populations. However, no difference in potential effects of these hydrograph elements is expected on Green Sturgeon populations between the No Action Alternative and current conditions.

White Sturgeon

No difference in potential effects on White Sturgeon is expected between the No Action Alternative and current conditions. White Sturgeon are uncommon in the Trinity River and their distribution is likely limited to the lowermost reaches. Moyle et al. (2015) indicate that the Trinity River is unlikely to support a White Sturgeon population, although individuals are periodically observed (e.g., Benson et al. 2007). While natural hydrograph elements are expected to provide beneficial habitat conditions for White Sturgeon, no difference in effects of the variable annual flow regime are expected between the No Action Alternative and current conditions.

Pacific Lamprey

Habitat conditions for Pacific Lamprey in the Trinity River are expected to improve under the No Action Alternative compared to current conditions. Under the No Action Alternative, Trinity River flow below Lewiston Dam would continue to be managed to improve habitat conditions for anadromous fish. Seasonal flow releases in addition to water-year-specific peak flows would continue to include natural hydrograph elements that promote life-stage specific habitat attributes. Under the No Action Alternative, the variable annual flow regime including peak flows is expected to maintain favorable habitat elements for Pacific Lamprey spawning, rearing, and out-migration. While there is no difference in the implementation of the variable annual flow regime between the No Action Alternative and current conditions, the synergistic effect of these flows interacting with the channel's morphological conditions and restoration actions into the future is expected to foster a dynamic river channel and floodplain system, which is likely to improve habitat conditions for Pacific Lamprey under the No Action Alternative compared to current conditions.

American Shad

No difference in the potential effects on American Shad is expected between the No Action Alternative and current conditions. American Shad occur in the lowermost reaches of the Trinity River. While natural hydrograph elements are expected to provide beneficial habitat conditions for American Shad, no difference in the effects of the variable annual flow regime is expected between the No Action Alternative and current conditions.

Potential changes to aquatic resources due to implementing restoration actions under the Trinity River ROD

Mechanical channel rehabilitation includes the removal of riparian berms (44 areas), establishing side channels (3 sites), and increased flows to promote creation of alternate bar sequences. Restoration actions are focused on the approximately 40 river miles (64 kilometers) from Lewiston Dam to the North Fork Trinity River.

The sediment management program includes gravel supplementation in reaches downstream of Lewiston Dam to address the effects of reduced coarse sediment supply intercepted by upstream dams by increasing spawning gravel quantity and improving spawning gravel quality by reducing fine sediment (sand). Coarse sediment introductions are based on water year type and modeled and measured transport each year (ROD: 14).

The watershed restoration program is intended to address land use practices that contribute to degraded habitat conditions for anadromous fish in the Trinity River. Restoration actions include reducing fine sediment supply from roads through road maintenance, rehabilitation, and decommissioning on private and public lands.

The infrastructure improvement component is intended to structurally improve, relocate or otherwise address infrastructure that may be affected by implementing peak flow releases under the variable annual flow regime for the Trinity River.

Coho Salmon

Under the No Action Alternative, habitat restoration actions including mechanical channel rehabilitation, sediment management, and watershed restoration are expected to improve habitat conditions for Coho Salmon spawning and juvenile rearing compared to current conditions. Spawning gravel supplementation is intended to increase spawning habitat quantity by increasing coarse sediment supply, while upslope restoration is intended to reduce fine sediment supply to tributary and mainstem habitats, thereby improving spawning gravel quality. Channel rehabilitation actions are intended to improve habitat diversity (including hydraulic diversity) and complexity, which is expected to improve rearing habitat conditions for juvenile Coho Salmon. Restoration actions are specifically designed with the intent of improving habitat conditions for Coho Salmon. Based on the performance of Phase 1 actions, the benefits of restoration actions on Coho Salmon populations are expected to increase over time as restoration sites are exposed to flows (particularly higher flows occurring during wet and extremely wet water years) and interact with river processes and as the 40-mile restoration reach becomes a more dynamic riverine system (Buffington et al. 2014).

Chinook Salmon (Spring-Run and Fall-Run)

Under the No Action Alternative, habitat restoration actions including mechanical channel rehabilitation, sediment management, and watershed restoration are expected to improve habitat conditions for Chinook Salmon spawning and juvenile rearing compared to current conditions. Spawning gravel supplementation is intended to increase spawning habitat quantity by increasing coarse sediment supply, while upslope restoration is intended to reduce fine sediment supply to tributary and mainstem habitats, thereby improving spawning gravel quality. Channel rehabilitation actions are intended to improve habitat diversity (including hydraulic diversity) and complexity, which is expected to improve rearing habitat conditions for juvenile Chinook Salmon. Restoration actions are specifically designed with the intent of improving habitat conditions for Chinook Salmon. Based on the performance of Phase 1 actions, the benefits of restoration actions on Chinook Salmon populations are expected to increase over time as restoration sites are exposed to flows (particularly higher flows occurring during wet and extremely wet water years) and interact with river processes and as the 40-mile restoration reach becomes a more dynamic riverine system (Buffington et al. 2014).

Steelhead (Winter-Run and Summer-Run)

Under the No Action Alternative, habitat restoration actions including mechanical channel rehabilitation, sediment management, and watershed restoration are expected to improve habitat conditions for Steelhead spawning and juvenile rearing compared to current conditions. Spawning gravel supplementation is intended to increase spawning habitat quantity by increasing coarse sediment supply, while upslope restoration is intended to reduce fine sediment supply to tributary and mainstem habitats, thereby improving spawning gravel quality. Channel rehabilitation actions are intended to improve habitat diversity (including hydraulic diversity) and complexity, which is expected to improve rearing habitat conditions for juvenile Steelhead. Restoration actions are specifically designed with the intent of improving habitat conditions for Steelhead. Based on the performance of Phase 1 actions, the benefits of restoration actions on Steelhead populations are expected to increase over time as restoration sites are exposed to flows (particularly higher flows occurring during wet and extremely wet water years) and interact with river processes and as the 40-mile restoration reach becomes a more dynamic riverine system (Buffington et al. 2014).

Green Sturgeon

No difference in the potential effects of habitat restoration on Green Sturgeon is expected between the No Action Alternative and current conditions. Green Sturgeon are not expected to occur in the restoration reach, and the effects of restoration actions are not expected to affect Green Sturgeon populations in the Trinity River differently under the No Action Alternative compared to current conditions.

White Sturgeon

No difference in the potential effects of habitat restoration on White Sturgeon is expected between the No Action Alternative and current conditions. White Sturgeon are uncommon in the Trinity River and are not expected to occur in the restoration reach. The effects of restoration actions are not expected to affect White Sturgeon in the Trinity River differently under the No Action Alternative compared to current conditions.

Pacific Lamprey

Under the No Action Alternative, habitat restoration actions including mechanical channel rehabilitation, sediment management, and watershed restoration are expected to improve habitat conditions for Pacific Lamprey spawning and rearing compared to current conditions. Spawning gravel supplementation is intended to increase spawning habitat quantity by increasing coarse sediment supply. Channel rehabilitation actions are intended to improve habitat diversity (including hydraulic diversity) and complexity, which is expected to improve rearing habitat conditions for Pacific Lamprey. Based on the performance of Phase 1 actions, the benefits of restoration actions on Pacific Lamprey populations are expected to increase over time as restoration sites are exposed to flows (particularly higher flows occurring during wet and extremely wet water years) and interact with river processes and as the 40-mile restoration reach becomes a more dynamic riverine system (Buffington et al. 2014).

American Shad

No difference in the potential effects of habitat restoration on American Shad is expected between the No Action Alternative and current conditions. American Shad are not expected to occur in the restoration reach and the effects of restoration actions are not expected to affect American Shad populations in the Trinity River differently under the No Action Alternative compared to current conditions.

Potential changes to aquatic resources due to implementing monitoring and adaptive management under the Trinity River ROD

The Adaptive Environmental Assessment and Management Program is intended to monitor physical and biological effects in the Trinity River resulting from implementing the Trinity River ROD components.

Coho Salmon

The adaptive management component of the Trinity River ROD is intended to improve the effectiveness of flow management and restoration actions over time and is expected to improve habitat conditions for Coho Salmon under the No Action Alternative compared to current conditions. With continued monitoring and evaluation of the effects of flow releases and restoration actions under the Trinity River ROD, modifications in the effectiveness of these actions to improve outcomes is likely to result in increased benefits to Coho Salmon populations in the Trinity River under the No Action Alternative compared to current conditions.

Chinook Salmon (Spring-Run and Fall-Run)

The adaptive management component of the Trinity River ROD is intended to improve the effectiveness of flow management and restoration actions over time and is expected to improve habitat conditions for Chinook Salmon under the No Action Alternative compared to current conditions. With continued monitoring and evaluation of the effects of flow releases and restoration actions under the Trinity River ROD, modifications in the effectiveness of these actions to improve outcomes is likely to result in increased benefits to Chinook Salmon populations in the Trinity River under the No Action Alternative compared to current conditions.

Steelhead (Winter-Run and Summer-Run)

The adaptive management component of the Trinity River ROD is intended to improve the effectiveness of flow management and restoration actions over time and is expected to improve habitat conditions for Steelhead under the No Action Alternative compared to current conditions. With continued monitoring and evaluation of the effects of flow releases and restoration actions under the Trinity River ROD, modifications in the effectiveness of these actions to improve outcomes is likely to result in increased benefits to Steelhead populations in the Trinity River under the No Action Alternative compared to current conditions.

Green Sturgeon

No difference in the potential effects of monitoring and adaptive management on Green Sturgeon is expected between the No Action Alternative and current conditions. Green Sturgeon are not expected to occur in the restoration reach, and the potential effects of adaptively managing flows and restoration actions are not expected to affect Green Sturgeon populations in the Trinity River differently under the No Action Alternative compared to current conditions.

White Sturgeon

No difference in the potential effects of monitoring and adaptive management on White Sturgeon is expected between the No Action Alternative and current conditions. White Sturgeon are uncommon in the Trinity River and are not expected to occur in the restoration reach. The potential effects of adaptively managing flows and restoration actions are not expected to affect White Sturgeon in the Trinity River differently under the No Action Alternative compared to current conditions.

Pacific Lamprey

The adaptive management component of the Trinity River ROD is intended to improve the effectiveness of flow management and restoration actions over time and is expected to improve habitat conditions for Pacific Lamprey under the No Action Alternative compared to current conditions. With continued monitoring and evaluation of the effects of flow releases and restoration actions under the Trinity River ROD, modifications in the effectiveness of these actions to improve outcomes is likely to result in increased benefits to Pacific Lamprey populations in the Trinity River under the No Action Alternative compared to current conditions.

American Shad

No difference in the potential effects of monitoring and adaptive management on American Shad is expected between the No Action Alternative and current conditions. American Shad are not expected to occur in the restoration reach, and the potential effects of adaptively managing flows and restoration actions are not expected to affect American Shad populations in the Trinity River differently under the No Action Alternative compared to current conditions.

Potential changes to fishery resources due to other contributing factors not included in the Trinity River ROD

In addition to potential effects of the Trinity River ROD on fishery resources in the Trinity River, other potential factors that may influence future trends in anadromous fish populations in the Trinity River include future effects or continuing trends related to land use, water demand, human population growth, climate change, restoration actions, invasive or nonnative species, effects of hatcheries, or fish population trends (effects from outside of the Trinity River). Of these, land use, climate change, restoration actions (not included in the Trinity River ROD), nonnative species, and population trends (beyond the influence of the Trinity River ROD) are the most likely to potentially affect future fishery resources in the Trinity River compared to current conditions.

Land use practices such as timber harvest, agriculture (including cannabis cultivation), and development, among others, may have a negative effect on anadromous fish populations in the Trinity River, with the greatest effects likely to be within tributary basins. These continuing disturbances are likely to have a minor negative effect on future fishery resources in the Trinity River within the timeframe of this analysis (i.e., up to 2030).

The potential effects of climate change are expected to influence future habitat conditions; however, the effects within the timeframe of this analysis (i.e., up to 2030) are likely to be minor. It is anticipated that climate change will increase the frequency of short-duration, high-magnitude rainfall events and reduce annual snowpack. It is also anticipated that annual variability in precipitation will increase, resulting in more extreme conditions (e.g., increased frequency and magnitude of flooding/drought) (Swain et al. 2018). For unregulated rivers, reduced snowpack would shift the spring snowmelt runoff period earlier and reduce the magnitude and duration of these flows. For regulated rivers, earlier runoff and reduced snowpack could reduce reservoir storage going into summer. In combination, these factors may result in reduced flows and increased water temperatures during the summer and early fall. In addition, average air temperatures are expected to continue to increase in the Trinity River basin due to climate change (Cayan et al. 2012), further contributing to warmer summer water temperatures.

In addition to restoration actions being implemented under the Trinity River ROD, other restoration actions intended to improve habitat conditions for anadromous fish are widespread. Restoration activities are occurring and ongoing on federal, state, local, tribal, and private lands within the Trinity River basin and are expected to improve habitat conditions for anadromous fish.

Nonnative Brown Trout in the Trinity River may have a negative effect on anadromous fish populations (particularly salmonids) resulting from predation on juveniles during rearing and out-migration. Studies indicate that Brown Trout can consume a substantial proportion of juvenile native salmonid outmigrants produced in the Trinity River upstream of the North Fork (Alvarez 2017).

Anadromous fish populations in the Trinity River are influenced by habitat conditions throughout their life history, which for these populations includes a substantial component outside the Trinity River basin, specifically the Klamath River and its estuary, and the marine environment. Conditions in the Klamath

River are variable annually, with occasional high summer water temperatures and disease outbreaks known to be factors that can affect salmonid populations. In addition, conditions in the marine environment are critical and marine survival can vary widely from year-to-year.

Coho Salmon

Other potential factors that may influence future Coho Salmon populations in the Trinity River include land use, climate change, restoration actions, invasive species, and population trends. Land use and climate change may negatively affect habitat conditions for anadromous fish in the future; however, the effects leading up to 2030 are expected to be relatively minor compared to current conditions. Predation by nonnative Brown Trout on juvenile Coho Salmon may suppress juvenile production. However, the magnitude of the potential effect is largely dependent on the abundance of (mostly large) Brown Trout, and future trends in the Brown Trout population are uncertain. The effects of restoration actions (other than those detailed in the Trinity River ROD) under the No Action Alternative are expected to improve spawning and rearing habitat for Coho Salmon compared to current conditions. Habitat conditions in the marine environment are likely to affect Coho Salmon populations in the Trinity River; however, the possible trajectory of such an effect could be positive/beneficial, negative/detrimental, or neutral. The potential effects of habitat conditions in the Klamath River are unlikely to affect Coho Salmon populations in the Trinity River compared to current conditions. Management actions to reduce water temperatures and control disease outbreaks in the lower Klamath River have been successful and are expected to continue into the future. In addition, Coho Salmon adult upstream migration typically occurs after the warmest periods when disease outbreaks are less likely (USFWS 2000).

Chinook Salmon (Spring-Run and Fall-Run)

Other potential factors that may influence future Chinook Salmon populations in the Trinity River include land use, climate change, restoration actions, invasive species, and population trends. Land use and climate change may negatively affect habitat conditions for anadromous fish in the future; however, the effects leading up to 2030 are expected to be relatively minor compared to current conditions. Predation by nonnative Brown Trout on juvenile Chinook Salmon could suppress juvenile production. However, the magnitude of the potential effect is largely dependent on the abundance of (mostly large) Brown Trout, and future trends in the Brown Trout population are uncertain. The effects of restoration actions (other than those detailed in the Trinity River ROD) under the No Action Alternative are expected to improve spawning and rearing habitat for Chinook Salmon compared to current conditions. Habitat conditions in the marine environment are likely to affect Chinook Salmon populations in the Trinity River; however, the possible trajectory of such an effect could be positive/beneficial, negative/detrimental, or neutral. The potential effects of habitat conditions in the Klamath River are unlikely to affect Chinook Salmon populations in the Trinity River compared to current conditions. Management actions to reduce water temperatures and control disease outbreaks in the lower Klamath River have been successful and are expected to continue into the future.

Steelhead (Winter-Run and Summer-Run)

Other potential factors that may influence future Steelhead populations in the Trinity River include land use, climate change, restoration actions, invasive species, and population trends. Land use and climate change may negatively affect habitat conditions for anadromous fish in the future; however, the effects leading up to 2030 are expected to be relatively minor compared to current conditions. Predation by nonnative Brown Trout on juvenile Steelhead could suppress juvenile production. However, the magnitude of the potential effect is largely dependent on the abundance of (mostly large) Brown Trout, and future trends in the Brown Trout population are uncertain. The effects of restoration actions (other than those detailed in the Trinity River ROD) under the No Action Alternative are expected to improve spawning and rearing habitat for Steelhead compared to current conditions. Habitat conditions in the marine environment are likely to affect Coho Salmon populations in the Trinity River; however, the possible trajectory of such an effect could be positive/beneficial, negative/detrimental, or neutral. The potential effect of habitat conditions in the Klamath River is unlikely to affect Steelhead populations in the Trinity River compared to current conditions. Management actions to reduce water temperatures and control disease outbreaks in the lower Klamath River have been successful and are expected to continue into the future. In addition, Steelhead adult upstream migration typically occurs before (Summer-Run) or after (Winter-Run) the warmest periods, when disease outbreaks are less likely (USFWS 2000).

Green Sturgeon

No difference in other potential effects that would influence Green Sturgeon populations in the Trinity River into the future is expected between the No Action Alternative and current conditions.

White Sturgeon

No difference in other potential effects that would influence White Sturgeon populations in the Trinity River into the future is expected between the No Action Alternative and current conditions.

Pacific Lamprey

No difference in other potential effects that would influence Pacific Lamprey populations in the Trinity River into the future is expected between the No Action Alternative and current conditions.

American Shad

No difference in other potential effects that would influence American Shad populations in the Trinity River into the future is expected between the No Action Alternative and current conditions.

Potential changes to aquatic resources due to Trinity River flow during late summer

The Klamath LTP presented detailed model-supported evaluations of flow augmentation volumes expected to result from implementation of the Klamath LTP for different water year types (Reclamation 2016: Chapter 4).

Annual differences in flow augmentation volumes during the CalSim II period of analysis (1922 to 2003) ranged from zero to approximately 145 TAF (Reclamation 2016: 4-28). Changes in Trinity River flow below Lewiston Dam predicted to occur under implementation of the Klamath LTP are restricted to the months of August and September. CalSim II model output was used to predict monthly mean flow release values by water year type (Reclamation 2016: 4-26). Predicted increases in monthly mean flow above the typical 450 cfs summer baseflow specified by the TRRP flow schedule range from 10 cfs (2% increase) to 249 cfs (55%) cfs in August and 27 cfs (6%) to 461 cfs (115%) in September, depending on water year type (Reclamation 2016: 4-35). Flow exceedance probabilities calculated by Reclamation (2016: 7-62) indicate that, under implementation of the Klamath LTP, releases from Lewiston Dam would be, on average, at the 450 cfs base flow greater than 75% of the time. During years when late-summer augmentation flow releases are necessary, more than 50% of the releases are expected to be less than 1,000 cfs and 90% less than 1,500 cfs, with only about 5% exceeding 2,000 cfs and a maximum release of 3,800 cfs (Reclamation 2016: 7-61). Flow greater than 1,500 cfs is associated with preventative and emergency pulse flows conducted over a short time frame of 1 to 5 days (plus ramping).

Coho Salmon

The late-summer flow releases associated with the ongoing implementation of the Klamath LTP and the projected slight increase in its implementation under the No Action Alternative has potential to affect Coho Salmon populations in the Trinity River by 2030 compared with current conditions. Increased August and September flow would primarily affect rearing juveniles since most adults generally do not enter the lower Trinity River until mid-September (CDFG 2009: 22). However, increased September flow could facilitate migration of the early portion of the adult Coho Salmon run from the lower Klamath and Trinity Rivers into cooler upstream reaches and improve survival and eventual reproductive success by increasing water depth and associated cover. Increased late-summer flow may have a short-term influence on juvenile Coho Salmon rearing habitat quality and quantity in the thermally suitable reaches of the Trinity River where they over summer (primarily in the reach approximately 15 river kilometers below Lewiston Dam; NMFS 2014b: 39-6). In some locations increased flow and water surface elevation would facilitate access to high-flow side channels and alcoves associated with restoration sites (Reclamation 2016: 7-63), which may impart short term benefits in growth and survival. However, changes in water velocity associated with flow increases may also require some juvenile Coho Salmon to leave established territories in search of new low-velocity rearing habitats that the species prefers, which could expose them to increased predation by nonnative Brown Trout and other predators. Furthermore, the higher magnitude flow releases associated with preventative and emergency pulse flows may overtop berms along the river channel in some locations and increase the risk of stranding juveniles as flow returns to the baseflow (Reclamation 2016: 7-61).

Overall, flow-related effects of continued implementation of the Klamath LTP are expected to be negligible or net positive on Coho Salmon populations under the No Action Alternative compared with current conditions.

Spring-Run Chinook Salmon

Both Spring-Run Chinook Salmon adults and rearing juveniles are present in the Trinity River during August and September and therefore may be affected by increased flow from increased Klamath LTP augmentation. During these months, adults holding in deep pool habitat begin to transition to spawning habitats, primarily upstream of the North Fork Trinity River. The potential effects of increased stream flow on adult holding behavior are uncertain but are expected to be minimal. Spawning does not typically begin until mid-September, but pre-spawning and spawning behavior of some portion of the populations could be affected by flow releases during September. In years with flow augmentation releases, particularly higher magnitude flow associated with preventative and emergency pulse flows, some early-spawning Spring-Run Chinook Salmon redds could be dewatered as flow returns to the baseflow (Reclamation 2016: 7-61). Effects of Klamath LTP augmentation flows on the component of the juvenile Spring-Run Chinook Salmon population that is present during August and September (stream-type) are expected to be similar to those described for juvenile Coho Salmon—potential short-term access to additional habitats on the channel margins and floodplains, potential for stranding when flow recedes following augmentation, and vulnerability to predation during movement caused by fluctuating flow. Overall, flow-related effects of continued implementation of the Klamath LTP may be minor for Spring-Run Chinook Salmon populations under the No Action Alternative compared with current conditions.

Fall-Run Chinook Salmon

Most juvenile Fall-Run Chinook Salmon emigrate from the Trinity River prior to summer; therefore, the effects of increased stream flow associated with implementation of the Klamath LTP are expected to be limited to the adult life stage. Adult Fall-Run Chinook Salmon typically begin entering the Trinity River in August and begin spawning in October. Therefore, effects of increased stream flow in August and September are primarily during the migration and pre-spawning periods. Flow augmentation associated with the Klamath LTP was specifically designed to improve survival of adult Fall-Run Chinook Salmon in the lower Klamath River, including the Trinity River component of the run. Specifically, increasing flow during the late-summer adult migration period (1) increases water velocity, which hinders transmission of the free-swimming Ich life stage; (2) increases wetted channel area and pool depths, decreasing fish densities; and (3) cues migration of fish out of the lower Klamath River into upstream reaches in the Klamath and Trinity Rivers, improving survival and further decreasing densities. Additionally, as described below, increased flow releases from Lewiston Dam often reduce lower Klamath River water temperatures in the late summer, thereby improving migration conditions, reducing stress, and slowing the development of Ich and other pathogens (Reclamation 2016: 7-68). For this reason, increased summer flow associated with continued implementation of the Klamath LTP under the No Action Alternative is expected to have considerable, positive effects on the Fall-Run Chinook Salmon population in the Trinity River compared with current conditions.

Steelhead

Increased August and September stream flow associated with implementation of the Klamath LTP has potential to affect both migrating adult, half-pounder, and rearing juvenile Steelhead in the Trinity River. A portion of both the Summer-Run and Fall-Run components of the adult Steelhead population are either holding or migrating upstream in the Trinity River in August and September. Increased flow is expected to facilitate migration from the lower Klamath and Trinity Rivers into reaches further upstream and to improve adult survival by providing more water depth and cover. The half-pounder life history variant (Steelhead that return to freshwater after only 2 to 4 months at sea, overwinter in freshwater, and return to the ocean the following spring) may also benefit from increased flow in the lower Klamath River due to improved migration and feeding habitats associated with increased water velocity and depths. Potential effects of Klamath LTP augmentation flows on juvenile Steelhead include short-term access to additional habitats on the channel margins and floodplains, potential for stranding when flow recedes following augmentation, and vulnerability to predation during movement caused by fluctuating flows. Overall, increased late-summer flow associated with continued implementation of the Klamath LTP under the No Action Alternative is expected to have moderate, positive effects on the Steelhead population in the Trinity River compared with current conditions.

Green Sturgeon

Both post-spawn adult and juvenile Green Sturgeon can be present in the Trinity River during the late summer and therefore may be affected by increased August and September stream flow associated with implementation of the Klamath LTP. Under natural hydrological conditions, post-spawn Green Sturgeon that are holding in the Trinity River typically leave the river system when cued by increased stream flow in the fall; thus August and September augmentation flows, particularly higher magnitude flow associated with preventative and emergency pulse flow releases, have the potential to initiate this behavior earlier than it would otherwise occur. The potential survival and fitness consequences of early adult movement are unknown and likely depend on conditions (e.g., food availability and predation pressure) in the lower Klamath River, estuary, and ocean in late-summer compared with the fall. For example, a commercial and subsistence Salmon gill net fishery in the lower Trinity and Klamath river occurs to varying degrees in August and September (depending on annual quotas), and early migrating Green Sturgeon could be susceptible to capture. Juvenile Green Sturgeon begin to out-migrate from the Trinity River during their first summer, so late-summer augmentation flows have potential to improve their survival during this period. Overall, increased late-summer flow associated with continued implementation of the Klamath

LTP under the No Action Alternative is expected to have negligible effects on the Green Sturgeon population in the Trinity River compared with current conditions.

White Sturgeon

White Sturgeon are considered to be extremely rare in the Trinity River; therefore, implementation of the Klamath LTP under the No Action Alternative is unlikely to affect the White Sturgeon population in the Trinity River compared with current conditions.

Pacific Lamprey

During August and September augmentation flows, Pacific Lamprey holding adults and ammocoetes are present in the mainstem Trinity River. Following migration into freshwater from the ocean in the winter and spring and prior to spawning the subsequent spring, adult lampreys generally hold in protected areas associated with large cobble or boulder substrates or bedrock crevices (Starcevich et al. 2013). Effects of increases in late-summer stream flow on holding lampreys are not known but are expected to be minimal. Increased water velocities associated with late-summer augmentation flows, particularly the higher pulse flows, may disturb fine sediment ammocoete rearing habitats in portions of the summer baseflow channel. It is expected that some ammocoetes will redistribute to other areas of suitable habitat in response to these flows. During this redistribution, ammocoetes may be vulnerable to increased predation from nonnative Brown Trout and other predators. Additionally, as with juvenile salmonids, ammocoetes that move to rearing habitats on the high flow floodplain may become stranded when flow recedes. Overall, effects of increased flow on the Trinity River Pacific Lamprey population due to implementation of the Klamath LTP are expected to be minimal, with little to no difference between current conditions and the No Action Alternative.

American Shad

The nonnative anadromous American Shad is only present in the lower portion of the Trinity River during the summer, so late-summer augmentation flows are expected to have negligible effects on the Trinity River American Shad population, with no difference between current conditions and the No Action Alternative.

Potential changes to aquatic resources due to Trinity River water temperatures

Overall, implementation of the Klamath LTP was predicted to have a relatively minor effect on Trinity River water temperature at the below Lewiston Dam and Douglas City sites across all water year types and months, except in July of critically dry years when water temperatures are predicted to be 2.4°F to 2.7°F (4% to 5%) warmer at these sites, respectively (Reclamation 2016: 5-36). At sites further downstream (North Fork Trinity River, South Fork Trinity River, and Weitchpec), implementation of Klamath LTP flows results in minor predicted differences in temperature for all year types and months (less than +/-1°F) with the exception of (1) normal, dry, and critically dry year types in August and September when water temperatures were consistently cooler by up to 6.6°F (compared with not implementing the Klamath LTP) due to increased flow associated with augmentation releases; and (2) critically dry years in July when water temperatures are predicted to be 1.7°F warmer at the North Fork Trinity River site and 0.6°F to 0.7°F warmer at the South Fork Trinity River and Weitchpec sites (Reclamation 2016: 5-38).

Coho Salmon

Continued implementation of the Klamath LTP under the No Action Alternative and the associated effects on water temperatures are not expected to affect adult Coho Salmon (which generally do not enter the Trinity River until late summer or early fall) and have relatively little effect on juvenile Coho Salmon rearing in the Trinity River. Juvenile Coho Salmon are not generally expected to rear in the mainstem reaches downstream of Douglas City (NMFS 2014a). Although water temperature is predicted to increases in July at the Douglas City and below Lewiston Dam sites during critically dry years, water temperatures at these sites are still predicted to be at a level suitable for Coho Salmon rearing (Reclamation 2016: 5-37). The minor decrease in water temperatures predicted to occur during August and September in the reaches of the Trinity River where Coho Salmon typically rear may allow for a slight increase in the extent of thermally suitable habitat. Overall, water temperature changes associated with continued implementation of the Klamath LTP under the No Action Alternative are expected to have negligible effects on the Coho Salmon population in the Trinity River compared with current conditions.

Spring-Run Chinook Salmon

Both Spring-Run Chinook Salmon adults and rearing juveniles are present in the Trinity River during August and September and therefore may be affected by changes in late-summer water temperatures associated with Klamath LTP augmentation flows. During these months, adults holding in deep pool habitat begin to transition to spawning habitats, primarily upstream of the North Fork Trinity River. The effects of the relatively small decreases in late-summer water temperatures in the reach where most fish are holding are expected to be relatively small but positive. Spawning does not typically begin until mid-September, but some portion of pre-spawning and spawning adults could be positively affected by decreased water temperatures due to reduced stress. Effects of Klamath LTP augmentation flows on the component of the juvenile Spring-Run Chinook Salmon population that is present during August and September (stream-type) are expected to be similar to those described for juvenile Coho Salmon. Overall, temperature effects of continued implementation of the Klamath LTP may be minor for Spring-Run Chinook Salmon populations under the No Action Alternative compared with current conditions.

Fall-Run Chinook Salmon

Most juvenile Fall-Run Chinook Salmon emigrate from the Trinity River prior to summer, so the effects of increased stream flow associated with the Klamath LTP are expected to be limited to the adult life stage. Adult Fall-Run Chinook Salmon typically begin entering the Trinity River in August and begin spawning in October. Therefore, effects of August and September augmentation flows and associated changes in water temperature occur primarily during the migration and pre-spawning periods. Flow augmentation associated with the Klamath LTP was specifically designed to improve survival of adult Fall-Run Chinook Salmon in the lower Klamath River, including the Trinity River component of the run. Decreased late-summer water temperatures throughout the lower Trinity River are expected to reduce stress, improve migration conditions, reduce the thermal risk factors contributing to the potential for and severity of Ich infections, and promote migration of staging adults by reducing the number of days when daily average temperatures exceeds the level through to present a thermal migration barrier (73.4°F, Strange 2012: 1629). For these reasons, temperature reductions associated with continued implementation of the Klamath LTP under the No Action Alternative are expected to have considerable, positive effects on the Fall-Run Chinook Salmon population in the Trinity River compared with current conditions.

Steelhead

Effects of reduced August and September water temperatures associated with the Klamath LTP have potential to positively affect both migrating adult, half-pounder, and rearing juvenile Steelhead in the Trinity River, particularly in normal, dry, and critically dry water year types. Both adult and half-pounder Steelhead are present throughout the Trinity River in late-summer, and decreased water temperatures are expected to reduce stress, improve migration conditions, and reduce risk of disease transmission. Juvenile Steelhead are also present in the Trinity River during the late-summer and therefore may be affected by lowered water temperatures due to reduced stress and an expansion of the extent of thermally suitable habitat. Overall, reduced water temperatures associated with continued implementation of the Klamath LTP under the No Action Alternative are expected to have moderate, positive effects on the Steelhead population in the Trinity River compared with current conditions.

Green Sturgeon

Both post-spawn adult and juvenile Green Sturgeon can be present in the Trinity River during the late summer and therefore may be affected by water temperature changes associated with Klamath LTP flow augmentation. Effects of predicted water temperature changes on Green Sturgeon are uncertain but are expected to be similar to those described for anadromous salmonids. Overall, decreased late-summer water temperatures associated with continued implementation of the Klamath LTP under the No Action Alternative are expected to have relatively minimal, but positive effects on the Trinity River Green Sturgeon population compared with current conditions.

White Sturgeon

White Sturgeon are considered to be extremely rare in the Trinity River, so implementation of the Klamath LTP under the No Action Alternative is unlikely to affect the Trinity River White Sturgeon population compared with current conditions.

Pacific Lamprey

The temperature requirements and preferences of Pacific Lamprey overlap those of the anadromous salmonid species, but lamprey are generally more tolerant of warmer water temperatures during the freshwater and reproductive life stages (Moyle 2002). However, the relatively large decreases in water temperatures predicted for sites downstream of the North Fork Trinity River during normal, dry, and critically dry year types in August and September are expected to have overall positive effects on Pacific Lamprey, particularly in the downstream-most reaches where water temperatures approach values that are stressful to the species. Overall, water temperatures changes associated with continued implementation of the Klamath LTP under the No Action Alternative are expected to have minor effects on the Pacific Lamprey population in the Trinity River compared with current conditions.

American Shad

The nonnative anadromous American Shad is only present in the lower portions of the Trinity River during the summer, so water temperature changes associated with late-summer augmentation flows are expected to have negligible effects on the American Shad population in the Trinity River, with no difference between current conditions and the No Action Alternative.

O.3.2.1.5 Grass Valley Creek Flows from Buckhorn Dam

Under the No Action Alternative, fish habitat conditions in 2030 have the potential to differ from current conditions in Grass Valley Creek (GVC) primarily due to climate change, the influence of past and ongoing habitat restoration programs in the watershed, and the decreasing storage capacity of Buckhorn Reservoir (Swain et al. 2018: 1). Because of the relatively short timeframe, climate change is anticipated to have relatively minimal effects on habitat conditions relative to current conditions over the 10-year period leading up to 2030. In general, however, and over a longer timeframe, it is anticipated that climate change will result in more extreme conditions (e.g., increasing the frequency and magnitude of flooding and drought), which could negatively affect fish species using streams as migration corridors, over-summering locations, and spawning grounds.

Extensive restoration of logging roads and revegetation of hillslopes and riparian corridors have occurred in an effort to repair a history of poor logging practice in the GVC watershed. The effects of restoration have not been quantified but may become more evident by 2030 as vegetation matures, land use practices improve, and restoration actions decrease sedimentation and erosion in the watershed. Furthermore, decreases in fine sediment in GVC due to restoration efforts have the potential to improve spawning habitat conditions and increase egg-to-emergence survival of salmonids not only in GVC but also in the Trinity River.

Another potential source for a change in habitat conditions is the decreasing storage capacity of Buckhorn Reservoir. Buckhorn Reservoir was constructed in 1991 and is projected to have a useful life of 40 to 50 years (Reclamation 1986). Decreasing storage capacity through 2030 combined with extreme dry periods may result in elevated reservoir water temperatures which in turn may affect fish habitat downstream in Grass Valley Creek.

Potential changes to aquatic resources due to climate change in Grass Valley Creek

Coho Salmon

If predicted climate trends are accurate, the effects of increasingly extreme conditions could negatively affect Coho Salmon populations in GVC leading up to 2030 compared to current conditions. Extremely dry conditions causing particularly low stream flows could limit adult migration and increase water temperature to stressful or lethal levels during summer rearing. Conversely, extremely wet conditions causing particularly high stream flows (magnitude and duration) could displace overwintering juveniles and scour redds. Compared with current conditions, an increase in the occurrence of extreme dry-to-wet precipitation events may negatively affect populations of Coho Salmon in GVC.

Chinook Salmon (Spring-Run and Fall-Run)

If climate predictions are accurate, Chinook Salmon in 2030 will experience the effects of an increase in extreme dry-to-wet precipitation events. Extreme low flow conditions limit migration of adults, whereas extreme high flow conditions have the potential to displace juveniles and scour redds. Compared with current conditions, an increase in the occurrence of extreme dry-to-wet precipitation events may negatively affect populations of Chinook Salmon in GVC.

Steelhead (Winter-Run and Summer-Run)

If climate predictions are accurate, Steelhead in 2030 will experience the effects of an increase in extreme dry-to-wet precipitation events. Extreme low flow conditions limit migration of adults and have the potential to create dangerous temperature conditions for over-summering juveniles. Extreme high flow conditions have the potential to displace juveniles and scour redds. Compared with current conditions, an increase in the occurrence of extreme dry-to-wet precipitation events may negatively affect populations of Steelhead in GVC.

Pacific Lamprey

If climate predictions are accurate, Pacific Lamprey in 2030 will experience the effects of an increase in extreme dry-to-wet precipitation events. Extreme low flow conditions have the potential to create dangerous temperature conditions for over-summering ammocoetes. Extreme high flow conditions have the potential to displace ammocoetes and scour redds. Compared with current conditions, an increase in the occurrence of extreme dry-to-wet precipitation events may negatively affect populations of Pacific Lamprey in GVC.

Potential changes to aquatic resources due to past and ongoing restoration in Grass Valley Creek

Coho Salmon

Past and ongoing restoration of logging roads and revegetation of hillslopes and riparian corridors are anticipated to increasingly benefit Coho Salmon through 2030. The erosion of decomposed granite in the GVC watershed may be slowed with the maturation of revegetation projects and a reduction of practices known to contribute to erosion and sedimentation in the basin (e.g., logging). A decrease in erosion may have beneficial effects on Coho Salmon egg survival in GVC, given sedimentation can deprive eggs of the oxygen needed for survival. Compared with current conditions, past and continued restoration in the watershed may positively affect Coho Salmon populations in GVC.

Chinook Salmon (Spring-Run and Fall-Run)

Past and ongoing restoration of logging roads and revegetation of hillslopes and riparian corridors are anticipated to increasingly benefit Chinook Salmon through 2030. The erosion of decomposed granite in the GVC watershed may be slowed with the maturation of revegetation projects and restrictions of practices known to increase erosion (e.g., logging). A decrease in erosion may have beneficial effects on egg survival in GVC and the Trinity River, given sedimentation deprives eggs of the oxygen needed for survival. Compared with current conditions, past and continued restoration in the watershed may positively affect populations of Chinook Salmon in GVC.

Steelhead (Winter-Run and Summer-Run)

Past and ongoing restoration of logging roads and revegetation of hillslopes and riparian corridors are anticipated to increasingly benefit Steelhead through 2030. The erosion of decomposed granite in the GVC watershed may be slowed with the maturation of revegetation projects and restrictions of practices known to increase erosion (e.g., logging). A decrease in erosion may have beneficial effects on egg survival in GVC, given sedimentation deprives eggs of the oxygen needed for survival. Compared with current conditions, past and continued restoration in the watershed may positively affect populations of Steelhead in GVC.

Pacific Lamprey

Past and ongoing restoration of logging roads and revegetation of hillslopes and riparian corridors are anticipated to increasingly benefit Pacific Lamprey through 2030. The erosion of decomposed granite in the GVC watershed may be slowed with the maturation of revegetation projects and restrictions of practices known to increase erosion (e.g., logging). A decrease in erosion may have beneficial effects on egg survival in GVC, given sedimentation deprives eggs of the oxygen needed for survival. Compared with current conditions, past and continued restoration in the watershed may positively affect populations of Pacific Lamprey in GVC.

Potential changes to aquatic resources from the decreasing storage capacity of Buckhorn Reservoir on Grass Valley Creek

Coho Salmon

In 2030 Buckhorn Reservoir will be entering its 39^{th} year of a predicted lifespan of 40 to 50 years. Decreased storage capacity in Buckhorn Reservoir has the potential to increase water temperatures, negatively affecting juvenile Coho Salmon over-summering in GVC. Compared with current conditions, increased water temperatures resulting from decreased storage capacity may negatively affect populations of Coho Salmon in GVC.

Chinook Salmon (Spring-Run and Fall-Run)

In 2030 Buckhorn Reservoir will be entering its 39^{th} year of a predicted lifespan of 40 to 50 years. Decreased storage capacity in Buckhorn Reservoir has the potential to increase water temperatures in GVC. However, compared with current conditions, increased water temperatures resulting from decreased storage capacity will have minimal effects on populations of Chinook Salmon in GVC.

Steelhead (Winter-Run and Summer-Run)

In 2030 Buckhorn Reservoir will be entering its 39^{th} year of a predicted lifespan of 40 to 50 years. Decreased storage capacity in Buckhorn Reservoir has the potential to increase water temperatures, negatively affecting juvenile Steelhead over-summering in GVC. Compared with current conditions, increased water temperatures resulting from decreased storage capacity may negatively affect populations of Steelhead in GVC.

Pacific Lamprey

In 2030 Buckhorn Reservoir will be entering its 39^{th} year of a predicted lifespan of 40 to 50 years. Decreased storage capacity has the potential to increase water temperatures, negatively affecting Pacific Lamprey ammocoetes over-summering in GVC. Compared with current conditions, increased water temperatures resulting from decreased storage capacity may negatively affect populations of Pacific Lamprey ammocoetes in GVC.

O.3.2.2 *Sacramento River*

Potential changes to aquatic resources from adult rescue activities

The Yolo and Sutter bypasses play a vital role in flood protection in the Sacramento area. The Sacramento River Flood Control Project, a system of flood-relief structures and weirs that release Sacramento River and Feather River flows into the bypass, was developed by the Central Valley Flood Protection Board and the U.S. Army Corps of Engineers (USACE) to prevent flood damage (Nguyen 2017). The Yolo and Sutter bypasses inundate when high flow events exceed downstream channel capacity during large floods. Flooded bypasses are a benefit for juvenile Salmon that are washed downstream into the productive habitats of the Yolo Bypass; juvenile Salmon experience increased growth rates in the bypass compared to river channels (Nguyen 2017).

Climate change, which is predicted to bring physical change to ocean, river, and stream environments, is expected to result in additional changes that may affect anadromous fishes, including: diminished snow pack, altered stream flow volume and timing, stream temperature changes, and altered marine and freshwater food-chain dynamics. More intense storms or a shift in precipitation from snow to rain may alter the volume and timing of stream flows such that the timing, frequency, and duration of flooding in the Yolo and Sutter bypasses may also be altered. Compared to current conditions, these factors have potential to result in adverse effects on Sacramento Winter-Run Chinook Salmon, Central Valley Fall-Run/Late Fall-Run Chinook Salmon, Central Valley Spring-Run Chinook Salmon, California Central Valley Steelhead, and Southern DPS North American Green Sturgeon through the 2030 implementation period.

O.3.2.2.1 Winter-Run Chinook Salmon

Sacramento Winter-Run Chinook Salmon were listed as an endangered species in 1994 (59 FR 440) due to their continued decline and an increased variability in run sizes since first being listed as threatened in 1989, the expectation of weak returns in future years, and continued threats, including habitat loss and degradation, overharvest, disease and predation, and threats to genetic integrity and fitness due to hatchery programs (NMFS 2014c). Since the 1960s, Winter-Run Chinook Salmon populations have declined from an escapement of approximately 100,000 to fewer than 200 in the early 1900s. Populations rebounded slightly, with a three-year average of 13,700 from 2004 to 2006, but decreased again to under 3,000 in 2009 (NMFS 2014c). Spawning habitat is likely limited to the Sacramento River between the Keswick Dam and Red Bluff Diversion Dam.

When the Yolo and Sutter bypasses are flooded, adult Winter-Run Chinook Salmon have the potential to stray into the bypasses during their upstream migration and may become stranded when hydrologic connectivity within the bypass is lost. Currently, rescue and upstream relocation of these stranded adults does not occur. Adults that are stranded in the bypasses during their upstream migration will not be able to spawn, limiting the number of juvenile outmigrants, which would have adverse effects on the population as a whole. This will continue to be the case through 2030 under the No Action Alternative. Without implementation of adult rescue and associated benefits under the No Action Alternative, Winter-Run Chinook would continue to be exposed to the adverse effects of stranding through the 2030 implementation period.

An increased frequency of flooding of the Yolo and Sutter bypasses through 2030 is possible under current climate change predictions. If this were to occur, more Winter-Run Chinook adults may become stranded in the bypasses. Under the No Action Alternative, these adults would not be rescued, adversely affecting the population relative to current conditions.

O.3.2.2.2 Spring-Run Chinook Salmon

Central Valley Spring-Run Chinook Salmon were listed as threatened in 1999 (64 FR 50394), and this status was reaffirmed in 2005 (70 FR 37160). Historically, Spring-Run Chinook Salmon were present in the headwaters of all major rivers in the Central Valley absent of natural barriers to migration. Currently the only streams in which non-hybridized Spring-Run Chinook Salmon are supported are Mill, Deer, and Butte Creeks, all tributaries to the Sacramento River (NMFS 2014c). Between the 1880s and 1940s, the Central Valley supported runs as large as 600,000. Since, Spring-Run Chinook Salmon have experienced significant population declines, with run sizes fluctuating between 3,000 and 30,000 from 1970 through 2012 (NMFS 2014c). Primary threats to Spring-Run Chinook include the loss of historic spawning habitat, degradation of remaining habitat, and genetic mixing with hatchery populations from the Feather River Fish Hatchery (NMFS 2014c).

When the Yolo and Sutter bypasses are flooded, adult Spring-Run Chinook Salmon have the potential to stray into the bypasses during their upstream migration and may become stranded when hydrologic connectivity within the bypass is lost. Currently, rescue and upstream relocation of these stranded adults does not occur. Adults that are stranded in the bypasses during their upstream migration will not be able to spawn, limiting the number of juvenile outmigrants, which would have adverse effects on the population as a whole. This will continue to be the case through 2030 under the No Action Alternative. Without implementation of adult rescue and associated benefits under the No Action Alternative, Spring-Run Chinook would continue to be exposed to the adverse effects of stranding through the 2030 implementation period.

An increased frequency of flooding of the Yolo and Sutter bypasses through 2030 is possible under current climate change predictions. If this were to occur, more Spring-Run Chinook adults may become stranded in the bypasses. Under the No Action Alternative, these adults would not be rescued, adversely affecting the population relative to current conditions.

O.3.2.2.3 Fall- /Late Fall-Run Chinook Salmon

Central Valley Fall- /Late Fall-Run Chinook Salmon are a California Fish Species of Special Concern. Fall- /Late Fall-Run Chinook have been extirpated from a majority of their native spawning habitat upstream of Shasta Dam; most spawning currently occurs in the Sacramento River with a lesser amount in tributary streams. The runs are of concern because they depend greatly on hatchery production, which has genetic and ecological impacts including homogenized populations with reduced life history variability (Moyle et al. 2017). Fall- /Late Fall-Run Chinook historically spawned in all the major rivers of the Central Valley; today spawning occurs only as far upstream as the first impassable dams, which block an estimated 70% of historical spawning habitat (Yoshiyama et al. 2001). Fall-Run Chinook Salmon had an average return of 250,000 adult fish with an additional 375,000 harvested in commercial and recreational fisheries from 1967 to 1991, which dropped to 71,000 in 2008 and 53,000 in 2009, when the ocean fisheries remained closed. Escapement rebounded to 342,000 fish in 2012 (CDFW GrandTab 2011).

When the Yolo and Sutter bypasses are flooded, adult Fall- /Late Fall-Run Chinook Salmon have the potential to stray into the bypasses during their upstream migration and may become stranded when hydrologic connectivity within the bypass is lost. Currently, rescue and upstream relocation of these stranded adults does not occur. Adults that are stranded in the bypasses during their upstream migration will not be able to spawn, limiting the number of juvenile outmigrants, which, compounded by genetic threats to the ESU from hatchery reared fish and loss of historical habitat, would have adverse effects on the population as a whole through the 2030 implementation period.

An increased frequency of flooding of the Yolo and Sutter bypasses through 2030 is possible under current climate change predictions. If this were to occur, more Fall- /Late Fall-Run Chinook adults may become stranded in the bypasses. Under the No Action Alternative, these adults would not be rescued, adversely affecting the population relative to current conditions.

O.3.2.2.4 California Central Valley Steelhead

NMFS proposed that California Central Valley Steelhead be listed as endangered in 1996, concluding that the ESU was in danger of extinction due to habitat degradation, blockage of freshwater habitats, water allocation problems, genetic mixing with hatchery raised Steelhead, and extirpation from most of their historic range (NMFS 2014a). However, in 1998 NMFS determined that the risks to the ESU had diminished since 1996 and listed Central Valley Steelhead as threatened (63 FR 13347). Historically, Central Valley Steelhead were distributed throughout the Sacramento and San Joaquin Rivers, with at least 81 independent populations. Currently, 80% of all historical spawning habitat and 38% of historical spawning habitat are blocked by impassible dams (NMFS 2014a). The Central Valley Steelhead 5-year status review determined that, despite increased returns at several hatcheries in the Central Valley and increased percentages of wild Steelhead salvage at south Delta fish facilities, natural production of Steelhead throughout the Central Valley remained at very low levels and that the DPS was still in danger of extinction (NMFS 2016b).

When the Yolo and Sutter bypasses are flooded, adult Central Valley Steelhead have the potential to stray into the bypasses during their upstream migration and may become stranded when hydrologic connectivity within the bypass is lost. Currently, rescue and upstream relocation of these stranded adults does not occur. Adults that are stranded in the bypasses during their upstream migration will not be able to spawn, limiting the number of juvenile outmigrants, which, compounded by genetic threats to the ESU from hatchery reared fish and loss of historical habitat, would have adverse effects on the population as a whole. This will continue to be the case through 2030 under the No Action Alternative. Without implementation of adult rescue and associated benefits under the No Action Alternative, Central Valley Steelhead would continue to be exposed to the adverse effects of stranding through the 2030 implementation period. An increased frequency of flooding of the Yolo and Sutter bypasses through 2030 is possible under current climate change predictions. If this were to occur, more Central Valley Steelhead adults may become stranded in the bypasses. Under the No Action Alternative, these adults would not be rescued, adversely affecting the population relative to current conditions.

O.3.2.2.5 Green Sturgeon

Southern DPS North American Green Sturgeon were listed as threated under the federal ESA in 2006 (NMFS 2006). In the ruling, NMFS concluded that, while the DPS was not presently in danger of extinction, they were likely to become endangered in the foreseeable future due to the existence of only one spawning population (in the Sacramento River), substantial loss of spawning habitat in the upper Sacramento and Feather Rivers, mounting threats to habitat quality in the Sacramento River and Delta ecosystems, and salvage data indicating a decrease in the number of juveniles collected from 1968 and 2001 (NMFS 2006).

When the Yolo and Sutter bypasses are flooded, adult Green Sturgeon have the potential to stray into the bypasses during their upstream migration and may become stranded when hydrologic connectivity within the bypass is lost. Currently, rescue and upstream relocation of these stranded adults does not occur. Adults that are stranded in the bypasses during their upstream migration will not be able to spawn, which would have adverse effects on the population as a whole. This will continue to be the case through 2030 under the No Action Alternative. Without implementation of adult rescue and associated benefits under the No Action Alternative, Green Sturgeon would continue to be exposed to the adverse effects of stranding through the 2030 implementation period.

An increased frequency of flooding of the Yolo and Sutter bypasses through 2030 is possible under current climate change predictions. If this were to occur, more Green Sturgeon adults may become stranded in the bypasses. Under the No Action Alternative, these adults would not be rescued, adversely affecting the population relative to current conditions.

Potential changes to aquatic resources from trap and haul activities

O.3.2.2.6 Winter-Run Chinook Salmon

Sacramento Winter-Run Chinook Salmon were listed as an endangered species in 1994 (59 FR 440) due to their continued decline and an increased variability of run sizes since first being listed as threatened in 1989, the expectation of weak returns in future years, and continued threats, including habitat loss and degradation, overharvest, disease and predation, and threats to genetic integrity and fitness due to hatchery programs (NMFS 2014c). Since the 1960s, Winter-Run Chinook Salmon populations have declined from an escapement of approximately 1000,000 to fewer than 200 in the early 1900s. Populations rebounded slightly, with a three-year average of 13,700 from 2004 to 2006, but decreased again to under 3,000 in 2009 (NMFS 2014c). Spawning habitat is likely limited to the Sacramento River between the Keswick Dam and Red Bluff Diversion Dam.

Altered volume and timing of stream flows in addition to warmer stream temperatures resulting from warmer ambient air temperatures are possible effects of climate change that may result in stream conditions unsuitable for volitional downstream migration and survival. Under current conditions, there is no trap and haul strategy for juvenile Winter-Run Chinook Salmon. This will continue to be the case in 2030 under the No Action Alternative. Without implementation of juvenile trap and haul and associated benefits under the No Action Alternative, juvenile Winter-Run Chinook would be exposed to the potential adverse effects of low flows and elevated water temperatures leading to unsuccessful out-migration through the 2030 implementation period.

O.3.2.2.7 Spring-Run Chinook Salmon

Central Valley Spring-Run Chinook Salmon were listed as threatened in 1999 (64 FR 50394), and this status was reaffirmed in 2005 (70 FR 37160). Historically, Spring-Run Chinook Salmon were present in the headwaters of all major rivers in the Central Valley absent of natural barriers to migration. Currently the only streams in which non-hybridized Spring-Run Chinook Salmon are supported are Mill, Deer, and Butte Creeks, all tributaries to the Sacramento River (NMFS 2014c). Between the 1880s and 1940s, the Central Valley supported runs as large as 600,000. Since, Spring-Run Chinook Salmon have experienced significant population declines, with run sizes fluctuating between 3,000 and 30,000 from 1970 through 2012 (NMFS 2014c). Primary threats to Spring-Run Chinook include the loss of historic spawning habitat, degradation of remaining habitat, and genetic mixing with hatchery populations from the Feather River Fish Hatchery (NMFS 2014c).

Altered volume and timing of stream flows in addition to warmer stream temperatures resulting from warmer ambient air temperatures are possible effects of climate change that may result in stream conditions unsuitable for volitional downstream migration and survival. Under current conditions, there is no trap and haul strategy for juvenile Spring-Run Chinook Salmon. This will continue to be the case in 2030 under the No Action Alternative. Without implementation of juvenile trap and haul and associated benefits under the No Action Alternative, juvenile Spring-Run Chinook would be exposed to the potential adverse effects of low flows and elevated water temperatures leading to unsuccessful out-migration through the 2030 implementation period.

O.3.2.2.8 Fall- /Late Fall-Run Chinook Salmon

Central Valley Fall- /Late Fall-Run Chinook Salmon are a California Fish Species of Special Concern. Fall- /Late Fall-Run Chinook have been extirpated from a majority of their native spawning habitat upstream of Shasta Dam; most spawning currently occurs in the Sacramento River with a lesser amount in tributary streams. The runs are of concern because they depend greatly on hatchery production, which has genetic and ecological impacts including homogenized populations with reduced life history variability

(CDFW n.d.). Fall- /Late Fall-Run Chinook historically spawned in all the major rivers of the Central Valley; today spawning occurs only as far upstream as the first impassable dams, which block an estimated 70% of historical spawning habitat (Yoshiyama et al. 2001). Fall-Run Chinook Salmon had an average return of 250,000 adult fish with an additional 375,000 harvested in commercial and recreational fisheries from 1967 to 1991, which dropped to 71,000 in 2008 and 53,000 in 2009, when the ocean fisheries remained closed. Escapement rebounded to 342,000 fish in 2012 (CDFW GrandTab 2011).

Altered volume and timing of stream flows in addition to warmer stream temperatures resulting from warmer ambient air temperatures are possible effects of climate change that may result in stream conditions unsuitable for volitional downstream migration and survival. Under current conditions, there is no trap and haul strategy for juvenile Fall- /Late Fall-Run Chinook Salmon. This will continue to be the case in 2030 under the No Action Alternative. Without implementation of juvenile trap and haul and associated benefits under the No Action Alternative, juvenile Fall- /Late Fall-Run Chinook Salmon would be exposed to the potential adverse effects of low flows and elevated water temperatures leading to unsuccessful out-migration through the 2030 implementation period.

O.3.2.2.9 Central Valley Steelhead

NMFS proposed that California Central Valley Steelhead be listed as endangered in 1996, concluding that the ESU was in danger of extinction due to habitat degradation, blockage of freshwater habitats, water allocation problems, genetic mixing with hatchery raised Steelhead, and extirpation from most of their historic range (NMFS 2014a). However, in 1998 NMFS determined that the risks to the ESU had diminished since 1996 and listed Central Valley Steelhead as threatened (63 FR 13347). Historically, Central Valley Steelhead were distributed throughout the Sacramento and San Joaquin Rivers, with at least 81 independent populations. Currently, 80% of all historical spawning habitat and 38% of historical spawning habitat are blocked by impassible dams (NMFS 2014a). The Central Valley Steelhead 5-year status review determined that, despite increased returns at several hatcheries in the Central Valley and increased percentages of wild Steelhead salvage at south Delta fish facilities, natural production of Steelhead throughout the Central Valley remained at very low levels and that the DPS was still in danger of extinction (NMFS 2016b).

Altered volume and timing of stream flows in addition to warmer stream temperatures resulting from warmer ambient air temperatures are possible effects of climate change that may result in stream conditions unsuitable for volitional downstream migration and survival. Under current conditions, there is no trap and haul strategy for juvenile Central Valley Steelhead. This will continue to be the case in 2030 under the No Action Alternative. Without implementation of juvenile trap and haul and associated benefits under the No Action Alternative, juvenile Central Valley Steelhead would be exposed to the potential adverse effects of low flows and elevated water temperatures leading to unsuccessful out-migration through the 2030 implementation period.

O.3.2.2.10 Green Sturgeon

Southern DPS North American Green Sturgeon were listed as threated under the federal ESA in 2006 (NMFS 2006). In the ruling, NMFS concluded that, while the DPS was not presently in danger of extinction, they were likely to become endangered in the foreseeable future due to the existence of only one spawning population (in the Sacramento River), substantial loss of spawning habitat in the upper Sacramento and Feather Rivers, mounting threats to habitat quality in the Sacramento River and Delta ecosystems, and salvage data indicating a decrease in the number of juveniles collected from 1968 and 2001 (NMFS 2006).

Altered volume and timing of stream flows in addition to warmer stream temperatures resulting from warmer ambient air temperatures are possible effects of climate change that may result in stream conditions unsuitable for volitional downstream migration and survival. Under current conditions, there is no trap and haul strategy for Green Sturgeon. This will continue to be the case in 2030 under the No Action Alternative. Without implementation of juvenile trap and haul and associated benefits under the No Action Alternative, juvenile Green Sturgeon would be exposed to the potential adverse effects of low flows and elevated water temperatures leading to unsuccessful out-migration through the 2030 implementation period.

O.3.2.3 *Clear Creek*

O.3.2.3.1 Whiskeytown Reservoir Operations

Reclamation operates Whiskeytown Lake to (1) regulate inflows for power generation and recreation; (2) support upper Sacramento River temperature objectives; and (3) provide releases to Clear Creek.

Trinity River exports are first conveyed through Carr Powerplant before being released into Whiskeytown Lake. From Whiskeytown Lake, the water either continues to flow into Spring Creek Power Plant, ultimately outflowing into the Sacramento River below Keswick Dam, or is released from Whiskeytown Lake into Clear Creek. Although Whiskeytown Lake is primarily used as a conveyance system for cross-basin transfers, operations at both Carr and Spring Creek powerplants are coordinated to maintain specified water surface elevations for seasonal recreation.

Whiskeytown Lake is drawn down by approximately 35 TAF annually between November and April to regulate flows for winter and spring flood management. Heavy rainfall events occasionally result in spillway discharges to Clear Creek. Operations at Whiskeytown Lake during flood conditions are complicated by its operational relationship with the Trinity River, the Sacramento River, and Clear Creek. On occasion, water imports from the Trinity River to Whiskeytown Lake may be suspended to avoid exacerbating high flow conditions in the Sacramento Basin. Joint temperature control objectives similarly interact among the Trinity River, the Sacramento River, and Clear Creek. Two temperature curtains in Whiskeytown Lake were installed to pass cold water through the bottom layer of the reservoir and to limit passage of warm water from Carr Powerplant into Clear Creek or Spring Creek Powerplant.

Under the No Action Alternative and current conditions, flows from Whiskeytown Dam to Clear Creek would be managed for base flow of 50 cfs to 100 cfs based on downstream water rights, the 1963 Reclamation proposal to USFWS and NPS, predetermined CVPIA 3406(b)(2) flows, and NMFS BO Action I.1.1. Channel maintenance flows could occur when Whiskeytown Dam flood operations are conducted. Two pulse flows in Clear Creek of at least 600 cfs would occur in May and June for at least 3 days per pulse per year. Operations of both Carr and Spring Creek powerplants, which control flows into Whiskeytown Lake via Clear Creek Tunnel and out via Spring Creek Tunnel respectively, would continue to be managed to maintain specified seasonal water surface elevations to support reservoir recreation.

Potential changes to aquatic resources in Whiskeytown Reservoir due to operations

Hardhead

As a species of Moderate Concern (CA Conservation Status), Hardhead generally have declining, fragmented, and/or small populations that may be subject to rapid status change and that need management actions to prevent increased conservation concern (Moyle et al. 2015). Although there are no Hardhead population size estimates or trends available for Whiskeytown Lake, most populations are small, isolated, and likely declining (Moyle et al. 2015). Observations of Hardhead in tributaries to

Whiskeytown Lake (Wulff et al. 2012) indicate that recent (and presumably current) conditions can support at least small remnant populations in the reservoir and its tributaries. However, Hardhead are generally less abundant in reservoirs such as Whiskeytown that have variable water surface elevation and nonnative predatory bass (Moyle et al. 2015), suggesting that under the No Action Alternative, Hardhead populations could continue to decline through the 2030 implementation period.

Other Fish Species

Popular recreational fisheries for stocked and introduced nonnative game species including Rainbow Trout, Brown Trout, Kokanee Salmon, Brook Trout, Largemouth Bass, Smallmouth Bass, Spotted Bass, Bluegill, Black Crappie, Channel Catfish, and Brown Bullhead are managed by CDFW in Whiskeytown Lake. While current reservoir operations have supported sustained year-after-year recreational harvests, fish consumption advisories have been issued due to methylmercury accumulation in Sacramento Pikeminnow, Brook Trout, Sacramento Sucker, and black bass and sunfish species in Whiskeytown Lake (OEHHA 2019). Assuming continued methylmercury accumulation in these species does not result in further decreases in survival or reproductive success, these populations are anticipated to support continued recreational harvests under the No Action Alternative through 2030.

O.3.2.3.2 Clear Creek Flows

Reclamation operates Clear Creek flows in accordance with the 1963 Reclamation proposal to USFWS and the National Park Service (NPS), and the April 15, 2002 SWRCB permit, which established minimum flows to be released to Clear Creek at Whiskeytown Dam and continues to enhance gravel downstream of Whiskeytown Dam (BLM and NPS 2008). Minimum instream flows for Clear Creek downstream of Whiskeytown Dam range from 30 cfs to 70 cfs during critically dry years, and 50 cfs to 100 cfs during normal water years (Table O.3-A). Although the release schedule was never formalized and only specifies schedules for normal and critically dry water year types, Reclamation has operated according to the proposed schedule since May 1963 and attempts to meet the criteria for normal water year types during all but critically dry years.

Table O.3-A. Minimum instream flow under the No Action Alternative for Clear Creek downstream of Whiskeytown Dam

Period	Normal Year (cfs)	Critically Dry Year (cfs)
Jan. 1 to Oct. 31	50	30
Nov. 1 to Dec. 31	100	70

Modeled average monthly flows in Clear Creek under the No Action Alternative exceed the minimum instream flow schedule during all water years (Figure O.3-5). Under the No Action Alternative, the lowest monthly flow would occur during July and August of all water years when the modeled average is 85 cfs.

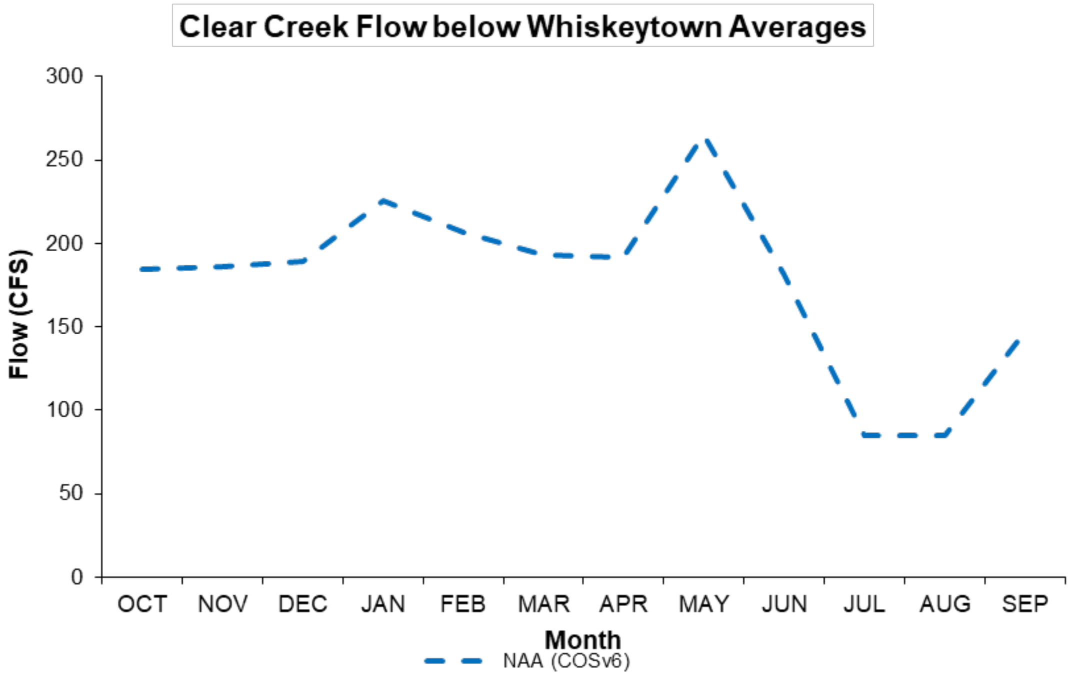


Figure O.3-5. Modeled average monthly flows in Clear Creek downstream of Whiskeytown Reservoir under the No Action Alternative.

Under the No Action Alternative, conditions in Clear Creek by 2030 would be different than under current conditions due to climate change, increased water demand, and environmental improvements associated with continued implementation of restoration projects. Modeled scenarios suggest possible effects of climate change may include changes in precipitation patterns, reduced snowpack, and earlier snowmelt (Reclamation 2015). Human population growth, land use patterns, and water use efficiency may increase future water demands. Climate change and increased water demands would likely alter flow release patterns in Clear Creek, which may increase challenges for migrating and spawning fish species using streams for migration, spawning, and rearing. Clear Creek supports several listed fish species, including Spring-Run and Fall-Run Chinook Salmon, Central Valley Steelhead, and Pacific Lamprey. Potential effects on listed fish species of the No Action Alternative compared to current conditions are presented below.

Potential changes to aquatic resources in Clear Creek from variation in flow

Spring-Run Chinook Salmon

Spring-Run Chinook Salmon in Clear Creek may experience adverse effects as a result of reduced flows accompanying environmental changes occurring through the 2030 implementation period compared to current conditions. These effects are likely to be negligible through the 2030 implementation period, and continued implementation of restoration projects in Clear Creek would provide population-level benefits. As a result, there would be no adverse effects on Spring-Run Chinook Salmon in Clear Creek under the No Action Alternative.

Fall-Run Chinook Salmon

Fall-Run Chinook Salmon in Clear Creek may experience adverse effects as a result of reduced flows accompanying environmental changes occurring through the 2030 implementation period compared to current conditions. These effects are likely to be negligible through the 2030 implementation period, and continued implementation of restoration projects in Clear Creek would provide population-level benefits. As a result, there would be no adverse effects on Fall-Run Chinook Salmon in Clear Creek under the No Action Alternative.

Central Valley Steelhead

Central Valley Steelhead in Clear Creek may experience adverse effects as a result of reduced flows accompanying environmental changes occurring through the 2030 implementation period compared to current conditions. These effects are likely to be negligible through the 2030 implementation period, and continued implementation of restoration projects in Clear Creek would provide population-level benefits. As a result, there would be no adverse effects on Central Valley Steelhead in Clear Creek under the No Action Alternative.

Pacific Lamprey

Pacific Lamprey in Clear Creek may experience adverse effects as a result of reduced flows accompanying environmental changes occurring through the 2030 implementation period compared to current conditions. These effects are likely to be negligible through the 2030 implementation period, and continued implementation of restoration projects in Clear Creek would provide population-level benefits. As a result, there would be no adverse effects on Pacific Lamprey in Clear Creek under the No Action Alternative.

Potential changes to aquatic resources in Clear Creek from variation in water temperature

Reclamation manages Whiskeytown releases to meet a daily average water temperature of: (1) 60°F at the Igo gage from June 1 through September 15; and (2) 56°F at the Igo gage from September 15 to October 31.

Spring-Run Chinook Salmon

Under the No Action Alternative, water temperatures in Clear Creek downstream of Whiskeytown Dam would be stress-inducing during September of critically dry years, suboptimal during September of all other year types, suboptimal during October of dry and critically dry years, optimal during October of all other year types, and optimal during November of all year types. Under the No Action Alternative, water temperatures would be optimal for rearing and outmigrating juvenile Spring-Run Chinook Salmon during all water years. Water temperatures would be optimal for migrating adult Spring-Run Chinook Salmon during all years, except during June of critically dry years when water temperatures would be in the suboptimal range.

Water temperatures during September of critically dry years would be only slightly above the suboptimal temperature range for Spring-Run Chinook Salmon eggs and fry (54°F to 58°F) under the No Action Alternative. Therefore, the No Action Alternative would likely have only a minimal adverse effect on Spring-Run Chinook Salmon.

Fall-Run Chinook Salmon

Modeling results show that water temperatures in Clear Creek would be suboptimal for Fall-Run eggs and emerging fry under the No Action Alternative during October of critically dry years; eggs and emerging fry would experience optimal temperatures in all other year types during their period of peak occurrence. Rearing and outmigrating juveniles as well as migrating adults would experience optimal temperatures during the entire period of their peak occurrence in all water year types. Overall, the No Action Alternative would have beneficial effects on Fall-Run Chinook Salmon, as modeled temperatures are within optimal ranges during the period of occurrence for all life stages except for eggs and emerging fry in October of critically dry years, in which temperatures would be suboptimal, and result in negligible adverse effects.

Central Valley Steelhead

Modeling results show that all life stages of California Central Valley Steelhead, except for migrating adults, experience temperatures under the No Action Alternative within the optimal range during their entire period of peak occurrence for all year types. Migrating Central Valley Steelhead adults experience suboptimal temperatures during the period of their peak occurrence during all year types. No life stages of Central Valley Steelhead experience stress inducing temperatures under the No Action Alternative. Overall, the No Action Alternative would have a slightly adverse effect on Central Valley Steelhead, as modeled temperatures are within optimal ranges during the period of occurrence for all life stages except for migrating adults, in which temperatures would be suboptimal, and result in negligible adverse effects.

Pacific Lamprey

Modeling results show that Pacific Lamprey would experience suitable temperature ranges in which spawning generally takes place during May of all water year types, and in April of critically dry water year types; temperatures are below the suitable temperature range for this life stage during all other water year types and months of peak occurrence. Modeled No Action Alternative temperatures do not exceed temperature ranges during the period of peak occurrence of ammocoetes and outmigrating adults during all water year types. Overall, the No Action Alternative is unlikely to adversely affect Pacific Lamprey in Clear Creek as suitable temperatures occur during part or all of the period of peak occurrence for all life stages.

O.3.2.3.3 Spring Creek Debris Dam

The Spring Creek Debris Dam (SCDD) was constructed to regulate runoff containing debris and acidic mine drainage in Spring Creek. This debris and acidic drainage originate at the Iron Mountain Mine (IMM) Superfund site near Redding, California. The IMM was mined from the 1860s through 1963 for copper, gold, pyrite, silver, and zinc (EPA 2018: i). Low pH runoff, laden with heavy metals, historically originated in tributaries (primarily Boulder Creek), then discharged to Spring Creek, and ultimately to the Spring Creek Arm of the Keswick Reservoir (a mainstem dam and reservoir on the Sacramento River). Acidic and heavy metal discharge also affects Keswick Reservoir. When Spring Creek water is buffered by the larger volume of water in the Keswick Reservoir, heavy metals precipitate from the water column, contaminating sediments.

The continuous release of metals from the IMM has resulted in historical fish kills and has contributed to a progressive decline in the fisheries population in the Sacramento River. Construction of the SCDD reduced the frequency and magnitude of fish kills; however, during extreme storm events, the SCDD has filled beyond capacity, spilling toxic levels of acid mine drainage into the Sacramento River on an average of every 2 to 3 years, causing episodes when emerging fry were killed (CVRWQCB 2002: 23). As a result, releases from the SCDD, Shasta Lake, and Whiskeytown Lake via the Spring Creek tunnel to Spring Creek Powerplant are coordinated under a Memorandum of Understanding (MOU) to remediate pH and acidic releases to Keswick Reservoir.

Releases from Whiskeytown Lake and other CVP reservoirs, along with other remedial actions, are coordinated by a 1980 MOU between Reclamation, CDFW, and SWRCB. This MOU was executed to implement actions that protect the Sacramento River system from heavy metal pollution from Spring Creek and adjacent watersheds. The MOU identifies agency actions and responsibilities and establishes release criteria based on allowable concentrations of total copper and zinc in the Sacramento River below Keswick Dam. Operations initially coordinated under the MOU have been subsequently modified by the 1992 Central Valley Project Operations Criteria and Plan, the 1993 Biological Opinion for the Operation of the Federal Central Valley Project and the California State Water Project, and the results of a 2002 Total Maximum Daily Load (TMDL) for Cadmium, Copper & Zinc in the Upper Sacramento River. Remedial actions at the IMM and in Keswick Reservoir are dictated by five records of decision (RODs) implemented between 1986 and 2004.

In order to minimize the build-up of metal concentrations in the Spring Creek arm of Keswick Reservoir, releases from the debris dam are coordinated with releases from Spring Creek Powerplant to keep the Spring Creek arm of Keswick Reservoir in circulation with the main water body of Keswick Lake.

The operation of SCDD is complicated during major heavy rainfall events. SCDD reservoir can fill to uncontrolled spill elevations in a relatively short time period, anywhere from days to weeks. Uncontrolled spills at SCDD can occur during major flood events on the upper Sacramento River and localized rainfall events in the Spring Creek watershed. During flood control events, Keswick releases may be reduced to meet flood control objectives at Bend Bridge when storage and inflow at Spring Creek Reservoir are high.

Because SCDD releases are maintained as a dilution ratio of Keswick releases to maintain the required dilution of copper and zinc, uncontrolled spills can and have occurred from SCDD. In this operational situation, high metal concentration loads during heavy rainfall are usually limited to areas immediately downstream of Keswick Dam because of the high runoff entering the Sacramento River, adding dilution flow. In the operational situation when Keswick releases are increased for flood control purposes, SCDD releases are also increased in an effort to reduce spill potential.

The 2002 TMDL for Cadmium, Copper & Zinc specifies numeric targets for dissolved cadmium, copper, and zinc. The primary mechanism for achieving those targets is on-going remediation and continued operations of the SCDD and related facilities in a reasonable and prudent manner in compliance with operations criteria set forth in the 1980 MOU, as well as the subsequent 1992 Central Valley Project Operations Criteria and Plan, and 1993 Biological Opinion for the Operation of the Federal Central Valley Project and the California State Water Project.

Both before and since the 2002 TMDL, remedial actions at the IMM site have greatly reduced the amount of metal contamination and increased the pH of waters entering the Spring Creek Reservoir. Numerous source control, water treatment, diversion, retention, and sediment remedial actions have significantly improved the water quality of discharges from SCDD. Current contaminant discharges from the Boulder Creek watershed (the primary contaminant source) are estimated to constitute less than 5% of the overall historical IMM discharges of copper and zinc (EPA 2018: i). Nonetheless, EPA expects exceedances of water quality standards downstream of Keswick Dam on the rare occasions when large early winter storms follow very dry summers.

No modifications to existing operations are proposed at the SCDD under the No Action Alternative. Discharges from the SCDD and Spring Creek Tunnel will continue to be managed for the benefit of fish species and other purposes downstream of Keswick Dam. Reclamation's water management actions remain key to providing for the safe release of the continuing IMM contaminant discharges.

Future operations of the SCDD are governed by an existing MOU and subsequent regulations outside of the proposed actions addressed in this EIS. Reclamation controls discharges from CVP facilities (including the SCDD and Spring Creek Tunnel) in accordance with the 1980 MOU and subsequent regulations to comply with the Basin Plan standards in the Sacramento River below Keswick Dam. The objectives laid out by the RODs include: achieving water quality criteria established under the Clean Water Act, reducing the mass discharge of toxic heavy metals through application of appropriate control technologies, minimizing the need to rely on special releases of California's valuable water resources to ensure compliance with water quality standards in the Sacramento River through special releases of waters to dilute toxic spills of IMM contaminants, protecting the Sacramento River ecosystem from releases of heavy metals from Spring Creek Arm by preventing the mobilization and redeposition of contaminated sediment into important fishery spawning habitats in the Sacramento River below Keswick Dam, and preventing adverse impacts on water quality and beneficial uses of the Sacramento River below Keswick Dam by reducing the metal loads and suspended solids associated with contaminated sediment discharges from Spring Creek Arm to the Sacramento River.

The most recent five-year review of the project found that there has been a significant decrease in total copper and total zinc measured at lower Spring Creek since the remedies have been implemented. Prior to the remedies being implemented, total copper concentrations often exceeded the Daily Maximum Discharge Standard of 300 μg/L, and total zinc concentrations frequently exceeded the Daily Maximum Discharge Standard of 1500 μg/L. Between 2012 and 2017, the range of total copper and zinc concentrations measured at lower Spring Creek decreased to approximately 50 μg/L to 150 μg/L and 90 μg/L to 800 μg/L, respectively. Water quality below Keswick Dam has likewise shown dramatic improvement. The prescribed remedies are effectively protecting the Sacramento River as a drinking water source and as an important fish habitat. There has been a 97% reduction in heavy metals downstream of Keswick Dam, eliminating fish kills and greatly improving water quality downstream (CVRWQCB 2002: 23).

Potential changes to aquatic resources due to Spring Creek Debris Dam operations

The current RODs covering remedial actions at the IMM and SCDD are to be implemented through 2030. Because they are expressly designed to improve water quality and habitat conditions, environmental conditions for all species of concern are expected to continue to improve under the No Action Alternative.

Under the No Action Alternative (and in the absence of future remedial actions or adaptive management to address potential negative environmental consequences), population growth, climate change, and basin development will potentially result in adverse effects. Higher temperatures and shifts in the timing or nature of precipitation (from snow to rain, for instance) due to climate change may have multiple effects including increased evapotranspiration, reducing the amount of water available for storage in SCDD reservoir. More intense storms or a shift in precipitation from snow to rain may increase the likelihood of uncontrolled spills over the SCDD. These shifts may require future modifications to the water management scenarios used to control heavy metal and acidic discharges from the SCDD.

The potential for a failure of SCDD before 2030, though unlikely, does exist under the No Action Alternative, and the release of toxic waste from IMM resulting from such a failure could be devastating to downstream fish species (Moyle et al. 2017: 106).

Winter-Run Chinook Salmon

Winter-Run Chinook Salmon abundance has declined substantially from a population of approximately 200,000 spawning adults in the 1960s to approximately 3,500 adults in 2015 (Good et al. 2005: 145; NMFS 2016f: 3). Efforts of the Livingston Stone National Fish Hatchery since 1998, when Winter-Run Chinook populations reached historically low levels of fewer than 1,000 spawning adults, have likely resulted in a small increase in recent population levels (Brown and Nichols 2003: 18), but the population reached a high point of only 18,000 adults in 2006 before again declining to current levels (NMFS 2016f: 3). The primary factors currently affecting Winter-Run Chinook abundance include loss of habitat following the construction of Shasta and Keswick Dams, warm water releases from Shasta Dam, fishery operations, heavy metal contamination from IMM, entrainment in water diversions, and loss of floodplain rearing habitat (NMFS 2016e: 19-23). While implementation of remedial actions at IMM and SCDD through 2030 under the No Action Alternative will slightly improve water quality and habitat conditions for Winter-Run Chinook, these operations are unlikely to overcome the other factors currently interacting to maintain Winter-Run Chinook populations at historically low levels.

The effects of climate change through 2030 on Winter-Run Chinook are difficult to quantify, but drought, low instream flow, and high water temperatures are known to exacerbate the degradation of Winter-Run Chinook habitat (NMFS 1997: III-2). Past droughts have even corresponded with episodes of extreme Winter-Run Chinook mortality, particularly when the droughts occurred in successive years (NMFS 1997: III-97; NMFS 2016e: 20).

In the unlikely event of SCDD failing before 2030, the resulting heavy metal contamination of Winter-Run Chinook habitat could eliminate much of the existing population (Moyle et al. 2017: 106).

Spring-Run Chinook Salmon

Spring-Run Chinook Salmon abundance has decreased from a historical high of 600,000 adults to an average of approximately 30,000 spawning adults in the 1970s to annual totals as low as 3,000 adults within the past decade (CDFW 1998: 1; NMFS 2016c: 15). The primary factors currently affecting Spring-Run Chinook abundance include loss of habitat and declines in water quality following dam construction and development along the Sacramento River, fishery operations, heavy metal contamination from IMM, entrainment in water diversions, and predation by nonnative species (Moyle et al. 2017: 86–91). While implementation of remedial actions at IMM and SCDD through 2030 under the No Action Alternative will slightly improve water quality and habitat conditions for Spring-Run Chinook, these operations are unlikely to overcome the other factors currently interacting to maintain Spring-Run Chinook at low levels.

The effects of climate change through 2030 on Spring-Run Chinook are difficult to quantify, but drought, low instream flow, and high water temperatures are known to exacerbate the degradation of Spring-Run Chinook habitat (Lindley et al. 2007: 11). Recent droughts have even corresponded with the lowest recorded Spring-Run Chinook abundance in the Sacramento Basin (NMFS 2016c: 17).

In the unlikely event of SCDD failing before 2030, the resulting downstream heavy metal contamination would be lethal for any Spring-Run Chinook individuals that encounter the plume of toxic water (Moyle et al. 2017: 89).

Fall-Run Chinook Salmon

Historical abundance of Fall-Run Chinook Salmon is not well-known but is estimated at around 1,000,000 spawning adults (Yoshiyama et al. 1998: 492). In recent years, abundance has changed from a somewhat consistent level around 250,000 spawning adults in the 1970s and 1980s to increasingly variable levels ranging between 850,000 adults in 2002 to fewer than 100,000 in 2009 (CDFW 2018a). Current populations of Fall-Run Chinook consist chiefly of hatchery-origin fish (Palmer-Zwahlen and Kormos 2015: 53). The primary factors affecting Fall-Run Chinook abundance include loss of habitat and declines in water quality following dam construction and development along the Sacramento River, fishery operations, heavy metal contamination from IMM, entrainment in water diversions, and predation by nonnative species (Moyle et al. 2017: 51–56). While implementation of remedial actions at IMM and SCDD through 2030 under the No Action Alternative will slightly improve water quality and habitat conditions for Fall-Run Chinook, these operations are unlikely to outweigh the other factors currently interacting to maintain Fall-Run Chinook population levels.

The effects of climate change through 2030 are difficult to quantify, but drought, low instream flow, and high water temperatures can result in suboptimal or lethal conditions for Fall-Run Chinook (Moyle et al. 2017: 58).

In the unlikely event of SCDD failing before 2030, the resulting downstream heavy metal contamination would be lethal for any Fall-Run Chinook individuals that encounter the plume of toxic water (Moyle et al. 2017: 54).

Central Valley Steelhead

Historical abundance of Central Valley Steelhead is not well-known but is estimated to be between 50,000 and 100,000 spawning adults (Moyle et al. 2017: 223). Estimated abundance declined from an average of approximately 6,500 adults between 1967 and 1991 to an average of approximately 1,300 between 1992 and 2006 (NMFS 2016b: 11–17). Steelhead abundance has since somewhat stabilized, with an estimated 4,600 spawning adults in 2016 (NMFS 2016b: 11–17). Current populations of Central Valley Steelhead consist chiefly of hatchery-origin fish (NMFS 2016b: 11–17). The primary factors affecting Steelhead abundance include loss of habitat and declines in water quality following dam construction and development along the Sacramento River, fishery operations, and predation by nonnative species (Moyle et al. 2017: 224–226). While implementation of remedial actions at IMM and SCDD through 2030 under the No Action Alternative will slightly improve water quality and habitat conditions for Central Valley Steelhead, these operations are unlikely to outweigh the other factors currently interacting to maintain Steelhead population levels.

The effects of climate change through 2030 on Central Valley Steelhead are difficult to quantify, but drought, low instream flow, and high water temperatures can result in additional degradation and loss of habitat (Moyle et al. 2017: 228). Recent historic drought years between 2012 and 2016 likely reduced survival of Central Valley Steelhead in the American River, so similar effects could be anticipated elsewhere during periods of extreme drought (NMFS 2016b: 36).

In the unlikely event of SCDD failing before 2030, the resulting downstream heavy metal contamination would be lethal for any Central Valley Steelhead individuals that encounter the plume of toxic water (Moyle et al. 2017: 54).

Green Sturgeon

Sufficient historical data do not exist to accurately identify Green Sturgeon population trends, but fish salvage data indicate an overall decline in juvenile abundance (NMFS 2018b: 4-6). Recent studies estimate a population of approximately 2,100 adults (Mora et al. 2018: 202). Despite the lack of knowledge of Green Sturgeon population trends, they are listed as threatened primarily due to loss of habitat, altered flow patterns, and declining habitat quality resulting from dam construction and development along the Sacramento River (NMFS 2018b: 14). While implementation of remedial actions at IMM and SCDD through 2030 under the No Action Alternative will slightly improve water quality and habitat conditions for Green Sturgeon, these operations are unlikely to outweigh the other factors currently interacting to affect Green Sturgeon population levels.

The effects of climate change through 2030 on Green Sturgeon are difficult to quantify, but drought, low instream flow, and high water temperatures can result in additional degradation and loss of habitat (NMFS 2018b: 28). Recent sampling efforts indicate a higher catch of larval Green Sturgeon in years with cooler water temperatures.

In the unlikely event of SCDD failing before 2030, the resulting downstream heavy metal contamination would be lethal for any Green Sturgeon individuals that encounter the plume of toxic water (Moyle et al. 2017: 54).

O.3.2.3.4 Clear Creek Restoration Program

Since the early 1980s, numerous studies have evaluated methods to rehabilitate and/or restore salmonid habitat along lower Clear Creek (Figure O.3-6). In the 1990s, additional studies were conducted following the adoption of CVPIA. The Western Shasta Resource Conservation District watershed management plan evaluated methods to achieve healthy fish populations, diverse biological habitats, recreational opportunities, clean and safe conditions for visitors, and protection of property rights developed by the Lower Clear Creek Coordinated Resource Management and Planning Group of local landowners, stakeholders, and agencies (WSRCD 1998). The plan's recommendations included:

- Remove the McCormick-Saeltzer Dam;
- Inject gravel downstream of Whiskeytown Dam and reconstruct gravel channels below McCormick-Saeltzer Dam to reduce stranding;
- Modify water release patterns from Whiskeytown Dam;
- Reduce exotic vegetation along Clear Creek; and
- Reduce sands in Clear Creek through erosion control programs in the lower watershed.

This and other studies led to the formation of the Lower Clear Creek Floodway Rehabilitation Project that was implemented under CVPIA. Initial actions under this project included gravel augmentation initiated in 1996, an increase in Whiskeytown Dam releases initiated in 2001, removal of the McCormick-Saeltzer Dam in 2001, reconstruction and revegetation of the floodway, and a reduction of watershed erosion.

According to BLM and NPS (2008), "the removal of Saeltzer Dam in 2000 opened nearly 12 miles of access to areas just downstream of Whiskeytown Dam for a total of 18 miles for Central Valley Spring-Run Chinook Salmon (and Central Valley Steelhead) habitat. Adult Central Valley Spring-Run Chinook Salmon migrate up-stream beginning early June in lower Clear Creek, throughout the project area, to the upper most reaches to spawn beginning early September and continue through early to mid-October. Since 2003, the USFWS has installed a temporary picket weir from late August through early November, to allow Spring-Run Chinook Salmon a spatial separation from Fall-Run Chinook Salmon, which otherwise have an overlap in spawning timing." Overlapping spawning timing could result in hybridization between spring and fall runs.

The goals of the Clear Creek Restoration Program are to (1) provide flows to allow sufficient spawning, incubation, rearing, and out-migration for Central Valley Chinook and Steelhead; (2) restore the stream channel and associated instream habitat; (3) operate the picket weir (segregation weir) to create reproductive isolation between Fall-Run (Fall-Run and Late Fall-Run) Chinook and Spring-Run Chinook; and (4) determine impacts of restoration actions on anadromous fish and geomorphology.

The program manages flows and temperatures through releases from Whiskeytown Dam on a year-round basis to improve survival and condition of Salmon and Steelhead in Clear Creek. The magnitude and timing of flows and water temperature are controlled to meet this goal. The 2009 NMFS BO RPA Action I.1.3 (Clear Creek Spawning Gravel Augmentation), implemented under the No Action Alternative, requires restoration on a two-mile section of Clear Creek floodplain and stream channel by annual gravel augmentation to recharge and maintain gravel supply (approximately 8,000 to 10,000 tons of gravel per year). The aim of the 2009 NMFS BO RPA Action I.1.3 is to create and maintain 347,288 square feet of usable spawning habitat in Clear Creek.

Under the No Action Alternative, the current goals of the Clear Creek Restoration Programs would continue to be pursued. Effects of flow and temperature are discussed under the Clear Creek Flows section of this EIS. This section analyzes effects of gravel augmentation and segregation weir operations of the Clear Creek Restoration Program on focal fish species under the No Action Alternative.

Potential changes in aquatic resources due to gravel augmentation and segregation weir operation

Spring-Run and Fall-Run Chinook Salmon

Whiskeytown Dam blocks coarse sediment supply to the lower portion of Clear Creek by trapping all coarse sediment, including gravel suitable for spawning, in the reservoir. A lack of spawning gravel delivery to lower Clear Creak has limited available salmonid spawning habitat, and this limitation has been further exacerbated by similar spawning timing of Spring-Run and Fall-Run Chinook leading to redd superimposition and some hybridization of the two runs. Mechanical gravel augmentation has helped to restore some gravel supply and increased available spawning habitat, which is particularly important as the amount of habitat present is less than the amount needed to support 7,920 adult Fall-Run Chinook Salmon (the target population level) in Clear Creek (USFWS 2015). Since 2003, the proportion of Spring-Run Chinook spawning in injected gravel has increased from approximately 15% to 60% in 2017 (Delta Stewardship Council 2018). There are no exact estimates on the use of injected gravel by Fall-Run Chinook. Continued gravel augmentation under the No Action Alternative would result in potential benefits to Fall-Run and Spring-Run Chinook by reducing redd superimposition and increasing available spawning habitat.

Operation of the segregation weir currently helps alleviate some of the hybridization which has occurred between Fall-Run and Spring-Run Chinook by preventing concurrent use of spawning habitat. While exact estimates of this benefit are not available, it is anticipated that further operation of the weir under the No Action Alternative would further isolate Fall-Run and Spring-Run Chinook, leading to population-level benefits compared to current conditions.

Central Valley Steelhead

Whiskeytown Dam blocks coarse sediment supply to the lower portion of Clear Creek by trapping all coarse sediment, including gravel suitable for spawning, in the reservoir. A lack of spawning gravel delivery to lower Clear Creak has limited available salmonid spawning habitat. Mechanical gravel augmentation has helped to restore some gravel supply and increased available spawning habitat. Since

2003, the proportion of Central Valley Steelhead spawning in injected gravel has increased from approximately 41% to 84% in 2018 (Delta Stewardship Council 2018). Continued gravel augmentation under the No Action Alternative would result in potential benefits to Central Valley Steelhead by increasing available spawning habitat.

Pacific Lamprey

Little data are available on Pacific Lamprey spawning in Clear Creek, but lamprey are assumed to occur throughout the accessible portion of Clear Creek downstream of Whiskeytown Dam. Like salmonids, lamprey numbers are presumably reduced from historical abundance due to the same factors that have affected anadromous salmonids (e.g., blocked passage and habitat alteration). Pacific Lamprey have similar life cycles to salmonids and require similar spawning conditions, which require substrate with gravel to create redds. It is anticipated that gravel augmentation in Clear Creek would benefit ocean returnees by providing higher quality substrates for spawning. While spawning trends and populations of Pacific Lamprey are not actively monitored in Clear Creek, salmonid data suggest that the spawning substrate habitat quality is likely to improve under the No Action Alternative compared to current conditions.

O.3.2.4 *Feather River*

O.3.2.4.1 FERC Project #2100-134

DWR releases water from their Oroville Complex Project (FERC Project No. 2100) into the lower Feather River to meet the requirements of FERC Project instream flow schedules and D-1641. Additionally, DWR balances its releases and the storage in Lake Oroville to meet flood control requirements, Sacramento–San Joaquin Delta export requirements, storage goals in the San Luis Reservoir, and water delivery objectives for contracted water agencies. Decisions on water-transfer timing from Lake Oroville on the Feather River to San Luis Reservoir in the southern Delta are based on different schedules and real-time factors, including current Delta conditions, reservoir storage volumes, storage targets, and environmental/regulatory requirements.

The Feather River contributes approximately 25% of the total flow to the Sacramento River, with a consistent pattern of higher flows in winter and spring and lower flows in summer and fall across all water year types (FERC 2007b). Prior to the completion of the Oroville Dam, the mean daily flow in the Feather River ranged from approximately 2,000 cfs in critically dry years to 18,000 cfs in wet years (Oroville gage 1906–1965). Following the completion of the Oroville Dam, the mean daily flow in the Feather River ranged from approximately 1,000 cfs during critically dry years to 12,000 cfs during wet years (Gridley gage 1969–2012) (Figures O.3-6 and O.3-7) (NMFS 2016a).

Under the No Action Alternative, minimum instream flows in the Feather River are set to 700 cfs to 800 cfs below the Thermalito Diversion Dam in the Low Flow Channel per the 2006 Settlement Agreement, and 750 cfs to 1,700 cfs below the Thermalito Afterbay outlet in the High Flow Channel (HFC) per the 1983 DWR-CDFG Agreement, with an additional CDFG/DWR operational objective of 2,800 cfs at the mouth of the Feather River from April through September (with options to vary flow depending on year types).

Potential changes to aquatic resources in the Feather River due to seasonal variation in flow

Climate change and increasing water demands may affect aquatic resources in the Feather River. Modeled scenarios suggest possible effects of climate change may include changes in precipitation patterns, reduced snowpack and runoff, and earlier snowmelt between now and 2030, which may affect future water supply in Lake Oroville and therefore releases into the Feather River (Reclamation 2015). It is also anticipated that climate change will result in more extreme dry-to-wet precipitation events, altered stream flow volume and timing, and lower late summer flows, which may increase challenges for migrating and spawning fish.

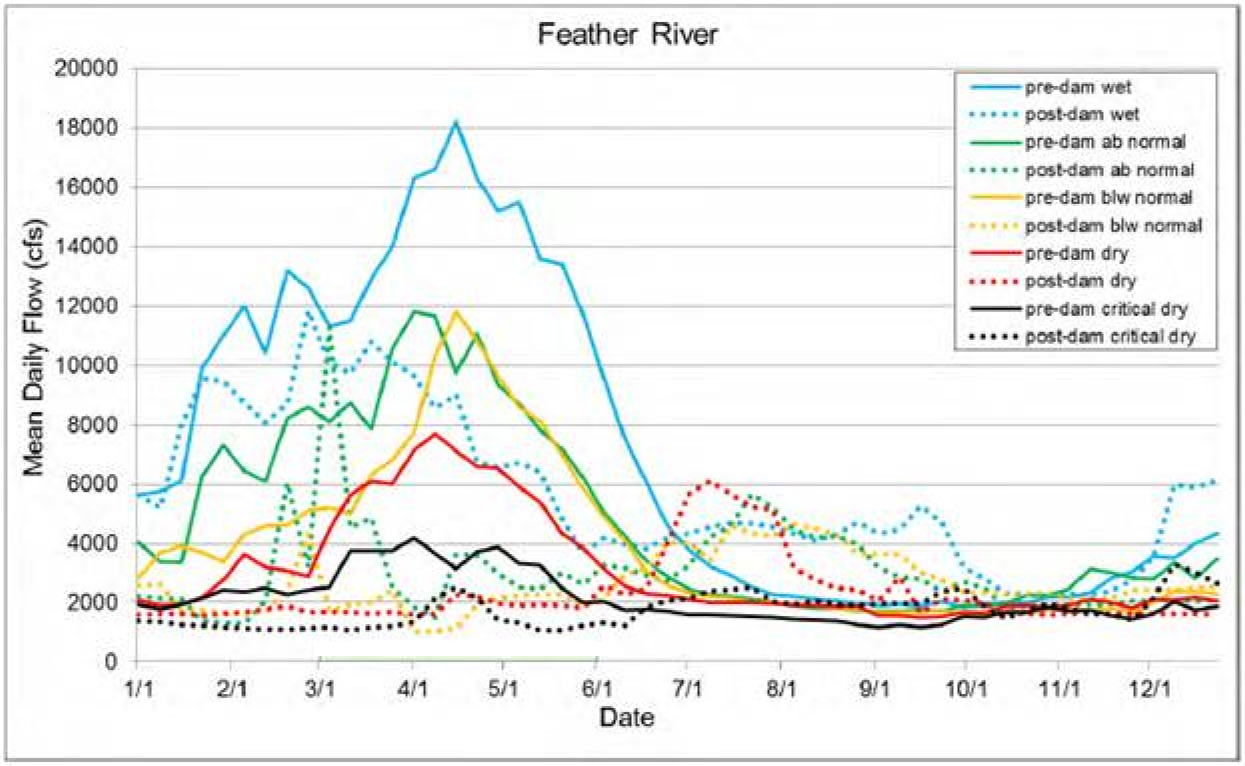


Figure O.3-6. Mean Daily Flow during All Water Year Types in the Feather River during Pre-Dam Years (Oroville Gage 1906–1965) and Post-Dam Years (Gridley Gage 1969–2012; NMFS 2016a).

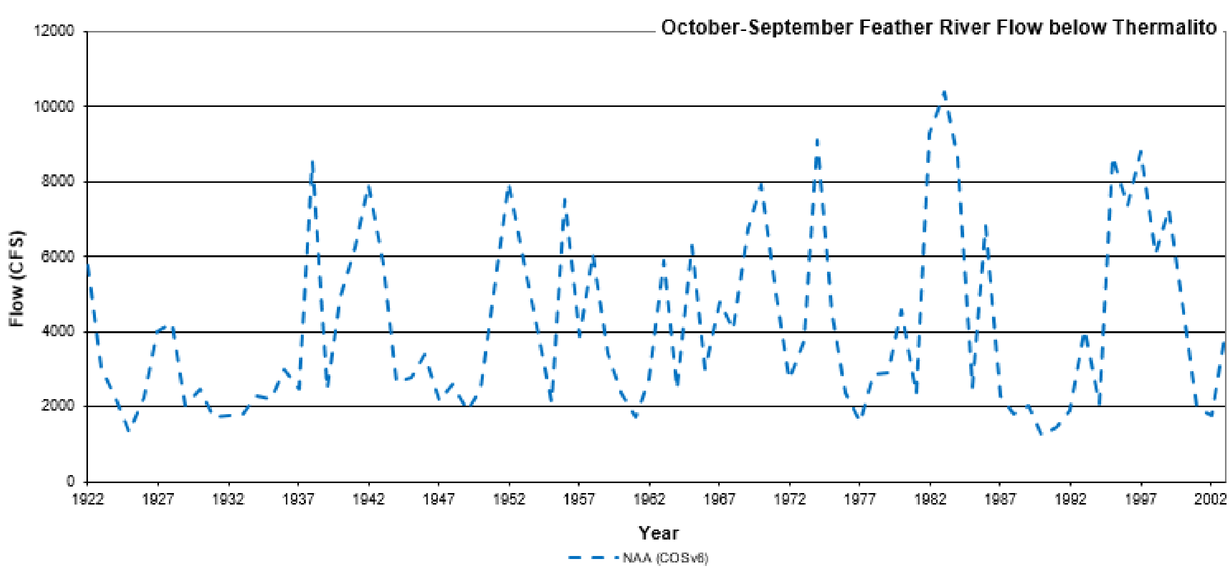


Figure O.3-7. CalSim Average Estimated Feather River Flow below Thermalito under the No Action Alternative.

Winter-Run Chinook Salmon

Winter-Run Chinook Salmon are not likely to be affected by the No Action Alternative compared to current conditions in the Feather River due to their limited distribution in the Feather River.

Spring-Run Chinook Salmon

Spring-Run Chinook Salmon in the Feather River have declined in number and continue to face several challenges; following the construction of the Oroville Complex, the number of naturally spawning Spring-Run Chinook in the Feather River has been periodically estimated between 2,908 fish in 1964 and 2 fish in 1978 with the number of natural spawning fish in the stream remaining low. Additionally, hybridization between Spring-Run and Fall-Run Chinook has brought their genetic integrity into question, complicating population estimates of any remnant independent Spring-Run Chinook in the Feather River (Good et al. 2005). Existing challenges facing Spring-Run Chinook include the loss of access to historical spawning and rearing habitat and diminished adult holding conditions (Yoshiyama et al. 1996). Currently, the Feather River contains approximately 18% of the total spawning and rearing habitat for Central Valley Spring-Run Chinook; however, Spring-Run Chinook in the Feather River are nearly entirely limited to hatchery spawning. These conditions would likely continue into 2030 under the No Action Alternative.

Fall-Run Chinook Salmon

Fall-Run Chinook Salmon occur in the Feather River year-round. Adults begin their migration into the river in June with peak migration and spawning between October and March and complete their spawning by May. Fry and juveniles may occur in the river year-round, but peak out-migrating periods occur from January through April and August through November, and lesser migrations in May through July (NMFS 2016a; DWR and Reclamation 2016).

Existing challenges facing Chinook Salmon in the Feather River include upstream passage barriers, altered flow regime, high water temperature, habitat quality, entrainment in water diversions, and loss of riparian and floodplain habitat. Fall-Run Chinook Salmon downstream of the Thermalito Afterbay Outlet could be affected by altered stream flow volume and timing, lower late summer flows, and higher water temperatures leading up to 2030, when compared to current conditions, as a result of climate change.

Central Valley Steelhead

Steelhead in the Feather River primarily spawn within the Oroville Complex Boundary between the Fish Barrier Dam near the hatchery and the Thermalito Afterbay Outlet, although a small amount of spawning occurs downstream of the Thermalito Afterbay Outlet (FERC 2007b). Steelhead downstream of the Thermalito Afterbay Outlet could be affected by altered stream flow volume and timing, lower late summer flows, and higher water temperatures leading up to 2030, when compared to current conditions, as a result of climate change.

North American Green Sturgeon

North American Green Sturgeon are thought to have historically spawned in the Sacramento, Feather, and San Joaquin Rivers (Adams et al. 2007). While regular occurrence of Green Sturgeon has been verified in the Sacramento River, only intermittent observations have been reported in the lower Feather River at the

Thermalito Afterbay Outlet (Beamesderfer et al. 2007; Seesholtz and Manuel 2012). Green Sturgeon in the Feather River could face conditions under the No Action Alternative in 2030 that, when compared to current conditions, may have altered stream flow volume and timing, lower late summer flows, and a rise in water temperatures due to climate change.

Potential changes to aquatic resources in the Feather River due to changes in water temperature from differences in flow

Streamflow, combined with other environmental drivers, has the potential to affect aspects of water quality such as temperature. Water temperatures affect the condition and survival of fish species during all stages of their life cycle. Optimal water temperatures can facilitate physiological responses including improved growth rates and heightened immune systems, which lead to a higher likelihood of survival. In contrast, effects of suboptimal water temperatures include an inability to satisfy metabolic demand and acute to chronic physiological stress, potentially leading to mortality (Stillwater Sciences 2006; Martin et al. 2017).

Water temperatures in the Feather River follow a seasonal pattern, where on average, they peak around 72°F in July to August and reach a minimum of around 47°F in January (Figure O.3-8). Increased flow releases from the Oroville Complex facilities can influence water temperatures in summer and fall when air temperatures and solar radiation levels are at their highest. Minimum water temperatures in the Feather River are predicted to be similar across all water year types, but water temperatures can reach a maximum up to 4°F warmer (approximately 75°F) in critically dry years compared to wet years (approximately 71°F; Figure O.3-9). The effects of water temperature on fish in the Feather River vary among species and life stages; however, water temperatures under current conditions and the No Action Alternative surpass suboptimal levels for Chinook Salmon between 58°F and 75.2°F, for Steelhead between 55°F and 70°F, and for Green Sturgeon between 66°F and 70°F (Table O.3-3).

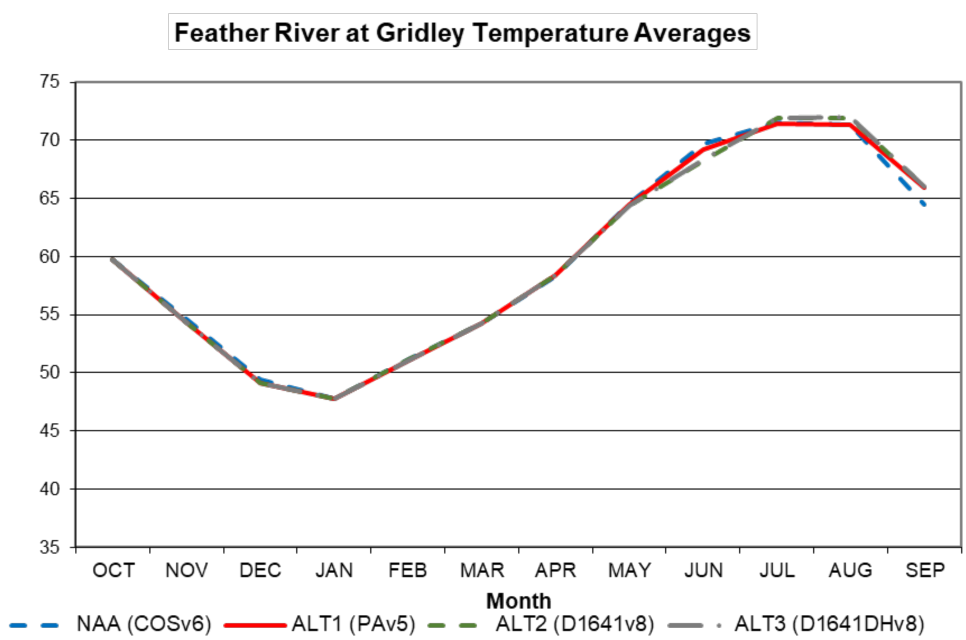


Figure O.3-8. RecTemp Average Feather River water Temperatures at Gridley Bridge under the No Action Alternative, Alternative 1, Alternative 2, and Alternative 3 Scenarios.

Figure O.3-9. RecTemp average estimated Feather River water temperatures at Gridley Bridge in Wet, Above Normal, Below Normal, Dry, and Critically Dry Water Year Types under the No Action Alternative, Alternative 1, Alternative 2, and Alternative 3 Scenarios

Table O.3-3. Water Temperatures Suitable for Spring- and Fall-Run Chinook, Central Valley Steelhead, and Green Sturgeon by Life Stage

Life Stage	Peak Occurrence	Optimal	Suboptimal	Stress-inducing
Spring-Run Chinook				
Eggs to fry	September to October	< 54°F	54°F to 58°F	> 58°F
Rearing to out-migrating	November to May	< 60°F	60°F to 65°F	> 65°F
Migrating adults	March to June	< 56°F	56°F to 65°F	> 65°F
Adult holding	May to August	< 60.8°F	60.8°F to 66.2°F	> 66.2°F
Fall-Run Chinook				
Eggs to fry	October to April	48.2°F to 55.4°F	55.4°F to 62.6°F	> 62.6°F
Rearing to out-migrating	April to June	55.4°F to 68°F	68°F to 75.2°F	> 75.2°F
Migrating adults	June to April	50°F to 68°F	68°F to 69.8°F	> 69.8°F
Central Valley Steelhead				
Eggs to fry	January	46°F to 52°F	52°F to 55°F	> 55°F
Rearing to out-migrating	January to May	< 65°F	65°F to 68°F	> 68°F
Migrating adults	September to October	< 52°F	52°F to 70°F	> 70°F
Adult holding	December to March	< 60.8°F	60.8°F to 66.2°F	> 66.2°F
Green Sturgeon				
Eggs to fry	May to July	53°F to 65°F	65°F to 66°F	> 66°F
Rearing to out-migrating	May to October	58°F to 66°F	66°F to 69°F	> 69°F
Migrating adults	March to May	53°F to 64°F	64°F to 66°F	> 66°F
Post-spawn adults	March to August	46°F to 68°F	68°F to 70°F	>70°F

Sources: NMFS 2016a; Stillwater Sciences 2006; CDFG 2012a, 2012b.

Additionally, although stream flows would remain the same under the No Action Alternative, mean air temperatures are predicted to increase by 4.5°F (2.5°C) by mid-century as a result of climate change, and could increase by 5.4°F (3°C), based on more extreme climate change predictions (Wang et al. 2018). Climate change is also predicted to result in overall increased precipitation of up to two inches, a higher frequency of short-duration high-rainfall events, fewer moderate-rainfall events with prolonged durations, less snowpack in winter and early spring months, altered stream flow volume and timing, and lower late summer flows by mid-century, although again, more extreme climate change predictions include decreased precipitation of up to 20 inches (Wang et al. 2018).

Because water temperatures under current conditions surpass suboptimal levels (greater than maximums of 55°F and 75.2°F) for several species and life stages in all water year types, and reach stress-inducing levels (greater than maximums of 58°F and 75.2°F) during some water year types (Table O.3-3; Figure O.3-9), there is potential for continued adverse temperature-related effects on Feather River Spring-Run Chinook Salmon, Fall-Run/Late Fall-Run Chinook Salmon, and Central Valley Steelhead under both current conditions and the No Action Alternative. and reach stress-inducing levels (greater than maximums of 58°F and 75.2°F) during some water year types (Table O.3-3; Figure O.3-9), there is potential for continued adverse temperature-related effects on Feather River Spring-Run Chinook Salmon, Fall-Run Chinook Salmon, and Central Valley Steelhead under both current conditions and the No Action

Alternative. Additionally, if climate change estimates are accurate, water temperatures in the Feather River would likely increase by 2030 under the No Action Alternative, further exasperating adverse temperature-related effects for these species, when compared to current conditions, discussed in more detail below.

Winter-Run Chinook Salmon

Winter-Run Chinook are not likely to be affected by changes in flow under the No Action Alternative compared to current conditions due to their limited distribution in the Feather River.

Spring-Run Chinook Salmon

Effects of water temperature on Spring-Run Chinook have been heavily studied in the Feather River, resulting in an understanding of the optimal (beneficial), suboptimal, and stress-inducing (adverse) temperature ranges for each life stage during its period of peak abundance (Table O.3-3).

There is no difference in water temperature between the No Action Alternative and current conditions for Spring-Run Chinook; however, water temperatures under both scenarios would fall in the stress-inducing range for portions of all life stages present (Figure O.3-9and Table O.3-3). The average water temperatures currently, and under the No Action Alternative, fall in the stress-inducing range during the peak occurrence period of egg incubation and fry in all water year types. Similarly, average water temperatures are within the stress-inducing range during the peak occurrence period of rearing and out-migrating juveniles in May of above normal, below normal, dry, and critically dry water year types. Migrating adults would also encounter stress inducing temperatures toward the end of the migration season (i.e., May through June) and would continue to encounter these temperatures downstream of the Thermalito Afterbay outlet for the entirety of the holding period, across all water year types (Figure O.3-9 and Table O.3-3). Under the No Action Alternative, water temperatures in the Feather River would likely increase by 2030 due to climate change, further exasperating adverse temperature-related effects for each life stage of Spring-Run Chinook, when compared to current conditions. Therefore, the No Action Alternative has the potential for slightly adverse water temperature-related effects on all life stages of Spring-Run Chinook Salmon compared to current conditions.

Fall-Run Chinook Salmon

Effects of water temperature on Fall-Run Chinook have been heavily studied in the Feather River, resulting in an understanding of the optimal (beneficial), suboptimal, and stress-inducing (adverse) temperature ranges for each life stage (Table O.3-3).

There is no difference in water temperature between the No Action Alternative and current conditions for Fall-Run Chinook; however, water temperatures under both scenarios would fall in the stress-inducing range for incubating eggs and fry as well as migrating adults (Figure O.3-9 and Table O.3-3). The average water temperatures currently, and under the No Action Alternative, fall in the stress-inducing range during the peak occurrence period of egg incubation and fry in April of above normal, below normal, and dry water years, as well as in April and October of critically dry water years. Migrating adults would also encounter stress inducing temperatures before September in most water years (Figure O.3-9 and Table O.3-3). Under the No Action Alternative, water temperatures in the Feather River would likely increase by 2030 due to climate change, further exasperating adverse temperature-related effects for each life stage of Fall-Run Chinook, when compared to current conditions. Therefore, the No Action Alternative has the potential for slightly adverse water temperature-related effects on incubating eggs and fry and migrating adults Fall-Run Chinook Salmon compared to current conditions.

Central Valley Steelhead

Effects of water temperature on Central Valley Steelhead have been heavily studied, resulting in an understanding of the optimal (beneficial), suboptimal, and stress-inducing (adverse) temperature ranges for each life stage during its period of peak abundance (Table O.3-3). Central Valley Steelhead eggs, fry, and holding adults are present in the Feather River in winter and spring months; however, juveniles typically migrate to the ocean after spending 1 to 3 years in freshwater (CDFG 1996). Steelhead fry and fingerlings rear and migrate downstream during most months of the year, but the peak period of emigration is January through May (Table O.3-3).

There is no difference in water temperature between the No Action Alternative and current conditions for Central Valley Steelhead; however, water temperatures under both scenarios would fall in the stress-inducing range downstream of the Thermalito Afterbay outlet for rearing juveniles, given the potential to occur for up to 3 years in the stream (Figure O.3-9 and Table O.3-3). Under the No Action Alternative, water temperatures in the Feather River downstream of the Thermalito Afterbay outlet would likely increase by 2030 due to climate change, further exasperating adverse temperature-related effects for holding juvenile Steelhead when compared to current conditions. Given that current conditions limit rearing habitat to upstream of the Thermalito Afterbay outlet, there is likely only a negligible adverse water temperature-related effects on rearing juvenile Steelhead under the No Action Alternative compared to current conditions.

North American Green Sturgeon

Effects of water temperature on Green Sturgeon have been heavily studied in the Feather River, resulting in an understanding of the optimal (beneficial), suboptimal, and stress-inducing (adverse) temperature ranges for each life stage (Table O.3-3).

There is no difference in water temperature between the No Action Alternative and current conditions for Green Sturgeon; however, water temperatures under both scenarios would fall in the stress-inducing range for portions of all life stages present (Figure O.3-9 and Table O.3-3). The average water temperatures currently, and under the No Action Alternative, fall in the stress-inducing range during the peak occurrence period of egg incubation and fry in all water year types. Similarly, average water temperatures are within the stress-inducing range during the peak occurrence period of rearing and out-migrating juveniles in all water year types. Migrating adults would also encounter stress inducing temperatures toward the end of the migration season (i.e., May) of above normal, below normal, dry, and critically dry water year types (Figure O.3-9 and Table O.3-3). Under the No Action Alternative, water temperatures in the Feather River would likely increase by 2030 due to climate change, further exasperating adverse temperature-related effects for each life stage of Green Sturgeon, when compared to current conditions. Therefore, the No Action Alternative has the potential for slightly adverse water temperature-related effects on all life stages of Green Sturgeon compared to current conditions.

O.3.2.5 *American River*

Potential changes to aquatic resources in the American River from flood control

Flood Control for the American River at Folsom Dam would be the same under the No Action Alternative compared to the existing condition, since flood control follows the USACE Water Control Manual. The Water Control Manual has been updated over time, and a new Water Control Manual was developed that utilizes forecasted inflow as the criteria for determining flood control releases. The new manual looks ahead five days and considers the forecasted inflow volume for the total of those five days. If that volume exceeds a threshold, a flood control release is specified. The concept is to pre-emptively draw the reservoir down in anticipation of high inflows, thus providing space to store the rain event when it arrives. This will allow Reclamation to pass higher precipitation events with lower peak releases which relieves stress on the downstream levees and provides a higher level of flood protection to downstream areas.

Potential changes to aquatic resources from Folsom Reservoir operations in the American River to meet Delta salinity requirements

Folsom Reservoir operations to address Delta water quality requirements under D-1641 would not change under the No Action Alternative, compared to existing conditions. Folsom Reservoir flow requirements include releases to meet Delta standards under D-1641, as needed. Since Folsom Reservoir is the closest reservoir to the Delta, releases from Folsom can more quickly address Delta water quality requirements. Releases to address Delta water quality objectives would be conducted, as needed, in coordination with the American River stakeholders. Releases to address Delta water quality objectives would improve water quality conditions, and thus habitat conditions for fish and other aquatic species in the Delta when hydrologic conditions are negatively affecting salinity levels.

Potential changes to aquatic resources from flows in the American River

Flows in the American River below Nimbus Dam would be the same under the No Action Alternative compared to the existing condition, since flow management for the No Action Alternative is according to the American River 2006 Flow Management Standard, the same as under the existing condition. Under the No Action Alternative, flow releases follow the existing conditions and current flow operations in the lower American River were flows are managed according to the American River 2006 Water Forum Lower American Flow Management Standard (Water Forum 2006), with the objective of providing suitable conditions for Fall-Run Chinook Salmon and Steelhead. Under the Flow Management Standard, flows are managed according to the Minimum Flow Requirements (MFR), which establishes minimum flows, as measured by the total release at Nimbus Dam, which vary throughout the year in response to the hydrology of the Sacramento and American River basins. The October 1 through December 31 MFR range between 800 and 2,000 cfs. The January 1 through Labor Day MFR range between 800 and 1,750 cfs. The post Labor Day through September MFR range between 800 and 1,500 cfs. As a general rule, the MFR must equal or exceed 800 cfs year round. Narrowly defined exceptions to this rule allow Nimbus releases to drop below 800 cfs to avoid depletion of water storage in Folsom Reservoir when dry or critical hydrologic conditions are forecasted to occur. These narrowly defined exceptions to the MFR are an important component of the Flow Management Standard. Since the No Action Alternative follows the existing condition, implementation of the No Action Alternative would result in no change to flows in the lower American River.

Potential changes to aquatic resources in the American River due to changes in water temperature

Water temperatures in the American River at Watt Avenue would be the same under the No Action Alternative as under the existing conditions, since the temperature objectives for the No Action Alternative is according to the American River 2006 Flow Management Standard, the same as under the existing condition. Current objectives for water temperatures in the Lower American River address the needs for Steelhead incubation and rearing during the late spring and summer, and for Fall–Run Chinook Salmon spawning and incubation starting in late October or early November. However, only in wetter hydrologic conditions is the volume of cold water sufficient to meet the majority of the water temperature objectives.

Potential changes to aquatic resources in the American River from habitat restoration

Habitat restoration projects are not proposed under the No Action Alternative, therefore, there would be no changes to habitat in the lower American River.

O.3.2.6 *Stanislaus River*

Potential changes to aquatic resources in the Stanislaus River due to changes in flow

Reclamation operates the Stanislaus River separately from the other CVP reservoirs. While releases from New Melones Reservoir provide inflow to the Delta, Reclamation does not operate New Melones for Delta salinity, outflow, or export requirements. As described in Appendix C, *Facility Descriptions,* Reclamation is required to operate releases from the East Side Division reservoirs according to the New Melones year-type specific minimum flow schedules. Tables X1 through X5 in Appendix 1 indicate the specific minimum flow schedule that Reclamation currently operations for the East Side Division reservoir. However, the flow schedule does not preclude Reclamation from making higher releases for fishery benefits or other operational criteria[6]. Under the No Action Alternative, Reclamation would continue to meet the minimum flow schedule, to their best ability, as described in the 2009 NMFS BO RPA Action III.1.3. Reclamation currently manages flow (based on releases measured at Goodwin Dam) to provide habitat for all life history stages of Steelhead and to incorporate habitat maintaining geomorphic flows in a flow pattern that would provide migratory cues to smolts and facilitate out-migrant smolt movement.

Potential changes to aquatic resources in the Stanislaus River due to changes in water temperature

Cold water in the Stanislaus River is affected by the cold-water pool in New Melones Reservoir and air temperatures. Reclamation manages the cold-water supply and makes cold-water releases from New Melones Reservoir to provide suitable temperatures for Steelhead rearing, spawning, egg incubation smoltification, and adult migration in the Stanislaus River downstream of Goodwin Dam.

Under the No Action Alternative, water temperature Reclamation will continue, where feasible, to manage the cold water supply within New Melones as described in 2009 NMFS RPA Action III.1.2, with the objective of providing suitable temperatures for Central Valley Steelhead rearing, spawning, egg incubation, smoltification, and adult migration in the river downstream of Goodwin Dam. There are no temperature control devices at New Melones, Goodwin, or Tulloch Dams; thus, temperature management flexibility is limited to storage and flow management under certain conditions. Under the No Action Alternative, Central Valley Steelhead would continue to be vulnerable to elevated temperatures in dry and critically dry years, even if actions are taken to improve temperature management. The frequency of these occurrences is expected to increase with climate change-related temperature increases.

O.3.2.7 *San Joaquin River*

Potential changes to aquatic resources in the San Joaquin River due to changes in flow

The San Joaquin River is highly altered and as a result, flow within the River is a more complex issue. Currently, the San Joaquin River Restoration Program is working toward re-establishing contiguous in the river below Sack Dam. Progress is advancing toward this goal, but anadromous fish are currently collected at the San Joaquin River above the Merced River and moved to the upper reaches. Therefore

[6] https://www.westcoast.fisheries.noaa.gov/publications/Central_Valley/Water%20Operations/Operations,%20Criteria%20and%20Plan/040711_ocap_opinion_2011_amendments.pdf, February 18, 2019

flow between the upper San Joaquin and lower San Joaquin River (where many tributaries contribute) respond differently. Analyses of flow for the No Action Alternative and Alternatives 1 through 3 show that releases in the San Joaquin River below Millerton Reservoir will remain the same for all alternatives (Figure O.3-10). Therefore, no change is anticipated as a result in the upper San Joaquin River.

Flow at Vernalis in the San Joaquin River represents all contributions from the upper San Joaquin, Merced, Tuolumne, and Stanislaus Rivers combined. Flow contributions vary based on program alternatives in the tributaries; therefore, flow in the San Joaquin River changes as well (Figure O.3-11). Overall, there is not a substantial change between the No Action Alternative and Alternatives 1 through 3. Average flows follow the same general trend, rising early in the year to peak in spring and then generally decrease. The differences between annual average flow also is within 50 cfs of each alternative, representing no greater than 1.1% variation between all alternatives. Differences by water year type are again very similar, therefore substantial variation between all alternatives is not expected.

The San Joaquin River below the Merced confluence primarily represents a migration corridor. Salmonids and other potential species such as Sturgeon migrate between tributaries and the Delta through the San Joaquin River. Therefore the exposure to the lower San Joaquin River is temporary and generally during adult return or juvenile out-migration.

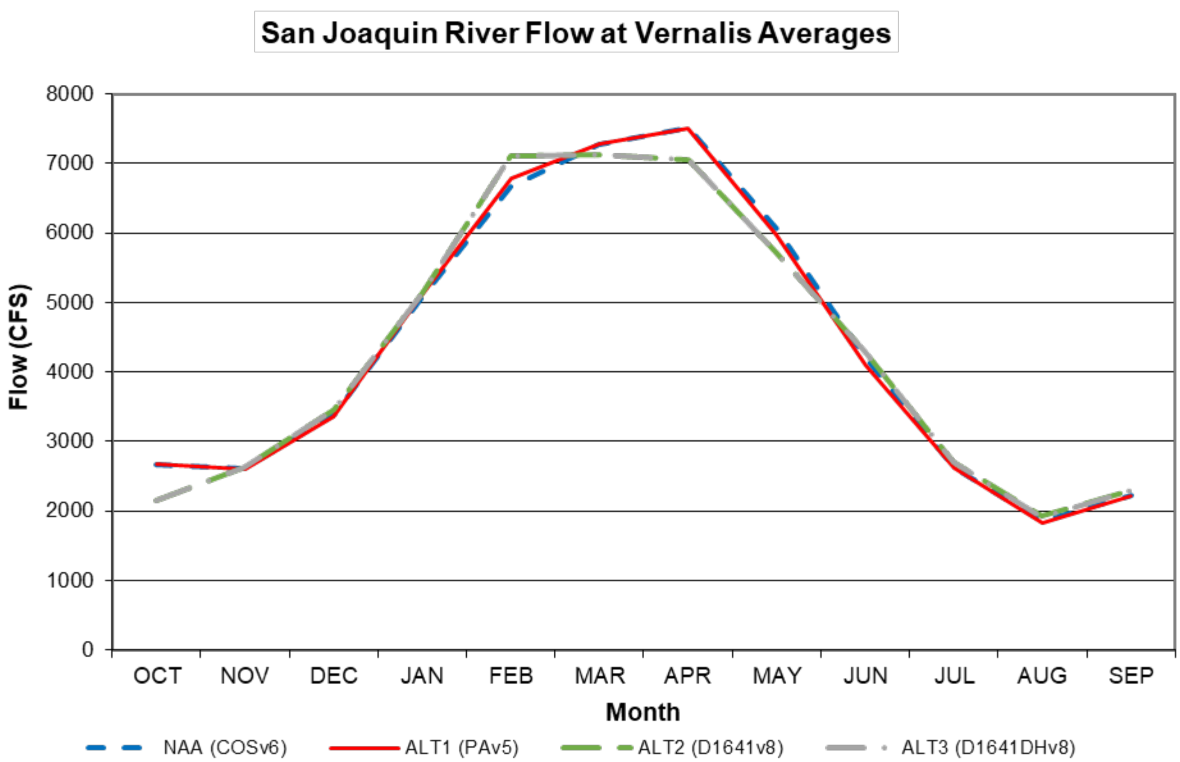


Figure O.3-10. Average Flow by Month at Vernalis on the San Joaquin River

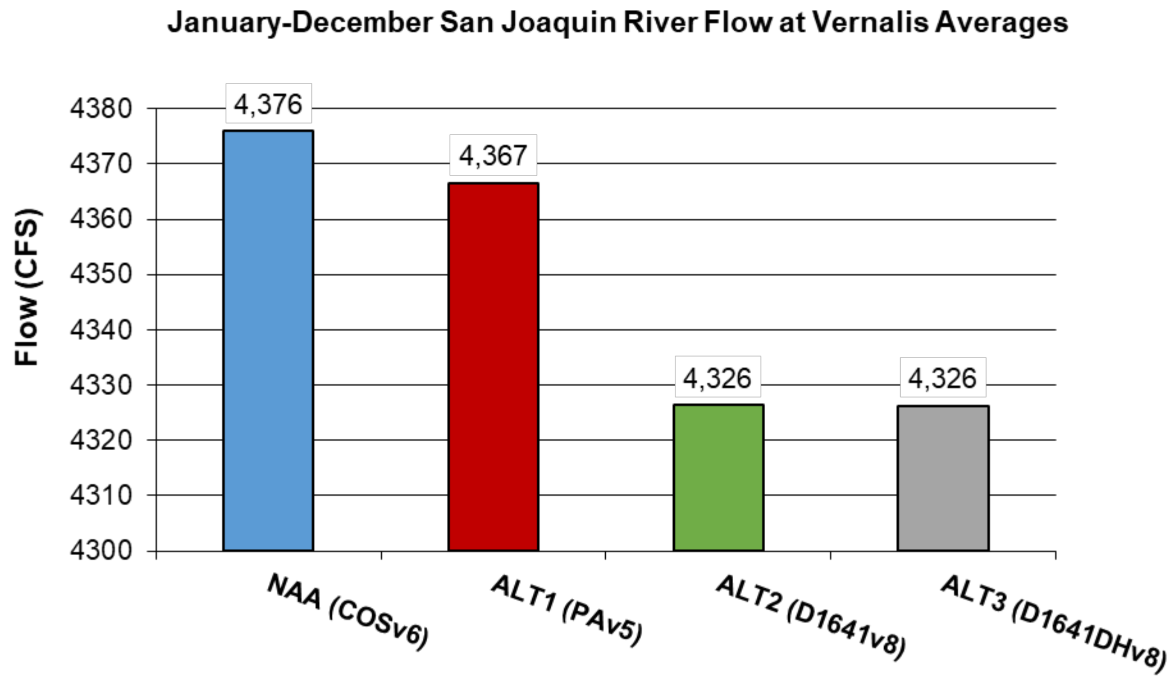


Figure O.3-11. Average Annual Flow Occurring at Vernalis on the San Joaquin River

Potential changes to aquatic resources in the San Joaquin River due to changes in water temperature

Variations in flow and reservoir storage both can result in direct changes to water temperature through the thermal buffering capacity of water based on volume of storage or discharge. There are no changes in outflow release from Friant Dam at Millerton Lake (Figure O.3-12). Therefore, no changes in temperature as a result of flow or storage are expected in the upper San Joaquin River.

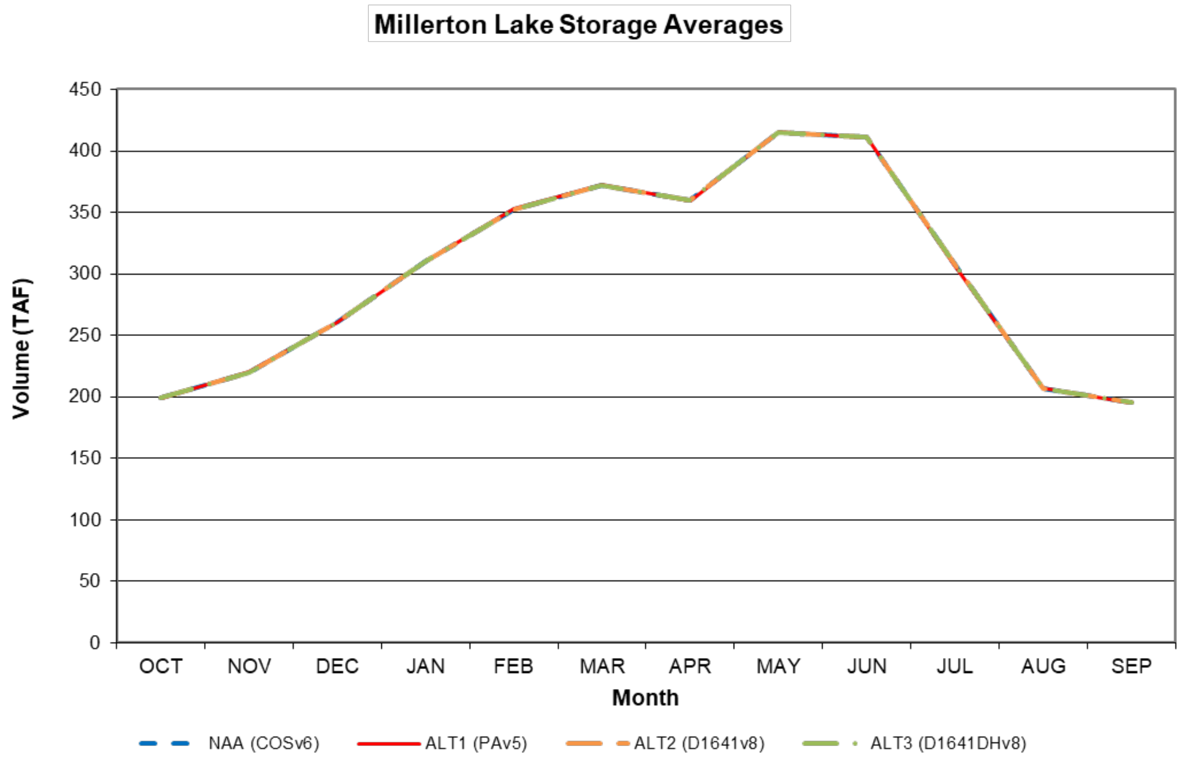


Figure O.3-12. Average Monthly Reservoir Volume at Millerton Lake on the San Joaquin River

In the lower San Joaquin River, changes in flow are expected to be relatively minimal as discussed above. Given the low variation in flow between program alternatives, little change in temperature is also anticipated. Figure O.3-13 shows the relatively similar average temperature modeled at Vernalis on the San Joaquin River. Average annual water temperature is expected to change by no more than 0.2°F between all project alternatives. Based on these results there does not appear to be any notable effect to water temperature.

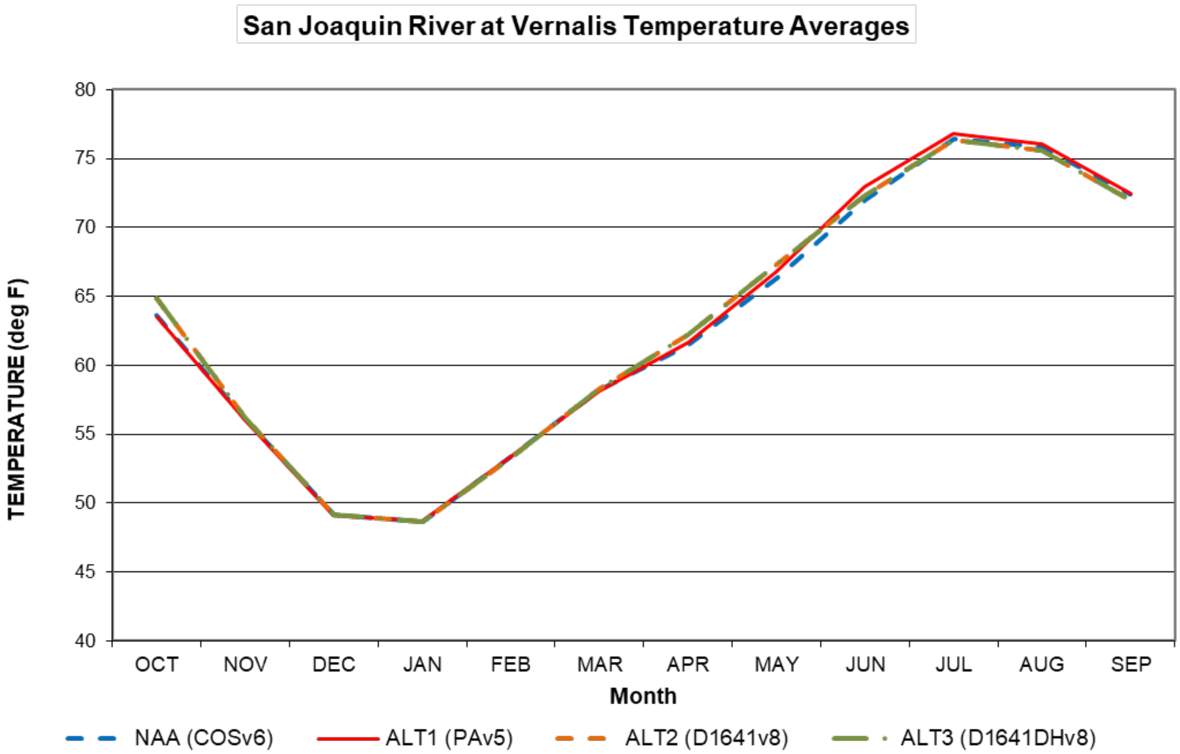


Figure O.3-13. Average Monthly Water Temperature at Vernalis by Project Alternative

Potential changes to aquatic resources in the San Joaquin River due to restoration activities

Proposed restoration activity in the San Joaquin River includes the San Joaquin River Restoration Program in the upper San Joaquin River and programmatic lower San Joaquin River Habitat restoration. Both of these activities may result in temporary disturbance to habitat and may expose nearby fish stressful conditions. Elevated turbidity, noise, and exclusion from habitat are all temporary potential effects as a result of restoration activity. Each of these potential issues will be mitigated for through regulatory review and established best management practices. The timing of activities will be focused on periods known for the least likely presence of protected species. The temporary nature of these activities will limit the potential for any lasting impact to the surrounding aquatic community. In addition, the benefit of the action will likely result in long-term improvements to the habitat and aquatic inhabitants.

O.3.2.8 *Bay Delta*

O.3.2.8.1 Delta Smelt

Potential changes to Delta Smelt due to seasonal operations

The No Action Alternative would include continuation of current seasonal operations, from which the primary potential effects to Delta Smelt include south Delta entrainment (limited by the OMR criteria from the USFWS [2008] BO), food web productivity entrainment (limited by the USFWS [2008] BO requirement to restore 8,000 acres of tidal habitat, which has the potential to reduce effects relative to current conditions, as described further below in *Potential changes to Delta Smelt from tidal habitat restoration* and effects to the extent of fall abiotic habitat (limited by the USFWS [2008] fall X2 requirement).

Potential changes to Delta Smelt due to changes in Delta Cross Channel operations

As noted in the Final Biological Assessment on the Reinitiation of Consultation on the Coordinated Long-Term Operation of the Central Valley Project and State Water Project (ROC LTO BA), it is unknown what if any direct impacts occur to Delta Smelt from opening or closing the DCC gates, and there is limited occurrence of Delta Smelt near the DCC (Reclamation 2019). Under the No Action Alternative, no changes are proposed to DCC operational criteria relative to current conditions, so any effects to Delta Smelt under the No Action Alternative would continue as currently occurring.

Potential changes in Delta Smelt survival related to the Temporary Barriers Project

Under the No Action Alternative, potential effects of the Temporary Barriers Project on Delta Smelt would be expected to be similar to the effects under current conditions (i.e., near-field predation and potential effects on transport of *P. forbesi* to the low salinity zone; see also ROC LTO BA. The spring HOR barrier has the potential to influence entrainment risk for larval/early juvenile Delta Smelt, but consistent with current practice the barrier would only be installed if Delta Smelt entrainment risk would not be affected.

Potential changes to Delta Smelt from Contra Costa Water District operations

Contra Costa Water District operations under the No Action Alternative would not change from current conditions and therefore would be expected to have similar effects to Delta Smelt, i.e., negligible entrainment and hydrodynamic effects (Reclamation 2019).

Potential changes to Delta Smelt from North Bay Aqueduct operations

North Bay Aqueduct Barker Slough Pumping Plant operations would not differ between the No Action Alternative and current conditions, so the effects to Delta Smelt would be expected to be similar under the No Action Alternative as currently occurring, i.e., potential entrainment, impingement, near-field predation, and entrainment of Delta Smelt food, which could have limited effects on Delta Smelt given low occurrence in the vicinity of the Barker Slough Pumping Plant (Reclamation 2019).

Potential changes to Delta Smelt from water transfers

Under the No Action Alternative, the water transfer window would remain the same as currently in place, i.e., July to September. This period avoids the occurrence of Delta Smelt in the south Delta (Reclamation 2019) and therefore limits entrainment and predation risk at the south Delta export facilities.

Potential changes to Delta Smelt from Clifton Court aquatic weed and algal bloom management

Continuation of the current aquatic weed removal program in Clifton Court Forebay under the No Action Alternative would be expected to have little to no effect on Delta Smelt as a result of the timing of the action avoiding the main period of Delta Smelt potential occurrence.

Potential changes to Delta Smelt due to changes from Tracy and Skinner fish facilities

Under the No Action Alternative, potential effects from the Tracy and Skinner fish facilities would continue as currently occurring. This includes Delta Smelt mortality from pre-screen loss, collection, handling, transport, and release, with only a very small fraction potentially surviving the salvage process (Reclamation 2019). The potential effects from the Tracy and Skinner fish salvage facilities under the No

Action Alternative would be limited by continued management based on the USFWS (2008) BO criteria for OMR management, as previously outlined in *Potential effects from seasonal operations*.

Potential changes to Delta Smelt due to changes from Suisun Marsh facilities

Under the No Action Alternative, the Suisun Marsh facilities would continue to be operated as currently occurs, with potential limited effects to Delta Smelt such as entrainment (Reclamation 2019).

Potential changes to Delta Smelt due to changes from tidal habitat restoration

Under the No Action Alternative, completion of the 8,000 acres of tidal habitat restoration required by the USFWS (2008) BO would add approximately 6,000 acres of tidal habitat relative to current conditions. This has the potential to provide positive effects on Delta Smelt as a result of increased food availability, thus offsetting potential food productivity negative effects described previously in *Potential changes to Delta Smelt due to seasonal operations*, as well potentially providing habitat for occupation by Delta Smelt depending on presence of suitable habitat features such as relatively high turbidity (Reclamation 2019). Potential negative effects from contaminants (e.g., methylmercury) would be addressed with minimization measures.

O.3.2.8.2 Longfin Smelt

Potential changes to Longfin Smelt due to seasonal operations

The No Action Alternative would include continuation of current seasonal operations, from which the primary potential effects to Longfin Smelt include south Delta entrainment (mitigated by the OMR criteria from the CDFG [2009] ITP requirements) and habitat quality (mitigated by the CDFG [2009] ITP requirement to restore 800 acres of intertidal and associated subtidal habitat in a mesohaline part of the estuary). Operations have the potential to influence population abundance through effects on winter-spring Delta outflow (Nobriga and Rosenfield 2016), although the extent to which interannual differences are operations- versus hydrology-related is uncertain (Maunder et al. 2015); any effects under the No Action Alternative would continue consistent with current conditions.

Potential changes to Longfin Smelt due to changes in Delta Cross Channel operations

Under the No Action Alternative, no changes are proposed to DCC operational criteria relative to current conditions, so any effects to Longfin Smelt under the No Action Alternative would continue as currently occurring.

Potential changes in Longfin Smelt survival related to the Temporary Barriers Project

Under the No Action Alternative, potential effects of the Temporary Barriers Project on Longfin Smelt would be expected to be similar in nature but less than the effects to Delta Smelt under current conditions (i.e., near-field predation for smelts occurring in the vicinity; see also ROC LTO BA, with less effect to Longfin Smelt than Delta Smelt because Longfin Smelt are generally further downstream than Delta Smelt (Merz et al. 2011; Merz et al. 2013; Kimmerer et al. 2013). When installed, the spring HOR barrier presumably has the potential to influence entrainment risk for juvenile Longfin Smelt as it does for Delta Smelt, although entrainment risk is managed such that hydrodynamic effects of the barrier would be reflected in OMR flows and therefore accounted for.

Potential changes to Longfin Smelt from Contra Costa Water District operations

Contra Costa Water District operations under the No Action Alternative would not change from current conditions and therefore would be expected to have similar effects to Longfin Smelt, i.e., negligible entrainment and hydrodynamic effects per analyses undertaken for Delta Smelt (Reclamation 2019).

Potential changes to Longfin Smelt from North Bay Aqueduct operations

North Bay Aqueduct Barker Slough Pumping Plant operations would not differ between the No Action Alternative and current conditions, so the effects to Longfin Smelt would be expected to be similar under the No Action Alternative as currently occurring, i.e., potential entrainment, impingement, near-field predation, and entrainment of Longfin Smelt food, as suggested for Delta Smelt (Reclamation 2019). Potential effects are limited under the CDFG (2009) ITP because DWR must operate Barker Slough Pumping Plant with a maximum 7-day average diversion rate that does not exceed 50 cfs from January 15 through March 31 of dry and critically dry water year types (per the current forecast based on D-1641) if larval Longfin Smelt are detected at Station 716 during the annual Smelt Larval Survey.

Potential changes to Longfin Smelt from water transfers

Under the No Action Alternative, the water transfer window would remain the same as currently in place, i.e., July to September. This period avoids the occurrence of Longfin Smelt in the south Delta (Merz et al. 2013) and therefore avoids entrainment and predation risk at the south Delta export facilities.

Potential changes to Longfin Smelt from Clifton Court aquatic weed removal

Continuation of the current aquatic weed removal program in Clifton Court Forebay under the No Action Alternative would be expected to have little to no effect on Longin Smelt as a result of the timing of the action avoiding the main period of Longfin Smelt potential occurrence (Grimaldo et al. 2009).

Potential changes to Longfin Smelt due to changes from Tracy and Skinner fish facilities

Under the No Action Alternative, potential effects from the Tracy and Skinner fish facilities would continue as currently occurring. This includes mortality from pre-screen loss, collection, handling, transport, and release, with only a very small fraction potentially surviving the salvage process (CDFG 2009a). The potential effects from the Tracy and Skinner fish salvage facilities under the No Action Alternative would be limited by continued management based on the CDFG (2009a) ITP criteria for OMR management, as previously outlined in *Potential changes to Longfin Smelt due to seasonal operations*.

Potential changes to Longfin Smelt due to changes from Suisun Marsh facilities

Under the No Action Alternative, the Suisun Marsh facilities would continue to be operated as currently occurs, with potential limited effects to Longfin Smelt such as entrainment (CDFG 2009a).

Potential changes to Longfin Smelt due to changes from tidal habitat restoration

Under the No Action Alternative, completion of the 8,000 acres of tidal habitat restoration required by the USFWS (2008) BO would add approximately 6,000 acres of tidal habitat relative to current conditions. This has the potential to provide positive effects to Longfin Smelt as a result of increased food availability to larvae, given relatively frequent occurrence in the north Delta (Merz et al. 2013), as well as potentially providing habitat for occupation by Longfin Smelt depending on presence of suitable habitat features. As previously described for Delta Smelt, potential negative effects from contaminants (e.g., methylmercury) would be addressed with mitigation measures such as MM-AQUA-9 (Appendix E, Mitigation Measures).

Potential positive and negative effects of completion of the 8,000 acres of tidal habitat restoration would be expected to be less than to Delta Smelt because Longfin Smelt generally occurs more downstream in the Bay-Delta than Delta Smelt (Merz et al. 2011; Merz et al. 2013; Kimmerer et al. 2013; Grimaldo et al. 2017).

O.3.2.8.3 Sacramento River Winter Run Chinook Salmon

Potential changes to aquatic resources due to seasonal operations

The No Action Alternative would include continuation of current seasonal operations, from which the primary potential effects to Winter-Run Chinook include south Delta entrainment and reduced velocities within some migratory corridors. The BO requirement to restore 8,000 acres of tidal habitat has the potential to reduce effects relative to current conditions, as described further below in *Potential effects from Tidal Habitat Restoration (Complete 8,000 Acres from 2008 BO*).

Potential changes to aquatic resources due to Delta Cross Channel operations

Winter-Run Chinook salmon are vulnerable to entrainment into the Delta Cross Channel if they are present when the gates are open. Individuals entrained into the Delta Cross Channel enter the interior Delta where survival rates are lower relative to fish that remain in the main stem Sacramento River. Under the No Action Alternative, operation of the DCC, and resulting probabilities of entrainment would remain the same as the current condition.

Potential changes to aquatic resources due to the Temporary Barriers Project

Few if any Winter-Run Chinook Salmon would be expected to occur in the region of the Temporary Barriers during the period when they are installed. Any potential effect under the No Action Alternative would be similar to the existing condition.

Potential changes to aquatic resources due to Contra Costa Water District operations

Contra Costa Water District operations under the No Action Alternative would not change from current conditions and therefore would be expected to have similar effects on Winter-Run Chinook Salmon, i.e., negligible entrainment and hydrodynamic effects.

Potential changes to aquatic resources due to North Bay Aqueduct operations

North Bay Aqueduct Barker Slough Pumping Plant operations would not differ between the No Action Alternative and current conditions, so the effects to Winter Run would be expected to be similar under the No Action Alternative as currently occurring. Few juvenile salmonids are collected in monitoring efforts associated with the project and potential effects are negligible.

Potential changes to aquatic resources due to water transfers

Under the No Action Alternative, the water transfer window would remain the same as currently in place, i.e., July to September. This period is outside of the migration window for Winter Run Chinook Salmon in the Delta.

Potential changes to aquatic resources from Clifton Court aquatic weed removal

Continuation of the current aquatic weed removal program in Clifton Court Forebay under the No Action Alternative would be expected to have little to no effect on Winter-Run as a result of the timing of the action avoiding the main period of Winter-Run occurrence.

Potential changes to aquatic resources due to changes from Tracy and Skinner fish facility improvements

Under the No Action Alternative, potential effects from the Tracy and Skinner fish facilities would continue as currently occurring. This includes mortality from pre-screen loss, collection, handling, transport, and release. The potential effects from the Tracy and Skinner fish salvage facilities under the No Action Alternative would be limited by continued management based on the NMFS (2009) BO RPA.

Potential changes to aquatic resources due to changes from Suisun Marsh facilities

Under the No Action Alternative, the Suisun Marsh facilities would continue to be operated as currently occurs, with potential limited effects to Winter-Run such as delay of adults migrating through Montezuma Slough and predation of juveniles around the salinity control gates.

Potential changes to aquatic resources due to tidal habitat restoration

Under the No Action Alternative, completion of the 8,000 acres of tidal habitat restoration required by the USFWS (2008) BO would add approximately 6,000 acres of tidal habitat relative to current conditions. This has the potential to provide positive effects on Winter-Run as a result of increased food availability, and rearing habitat. Potential negative effects from contaminants (e.g., methylmercury) would be addressed with minimization measures.

O.3.2.8.4 Central Valley Spring Run Chinook Salmon

Potential changes to aquatic resources due to seasonal operations

The No Action Alternative would include continuation of current seasonal operations, from which the primary potential effects to Spring-Run Chinook include south Delta entrainment and reduced flow velocities within some migratory corridors. The BO requirement to restore 8,000 acres of tidal habitat has the potential to reduce effects relative to current conditions, as described further below in *Potential effects from Tidal Habitat Restoration (Complete 8,000 Acres from 2008 BO*).

Potential changes to aquatic resources due to Delta Cross Channel operations

Sacramento River-origin Spring-Run Chinook salmon are vulnerable to entrainment into the Delta Cross Channel if they are present when the gates are open. Individuals entrained into the Delta Cross Channel enter the interior Delta where survival rates are lower relative to fish that remain in the main stem Sacramento River. San Joaquin River-origin fish would not be exposed to the DCC. Under the No Action Alternative, operation of the DCC, and resulting probabilities of entrainment would remain the same as the current condition.

Potential changes to aquatic resources due to the Temporary Barriers Project

Few if any Sacramento River-origin Spring-Run Chinook Salmon would be expected to occur in the region of the Temporary Barriers during the period when they are installed. A greater fraction of San Joaquin River-origin Spring Run would be expected to be exposed to the barriers. Any potential effect under the No Action Alternative such as reduced survival would be similar to the existing condition.

Potential changes to aquatic resources due to Contra Costa Water District operations

Contra Costa Water District operations under the No Action Alternative would not change from current conditions and therefore would be expected to have similar effects on Spring-Run Chinook Salmon, i.e., negligible entrainment and hydrodynamic effects.

Potential changes to aquatic resources due to North Bay Aqueduct operations

North Bay Aqueduct Barker Slough Pumping Plant operations would not differ between the No Action Alternative and current conditions, so the effects to Spring Run would be expected to be similar under the No Action Alternative as currently occurring. Few juvenile salmonids are collected in monitoring efforts associated with the project and potential effects are negligible. San Joaquin River-origin Spring run would not be exposed to this facility.

Potential changes to aquatic resources due to water transfers

Under the No Action Alternative, the water transfer window would remain the same as currently in place, i.e., July to September. This period is outside of the migration window for Spring Run Chinook Salmon in the Delta.

Potential changes to aquatic resources from Clifton Court aquatic weed removal

Continuation of the current aquatic weed removal program in Clifton Court Forebay under the No Action Alternative would be expected to have little to no effect on Spring-Run as a result of the timing of the action avoiding the main period of Spring-Run occurrence.

Potential changes to aquatic resources due to changes from Tracy and Skinner fish facility improvements

Under the No Action Alternative, potential effects from the Tracy and Skinner fish facilities would continue as currently occurring. This includes mortality from pre-screen loss, collection, handling, transport, and release. The potential effects from the Tracy and Skinner fish salvage facilities under the No Action Alternative would be limited by continued management based on the NMFS (2009) BO RPA.

Potential changes to aquatic resources due to changes from Suisun Marsh facilities

Under the No Action Alternative, the Suisun Marsh facilities would continue to be operated as currently occurs, with potential limited effects to Spring-Run such as delay of adults migrating through Montezuma Slough and predation on juveniles around the salinity control gates.

Potential changes to aquatic resources due to tidal habitat restoration

Under the No Action Alternative, completion of the 8,000 acres of tidal habitat restoration required by the USFWS (2008) BO would add approximately 6,000 acres of tidal habitat relative to current conditions. This has the potential to provide positive effects on Spring-Run as a result of increased food availability, and rearing habitat. Potential negative effects from contaminants (e.g., methylmercury) would be addressed with minimization measures.

O.3.2.8.5 Central Valley Fall Run Chinook Salmon

Potential changes to aquatic resources due to seasonal operations

The No Action Alternative would include continuation of current seasonal operations, from which the primary potential effects to Fall-Run Chinook include south Delta entrainment and reduced flow velocities within some migratory corridors. The BO requirement to restore 8,000 acres of tidal habitat has the potential to reduce effects relative to current conditions, as described further below in *Potential effects from Tidal Habitat Restoration (Complete 8,000 Acres from 2008 BO*).

Potential changes to aquatic resources due to Delta Cross Channel operations

Sacramento River-origin Fall-Run Chinook salmon are vulnerable to entrainment into the Delta Cross Channel if they are present when the gates are open. Individuals entrained into the Delta Cross Channel enter the interior Delta where survival rates are lower relative to fish that remain in the main stem Sacramento River. San Joaquin River-origin fish would not be exposed to the DCC. Under the No Action Alternative, operation of the DCC, and resulting probabilities of entrainment would remain the same as the current condition.

Potential changes to aquatic resources due to the Temporary Barriers Project

Few if any Sacramento River-origin Fall-Run Chinook Salmon would be expected to occur in the region of the Temporary Barriers during the period when they are installed. A greater fraction of San Joaquin River-origin Fall Run would be expected to be exposed to the barriers. Any potential effect under the No Action Alternative such as reduced survival would be similar to the existing condition.

Potential changes to aquatic resources due to Contra Costa Water District operations

Contra Costa Water District operations under the No Action Alternative would not change from current conditions and therefore would be expected to have similar effects on Fall-Run Chinook Salmon, i.e., negligible entrainment and hydrodynamic effects.

Potential changes to aquatic resources due to North Bay Aqueduct operations

North Bay Aqueduct Barker Slough Pumping Plant operations would not differ between the No Action Alternative and current conditions, so the effects to Fall Run would be expected to be similar under the No Action Alternative as currently occurring. Few juvenile salmonids are collected in monitoring efforts associated with the project and potential effects are negligible. San Joaquin River-origin Fall run would not be exposed to this facility.

Potential changes to aquatic resources due to water transfers

Under the No Action Alternative, the water transfer window would remain the same as currently in place, i.e., July to September. This period is outside of the migration window for Fall Run Chinook Salmon in the Delta.

Potential changes to aquatic resources from Clifton Court aquatic weed removal

Continuation of the current aquatic weed removal program in Clifton Court Forebay under the No Action Alternative would be expected to have little to no effect on Fall-Run as a result of the timing of the action avoiding the main period of Fall-Run occurrence.

Potential changes to aquatic resources due to changes from Tracy and Skinner fish facility improvements

Under the No Action Alternative, potential effects from the Tracy and Skinner fish facilities would continue as currently occurring. This includes mortality from pre-screen loss, collection, handling, transport, and release. The potential effects from the Tracy and Skinner fish salvage facilities under the No Action Alternative would be limited by continued management based on the NMFS (2009) BO RPA.

Potential changes to aquatic resources due to changes from Suisun Marsh facilities

Under the No Action Alternative, the Suisun Marsh facilities would continue to be operated as currently occurs, with potential limited effects to Fall-Run such as delay of adults migrating through Montezuma Slough and predation on juveniles around the salinity control gates.

Potential changes to aquatic resources due to tidal habitat restoration

Under the No Action Alternative, completion of the 8,000 acres of tidal habitat restoration required by the USFWS (2008) BO would add approximately 6,000 acres of tidal habitat relative to current conditions. This has the potential to provide positive effects on Fall-Run as a result of increased food availability, and rearing habitat. Potential negative effects from contaminants (e.g., methylmercury) would be addressed with minimization measures.

O.3.2.8.6 California Central Valley Steelhead

Potential changes to aquatic resources due to seasonal operations

The No Action Alternative would include continuation of current seasonal operations, from which the primary potential effects to CCV steelhead include south Delta entrainment and reduced flow velocities within some migratory corridors. The BO requirement to restore 8,000 acres of tidal habitat has the potential to reduce effects relative to current conditions, as described further below in *Potential effects from Tidal Habitat Restoration (Complete 8,000 Acres from 2008 BO*).

Potential changes to aquatic resources due to Delta Cross Channel operations

Sacramento River-origin steelhead are vulnerable to entrainment into the Delta Cross Channel if they are present when the gates are open. Individuals entrained into the Delta Cross Channel enter the interior Delta where survival rates are lower relative to fish that remain in the main stem Sacramento River. San Joaquin River-origin fish would not be exposed to the DCC. Under the No Action Alternative, operation of the DCC, and resulting probabilities of entrainment would remain the same as the current condition.

Potential changes to aquatic resources due to the Temporary Barriers Project

Few if any Sacramento River-origin CCV steelhead would be expected to occur in the region of the Temporary Barriers during the period when they are installed. A greater fraction of San Joaquin River-origin CCV steelhead would be expected to be exposed to the barriers. Any potential effect under the No Action Alternative such as reduced survival would be similar to the existing condition.

Potential changes to aquatic resources due to Contra Costa Water District operations

Contra Costa Water District operations under the No Action Alternative would not change from current conditions and therefore would be expected to have similar effects on CCV steelhead, i.e., negligible entrainment and hydrodynamic effects.

Potential changes to aquatic resources due to North Bay Aqueduct operations

North Bay Aqueduct Barker Slough Pumping Plant operations would not differ between the No Action Alternative and current conditions, so the effects to CCV steelhead would be expected to be similar under the No Action Alternative as currently occurring. Few juvenile salmonids are collected in monitoring efforts associated with the project and potential effects are negligible. San Joaquin River-origin CCV steelhead would not be exposed to this facility.

Potential changes to aquatic resources due to water transfers

Under the No Action Alternative, the water transfer window would remain the same as currently in place, i.e., July to September. This period is outside of the migration window for CCV steelhead in the Delta.

Potential changes to aquatic resources from Clifton Court aquatic weed removal

Continuation of the current aquatic weed removal program in Clifton Court Forebay under the No Action Alternative would be expected to have little to no effect on CCV steelhead as a result of the timing of the action avoiding the main period of occurrence.

Potential changes to aquatic resources due to changes from Tracy and Skinner fish facility improvements

Under the No Action Alternative, potential effects from the Tracy and Skinner fish facilities would continue as currently occurring. This includes mortality from pre-screen loss, collection, handling, transport, and release. The potential effects from the Tracy and Skinner fish salvage facilities under the No Action Alternative would be limited by continued management based on the NMFS (2009) BO RPA.

Potential changes to aquatic resources due to changes from Suisun Marsh facilities

Under the No Action Alternative, the Suisun Marsh facilities would continue to be operated as currently occurs, with potential limited effects to CCV steelhead such as delay of adults migrating through Montezuma Slough and predation on juveniles around the salinity control gates.

Potential changes to aquatic resources due to tidal habitat restoration

Under the No Action Alternative, completion of the 8,000 acres of tidal habitat restoration required by the USFWS (2008) BO would add approximately 6,000 acres of tidal habitat relative to current conditions. This has the potential to provide positive effects on CCV steelhead as a result of increased food availability, and rearing habitat. Potential negative effects from contaminants (e.g., methylmercury) would be addressed with minimization measures.

O.3.2.8.7 North American Green Sturgeon southern DPS

Potential changes to aquatic resources due to seasonal operations

The No Action Alternative would include continuation of current seasonal operations, from which the primary potential effects to Green Sturgeon include south Delta entrainment and reduced flow velocities within some migratory corridors. The BO requirement to restore 8,000 acres of tidal habitat has the potential to reduce effects relative to current conditions, as described further below in *Potential effects from Tidal Habitat Restoration (Complete 8,000 Acres from 2008 BO*).

Potential changes to aquatic resources due to Delta Cross Channel operations

Green Sturgeon are vulnerable to entrainment into the Delta Cross Channel if they are present when the gates are open. Individuals entrained into the Delta Cross Channel enter the interior Delta. It is not known if survival of Green Sturgeon is lower in the interior Delta as has been observed for Chinook Salmon. Under the No Action Alternative, operation of the DCC, and resulting probabilities of entrainment would remain the same as the current condition.

Potential changes to aquatic resources due to the Temporary Barriers Project

Few if any Green Sturgeon would be expected to occur in the region of the Temporary Barriers during the period when they are installed due to their expected preference for large channels in the western Delta. If juvenile Green Sturgeon experience effects similar to Chinook Salmon, there may be reduced survival and passage delays. Any potential effect under the No Action Alternative would be similar to the existing condition.

Potential changes to aquatic resources due to Contra Costa Water District operations

Contra Costa Water District operations under the No Action Alternative would not change from current conditions and therefore would be expected to have similar effects. Green Sturgeon are not expected to occur near the facility as no Green Sturgeon have been collected in CDFW monitoring efforts and the habitat present is not expected to be used by Green Sturgeon.

Potential changes to aquatic resources due to North Bay Aqueduct operations

North Bay Aqueduct Barker Slough Pumping Plant operations would not differ between the No Action Alternative and current conditions, so the effects to Green Sturgeon would be expected to be similar under the No Action Alternative as currently occurring. Green Sturgeon are expected to be fully screened at this facility.

Potential changes to aquatic resources due to water transfers

Under the No Action Alternative, the water transfer window would remain the same as currently in place, i.e., July to September. Green Sturgeon may benefit from increased flow velocities in Delta channels during the expanded transfer window and effects from entrainment at the south Delta facilities is limited due to the low occurrence of Green Sturgeon at the salvage facilities.

Potential changes to aquatic resources from Clifton Court aquatic weed removal

Continuation of the current aquatic weed removal program in Clifton Court Forebay under the No Action Alternative would be expected to have little effect on Green Sturgeon because the occur infrequently at the SWP.

Potential changes to aquatic resources due to changes from Tracy and Skinner fish facility improvements

Under the No Action Alternative, potential effects from the Tracy and Skinner fish facilities would continue as currently occurring. This includes mortality from pre-screen loss, collection, handling, transport, and release. The potential effects from the Tracy and Skinner fish salvage facilities under the No Action Alternative would be limited by continued management based on the NMFS (2009) BO RPA.

Potential changes to aquatic resources due to changes from Suisun Marsh facilities

Under the No Action Alternative, the Suisun Marsh facilities would continue to be operated as currently occurs, with potential limited effects related to entrainment. However, monitoring near some facilities have no identified Green Sturgeon and the configuration of the diversions combined with the strong swimming ability of juvenile Green Sturgeon suggests only limited effects are likely.

Potential changes to aquatic resources due to tidal habitat restoration

Under the No Action Alternative, completion of the 8,000 acres of tidal habitat restoration required by the USFWS (2008) BO would add approximately 6,000 acres of tidal habitat relative to current conditions. This has the potential to provide positive effects on Green Sturgeon as a result of increased food availability, and rearing habitat. Potential negative effects from contaminants (e.g., methylmercury) would be addressed with minimization measures.

O.3.2.9 *Nearshore Pacific Ocean on the California Coast*

O.3.2.9.1 Southern Resident Killer Whale

Potential changes to Southern Resident Killer Whale from Chinook Salmon prey abundance

As summarized in the ROC LTO BA, potential effects to Southern Resident Killer Whale as a result of SWP/CVP operations could occur as a result of effects to Chinook Salmon prey abundance; Central Valley Chinook Salmon have generally medium priority among other stocks in the diet of Southern Resident Killer Whale, and hatchery influence appears to be large. The potential effects of the No Action Alternative on Chinook Salmon are described above in Section O.3.2.1, *Trinity River*; O.3.2.2, *Sacramento River*; O.3.2.3, *Clear Creek*; O.3.2.4, *Feather River*; O.3.2.5, *American River*; O.3.2.6, *Stanislaus River*; O.3.2.7, *San Joaquin River*; and O.3.2.8, *Bay Delta*. Under the No Action Alternative, such effects generally would continue similar to current conditions, which include water operations and other activities as a result of the NMFS (2009) BO that are not likely to result in local depletion of Southern Resident Killer Whale prey (NMFS 2009c: 718). Effects on Southern Resident Killer Whales are potentially limited by the medium importance of Central Valley Chinook Salmon stocks to Southern Resident Killer Whale diet and the relatively high representation of hatchery-origin juvenile Chinook Salmon, many of which are released downstream of the Delta (Reclamation 2019).

O.3.3 Alternative 1 – Project-Level Effects

O.3.3.1 *Trinity River*

O.3.3.1.1 Seasonal Operations

Under Alternative 1, seasonal operations in Trinity Reservoir would continue to be integrated with Shasta Reservoir operations, as described in the No Action Alternative.

Potential changes to aquatic resources from changes in reservoir storage

Model results predict that under Alternative 1, storage volume in Trinity Lake would remain the same as under the No Action Alternative in most water year types. However, in dry and critically dry water years (40-30-30 Index) storage volume would increase throughout the entire year compared to the No Action Alternative (Figure O.3-14). On average, storage is expected to increase by 63 TAF under Alternative 1 in dry and critically dry years.

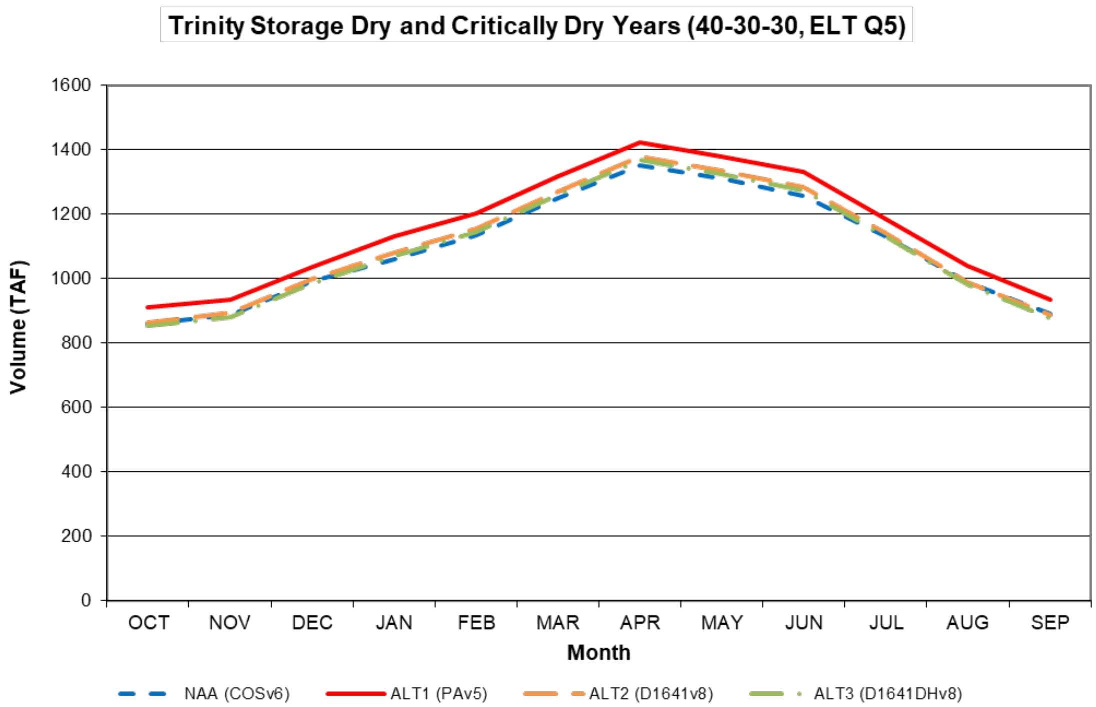


Figure O.3-14. Average Monthly Storage in Trinity Lake for the No Action Alternative and Alternatives 1, 2, and 3 in Dry and Critically Dry Water Year Types (40-30-30 Index)

The effects of changes in reservoir storage conditions as they relate to water temperature can be assessed by looking at temperatures in the Trinity River downstream of Trinity Dam. Average monthly water temperatures in the Trinity River downstream of Trinity Dam would remain similar under Alternative 1 compared to the No Action Alternative (Figure O.3-15). Maximum modeled water temperatures in the Trinity River downstream of Trinity Dam are generally similar under Alternative 1 compared to the No Action Alternative except in August when temperatures are approximately 4°F higher under Alternative 1 and in October when temperatures are approximately 4°F lower under Alternative 1 compared to the No Action Alternative.

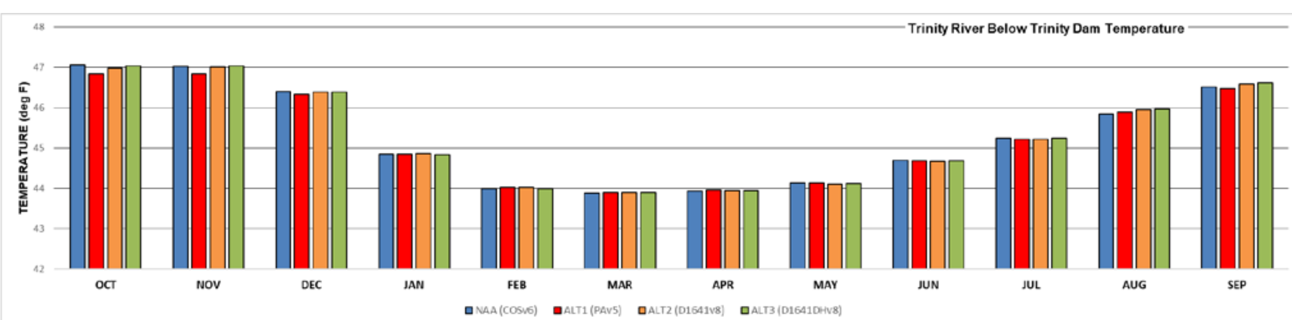


Figure O.3-15. Average Trinity River Water Temperatures below Trinity Dam for the period October to September, Average of All Water Year Types

No focal fish species occur in Trinity Lake or in the Trinity River downstream of Trinity Dam. Effects of Trinity Reservoir storage on fish in the Trinity River downstream of Lewiston Dam are described below.

Potential changes to aquatic resources from variation in flow

Under Alternative 1 flows in the Trinity River downstream of Lewiston Dam would be similar to flows under the No Action Alternative in most months and water year types. However, in wet years, flows would increase in December under Alternative 1 compared to the No Action Alternative (1,297 cfs versus 1,192 cfs). In above normal water years, flows under Alternative 1 would decrease in November compared to the No Action Alternative (625 cfs versus 678 cfs) and increase in February compared to the No Action Alternative (833 cfs versus 528 cfs). In critically dry years, flows under Alternative 1 would decrease compared to the No Action Alternative in September and October from 870 cfs to 818 cfs and from 342 cfs to 311 cfs, respectively. November flows would increase in critically dry years from 275 cfs to 300 cfs compared to the No Action Alternative.

Coho Salmon

Flows in the Trinity River downstream of Lewiston Dam would generally be similar under Alternative 1 compared to the No Action Alternative. Minor differences (<10%) in November and December of some water year types may affect spawning and juvenile rearing habitat for Coho Salmon. Based on previous flow habitat relationship studies in the Trinity River (USFWS 1999), this difference in flow is not expected to result in a detectable effect on Coho Salmon spawning or juvenile rearing habitat (USFWS 1999). Flows in February of above normal water years would increase by approximately 58% under Alternative 1 (833 cfs) compared to the No Action Alternative (528 cfs). This increase in flow could increase the likelihood of Coho Salmon egg mortality due to redd scour, potentially resulting in reduced incubation success in areas where local conditions contribute to substantial mobilization of gravel in the redds.

Spring-Run Chinook Salmon

Flows in the Trinity River downstream of Lewiston Dam would generally be similar under Alternative 1 compared to the No Action Alternative. Minor differences (<10%) in November of some water year types may affect spawning and juvenile rearing habitat for Spring-Run Chinook Salmon. Based on previous flow habitat relationship studies in the Trinity River (USFWS 1999), this difference in flow is not expected to result in a detectable effect on Spring-Run Chinook Salmon spawning or juvenile rearing habitat (USFWS 1999). Flows in above normal water years in February would increase by approximately 58% under Alternative 1 (833 cfs) compared to the No Action Alternative (528 cfs). This increase in flow could increase the likelihood of Spring-Run Chinook Salmon egg mortality due to redd scour, potentially resulting in reduced incubation success in areas where local conditions contribute to substantial mobilization of gravel in the redds.

Fall-Run Chinook Salmon

Flows in the Trinity River downstream of Lewiston Dam would generally be similar under Alternative 1 compared to the No Action Alternative. Minor differences (<10%) in November of some water year types may affect spawning habitat for Fall-Run Chinook Salmon. Based on previous flow habitat relationship studies in the Trinity River (USFWS 1999), this difference in flow is not expected to result in a detectable effect on Fall-Run Chinook Salmon spawning habitat (USFWS 1999). Flows in February of above normal water years would increase by approximately 58% under Alternative 1 (833 cfs) compared to the No Action Alternative (528 cfs). This increase in flow could increase the likelihood of Fall-Run Chinook Salmon egg mortality due to redd scour, potentially resulting in reduced incubation success in areas where local conditions contribute to substantial mobilization of gravel in the redds.

Steelhead (Winter- and Summer-Run)

Flows in the Trinity River downstream of Lewiston Dam would generally be similar under Alternative 1 compared to the No Action Alternative. Flow under Alternative 1in February of above normal water years would increase by approximately 58% (833 cfs) compared to the No Action Alternative (528 cfs). This increase in flow may reduce the amount of spawning habitat for Steelhead. Based on previous flow habitat relationship studies in the Trinity River (USFWS 1999: 123), increasing flows from 500 cfs to 800 cfs showed little change in the amount of spawning habitat for Steelhead in the Trinity River from downstream of Lewiston Dam to the confluence with Dutch Creek.

Green Sturgeon

Green Sturgeon occur within the lower 43 miles of the Trinity River, approximately 70 miles downstream of Lewiston Dam. Water temperature and habitat conditions within this section of the Trinity River are heavily influenced by several large tributaries that enter the Trinity River (e.g., the North Fork Trinity River, New River, and the South Fork Trinity River). As a result, minor changes in reservoir operations are likely to be undetectable this far downstream. Therefore, changes in flow under Alternative 1 would not affect Green Sturgeon.

White Sturgeon

White Sturgeon are not likely to be affected by changes in reservoir operations under Alternative 1 compared to the No Action Alternative due to their limited distribution in the lower Klamath River, primarily in the estuary.

Pacific Lamprey

Flows in the Trinity River downstream of Lewiston Dam would generally be similar under Alternative 1 compared to the No Action Alternative. However, minor differences (<10%) in flow would exist under Alternative 1 in November and December of some water year types and more significant increases in flow in February of above normal water years (833 cfs compared to 528 cfs under the No Action Alternative) are expected. Increased flows in February overlap with the Pacific Lamprey adult migration period but are not expected to affect migration because Pacific Lamprey migration spans multiple seasons and associated flows. Although previous flow habitat relationship studies in the Trinity River (USFWS 1999) did not focus on Pacific Lamprey, results for salmonids suggest that changes in flow under Alternative 1 would not result in a detectable effect on juvenile rearing or adult holding habitat for Pacific Lamprey compared to the No Action Alternative.

American Shad

American Shad are primarily found in the lower Klamath River but may occur in the lower sections of the Trinity River up to approximately RM 24 at the town of Willow Creek. Water temperature and habitat conditions within this section of the Trinity River are heavily influenced by several large tributaries that enter the Trinity River (e.g., the North Fork Trinity River, New River, and the South Fork Trinity River). As a result, minor changes in reservoir operations are likely to be undetectable this far downstream. Therefore, changes in flow under Alternative 1 would not affect American Shad.

Potential changes to aquatic resources due to variation in temperature

Modeling results indicate that monthly average water temperature in the Trinity River downstream of Lewiston Dam would be similar between the No Action Alternative and Alternative 1. Differences in monthly average temperature between Alternative 1 and the No Action Alternative are less than 0.5°F for all months of the year (Figure O.3-16). Modeled maximum temperatures in the Trinity River are lower under Alternative 1 compared to the No Action Alternative in July and October and higher in August, September, and December, with similar maximum temperatures in the remaining months (Figure O.3-17 and Table O.3-4).

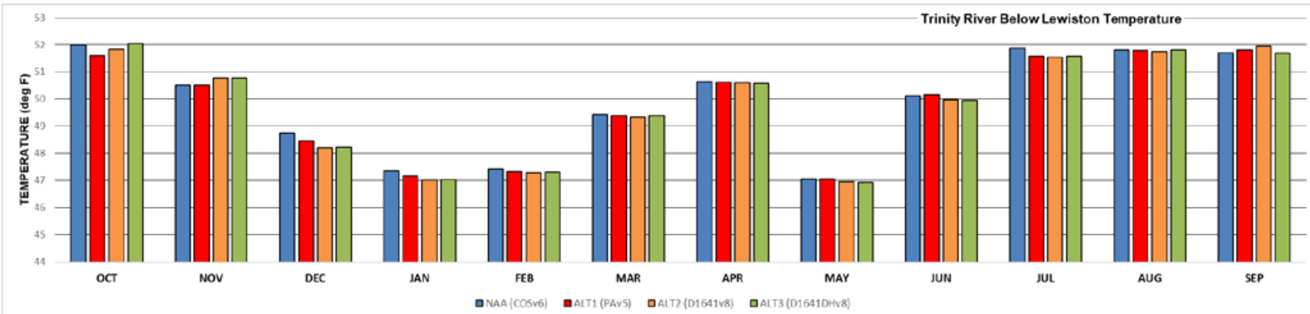


Figure O.3-16. Average Trinity River Water Temperatures below Lewiston Dam for the Period October to September, Average of All Water Year Types

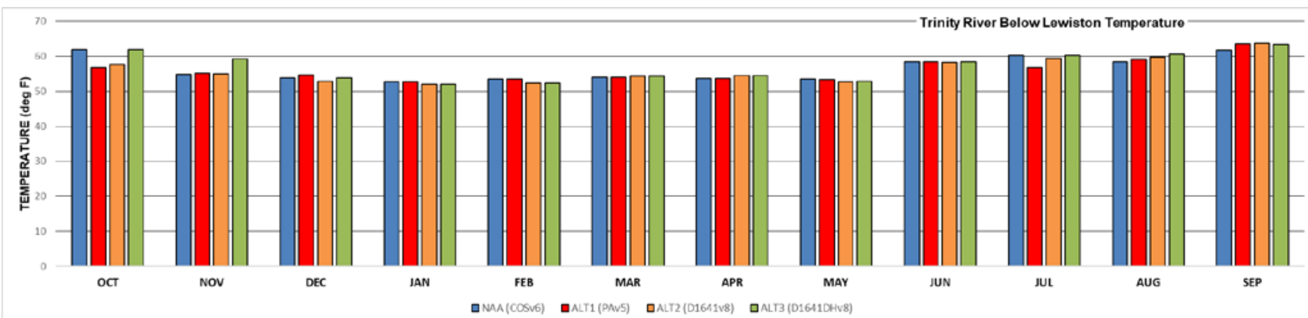


Figure O.3-17. Maximum Trinity River Water Temperatures below Lewiston Dam for the Period October to September, Average of All Water Year Types

Table O.3-4. Maximum Trinity River Water Temperatures below Trinity Dam for the Period October–September, Average of All Water Year Types (Differences >1°F Are Highlighted)

Alt	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
No Action Alternative	61.8	54.8	53.8	52.7	53.4	54.1	53.7	53.5	58.4	60.3	58.4	61.8
ALT 1	56.7	55.2	54.6	52.6	53.5	54.0	53.7	53.4	58.4	56.9	59.1	63.5
ALT 2	57.6	55.1	52.8	52.0	52.4	54.4	54.5	52.7	58.4	59.4	59.7	63.8
ALT 3	61.9	59.3	53.9	52.0	52.4	54.4	54.5	52.9	58.4	60.3	60.6	63.4

In a previous study that looked at flow and water temperatures in the Trinity River (USFWS 1999), results indicated that flows do not have a significant influence on water temperatures from mid-October through early April when cooler air temperatures help maintain cold water temperatures even when flow releases drop below 150 cfs. Once tributary influence begins to decrease and meteorological conditions warm from May to mid-July, flow releases become more influential on downstream temperatures, particularly during hot-dry conditions. Maintaining a flow of 450 cfs during the summer and early fall was found to meet the water temperature objectives for the Trinity River when water released from Lewiston Dam was 53°F or less (USFWS 1999: 203). Water temperatures are most influenced by flow releases from May through mid-October. Flows from May through October would be similar under Alternative 1 compared to the No Action Alternative in most water year types, with the exception of critically dry water years. In critically dry water years under Alternative 1, flows in September and October would decrease by approximately 6% to 9% compared to the No Action Alternative, from 870 cfs to 818 cfs and from 342 cfs to 311 cfs, respectively. Based on modeling results, changes in flow under Alternative 1 are not likely to have a detectable change in water temperature in the Trinity River downstream of Lewiston Dam in all but critically dry years.

Coho Salmon

Water temperatures in the Trinity River below Lewiston Dam are generally expected to be similar under Alternative 1 compared to the No Action Alternative. Monthly average temperatures are slightly lower under Alternative 1 than under the No Action Alternative, with water temperatures up to 1°F lower under Alternative 1 in July, September, and October and less than 1°F higher from November to January (Figure O.3-16). Modeled maximum temperatures in the Trinity River are approximately 3°F to 5°F lower under Alternative 1 compared to the No Action Alternative in July and October and approximately 1°F to 2°F higher in August, September, and December with similar maximum temperatures in the remaining months. Maximum temperatures under Alternative 1 in August and September exceed the NCRWQCB (2018) objectives for the Trinity River. Under both the No Action Alternative and Alternative 1, water temperatures exceed the NCRWQCB objectives during this time; however, further increases in temperature that would occur under Alternative 1 may further reduce juvenile Coho Salmon rearing success. Conversely, the decreased maximum temperatures under Alternative 1 in July meet the NCRWQCB (2018) objectives for the Trinity River, and the cooler October water temperatures are likely to improve juvenile rearing conditions compared to the No Action Alternative.

Spring-Run Chinook Salmon

Water temperatures in the Trinity River below Lewiston Dam are generally expected to be similar under Alternative 1 compared to the No Action Alternative. Monthly average temperatures would be slightly lower under Alternative 1 than under the No Action Alternative, with water temperatures up to 1°F lower under Alternative 1 in July, September, and October and less than 1°F higher from November to January (Figure O.3-16). Modeled maximum temperatures in the Trinity River would be approximately 3°F to 5°F lower under Alternative 1 compared to the No Action Alternative in July and October and approximately 1°F to 2°F higher in August, September, and December, with similar maximum temperatures in the remaining months. Spring-Run Chinook Salmon spawning usually peaks in October but typically ranges from the third week of September through November. Maximum August and September temperatures would exceed the NCRWQCB (2018) objectives for the Trinity River under both the No Action Alternative and Alternative 1. However, the further increases in temperature that would occur under Alternative 1 may reduce Spring-Run Chinook Salmon adult migration and spawning success. Conversely, the reduced maximum temperatures predicted under Alternative 1 in July meet the NCRWQCB (2018) objectives for the Trinity River and are likely to improve Spring-Run Chinook Salmon adult migration compared to conditions under the No Action Alternative, while decreased temperatures in October would improve spawning conditions compared to conditions under the No Action Alternative.

Fall-Run Chinook Salmon

Water temperatures in the Trinity River below Lewiston Dam are generally expected to be similar under Alternative 1 compared to the No Action Alternative. Monthly average temperatures are slightly lower under Alternative 1 than under the No Action Alternative, with water temperatures up to 1°F lower under Alternative 1 in July, September, and October and less than 1°F higher from November to January (Figure O.3-16). Modeled maximum temperatures in the Trinity River are approximately 3°F to 5°F lower under Alternative 1 compared to the No Action Alternative in July and October and approximately 1°F to 2°F higher in August, September, and December, with similar maximum temperatures in the remaining months. Fall-Run Chinook Salmon spawning usually occurs between October and December, with peak spawning activity occurring in November. Maximum August and September temperatures would exceed the NCRWQCB (2018) objectives for the Trinity River under both the No Action Alternative and Alternative 1. However, the further increases in temperature that would occur under Alternative 1 may negatively affect Fall-Run Chinook Salmon adult migration compared to the No Action Alternative. Conversely, reduced October temperatures predicted under Alternative 1 would improve spawning conditions compared to conditions under the No Action Alternative.

Steelhead (Winter-Run and Summer-Run)

Water temperatures in the Trinity River below Lewiston Dam are generally expected to be similar under Alternative 1 compared to the No Action Alternative. Monthly average temperatures would be slightly lower under Alternative 1 than under the No Action Alternative, with water temperatures up to 1°F lower under Alternative 1 in July, September, and October, and less than 1°F higher from November to January (Figure O.3-16). Modeled maximum temperatures in the Trinity River would be approximately 3°F to 5°F lower under Alternative 1 compared to the No Action Alternative in July and October, and approximately 1°F to 2°F higher in August, September, and December, with similar maximum temperatures in the remaining months. Maximum temperatures under Alternative 1 would increase in August and September, exceeding the NCRWQCB (2018) objectives for the Trinity River. Under both the No Action Alternative and Alternative 1, water temperatures would exceed the NCRWQCB objectives in this time. However, the larger increases in temperature that would occur under Alternative 1 may further reduce juvenile Steelhead rearing success. Conversely, the reduced maximum temperatures under Alternative 1 that would occur in July meet the NCRWQCB (2018) objectives for the Trinity River, and the cooler temperatures in October, would improve juvenile rearing conditions compared to the No Action Alternative.

Green Sturgeon

Green Sturgeon occur within the lower 43 miles of the Trinity River, approximately 70 miles downstream of Lewiston Dam. Water temperature and habitat conditions within this section of the Trinity River are heavily influenced by several large tributaries that enter the Trinity River (e.g., the North Fork Trinity River, New River, and the South Fork Trinity River). As a result, minor changes in reservoir operations are likely to be undetectable this far downstream. Results of previous water temperature modeling for the Trinity River (USFWS 1999) predicted a difference of approximately 1°F in water temperature for flows of 300 cfs and 450 cfs near RM 43 with smaller temperature differences expected downstream of RM 43 to the confluence of the Trinity and Klamath Rivers. Therefore, changes in flow and water temperature under Alternative 1 would not affect Green Sturgeon.

White Sturgeon

White Sturgeon would not be affected by changes in reservoir operations under Alternative 1 compared to the No Action Alternative due to their limited distribution in the lower Klamath River, primarily in the estuary.

Pacific Lamprey

Model results predict that water temperatures in the Trinity River below Lewiston Dam would be similar under Alternative 1 compared to the No Action Alternative. Monthly average temperatures would be slightly lower under Alternative 1 than under the No Action Alternative, with water temperatures up to 1°F lower under Alternative 1 in July, September, and October, and less than 1°F higher from November to January (Figure O.3-16). Maximum temperatures in the Trinity River would be approximately 3°F to 5°F lower under Alternative 1 compared to the No Action Alternative in July and October, and approximately 1°F to 2°F higher in August, September, and December, with similar maximum temperatures in the remaining months. Maximum temperatures under Alternative 1 in August and September would exceed the NCRWQCB (2018) objectives for the Trinity River and may reduce Pacific Lamprey juvenile rearing success; however, decreased temperatures under Alternative 1 in July and October are likely to improve juvenile rearing conditions compared to the No Action Alternative.

American Shad

American Shad are primarily found in the lower Klamath River but may occur in the lower sections of the Trinity River up to approximately RM 24 at the town of Willow Creek. Water temperature and habitat conditions within this section of the Trinity River are heavily influenced by several large tributaries that enter the Trinity River (e.g., the North Fork Trinity River, New River, and the South Fork Trinity River). As a result, minor changes in reservoir operations are likely to be undetectable this far downstream. Results of previous water temperature modeling for the Trinity River (USFWS 1999) predicted a difference of approximately 1°F in water temperature for flows of 300 cfs and 450 cfs near RM 24 with smaller temperature differences expected downstream to the confluence of the Trinity and Klamath Rivers. Therefore, changes in water temperature under Alternative 1 would not affect American Shad.

O.3.3.1.2 Trinity River Record of Decision

The Trinity River ROD is being implemented under both Alternative 1 and the No Action Alternative. Therefore, implementation of the variable annual flow regime, restoration actions, and monitoring and adaptive management, per the Trinity River ROD under Alternative 1 would have similar effects as the No Action Alternative on Coho Salmon, Chinook Salmon (Spring- and Fall-Run), Steelhead (Winter- and Summer-Run), Green Sturgeon, White Sturgeon, Pacific Lamprey, and American Shad.

O.3.3.2 *Sacramento River*

Potential changes to aquatic resources in the Sacramento River from seasonal operations

Under all the Project alternatives, flows in the upper Sacramento River result from controlled releases from Shasta and Keswick reservoirs, as well as transfers from the Trinity River and natural accretions. The releases and transfers are determined by a suite of laws, regulations, contracts, and agreements to address demands of water users, requirements for water quality, and needs of fish populations throughout the river and the Delta. In particular, operations of all the alternatives are regulated by SWRCB's D-1641 decision, which requires flow releases to meet Delta standards, and their WRO 90-5 decision, which requires cold water releases to meet temperature targets at compliance points in the upper Sacramento River. Dry hydrologic conditions often lead to inadequate storage in Shasta for operators to provide suitable conditions for salmonids and other native species in the upper Sacramento River. In most cases, however, water temperature rather than flow is the limiting factor creating unsuitable conditions, as discussed below. The primary differences between the No Action Alternative and Alternative 1 for the Sacramento River upstream of the Delta with regard to seasonal operations is in operations of Shasta and Keswick reservoirs for coldwater pool management and the No Action Alternative requirement for Fall X2. The other proposed Alternative 1 components that are integral to seasonal operations include Shasta Cold Water Pool Management and Fall and Winter Refill and Redd Management. The effects of these components, especially with respect to water temperatures, are included in the following discussion of seasonal operations under Alternative 1.

CalSim II modeling indicates that average flow released at Keswick Dam under Alternative 1 would generally be higher than or similar to flow under No Action Alternative, except in wet and above normal water years during September and November, when the Alternative 1 flows would be substantially lower than the No Action Alternative flows (Table O.3-5). The higher September and November flows under the No Action Alternative result from Fall X2 releases, which are not included in Alternative 1. Table O.3-5 shows that the highest flows for both alternatives occur primarily during winter of wet and above normal water years and during summer of all water year types. Flow releases are high during summer to satisfy downstream demands of water users and Delta water quality, and to meet water temperature requirements of incubating Winter-Run Chinook Salmon eggs and alevins downstream of Keswick Dam. A minimum flow of 3,250 cfs is required from Keswick Dam to the RBDD during October through March (NCWA 2014).

Table O.3-5. CalSim II Monthly Average Flow (cfs) by Water Year Type and Month below Keswick Dam for No Action Alternative, Alternative 1 and Differences between Them

Alternative[1,2,3]	**Monthly Flow (cfs)**											
Water Year Type[4]	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
No Action Alternative												
Wet (32%)[5]	7,908	9,796	7,444	17,876	19,288	16,127	8,458	8,662	8,940	13,440	10,474	14,063
Above Normal (16%)	7,054	10,124	6,406	7,629	16,401	8,534	5,221	7,925	10,359	15,316	10,494	9,972
Below Normal (13%)	5,842	4,960	7,558	3,285	7,149	3,925	3,803	7,867	10,930	14,421	10,624	5,493
Dry (24%)	5,660	5,111	8,652	3,697	3,564	3,961	3,719	7,014	10,368	12,658	8,608	4,995
Critically Dry (15%)	4,829	3,755	3,251	3,392	3,580	3,509	4,065	6,895	8,984	10,947	7,793	4,729
Alternative 1												
Wet (32%)	7,715	6,274	9,509	18,983	19,458	16,213	8,572	8,912	9,047	13,352	10,647	8,317
Above Normal (16%)	7,055	7,059	7,624	8,995	17,580	9,220	5,247	8,410	10,738	15,382	10,503	5,266
Below Normal (13%)	5,767	4,961	7,578	4,681	8,163	4,794	4,242	8,845	12,257	14,609	10,807	6,008
Dry (24%)	5,811	5,213	9,023	3,823	3,565	4,344	3,741	7,870	11,441	12,525	8,801	4,931
Critically Dry (15%)	4,823	3,977	3,288	3,368	3,460	3,933	4,012	7,131	9,729	10,481	7,737	4,820
Alternative 1 minus No Action Alternative[6]												
Wet (32%)	-193	-3,522	2,065	1,108	170	85	114	249	106	-89	173	-5,746
Above Normal (16%)	1	-3,065	1,218	1,366	1,179	686	26	484	379	66	9	-4,706
Below Normal (13%)	-75	1	19	1,396	1,014	869	439	977	1,327	188	183	515
Dry (24%)	151	102	370	125	1	383	22	856	1,073	-133	193	-64
Critically Dry (15%)	-6	222	38	-24	-120	424	-54	236	746	-466	-56	92

1 Results based on the 82-year simulation period.
2 Results displayed with calendar year - year type sorting.
3 All scenarios are simulated at ELT (Early Long-Term) Q5 with 2025 climate change and 15 cm sea level rise.
4 Water year types as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999).
5 Percent of years of each type given in parentheses.
6 Bold green font indicates greater than 5% increase in flow; bold red font indicates greater than 5% reduction in flow.

Under the No Action Alternative and Alternative 1, the upper Sacramento River's water temperatures are controlled by selective withdrawal through the temperature control device (TCD) in Shasta Reservoir and by balancing releases between Lewiston (Trinity River) and Shasta reservoirs. The water temperature operations have three principal objectives: 1) provide enough cold water to optimize survival of the current year's Winter-Run Chinook Salmon eggs and alevins and those of other salmonids (Chinook Salmon and steelhead), 2) stabilize water levels through the fall to avoid dewatering redds and stranding juveniles of Winter-Run and other salmonids, and 3) conserve and rebuild Shasta storage in the fall and winter to provide the coldwater pool resources needed to optimize survival of the next year's Winter-Run eggs and alevins and those of other salmonids. Protection of other salmonids, especially Spring-Run Chinook Salmon and steelhead, is an important objective, but Winter-Run Chinook Salmon is the principal target of operations because it alone has no spawning habitat other than that in the upper Sacramento River (with some recent spawning in Battle Creek and Clear Creek). The seasonal operation of the TCD is generally as follows: during winter, early spring, and as long thereafter as possible, the highest elevation gates are utilized to draw water from the upper portions of the reservoir and conserve the deeper, colder water; during late spring and summer, the operators begin the seasonal progression of opening deeper gates as Shasta Reservoir surface elevation decreases, cold water is utilized, and downstream warming of the river accelerates; and during late summer and fall, the TCD side gates are opened to utilize the remaining coldwater pool as necessary. This year-round Shasta management program is expected to minimize frequency and duration of temperature-related egg mortality of Winter-Run and other salmonids in dry and critically dry years, thus reducing, though not eliminating, the population level stress of these temperature-related mortalities (NMFS 2011).

The main changes in water temperature management between the No Action Alternative and Alternative 1 would be in how the TCD would be operated to preserve sufficient coldwater pool through the summer and fall, the water temperature thresholds adopted for protection of Winter-Run and other salmonids, and the addition of real-time monitoring of Winter-Run behavior to support decision making. The water temperature threshold adopted for protection of salmonids under No Action Alternative operations is 56°F. However, high mortalities during recent extreme drought years and new analytical tools have demonstrated that a 56°F temperature limit does not sufficiently safeguard Winter-Run eggs and alevins (NMFS 2017a, Martin et al. 2017; Anderson 2018). Based on analyses using the new analytical tools, the Alternative 1 operations would use a water temperature threshold of 53.5°F.

Under the proposed Alternative 1 Shasta Cold Water Pool Management, operations during summer and fall would be based on the coldwater pool storage on May 1, combined with summer and fall predictions from water temperature modeling. In years with high May 1 coldwater pool storage (> 2.8 MAF), operators would manage temperature releases to maintain a water temperature of 53.5°F in the Sacramento River upstream of the Clear Creek confluence (CCR) beginning when real-time monitoring indicated that the Winter-Run population had begun spawning and ending October 31, or when fry had emerged from an estimated 95% of the Winter-Run redds, whichever was earlier. In years with an intermediate level of May 1 cold water storage, the coldwater pool is generally insufficient to maintain 53.5°F at CCR through October, so operations would target developmental-stage-specific requirements of Winter-Run eggs and alevins, maintaining the 53.5°F threshold only for the period when the most temperature-sensitive developmental stage would be present. This period would be estimated from modeling using the new analytical tools discussed above (Martin et al. 2017; Anderson 2018). The duration of the 53.5°F protection period would be adjusted in proportion to the available coldwater pool on May 1. In years with low May 1 coldwater pool storage (e.g., <2.3 MAF), the temperature maintained at CCR would be gradually increased up to 56°F as necessary to conserve remaining coldwater pool through the period of Winter-Run egg and alevin incubation. Operators would minimize adverse effects of the higher water temperatures to the greatest extent possible, as determined by the latest egg mortality models, real-time monitoring, and current and expected future water availability. Finally, if operators could no longer maintain 56°F at CCR, they would operate to a less than optimal duration and temperature target, which would be determined in real-time with technical assistance from NMFS and USFWS. A more complete description of the Alternative 1 proposed water temperature management operations is provided in Chapter 4, *Proposed Action*..

Reclamation would regularly evalute the performance of the coldwater pool management by monitoring egg to fry survival in the river and compare actual survival levels with those expected from modeling. If actual mortality was greater than expected, Reclamation would work with the SRTTG to develop alternative protective strategies and measures for the early life stages. The egg to fry survival monitoring and associated actions is discussed in detail in in Chapter 4, *Proposed Action*.

Different measures would be explored to mitigate effects of the adverse water temperature conditions, including intervention measures such as increasing hatchery intake and trap and haul, as described later. In the fall and winter, reductions in flow releases to conserve storage for the following year would be balanced by the efforts to maintain suitable water temperatures, minimize dewatering redds of Winter-Run and other salmonids, and avoid stranding rearing juveniles. These measures are more fully discussed later under *Potential changes to aquatic resources in the Sacramento River from fall and winter refill and redd* maintenance.

HEC-5Q modeling was used to compare water temperature effects of the No Action Alternative and Alternative 1. It is important to understand, however, that the modeling does not provide a complete characterization of water temperature effects associated with Alternative 1 because it relies on shutter (TCD) operations for Alternative 1 that are quite similar to those of the No Action Alternative, which does not accurately represent actual shutter operation under Alternative 1. Furthermore, the HEC-5Q modeling includes little of the effects expected from the water temperature management improvements proposed for Alternative 1. These include the risk based water temperature management approach described above, the proposed operations of an improved TCD (as previously described), and a number of the other proposed measures described later, all of which would facilitate increased cold water storage, resulting in greater availability of cold water for protection of salmonids, especially in the late summer and early fall.

An additional caution regarding the HEC-5Q water temperature modeling results, particularly with regard to meeting water temperature criteria (e.g., 53.5°F water temperature at CCR criterion), relates to the time step used in the modeling. HEC-5Q, like the CalSim II model on which it relies for flow data, has a monthly time step and provides estimates of monthly mean water temperatures. However, most of the regulatory requirements to meet water temperature criteria apply to daily mean (or shorter duration) water temperatures. Daily means tend to be much more variable than monthly means and, therefore, the monthly mean water temperature estimates provided by HEC-5Q are not directly comparable to these regulatory criteria. For example, even with constant flows, daily water temperatures would fluctuate around the mean in response to variation in solar radiation and other meteorological conditions within a given month. In view of this limitation, it is helpful to consider the comparisons of temperature effects among the alternatives as indicating the relative likelihoods of exceeding temperature criteria, rather than whether or not the criteria are actually met. These considerations apply to the CalSim II flow data as well, but are less important for flow because there are fewer regulatory criteria for flow and, except during storm events, flow tends to be less variable than water temperature.

During the summer and much of the fall, water released from Keswick Dam warms downstream, resulting in warmer water temperatures in more downstream habitats. Therefore, the effects of the alternatives on fish populations depend on the habitat distributions of the populations as well as the results of temperature management operations. Winter-Run mostly spawn from Keswick Dam to about 6 miles downstream of the Clear Creek temperature gage, Spring-Run from Keswick Dam to about Balls Ferry, fall-run from Keswick Dam to about RBDD, late fall-run spawning distribution is similar to that of Winter-Run, and Green Sturgeon spawn downstream of the Cow Creek confluence to the GCID oxbow near Hamilton City (NMFS 2018b). Steelhead spawning areas in the upper Sacramento River are poorly known.

Based on the HEC-5Q modeling, the mean monthly water temperatures at Keswick Dam are roughly equal under the No Action Alternative and Alternative 1, except for October of wet, above normal, and dry water years, which have 1.3 to 1.5°F lower mean water temperatures under Alternative 1 than under the No Action Alternative, and August of dry years, which has 1.0°F lower mean water temperature under Alternative 1 (Table O.3-6). Note that the October mean water temperatures under the No Action Alternative are just above the 53.5°F temperature threshold and those under Alternative 1 are just below the threshold (Table O.3-6). A more detailed examination of this difference shows that mean October water temperatures are predicted to be less than the temperature threshold in 20% of the years under the No Action Alternative, while under Alternative 1 they are predicted to be less than the threshold in two-thirds of the years (Figure O.3-18). For August, the mean water temperatures are predicted to be below the threshold in 75% of years under the No Action Alternative and 91% of years under Alternative 1 (Figure O.3-19). Therefore, although the differences in October and August water temperatures between the No Action Alternative and Alternative 1 are not large, they occurs over a critical range for salmonids eggs and alevins. The largest predicted increase in mean water temperature under Alternative 1 is 0.9°F for September of Above Normal water years (Table O.3-5). This increase occurs over a range well below the critical temperature threshold and is therefore less likely to have a large effect on the salmonids. The differences between the No Action Alternative and Alternative 1 in September water temperatures at Keswick Dam are small (Figure O.3-20) relative to those at more downstream locations, as described below.

Table O.3-6. HEC-5Q Monthly Average Water Temperature (°F) by Water Year Type and Month at Keswick Dam for No Action Alternative, Alternative 1 and Differences between Them

Alternative1,2,3 Water Year Type4	**Monthly Temperature (°F)**											
	Oct	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
No Action Alternative												
Wet (32%)5	54.3	55.4	52.0	47.3	45.9	46.3	47.8	48.7	49.6	50.4	51.4	51.0
Above Normal (16%)	53.9	54.9	51.4	47.6	46.0	46.5	48.1	48.6	49.3	50.0	51.1	51.0
Below Normal (13%)	54.2	54.3	51.3	48.2	46.9	47.8	49.1	49.4	49.7	50.8	52.0	52.8
Dry (24%)	54.5	54.4	50.8	48.4	47.3	47.8	49.1	49.5	50.1	51.4	53.0	53.2
Critically Dry (15%)	58.9	56.3	51.5	48.2	47.1	48.1	49.5	50.7	52.3	53.9	56.2	58.4
Alternative 1												
Wet (32%)	52.7	54.7	51.7	47.5	46.0	46.4	47.8	48.7	49.6	50.5	51.3	51.5
Above Normal (16%)	52.4	54.1	51.1	47.7	46.0	46.6	48.2	48.6	49.4	50.1	51.4	51.9
Below Normal (13%)	53.7	54.8	51.9	48.4	47.0	47.9	49.3	49.2	49.7	50.7	51.6	52.6
Dry (24%)	53.2	54.8	51.4	48.5	47.4	47.9	49.2	49.4	49.9	51.2	52.0	52.6
Critically Dry (15%)	59.0	56.5	51.8	48.6	47.4	48.3	49.7	50.6	51.7	53.3	55.8	59.2
Alternative 1 minus No Action Alternative6												
Wet (32%)	-1.5	-0.7	-0.2	0.1	0.1	0.1	0.0	-0.1	0.1	0.1	-0.1	0.5
Above Normal (16%)	-1.5	-0.8	-0.3	0.0	0.1	0.1	0.1	0.0	0.1	0.1	0.2	0.9
Below Normal (13%)	-0.5	0.5	0.6	0.1	0.1	0.1	0.2	-0.3	0.0	-0.1	-0.4	-0.2
Dry (24%)	-1.3	0.4	0.6	0.1	0.2	0.0	0.1	0.0	-0.1	-0.1	-1.0	-0.6
Critically Dry (15%)	0.1	0.2	0.3	0.5	0.4	0.2	0.2	-0.2	-0.5	-0.6	-0.5	0.8

[1] Results based on the 82-year simulation period.
[2] Results displayed with calendar year - year type sorting.
[3] All scenarios are simulated at ELT (Early Long-Term) Q5 with 2025 climate change and 15 cm sea level rise.
[4] Water year types as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999)
[5] Percent of years of each type given in parantheses.
[6] Bold green font indicates greater than 1°F reduction in temperature, bold red font indicates greater than 1°F increase in temperature.

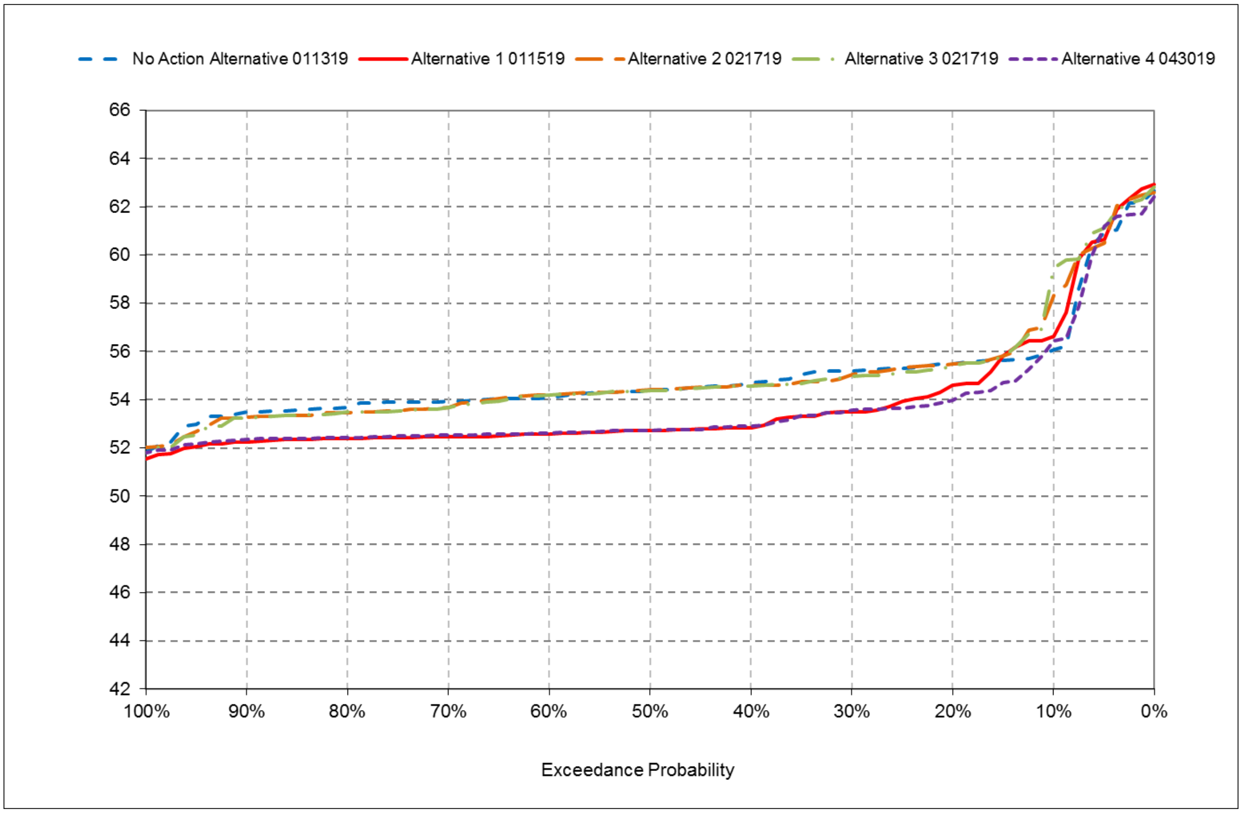


Figure O.3-18. HEC-5Q Sacramento River Water Temperatures at Keswick Dam under the No Action Alternative, Alternative 1, Alternative 2, Alternative 3 and Alternative 4; October

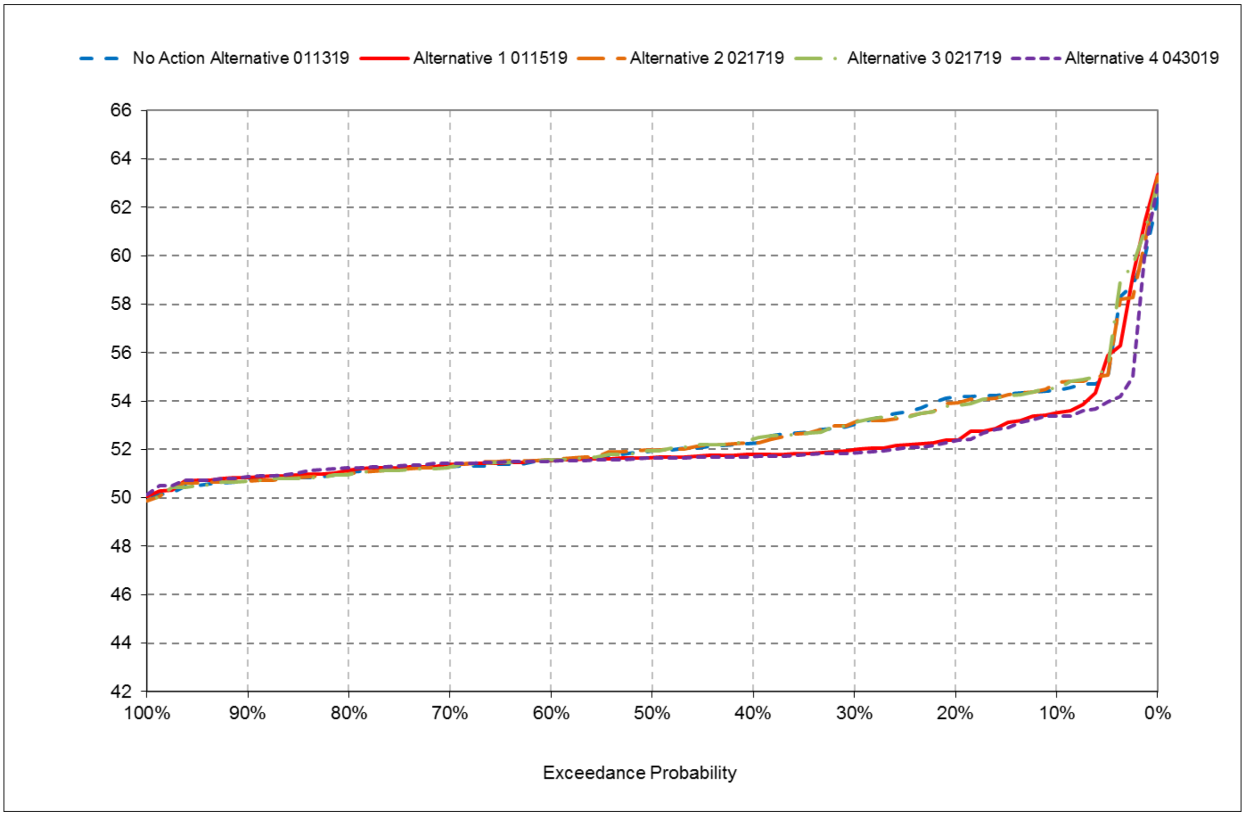


Figure O.3-19. HEC-5Q Sacramento River Water Temperatures at Keswick Dam under the No Action Alternative, Alternative 1, Alternative 2, Alternative 3 and Alternative 4; August

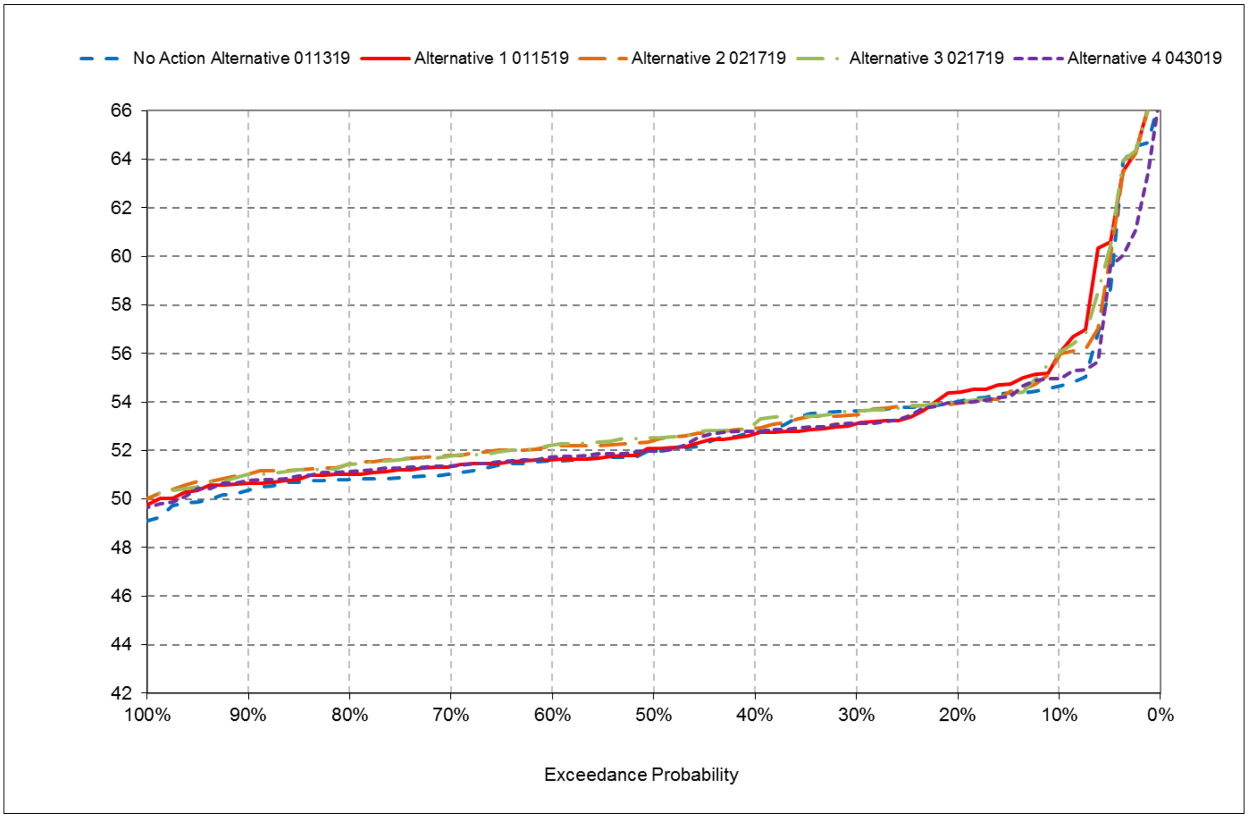


Figure O.3-20. HEC-5Q Sacramento River Water Temperatures at Keswick Dam under the No Action Alternative, Alternative 1, Alternative 2, Alternative 3 and Alternative 4; September

The HEC-5Q results indicate that late spring through early fall water temperatures in the Sacramento River at Clear Creek are slightly warmer than those at Keswick Dam, with larger increases in September water temperature between the No Action Alternative and Alternative 1 (Table O.3-7). At Balls Ferry, the temperatures are warmer still, and the October reductions in water temperature between the No Action Alternative and Alternative 1 are smaller, while the September increases are larger (Table O.3-8). Also, the October and August monthly mean water temperatures exceed the 53.5°F temperature threshold in all water year types under both alternatives (Table O.3-8) and, for the exceedance plots of annual mean October temperatures, the temperatures are below the threshold in only 20% of years under Alternative 1 and in no years under the No Action Alternative (Figure O.3-21). The Balls Ferry water temperature predictions for September are very different, with larger temperature increases from the No Action Alternative and Alternative 1 in wet and above normal water years than those noted for Keswick Dam, and mean water temperatures for these water year types exceeding the critical water temperature threshold under Alternative 1, but not under the No Action Alternative (Table O.3-8). October and November mean water temperatures are above (or equal to) the threshold under both alternatives. As discussed previously, the monthly mean water temperatures provide a rough estimate of the probability of mean daily water temperatures exceeding a temperature threshold. Therefore, when the monthly mean water temperature exceeds the temperature threshold, the probability or frequency of the daily mean temperature exceeding the threshold is greater than when the monthly mean water temperature is less than the threshold.

Table O.3-7. HEC-5Q Monthly Average Water Temperature (°F) by Water Year Type and Month at Clear Creek Confluence for No Action Alternative, Alternative 1 and Differences between Them

Alternative[1,2,3] Water Year Type[4]	Monthly Temperature (°F)											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
No Action Alternative												
Wet (32%)[5]	54.7	55.3	51.6	47.3	46.2	47.0	49.2	50.3	51.4	51.9	52.9	51.9
Above Normal (16%)	54.4	54.7	51.0	47.7	46.4	47.4	49.9	50.3	51.0	51.3	52.6	52.1
Below Normal (13%)	54.7	54.2	51.0	48.1	47.4	49.0	51.1	51.0	51.3	52.1	53.5	54.5
Dry (24%)	55.2	54.3	50.6	48.3	47.9	49.1	51.0	51.2	51.7	52.8	54.6	55.0
Critically Dry (15%)	59.4	56.1	51.2	48.2	47.8	49.5	51.4	52.4	54.0	55.5	57.8	59.8
Alternative 1												
Wet (32%)	53.3	54.6	51.4	47.5	46.3	47.1	49.2	50.2	51.5	52.0	52.8	52.9
Above Normal (16%)	53.1	53.9	50.8	47.7	46.4	47.4	49.9	50.3	51.0	51.4	52.8	53.7
Below Normal (13%)	54.3	54.7	51.5	48.2	47.4	49.0	51.1	50.6	51.2	52.1	53.0	54.2
Dry (24%)	54.0	54.6	51.1	48.4	48.0	49.0	51.2	51.1	51.5	52.7	53.6	54.4
Critically Dry (15%)	59.5	56.3	51.4	48.6	48.2	49.6	51.6	52.2	53.4	55.0	57.4	60.5
Alternative 1 minus No Action Alternative[6]												
Wet (32%)	-1.4	-0.7	-0.2	0.1	0.1	0.1	0.0	-0.1	0.0	0.1	-0.1	1.0
Above Normal (16%)	-1.4	-0.8	-0.3	0.0	0.0	0.0	0.1	-0.1	0.0	0.1	0.2	1.7
Below Normal (13%)	-0.4	0.5	0.5	0.1	0.0	0.0	0.0	-0.4	-0.1	-0.1	-0.4	-0.3
Dry (24%)	-1.2	0.3	0.5	0.1	0.1	0.0	0.1	-0.2	-0.2	-0.1	-1.0	-0.6
Critically Dry (15%)	0.1	0.2	0.2	0.4	0.3	0.2	0.2	-0.2	-0.6	-0.5	-0.4	0.8

[1] Results based on the 82-year simulation period.
[2] Results displayed with calendar year - year type sorting.
[3] All scenarios are simulated at ELT (Early Long-Term) Q5 with 2025 climate change and 15 cm sea level rise.
[4] Water year types as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999)
[5] Percent of years of each type given in parantheses.
[6] Bold green font indicates greater than 1°F reduction in temperature, bold red font indicates greater than 1°F increase in temperature.

Table O.3-8. HEC-5Q Monthly Average Water Temperature (°F) by Water Year Type and Month at Balls Ferry for No Action Alternative, Alternative 1 and Differences between Them

Alternative[1,2,3] Water Year Type[4]	Monthly Temperature (°F)											
	Oct	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
No Action Alternative												
Wet (32%)5	55.1	54.9	50.7	46.9	46.4	47.7	50.8	52.5	53.6	53.3	54.2	52.6
Above Normal (16%)	54.9	54.4	50.2	47.0	46.6	48.2	51.6	52.3	52.7	52.4	53.8	53.0
Below Normal (13%)	55.3	53.8	50.2	47.4	47.6	49.8	52.9	52.6	52.8	53.3	54.6	55.8
Dry (24%)	55.7	53.8	49.8	47.7	47.9	49.8	52.8	53.0	53.2	54.1	55.9	56.4
Critically Dry (15%)	59.7	55.7	50.1	47.9	48.2	50.4	53.0	54.0	55.4	56.7	59.1	60.8
Alternative 1												
Wet (32%)	53.8	54.2	50.7	47.1	46.5	47.8	50.8	52.4	53.6	53.4	54.1	54.0
Above Normal (16%)	53.7	53.5	50.0	47.2	46.6	48.2	51.7	52.1	52.7	52.5	54.0	55.2
Below Normal (13%)	54.9	54.3	50.7	47.6	47.6	49.7	52.8	52.1	52.6	53.2	54.2	55.4
Dry (24%)	54.6	54.1	50.3	47.9	48.0	49.8	52.9	52.7	52.8	53.9	55.0	55.8
Critically Dry (15%)	59.8	55.9	50.3	48.2	48.5	50.5	53.1	53.7	54.7	56.3	58.6	61.5
Alternative 1 minus No Action Alternative6												
Wet (32%)	-1.3	-0.7	0.0	0.1	0.1	0.1	0.0	-0.1	0.0	0.1	-0.1	1.4
Above Normal (16%)	-1.2	-0.9	-0.1	0.1	0.0	0.0	0.1	-0.1	0.0	0.1	0.2	2.2
Below Normal (13%)	-0.4	0.4	0.4	0.2	0.0	-0.1	-0.1	-0.5	-0.2	-0.1	-0.4	-0.4
Dry (24%)	-1.1	0.3	0.5	0.1	0.1	0.0	0.1	-0.3	-0.3	-0.1	-1.0	-0.5
Critically Dry (15%)	0.1	0.2	0.2	0.3	0.3	0.1	0.2	-0.2	-0.6	-0.5	-0.4	0.7

[1] Results based on the 82-year simulation period.
[2] Results displayed with calendar year - year type sorting.
[3] All scenarios are simulated at ELT (Early Long-Term) Q5 with 2025 climate change and 15 cm sea level rise.
[4] Water year types as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999)
[5] Percent of years of each type given in parantheses.
[6] Bold green font indicates greater than 1°F reduction in temperature, bold red font indicates greater than 1°F increase in temperature.

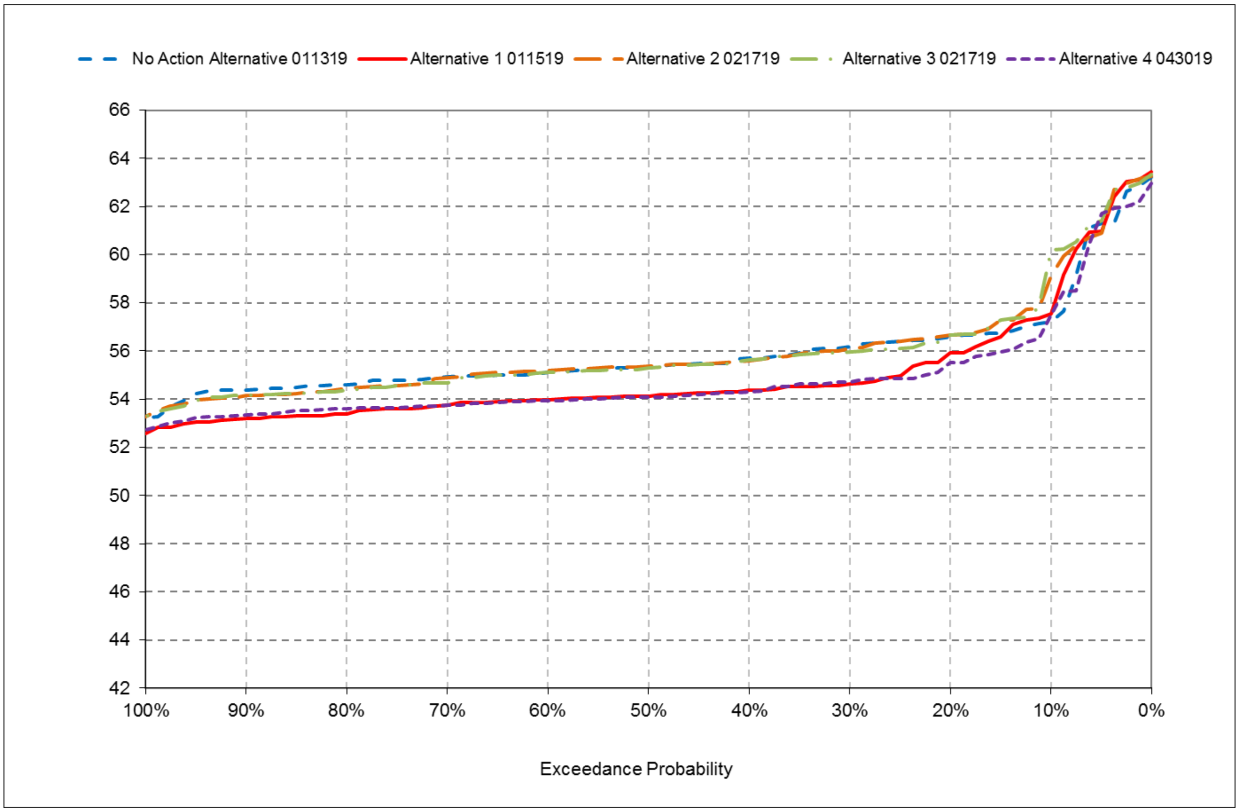


Figure O.3-21. HEC-5Q Sacramento River Water Temperatures at Balls Ferry under the No Action Alternative, Alternative 1, Alternative 2, Alternative 3 and Alternative 4; October

The downstream trends in water temperature conditions noted for Keswick Dam, Clear Creek and Balls Ferry continue to RBDD, with warmer late spring through early fall temperatures, smaller reductions in the October and August mean monthly temperatures between the No Action Alternative to Alternative 1, and larger increases in the September temperatures between the No Action Alternative and Alternative 1 (Table O.3-9). Under both the No Action Alternative and Alternative 1, the monthly mean water temperatures at RBDD for all water year types in April through October are above the critical water temperature threshold. The exceedance plots for the annual September mean temperatures shows that the temperature differences are largely limited to the cooler 50% of years (Figure O.3-22). These same patterns in water temperatures differences between the No Action Alternative and Alternative 1 continue downstream to Hamilton City and Knights Landing, where there is little difference between the No Action Alternative and Alternative 1 in monthly mean water temperatures in October and August, but relatively large differences (> 4°F) in wet and above normal Septembers (Table O.3-10 and O.3-11; Figures O.3-23 and O.3-24).

Table O.3-9. HEC-5Q Monthly Average Water Temperature (°F) by Water Year Type and Month at Red Bluff Diversion Dam for No Action Alternative, Alternative 1 and Differences between Them

Alternative[1,2,3] Water Year Type[4]	Monthly Temperature (°F)											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
No Action Alternative												
Wet (32%)5	56.2	54.3	49.3	46.5	47.0	49.3	53.7	56.7	59.1	58.1	58.9	55.4
Above Normal (16%)	56.2	53.7	48.8	46.6	47.1	50.0	54.9	56.9	57.8	56.5	58.3	56.3
Below Normal (13%)	56.6	53.3	48.9	46.7	48.0	51.7	56.4	56.7	57.4	57.4	58.8	60.1
Dry (24%)	57.1	53.0	48.5	46.9	48.3	51.5	56.1	57.5	57.9	58.5	60.6	60.9
Critically Dry (15%)	60.6	54.7	48.6	47.3	49.0	52.4	56.6	58.0	60.0	61.2	63.3	64.3
Alternative 1												
Wet (32%)	55.3	53.6	49.4	46.6	47.0	49.4	53.7	56.5	59.0	58.2	58.7	58.0
Above Normal (16%)	55.3	52.7	48.8	46.8	47.1	50.0	55.0	56.6	57.7	56.6	58.5	59.9
Below Normal (13%)	56.4	53.6	49.2	46.9	48.0	51.5	56.1	56.0	56.9	57.3	58.4	59.5
Dry (24%)	56.3	53.2	48.9	47.0	48.3	51.5	56.2	56.9	57.3	58.4	59.8	60.6
Critically Dry (15%)	60.7	54.9	48.7	47.5	49.2	52.4	56.7	57.7	59.2	61.0	63.0	64.8
Alternative 1 minus No Action Alternative6												
Wet (32%)	-0.9	-0.7	0.1	0.1	0.0	0.0	0.0	-0.2	0.0	0.1	-0.2	2.6
Above Normal (16%)	-0.9	-1.0	-0.1	0.1	0.0	0.0	0.0	-0.3	-0.1	0.1	0.2	3.6
Below Normal (13%)	-0.3	0.3	0.3	0.2	0.0	-0.2	-0.3	-0.7	-0.5	-0.1	-0.4	-0.6
Dry (24%)	-0.9	0.2	0.3	0.1	0.0	0.0	0.0	-0.5	-0.6	-0.1	-0.8	-0.4
Critically Dry (15%)	0.1	0.2	0.1	0.2	0.2	0.0	0.1	-0.3	-0.7	-0.2	-0.3	0.5

[1] Results based on the 82-year simulation period.
[2] Results displayed with calendar year - year type sorting.
[3] All scenarios are simulated at ELT (Early Long-Term) Q5 with 2025 climate change and 15 cm sea level rise.
[4] Water year types as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999)
[5] Percent of years of each type given in parantheses.
[6] Bold green font indicates greater than 1°F reduction in temperature, bold red font indicates greater than 1°F increase in temperature.

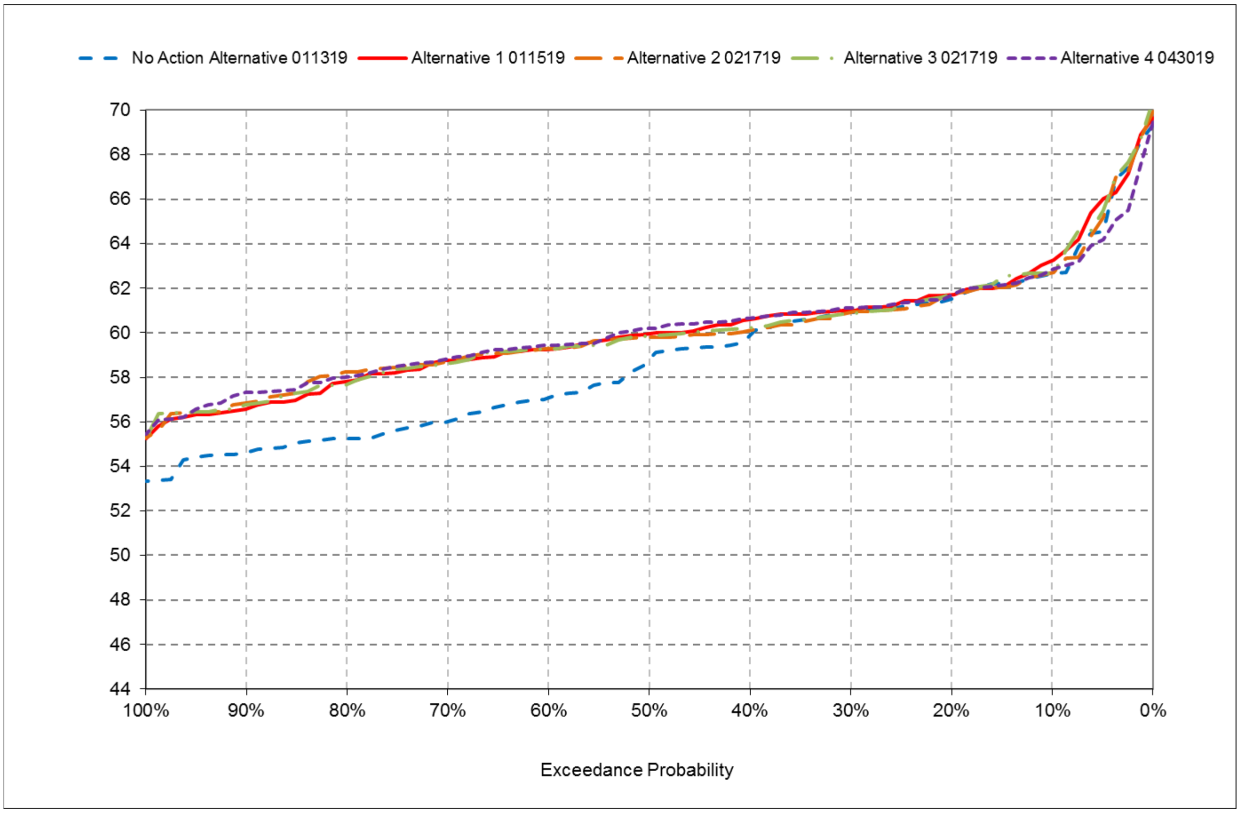


Figure O.3-22. HEC-5Q Sacramento River Water Temperatures at Red Bluff Diversion Dam under the No Action Alternative, Alternative 1, Alternative 2, Alternative 3 and Alternative 4; September

Table O.3-10. HEC-5Q Monthly Average Water Temperatures (degree Fahrenheit) by Water Year Type and Month below Hamilton City for No Action Alternative, Alternative 1 and Differences between Them

Alternative1,2,3 Water Year Type4	Monthly Temperature (°F)											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
No Action Alternative												
Wet (32%)5	57.8	54.3	48.9	46.5	47.4	50.4	55.4	60.2	64.1	63.0	63.7	58.2
Above Normal (16%)	58.0	53.6	48.6	46.7	47.6	51.1	56.8	61.0	62.8	61.0	62.9	59.6
Below Normal (13%)	58.5	53.5	48.5	46.7	48.6	53.1	58.9	60.7	62.0	61.8	63.2	64.2
Dry (24%)	59.1	53.3	48.3	46.9	49.0	52.8	58.5	61.5	62.7	63.1	65.3	65.1
Critically Dry (15%)	62.2	54.8	48.3	47.4	50.0	54.2	59.6	62.1	64.5	65.9	67.9	67.9
Alternative 1												
Wet (32%)	57.2	53.7	49.0	46.6	47.4	50.4	55.3	60.0	64.1	63.1	63.5	61.7
Above Normal (16%)	57.4	52.8	48.5	46.8	47.6	51.0	56.8	60.6	62.6	61.0	63.0	64.2
Below Normal (13%)	58.3	53.7	48.7	46.8	48.6	52.9	58.6	60.0	61.2	61.7	62.9	63.5
Dry (24%)	58.4	53.4	48.6	47.0	49.0	52.8	58.5	60.9	61.9	63.1	64.7	64.9
Critically Dry (15%)	62.2	55.0	48.4	47.5	50.2	54.2	59.7	61.8	63.7	65.9	67.6	68.2
Alternative 1 minus No Action Alternative6												
Wet (32%)	-0.6	-0.6	0.1	0.1	0.0	0.0	0.0	-0.2	-0.1	0.1	-0.2	3.5
Above Normal (16%)	-0.6	-0.8	-0.1	0.1	0.0	-0.1	0.0	-0.4	-0.2	0.1	0.1	4.6
Below Normal (13%)	-0.2	0.2	0.2	0.1	-0.1	-0.2	-0.3	-0.7	-0.7	-0.1	-0.3	-0.7
Dry (24%)	-0.7	0.1	0.3	0.1	0.0	0.0	0.0	-0.6	-0.8	0.0	-0.7	-0.2
Critically Dry (15%)	0.1	0.1	0.1	0.2	0.2	-0.1	0.1	-0.3	-0.8	0.0	-0.2	0.3

1 Results based on the 82-year simulation period.
2 Results displayed with calendar year - year type sorting.
3 All scenarios are simulated at ELT (Early Long-Term) Q5 with 2025 climate change and 15 cm sea level rise.
4 Water year types as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999).
5 Percent of years of each type given in parantheses.
6 Bold green font indicates greater than 1°F reduction in temperature, bold red font indicates greater than 1°F increase in temperature.

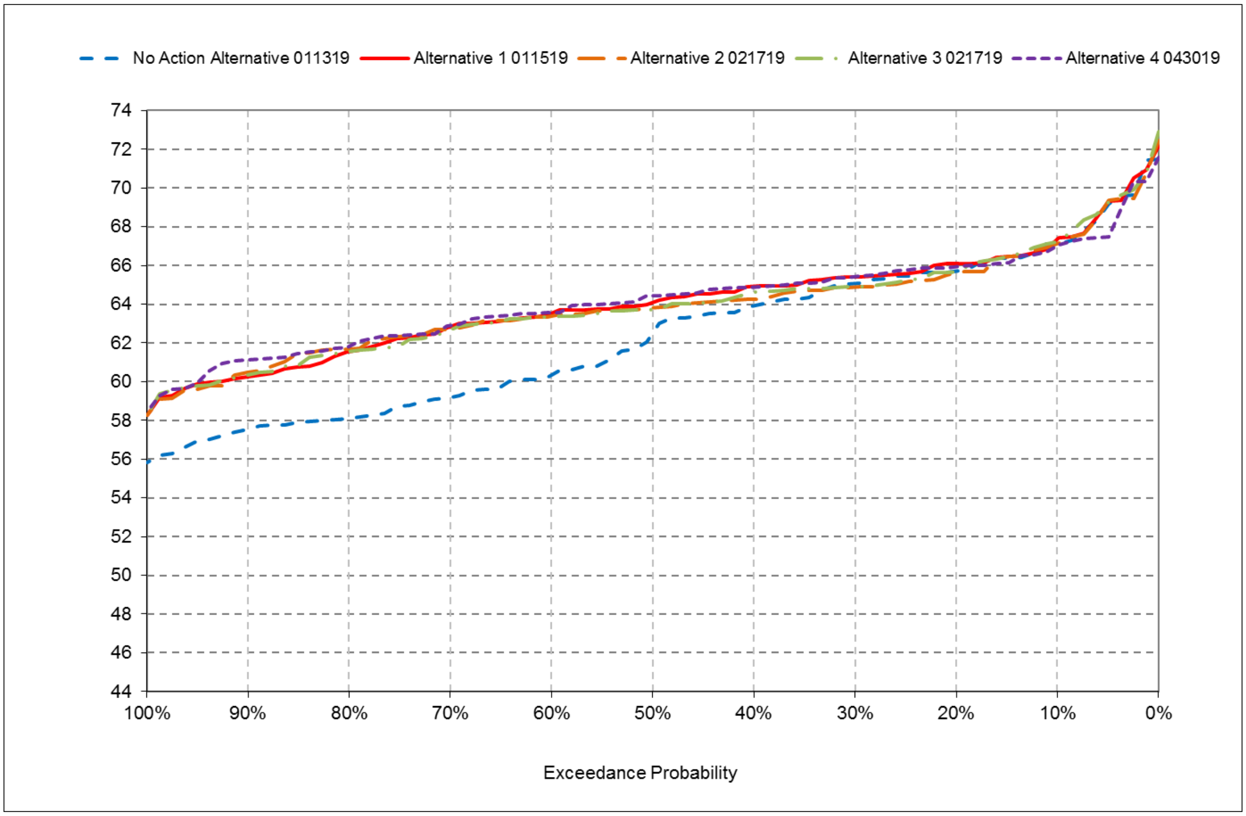


Figure O.3-23. HEC-5Q Sacramento River Water Temperatures below Hamilton City under the No Action Alternative, Alternative 1, Alternative 2, Alternative 3 and Alternative 4; September

Table O.3-11. HEC-5Q Monthly Average Water Temperature (°F) by Water Year Type and Month at Knights Landing for No Action Alternative, Alternative 1 and Differences between Them

Alternative1,2,3 Water Year Type4	**Monthly Temperature (°F)**											
	Oct	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
No Action Alternative												
Wet (32%)5	61.0	55.1	48.8	46.5	48.0	51.9	57.4	65.0	70.9	71.8	72.4	63.9
Above Normal (16%)	61.6	54.3	48.5	47.0	48.3	52.5	59.1	66.6	70.8	69.7	71.6	65.8
Below Normal (13%)	62.7	55.1	48.4	46.9	49.2	55.1	62.0	67.1	69.9	70.5	71.4	70.5
Dry (24%)	63.2	54.9	48.4	46.9	49.7	54.5	61.1	68.0	71.3	71.9	73.6	71.7
Critically Dry (15%)	65.9	56.9	48.5	47.5	51.1	56.5	63.2	68.6	72.4	74.3	75.5	73.3
Alternative 1												
Wet (32%)	61.2	55.0	48.8	46.6	48.0	51.9	57.4	64.7	70.8	71.9	72.2	68.2
Above Normal (16%)	61.8	54.1	48.4	47.0	48.3	52.5	59.1	66.2	70.4	69.7	71.7	70.4
Below Normal (13%)	62.5	55.1	48.6	47.0	49.2	54.8	61.7	66.4	68.8	70.5	71.3	69.9
Dry (24%)	62.8	54.9	48.6	47.0	49.8	54.5	61.1	67.4	70.2	72.0	73.3	71.6
Critically Dry (15%)	66.0	56.8	48.6	47.6	51.2	56.4	63.3	68.4	71.6	74.6	75.5	73.4
Alternative 1 minus No Action Alternative6												
Wet (32%)	0.2	-0.1	0.0	0.1	0.0	0.0	0.0	-0.2	-0.1	0.1	-0.1	4.3
Above Normal (16%)	0.3	-0.2	-0.1	0.0	0.0	-0.1	0.0	-0.4	-0.3	0.0	0.1	4.6
Below Normal (13%)	-0.2	0.1	0.2	0.1	-0.1	-0.3	-0.3	-0.7	-1.1	0.0	-0.1	-0.6
Dry (24%)	-0.4	-0.1	0.2	0.0	0.0	0.0	0.0	-0.7	-1.0	0.1	-0.3	-0.1
Critically Dry (15%)	0.1	0.0	0.1	0.1	0.1	-0.1	0.1	-0.2	-0.8	0.2	0.0	0.0

1 Results based on the 82-year simulation period.
2 Results displayed with calendar year - year type sorting.
3 All scenarios are simulated at ELT (Early Long-Term) Q5 with 2025 climate change and 15 cm sea level rise.
4 Water year types as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999)
5 Percent of years of each type given in parantheses.
6 Bold green font indicates greater than 1°F reduction in temperature, bold red font indicates greater than 1°F increase in temperature.

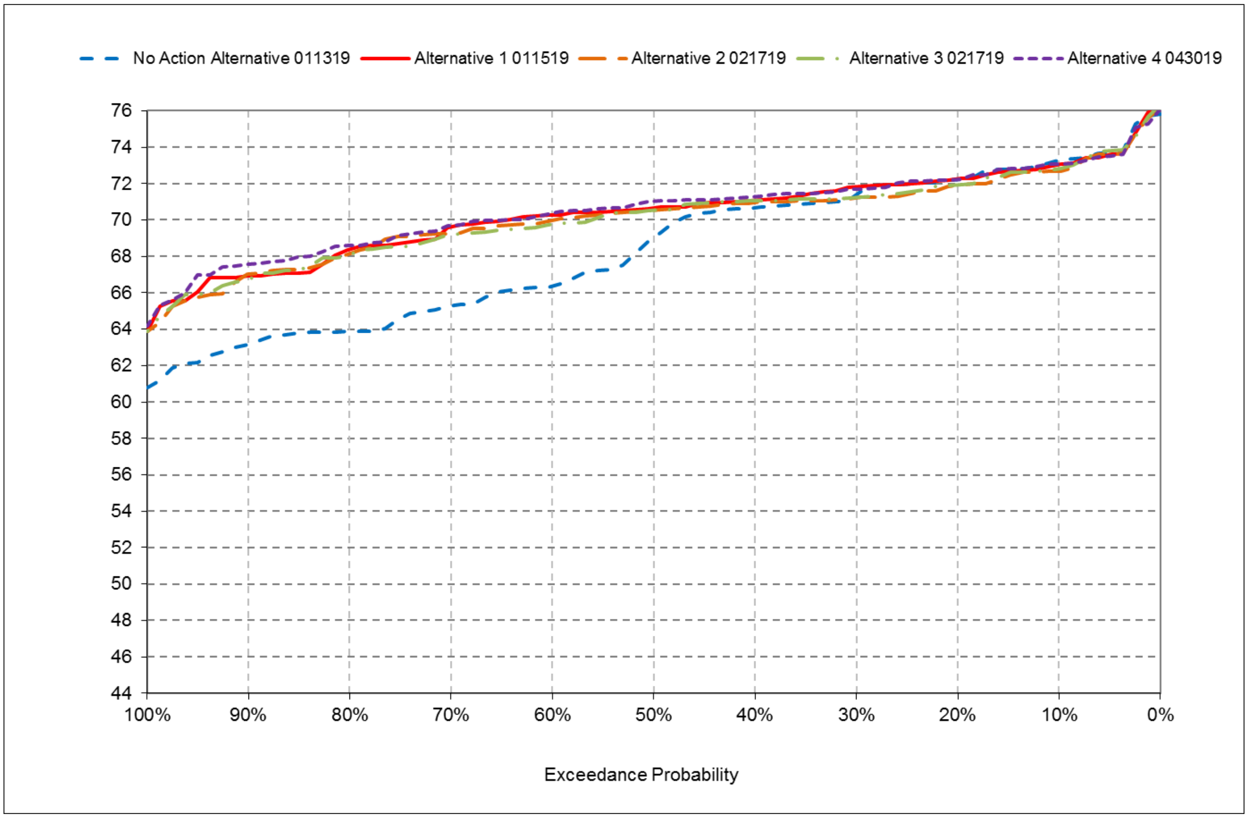


Figure O.3-24. HEC-5Q Sacramento River Water Temperatures at Knights Landing under the No Action Alternative, Alternative 1, Alternative 2, Alternative 3 and Alternative 4; September

The reduced downstream warming of the river in September of wet and above normal years under the No Action Alternative relative to the Alternative 1 is due, at least in part, to the much higher flow releases for Fall X2, as noted above (Table O.3-5 and O.3-12 through O.3-14). However, the reduced HEC-5Q mean August and October water temperatures under Alternative 1 (Figures O.3-18 and O.3-19) are likely due, at least in part, to the lower September and November flows under Alternative 1 relative to the No Action Alternative because the water thus conserved is used to reduce water temperature in October of the same year or is used to maintain the coldwater pool for a longer time in the following year. Note that November Fall X2 flow releases under the No Action Alternative do not result in lower downstream water temperatures relative to Alternative 1, because November air temperatures would, on average, be similar to or lower than the water temperatures.

The HEC-5Q temperature results, as previously cautioned, likely overestimate the Alternative 1 summer through early fall water temperatures because the HEC-5Q modeling does not include effects of several major operational and structural proposed water temperature management improvements included in Alternative 1. It is expected that with the proposed improvements included, Alternative 1 would provide cooler summer and fall water temperature releases than the No Action Alternative in all months in most years, with the possible exception of September, when water temperatures are warmer because the Alternative 1 would not include the Fall X2 flows that reduce downstream warming.

Table O.3-12. HEC-5Q Monthly Average Flow (cfs) by Water Year Type and Month at Red Bluff Diversion Dam for No Action Alternative, Alternative 1 and Differences between Them

Alternative[1,2,3] Water Year Type[4]	Monthly Flow (cfs) Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
No Action Alternative												
Wet (32%)[5]	8,728	12,255	12,422	29,982	31,345	25,200	14,018	11,059	9,426	12,709	9,781	14,320
Above Normal (16%)	7,927	12,554	11,235	16,772	26,458	16,158	9,459	9,611	10,203	14,275	9,759	10,210
Below Normal (13%)	6,820	6,705	11,915	7,608	12,849	7,303	6,118	8,845	10,980	13,721	10,131	5,837
Dry (24%)	6,538	7,784	15,279	7,303	9,573	9,042	6,326	8,214	10,498	12,221	8,358	5,349
Critically Dry (15%)	5,338	5,218	6,394	6,318	6,527	5,955	5,159	7,866	9,252	10,848	7,654	4,954
Alternative 1												
Wet (32%)	8,619	8,715	14,507	31,071	31,509	25,285	14,115	11,289	9,497	12,581	9,925	8,559
Above Normal (16%)	8,009	9,467	12,472	18,132	27,628	16,837	9,455	10,081	10,510	14,262	9,707	5,479
Below Normal (13%)	6,768	6,695	11,938	8,997	13,851	8,149	6,478	9,630	12,102	13,667	10,128	6,311
Dry (24%)	6,735	7,875	15,651	7,421	9,569	9,421	6,297	9,004	11,447	11,951	8,448	5,253
Critically Dry (15%)	5,374	5,449	6,431	6,293	6,407	6,376	5,075	8,072	9,956	10,328	7,542	5,058
Alternative 1 minus No Action Alternative[6]												
Wet (32%)	-109	-3,540	2,085	1,089	164	85	97	231	71	-128	144	-5,761
Above Normal (16%)	82	-3,087	1,238	1,360	1,169	679	-3	470	306	-12	-52	-4,731
Below Normal (13%)	-52	-10	23	1,389	1,002	846	360	785	1,122	-54	-3	474
Dry (24%)	197	91	372	118	-4	379	-29	790	949	-270	90	-95
Critically Dry (15%)	35	231	37	-25	-120	422	-84	205	704	-520	-112	103

1 Results based on the 82-year simulation period.
2 Results displayed with calendar year - year type sorting.
3 All scenarios are simulated at ELT (Early Long-Term) Q5 with 2025 climate change and 15 cm sea level rise.
4 Water year types as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999).
5 Percent of years of each type given in parantheses.
6 Bold green font indicates greater than 5% increase in flow; bold red font indicates greater than 5% reduction in flow.

Table O.3-13. HEC-5Q Monthly Average Flow (cfs) by Water Year Type and Month at Hamilton City for the No Action Alternative, Alternative 1 and Differences between Them

Alternative[1,2,3] Water Year Type[4]	Monthly Flow (cfs)											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
No Action Alternative												
Wet (32%)[5]	8,219	12,548	13,755	33,783	35,092	28,342	16,376	11,144	8,207	10,450	7,770	13,867
Above Normal (16%)	7,425	12,867	12,385	19,430	29,641	18,802	11,052	8,831	8,368	11,840	7,780	9,701
Below Normal (13%)	6,440	6,788	13,003	8,908	14,535	8,530	7,083	7,429	8,757	11,240	8,168	5,345
Dry (24%)	5,989	8,176	17,167	8,112	11,042	10,647	7,244	6,779	8,089	9,728	6,468	4,801
Critically Dry (15%)	4,854	5,153	7,089	6,934	7,312	6,875	5,290	6,238	7,000	8,573	5,874	4,436
Alternative 1												
Wet (32%)	8,125	9,018	15,840	34,872	35,256	28,427	16,473	11,370	8,272	10,330	7,912	8,102
Above Normal (16%)	7,520	9,793	13,627	20,790	30,810	19,481	11,048	9,298	8,669	11,836	7,728	4,970
Below Normal (13%)	6,396	6,790	13,026	10,296	15,537	9,376	7,443	8,199	9,872	11,151	8,164	5,819
Dry (24%)	6,207	8,278	17,539	8,230	11,039	11,025	7,215	7,555	9,039	9,458	6,558	4,705
Critically Dry (15%)	4,889	5,388	7,126	6,909	7,192	7,297	5,207	6,434	7,699	8,053	5,789	4,568
Alternative 1 minus No Action Alternative[6]												
Wet (32%)	-94	**-3,530**	**2,085**	1,089	164	85	97	226	65	-120	142	**-5,764**
Above Normal (16%)	95	**-3,074**	**1,243**	**1,360**	1,169	679	-3	**467**	301	-4	-52	**-4,731**
Below Normal (13%)	-44	2	23	**1,389**	**1,002**	**846**	**360**	**770**	**1,115**	-89	-4	**474**
Dry (24%)	219	102	372	118	-4	379	-29	**776**	**950**	-270	90	-95
Critically Dry (15%)	35	235	37	-25	-120	**422**	-83	196	**699**	**-520**	-86	132

1 Results based on the 82-year simulation period.
2 Results displayed with calendar year - year type sorting.
3 All scenarios are simulated at ELT (Early Long-Term) Q5 with 2025 climate change and 15 cm sea level rise.
4 Water year types as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999).
5 Percent of years of each type given in parentheses.
6 Bold green font indicates greater than 5% increase in flow; bold red font indicates greater than 5% reduction in flow.

Table O.3-14. HEC-5Q Monthly Average Flow (cfs) by Water Year Type and Month at Wilkins Slough for No Action Alternative, Alternative 1 and Differences between Them

Alternative[1,2,3] Water Year Type[4]	Monthly Flow (cfs)											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
No Action Alternative												
Wet (32%)[5]	7,511	12,176	11,622	18,870	19,567	17,810	14,598	9,612	6,426	7,574	5,293	13,916
Above Normal (16%)	6,711	11,184	11,185	16,976	18,484	17,432	12,412	7,174	6,171	8,650	5,448	9,654
Below Normal (13%)	6,046	6,466	11,361	10,381	13,627	9,842	7,454	5,489	5,958	7,948	5,637	5,132
Dry (24%)	5,215	8,027	12,724	9,098	12,422	12,174	8,077	4,381	5,159	6,678	4,291	4,665
Critically Dry (15%)	4,072	4,733	7,847	8,021	8,590	8,066	5,306	3,683	4,176	5,648	3,817	4,154
Alternative 1												
Wet (32%)	7,748	8,561	12,436	19,016	19,589	17,809	14,692	9,833	6,480	7,456	5,443	8,143
Above Normal (16%)	7,140	7,623	11,560	18,020	19,043	17,543	12,411	7,649	6,450	8,644	5,406	4,930
Below Normal (13%)	6,084	6,474	11,387	11,282	14,081	10,582	7,801	6,255	7,050	7,831	5,668	5,622
Dry (24%)	5,573	8,060	12,840	9,160	12,462	12,395	8,037	5,163	6,067	6,378	4,418	4,573
Critically Dry (15%)	4,130	4,972	7,869	7,978	8,466	8,492	5,196	3,891	4,864	5,097	3,774	4,286
Alternative 1 minus No Action Alternative[6]												
Wet (32%)	237	**-3,615**	**814**	146	22	0	94	221	54	-118	151	**-5,773**
Above Normal (16%)	**429**	**-3,561**	375	**1,044**	559	111	-1	**475**	279	-6	-42	**-4,723**
Below Normal (13%)	38	8	26	**901**	453	**739**	348	**765**	**1,092**	-117	31	**491**
Dry (24%)	**359**	33	116	62	40	221	-40	**782**	**908**	-300	127	-92
Critically Dry (15%)	58	**239**	22	-43	-124	**427**	-110	**207**	**689**	**-551**	-43	132

1 Results based on the 82-year simulation period.
2 Results displayed with calendar year - year type sorting.
3 All scenarios are simulated at ELT (Early Long-Term) Q5 with 2025 climate change and 15 cm sea level rise.
4 Water year types as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999).
5 Percent of years of each type given in parentheses.
6 Bold green font indicates greater than 5% increase in flow; bold red font indicates greater than 5% reduction in flow.

O.3.3.2.1 Sacramento River Winter-Run Chinook Salmon

O.3.3.2.2 Spawning and Egg/Alevin Incubation

Winter-Run Chinook Salmon adults spawn from May through August with peak spawning during June and July (Section O.2.4.2.1, *Winter-Run Chinook Salmon*). Fry emergence occurs up to 3 months after eggs are spawned, so effects of flow and water temperature on Winter-Run eggs and alevins may occur from May through November, but primarily occur during June through October.

As previously noted, CalSim II modeling indicates that mean monthly flow released at Keswick Dam under Alternative 1 would generally be higher than or similar to flow under No Action Alternative, except in wet and above normal water years during September and November, when the Alternative 1 flows would be substantially lower than the No Action Alternative flows (Table O.3-5). By September in most years, a large proportion of Winter-Run redds still contain incubating alevins. Assuming flows are stable enough to avoid dewatering the redds, which is generally true in September, the most important effect of flows on alevins is to transport dissolved oxygen to the developing alevins and to flush potentially toxic metabolites out of the redds. Although the mean September wet and above normal water year flows are substantially lower under Alternative 1 than under the No Action Alternative, the flows under Alternative 1 flows remain moderately high (>6,000 cfs) (Figure O.3-25). Flows at this level are expected to provide sufficient flow velocity to keep the redds clean and well oxygenated. With regard to redd dewatering, as described in the previous section, reductions in fall flow releases to conserve storage would be balanced by needs to maintain suitable water temperatures, minimize dewatering redds of Winter-Run and other salmonids, and avoid stranding rearing juveniles. Therefore, differences in flow between the No Action Alternative and Alternative 1 are expected to have little effect on Winter-Run Chinook Salmon spawning and incubation habitat.

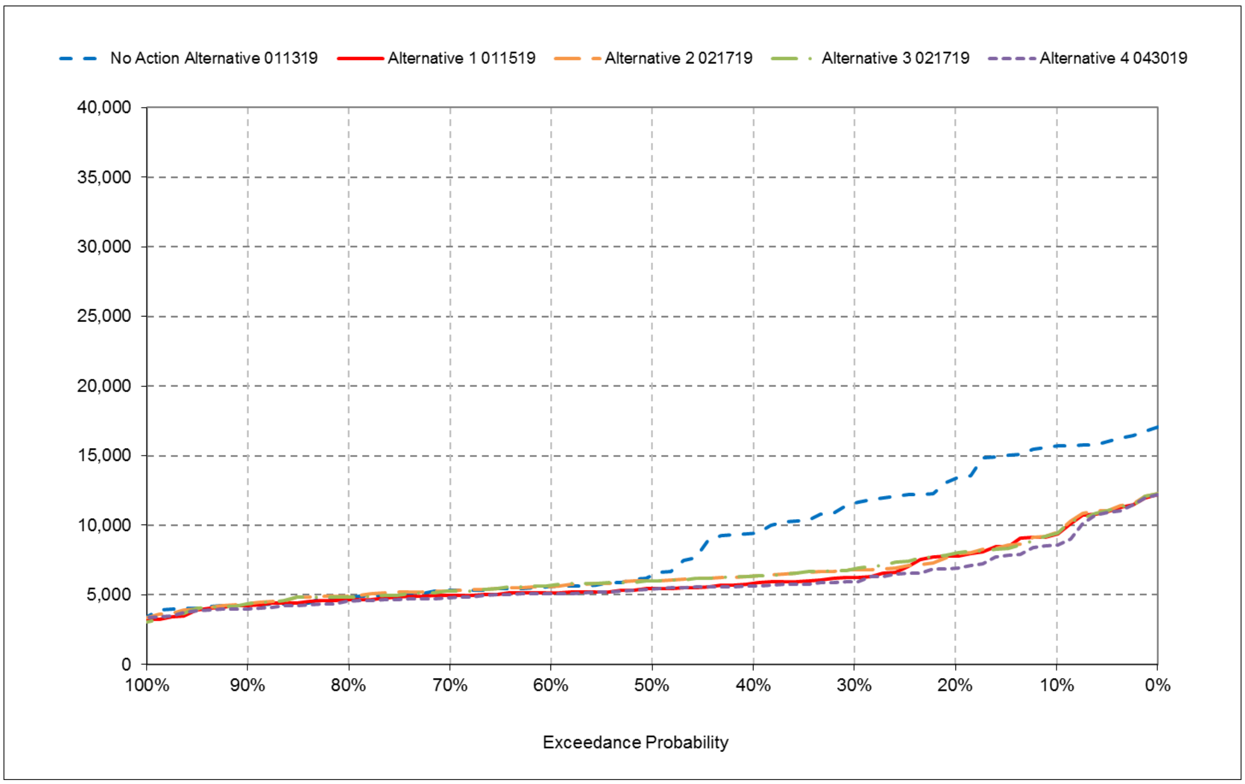


Figure O.3-25. CalSim II Sacramento River Flow at Keswick Dam under the No Action Alternative, Alternative 1, Alternative 2, Alternative 3 and Alternative 4; September

Differences between the No Action Alternative and Alternative 1 in water temperature during the Winter-Run spawning period may be important. As described in the previous section, HEC-5Q mean October water temperatures are predicted to be below the 53.5°F water temperature threshold in the majority of years under Alternative 1 and above the threshold in most years under the No Action Alternative (Figure O.3-18), and in August, the mean water temperatures are predicted to be above the threshold in about 25% of years under the No Action Alternative and 9% of years under Alternative 1 (Figure O.3-19).September water temperatures are expected to be higher under Alternative 1 than under the No Action

Alternative, but the increases are expected only for the most downstream portion of the Winter-Run spawning distribution and primarily for wet and above normal water years, for which the mean temperatures for both alternatives would mostly be below the water temperature threshold (Tables O.3-6 and O.3-7; Figure O.3-20).

The new analytical tools included in the proposed Alternative 1 water temperature management operations are primarily based on models developed from results of field studies during Winter-Run spawning in the upper Sacramento River by Martin et al. (2017) and Anderson (2018). These models, referred to hereinafter as the Matin and Anderson models, were used to compare water-temperature-related mortality of Winter-Run Chinook Salmon eggs and alevins under Alternative 1 and the No Action Alternative. The modeling was based on the HEC-5Q water temperature estimates for the years used in the HEC-5Q modeling (1922 to 2002). The results for all water year types combined indicate that egg/alevin mortality under Alternative 1 would be similar to or lower than that under the No Action Alternative, especially for the 30% to 5% of years with the highest mortality rates (Figure O.3-26). For many of those years, the annual mortality rate under Alternative 1 was almost 0.5 lower than that under the No Action Alternative for Anderson model and almost 0.3 lower for the Martin model. As discussed in the previous section, the proposed Alternative 1 water temperature management improvements are expected to result in significant October and August improvements in temperatures, driving the large reductions in temperature dependent mortality.

Figure O.3-26 combines results for all water year types, including wet years, when there is little temperature-related mortality. This obscures the modeling results for drier years, when egg/alevin mortalities are especially high. For critically dry years, the mortality modeling continues to show substantially lower mortality under Alternative 1 than under the No Action Alternative (Figure O.3-27).

The flow effects resulting from Alternative 1 would have a less-than-significant effect relative to the No Action Alternative on Winter-Run Chinook Salmon spawning and the egg and alevin life stages and the water temperature effects would be beneficial relative to the No Action Alternative.

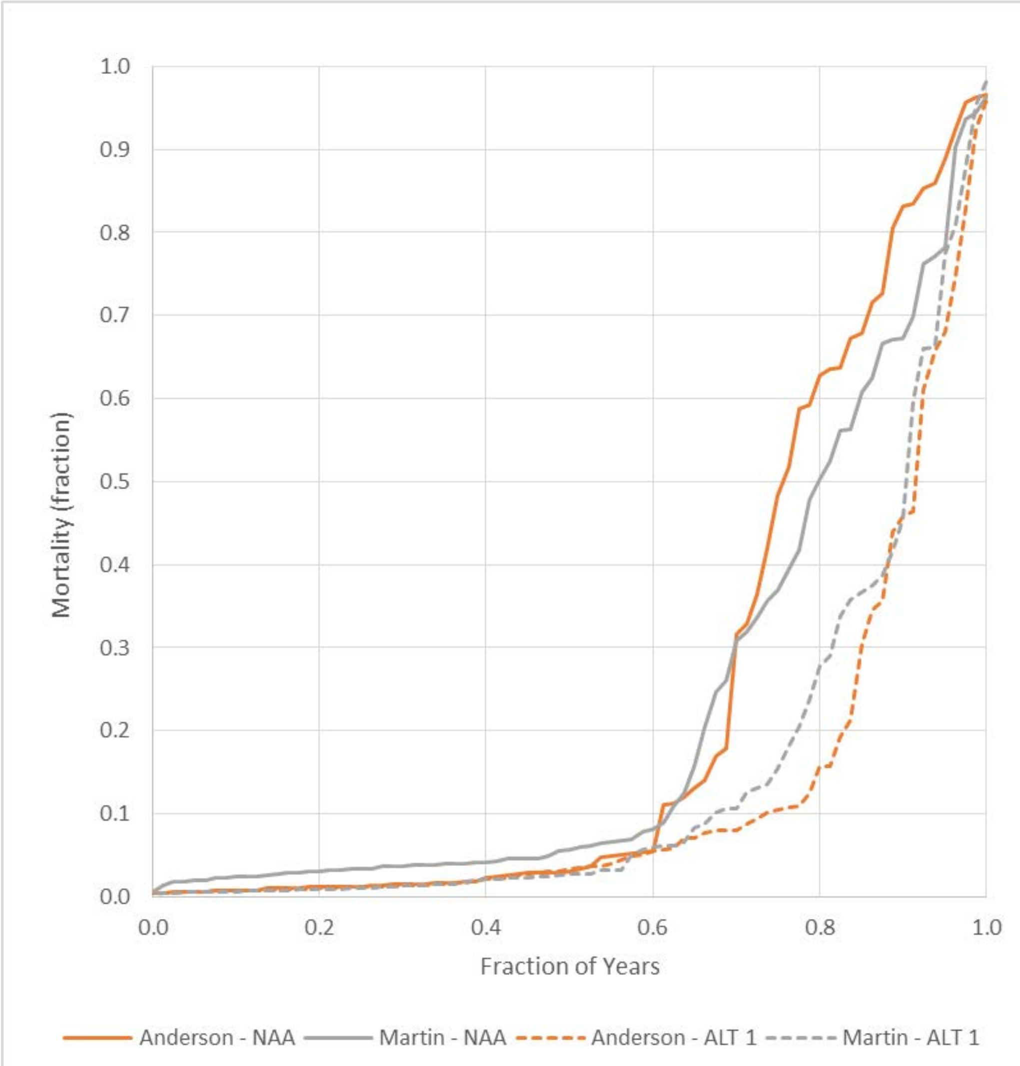


Figure O.3-26. Exceedances of Winter-Run Chinook Salmon Temperature-Dependent Egg Mortality, Alternative 1 vs. No Action Alternative; All Water Year Types.

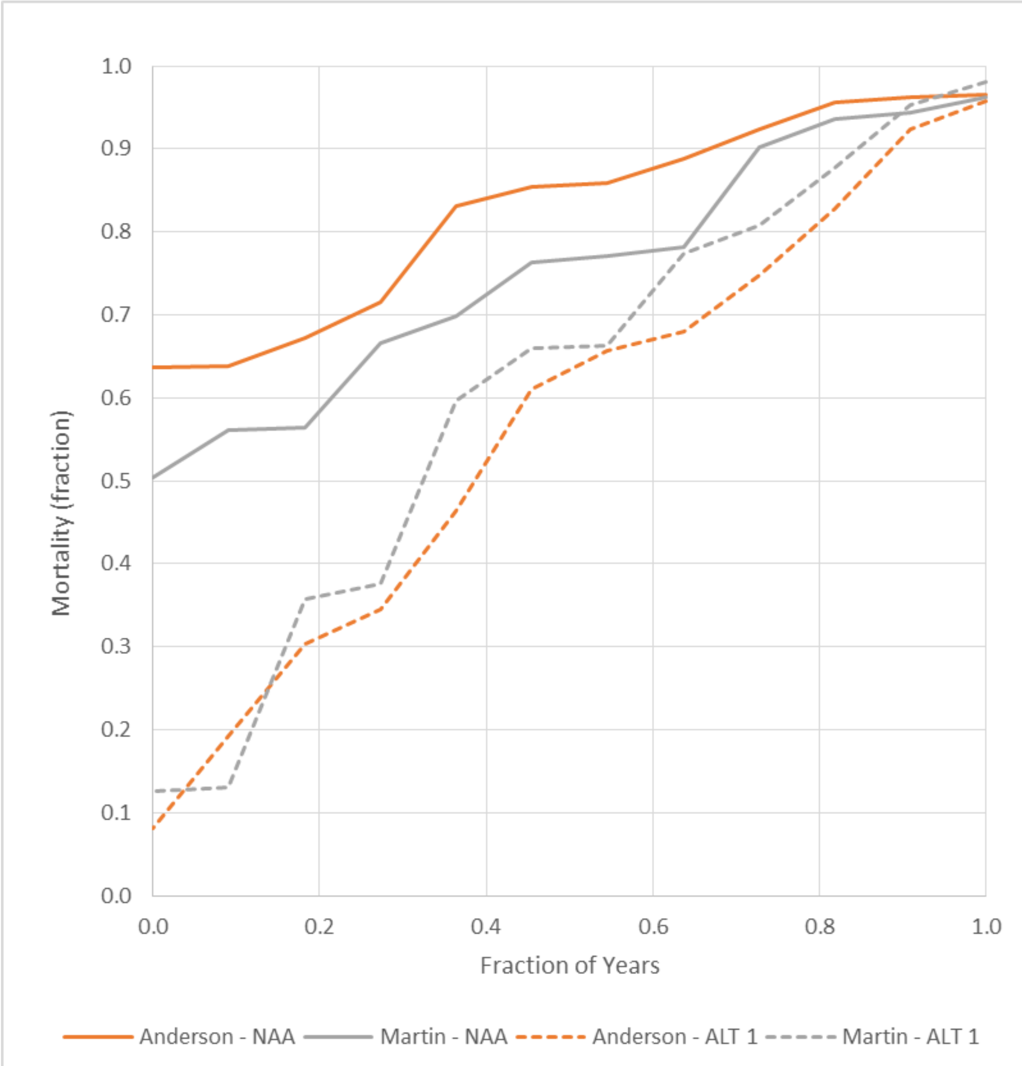


Figure O.3-27. Exceedances of Winter-Run Chinook Salmon Temperature-Dependent Egg Mortality, Alternative 1 vs. No Action Alternative; Critically Dry Water Years

Although the HEC 5Q results show little difference in water temperatures between the No Action Alternative and Alternative 1 in most months, the modeling for Alternative 1 does not include many of the actions of the new water temperature management operations and stuctures proposed for Alternative 1. It is expected that, througout the May through October period of operation, water temperatures under Alternative 1 would generally be more protective of Winter-Run Chinook Salmon spawning and egg/alevin incubation than the No Action Alternative.

Juvenile Rearing and Emigration

Winter-Run Chinook Salmon juveniles rear in the Sacramento River primarily from late summer to late winter, and emigrate from the river to the Delta beginning in November (see Section O.2.4.2.1, *Winter-Run Chinook Salmon*). The proportion of juveniles surviving to emigrate to the Delta depends largely on habitat conditions, including flow and water temperature. Inundated floodplain habitat has been shown to benefit growth and survival of juvenile salmon (Sommer et al. 2001, 2005; Katz et al. 2017), but natural flood flows largely determine the availability of this habitat, rather than operations of the CVP and SWP dams.

Sacramento River flow during the Winter-Run juvenile rearing and emigration period differs substantially between the No Action Alternative and Alternative 1 during some months, but the largest differences are generally limited to wetter water year types (Tables O.3-5, O.3-12 through O.3-14). The juveniles rear primarily in the upper and middle Sacramento River until about October, when they begin to appear in the lower river (e.g., Knights Landing) (del Rosario et al. 2013). As noted previously, because the No Action Alternative includes Fall X2 releases but not Alternative 1 does not, the mean monthly flows during September and November are much lower under Alternative 1 than under the No Action Alternative, which would potentially reduce suitable rearing habitat for juveniles (Tables O.3-5, O.3-12 through O.3-14; Figures O.3-25, O.3-28 and O.3-29).

Emigration of juvenile Winter-Run from the Sacramento River is triggered by pulse flows of about 14,000 cfs and above (at Wilkins Slough) (del Rosario et al. 2013). CalSim II September flows at Wilkins Slough exceed this threshold in about 18% of years under the No Action Alternative and never exceed it under Alternative 1, but September is too early for juvenile Winter-Run to emigrate to the Delta (del Rosario et al. 2013). For November, when Winter-Run juveniles are ready to emigrate, flow at Wilkins Slough is much higher under the No Action Alternative than under Alternative 1, but remains below the 14,000 cfs threshold for both alternatives, except for the highest 9% of flows (Figure O.3-29). There are no differences between the alternatives for these highest flows. An important limitation with this analysis is that the CalSim II flow estimates are monthly averages and Winter-Run emigration can be triggered by flow pulses that exceed 14,000 cfs for only a few days (del Rosario et al. 2013), so the flow differences in Figure O.3-29 incompletely represent the likelihood of triggering pulse flows occurring under the two alternatives.

Results from a more recent analysis suggest that the reduction in November flows from the No Action Alternative to Alternative 1 during wet and above normal water years could adversely affect Winter-Run juveniles emigrating at that time. The NMFS Southwest Fisheries Science Center ran statistical models using 2012-2017 tagging data from Spring-Run Chinook Salmon and Fall-Run Chinook Salmon and found a significant increase in smolt survival when Sacramento River flow at Wilkins Slough was above 9,100 cfs during the smolts out-migration period (Cordoleani et al. 2019). The CalSim II results for November at Wilkins Slough indicate that, under the No Action Alternative, 50% of years would have mean monthly flows that exceed the 9,100 cfs threshold, but that under Alternative 1 only 20% of years would exceed the threshold (Figure O.3-29). If these results apply to Winter-Run juveniles emigrating in November, they indicate a potential adverse effect of Alternative 1 on emigrating Winter-Run juveniles. The applicability of the results to Winter-Run are currently unknown, so the effect on Winter-Run is uncertain.

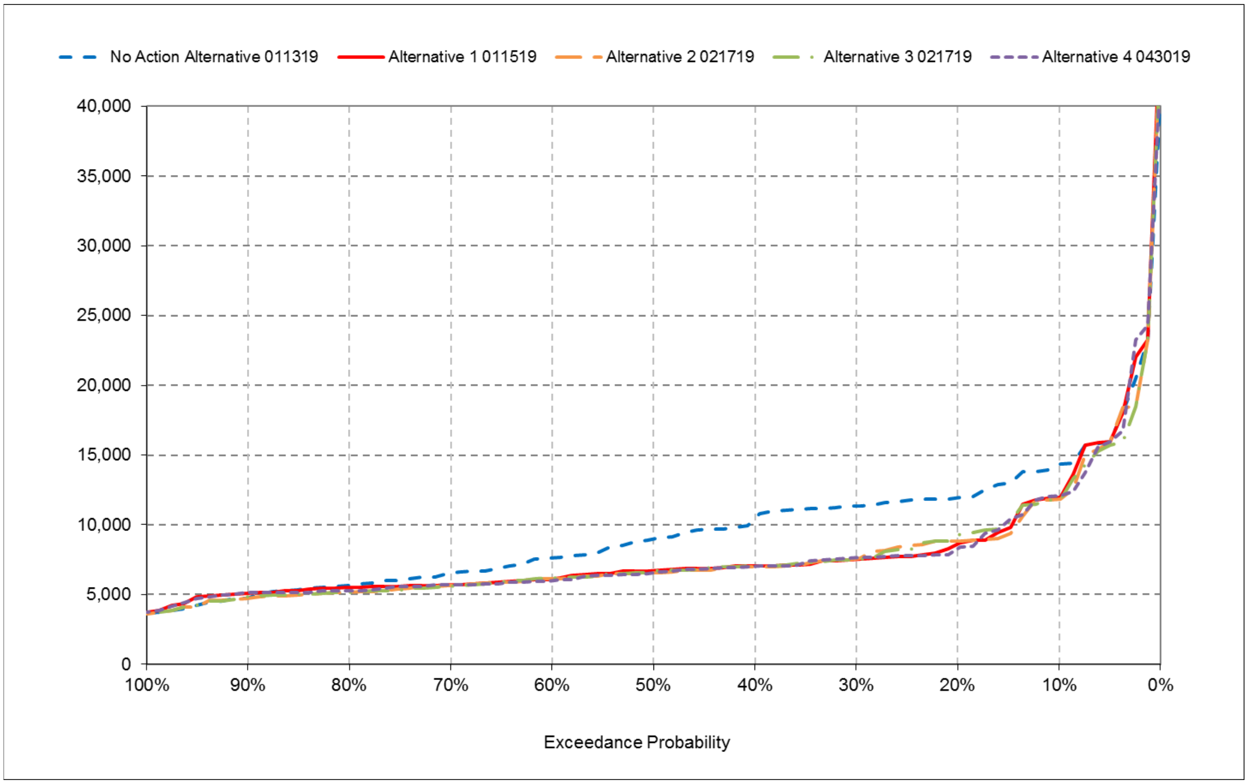


Figure O.3-28. CalSim II Sacramento River Flow at Hamilton City under the No Action Alternative, Alternative 1, Alternative 2, Alternative 3 and Alternative 4; November

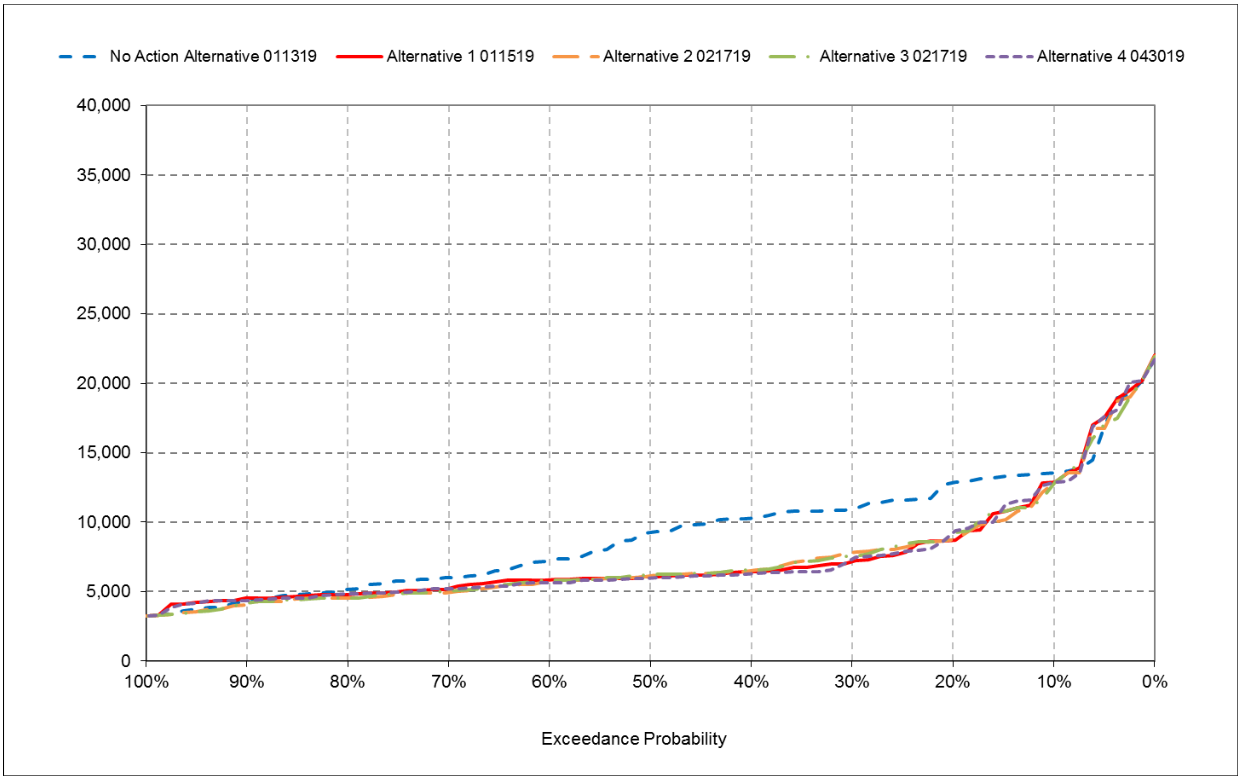


Figure O.3-29. CalSim II Sacramento River Flow at Wilkins Slough under the No Action Alternative, Alternative 1, Alternative 2, Alternative 3 and Alternative 4; November

The USEPA (2003) gives 61°F as the critical 7 day average daily maximum (7DADM) water temperature for Winter-Run Chinook Salmon juveniles rearing in the upper Sacramento River and 64°F (7DADM) for those rearing in the middle Sacramento River (Knights Landing). Under the No Action Alternative, NMFS currently requires Reclamation to maintain water temperature from May 15 through October 31 in the Sacramento River at no more than 56°F at compliance locations between Ball's Ferry and Red Bluff Diversion Dam (NMFS 2011; RPA 1.2.4). Alternative 1 proposes lowering this threshold in the future. Therefore, juveniles rearing in the upper Sacramento River are likely to be well protected from water temperature extremes through the end of October in all but the driest years.

Under the No Action Alternative and Alternative 1, mean monthly water temperatures at Keswick exceed the 61°F threshold in only about 5% of years in September and October, with no appreciable water temperatures differences between the alternatives for water temperatures greater than the 61°F threshold (Figures O.3-18 and O.3-20; Table O.3-6). The monthly average temperatures for these months should reasonably estimate daily mean temperatures because operations at Shasta and Keswick dams create relatively stable summer and fall flow and water temperature conditions in the upper Sacramento River. From November through March, by which month most juvenile Winter-Run have emigrated to the Delta, there are only minor differencs in mean water temperatures at all locations from Keswick Dam to Knights Landing (Tables O.3-6 through O.3-11).

The water temperature effects resulting from Alternative 1 on juvenile Winter-Run Chinook Salmon rearing in or emigrating from the Sacramento River would be less-than-significant relative to the No Action Alternative, but the flow effects would have a potentially significant impact on juvenile Winter-Run Chinook Salmon because the reductions in September flows in wet and above normal water years could reduce rearing habitat and the reductions November flows in wet and above normal water years could reduce smolt survival.

Adult Upstream Migration and Holding

Winter-Run Chinook Salmon adults enter the Sacramento River from the Delta and make their way to the upper Sacramento River, beginning as early as December. They hold in the upper River within 10 to 15 miles of Keswick Dam until they are ready to spawn, which may extend through August (Windell et al. 2017).

There are no flow or temperature requirements for the middle Sacramento River designed to protect fish. However, releases from Shasta Reservoir during November through early May may be reduced to conserve water for the May through October Winter-Run and Spring-Run spawning and incubation periods, resulting in reduced flow in the middle river (NMFS 2011: RPA I.2.2). Lower flow in the Sacramento River relative to flow from the lower Yolo and Sutter bypasses and agricultural drains may affect navigation cues and straying of Winter-Run adults into canals and behind weirs, increasing their stranding risk. Once the adults reach holding habitat in the upper Sacramento River, they are more directly affected by Shasta and Keswick reservoir operations designed to preserve cold water for the Winter-Run and Spring-Run spawning and incubation periods. During the December through August period of adult Winter-Run immigration and holding, the mean monthly flows under Alternative 1 at Keswick Dam, Hamilton City and Wilkins Slough would generally be similar to or greater than flows under the No Action Alternative, except during July of dry and critically dry water years at Hamilton City and Wilkins Slough (Tables O.3-5 and O.3-5 and O.3-6). However, the July flows at Hamilton City and Wilkins Slough under both alternatives would be high enough (>3,250 cfs) to allow upstream passage (Tables O.3-13 and O.3-14).

The USEPA (2003) gives 68°F as the critical 7DADM water temperature for Winter-Run Chinook Salmon adults migrating upstream in the Sacramento River and 61°F for adult Winter-Run holding in the upper river. There are few differences in HEC-5Q water temperature estimates between the No Action Alternative and Alternative 1 during any of the months that adult Winter-Run migrate upstream in the Sacramento River or hold in the upper river (Tables O.3-6 through O.3-11). However, the monthly mean water temperatures are moderately cooler under Alternative 1 at Hamilton City and Knights Landing sites during May, June and August in some of the water year types (Tables O.3-10 and O.3-11). Under both alternatives, the mean monthly water temperatures in the middle Sacramento River (Knights Landing) would be below the 68°F threshold for immigrating adults from December through April, but would exceed the threshold in May of critically dry water years and June through August of all water year types (Table O.3-11). Most Winter-Run adults have migrated upstream of RBDD by late May (see Section O.2.4.2.1, *Winter-Run Chinook Salmon*) and would therefore not be adversely affected by the elevated summer downstream water temperatures. In the upper Sacramento River from Keswick to Balls Ferry, the mean water temperatures would be well below the 61°F threshold for holding adults from December through August under both alternatives (Table O.3-6 through O.3-8).

Although the HEC 5Q results show little difference in water temperatures between the No Action Alternative and Alternative 1, the modeling for Alternative 1 does not include many of the actions of the new water temperature management operations and stuctures proposed for Alternative 1. It is expected that, during the May through October period of operation, water temperatures under Alternative 1 would in fact be more protective of Winter-Run Chinook Salmon adults than the No Action Alternative, particularly in the upper Sacramento River. Therefore, Alternative 1 is expected to have a beneficial effect on Winter-Run Chinook Salmon adult upstream migration and holding relative to the No Action Alternative.

O.3.3.2.3 Central Valley Spring-Run Chinook Salmon

Spawning and Egg/Alevin Incubation

Spring-Run Chinook Salmon adults spawn from August through October with peak spawning in September (see Section O.2.4.2.2, *Spring-Run Chinook Salmon*). Monitoring Spring-Run spawning in the mainstem Sacramento River is complicated due to lack of spatial/geographic segregation and temporal isolation from Fall-Run Chinook Salmon. Most spring-sun spawning occurs between the Keswick Dam and Ball Ferry Bridge (NMFS 2017b). Fry emergence occurs up to 3 months after eggs are spawned (Moyle 2002), so effects of flow in the upper Sacramento River on incubating Spring-Run eggs and alevins potentially occur from August through January, peaking in December.

As previously noted, CalSim II modeling indicates that mean monthly flow released at Keswick Dam under Alternative 1 would generally be higher than or similar to flow under No Action Alternative, except in wet and above normal water years during September and November, when the Alternative 1 flows would be substantially lower (up to 47% lower) than the No Action Alternative flows (Table O.3-5). Spawning and incubating eggs and alevins could be negatively or positively affected by the flow reductions. Assuming flows are stable enough to avoid dewatering the redds, which as noted previously is an important criterion for operators of Shasta and Keswick dams, the most important effect of flows on eggs and alevins is to transport dissolved oxygen to the developing eggs and alevins and to flush potentially toxic metabolites out of the redds. Although the mean September and November wet and above normal water year flows are substantially lower under Alternative 1 than under the No Action Alternative, the flows under Alternative 1 flows remain sufficiently high (>5,000 and >7,000 cfs for September and November, respectively) to provide the flow velocity needed to keep most redds clean and well oxygenated (Figure O.3-25). Therefore, differences in flow between the No Action Alternative and Alternative 1 are expected to have little effect on Spring-Run Chinook Salmon spawning and incubation habitat.

Differences in water temperature during the Spring-Run spawning period may be important. As described previously, HEC-5Q mean October water temperatures at Keswick Dam are predicted to be below the 53.5°F water temperature threshold in the majority of years under Alternative 1 and above the threshold in most years under the No Action Alternative (Figure O.3-18; Table O.3-6). Between the Clear Creek confluence and Balls Ferry, where more of the Spring-Run spawning occurs, more of the October mean monthly water temperatures under Alternative 1 exceed the threshold, especially in drier years, but most of them continue to be well below the No Action Alternative means (Tables O.3-7 and O.3-8). The same is true for August of drier water year types. September water temperatures in wet and above normal water years are expected to be higher under Alternative 1 than under the No Action Alternative, especially downstream of Keswick Dam (Tables O.3-7 through O.3-9), and the increases would result in more years with mean water temperatures exceeding the 53.5°F water temperature threshold, erspecially at Ball's Ferry (Figures O.3-30 and O.3-31). The critical temperature threshold for spawning adult Chinook Salmon in the Sacramento River is the same as that for eggs and alevins, 53.5°F (Martin et al. 2017) or 55.4°F (USEPA 2003).

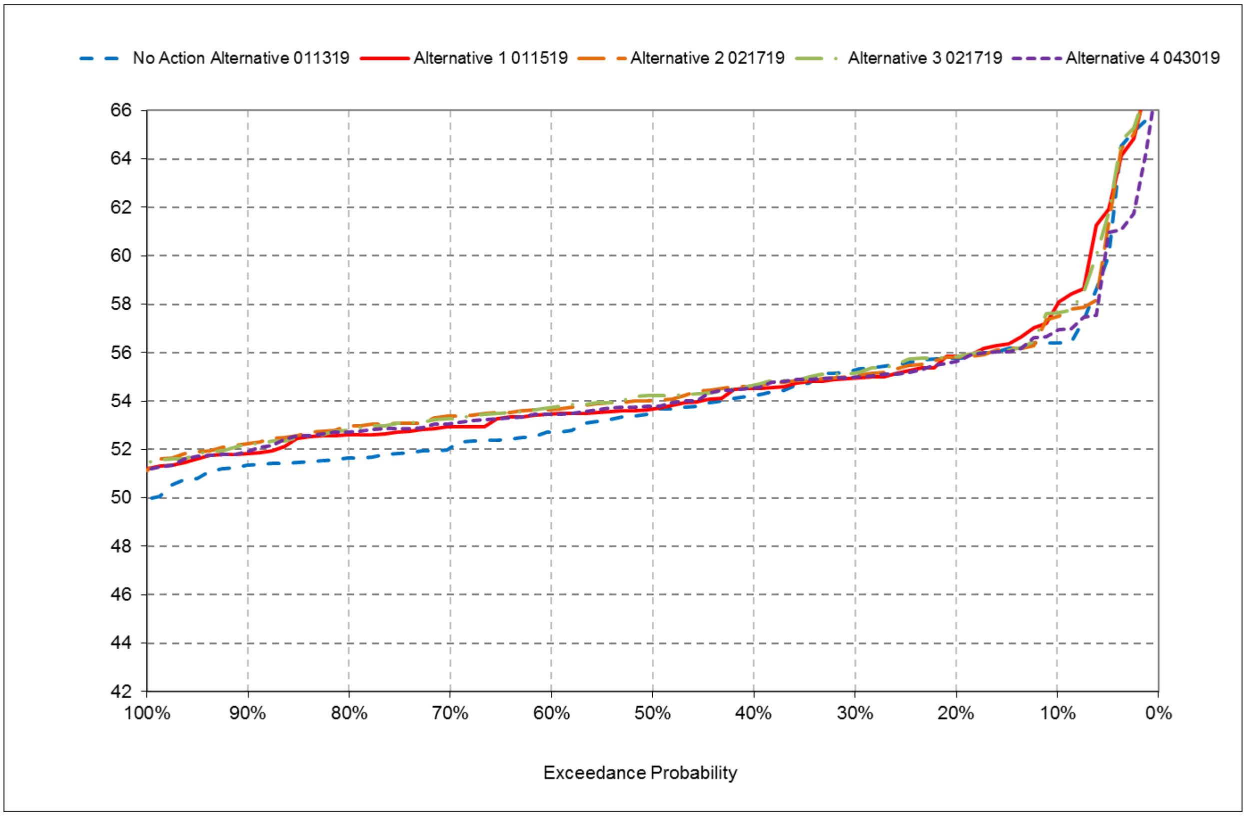


Figure O.3-30. HEC-5Q Sacramento River Water Temperatures at Clear Creek Confluence under the No Action Alternative, Alternative 1, Alternative 2, and Alternative 3; September

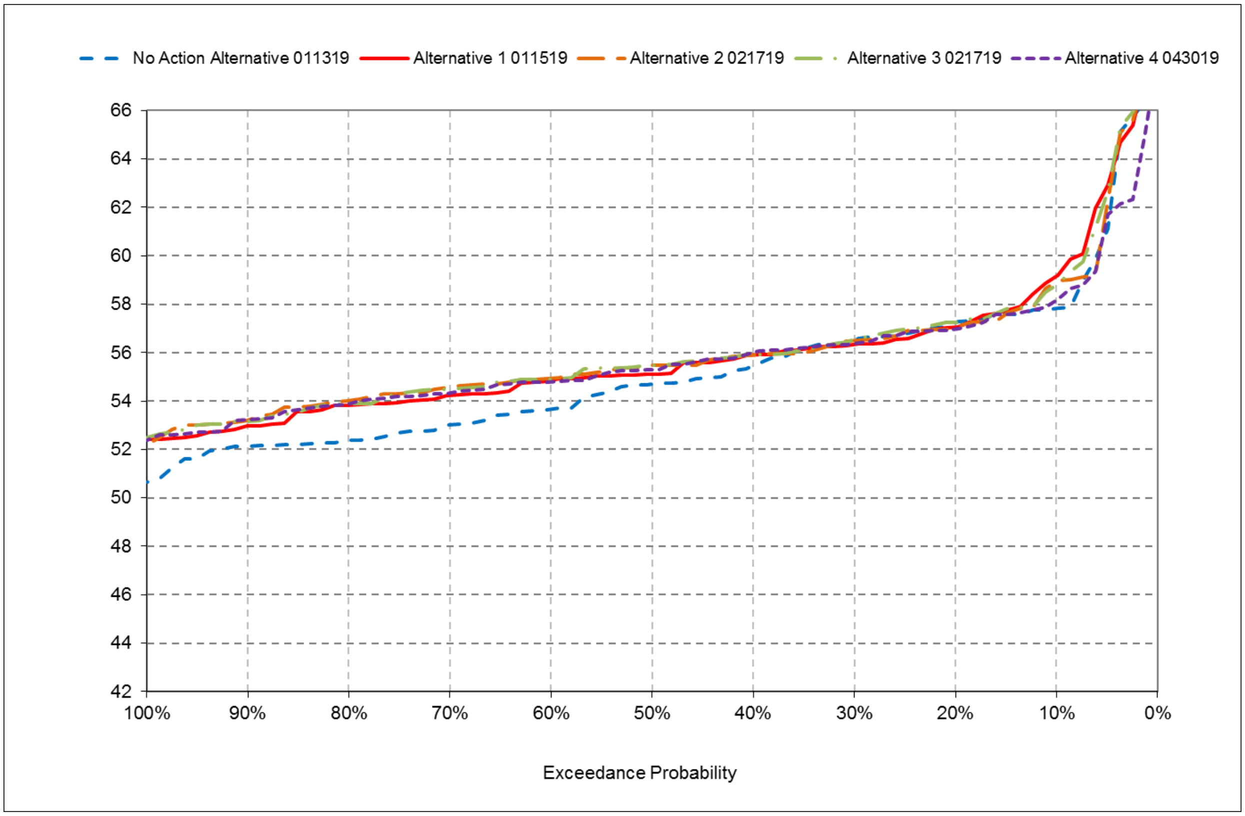


Figure O.3-31. HEC-5Q Sacramento River Water Temperatures at Balls Ferry under the No Action Alternative, Alternative 1, Alternative 2, and Alternative 3; September

The HEC-5Q modeling results, which show an increased exceedance of the 53.5°F water temperature threshold during September under Alternative 1 relative to the No Action Alternative suggest that Alternative 1 would have a significant adverse impact on Spring-Run spawning and egg and alevin incubation. However, as previously discussed, the HEC-5Q modeling results are believed to overestimate Alternative 1 water temperatures because the modeling relies on shutter (TCD) operations for Alternative 1 that are quite similar to those of the No Action Alternative, which does not accurately represent actual shutter operation under Alternative 1. Furthermore, the HEC-5Q modeling includes little of the effects expected from several of the major water temperature management improvements proposed for Alternative 1. These include the risk based water temperature management approach and the improved TCD described earlier, and a number of the other proposed measures, all of which would facilitate increased cold water storage, resulting in greater availability of cold water for protection of Spring-Run eggs and alevins.

It is concluded that Alternative 1 would have a less-than-significant impact on Spring-Run Chinook Salmon spawning and egg and alevin incubation with respect to flow and water temperature.

Juvenile Rearing and Emigration

Spring-Run Chinook Salmon juveniles rear in the Sacramento River primarily from November through early May and most emigrate to the Delta during December and again in March and April (see Section O.2.4.2.2, *Spring-Run Chinook Salmon*). Migratory cues, such as increased flow and/or turbidity from runoff, may spur emigration of juveniles from the upper Sacramento River basin when they have reached the appropriate stage of maturation (NMFS 2009). Inundated floodplain habitats have been shown to benefit growth and survival of juvenile salmon (Sommer et al. 2001, 2005; Katz et al. 2017), but natural flood flows largely determine the availability of this habitat, rather than operations of the CVP and SWP dams.

Based on the CalSim II modeling results, during most of the Spring-Run juvenile rearing and emigration period, Sacramento River flow would be higher under Alternative 1 than under the No Action Alternative at all locations and many of the increases would be greater than 5% (Tables O.3-5 and O.3-12 through O.3-14). However, the mean monthly flows for November of wet and above normal water years would be much lower under Alternative 1, because of the Fall X2 flows that are included in the No Action Alternative but not Alternative 1. Despite the reductions, the November flows under Alternative 1 remain relatively high (Tables O.3-5 and O.3-12 through O.3-14; Figures O.3-28 and O.3-29), so they are not expected to substantially affect rearing juveniles. Furthermore, as noted above, emigration occurs primarily in December and in the spring. Mean monthly flows would also be lower under Alternative 1 in January, February and April of critically dry water years, but all of these flows reductions are less than 5% (O.3-12 through O.3-14).

Results from a recent study suggest that for Spring-Run that do emigrate as early as November, the Alternative 1 flow reductions in November of wet and above normal water years would have a potentially adverse effect. The NMFS Southwest Fisheries Science Center ran statistical models using 2012-2017 tagging data from Spring-Run Chinook Salmon and Fall-Run Chinook Salmon and found a significant increase in smolt survival when Sacramento River flow at Wilkins Slough was above 9,100 cfs during the smolts emigration period (Cordoleani et al. 2019). The CalSim II results for November at Wilkins Slough indicate that 50% of years would have mean monthly flows that exceed the 9,100 cfs threshold under the No Action Alternative, and 20% of years would have flows that exceed the threshold under Alternative 1 (Figure (O.3-29). As shown by recent sampling at RBDD (Figure O.3-31-A) almost all Spring-Run juveniles emigrate from the upper Sacramento River after November, so the percentage of Spring-Run juveniles that would be affected by the expected reductions in November flows at Wilkins Slough would be small. Therefore changes in flow resulting from Alternative 1 are not expected to substantially affect rearing and emigrating juvenile Spring-Run Chinook Salmon.

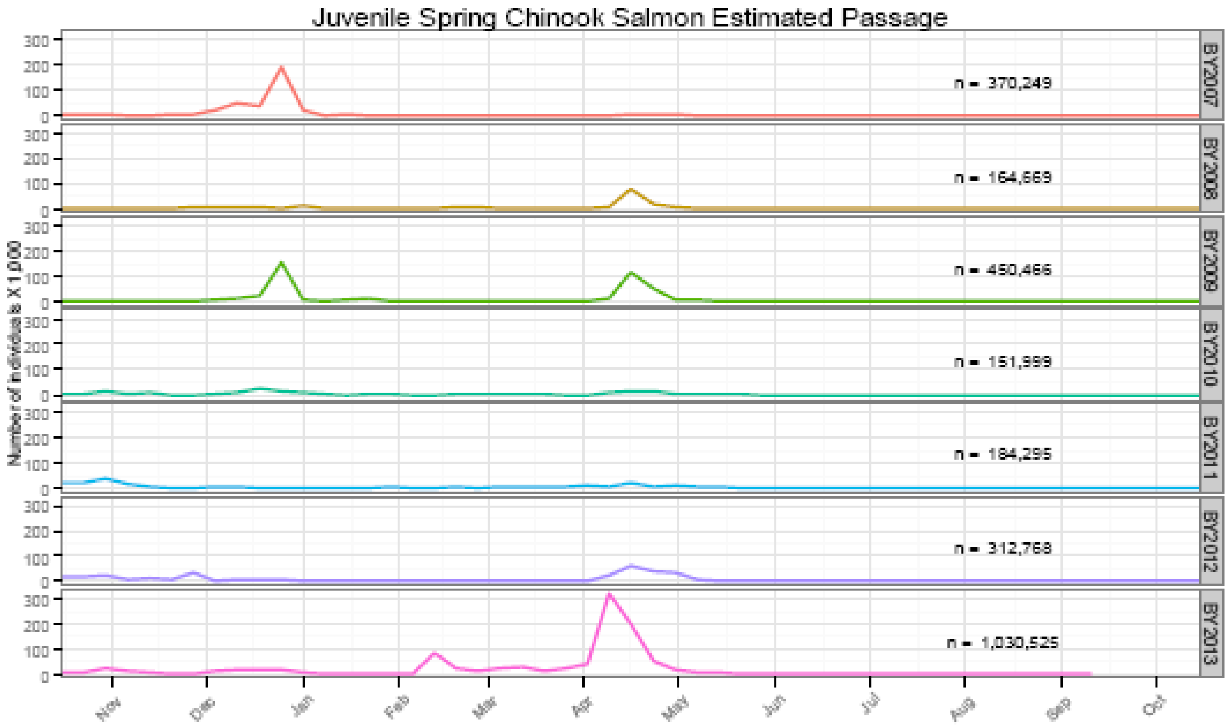


Figure O.3-31-A. Weekly Estimated Passage of Juvenile Spring-Run Chinook Salmon at Red Bluff Diversion Dam (RM244) by Brood Year (BY), Sampled using Rotary-Screw Trap.

The USEPA (2003) gives 61°F as the critical 7 day average daily maximum (7DADM) water temperature for Spring-Run Chinook Salmon juveniles rearing in the upper Sacramento River and 64°F (7DADM) for those rearing in the middle Sacramento River (Knights Landing). Under the No Action Alternative and Alternative 1, HEC-5Q estimates of mean monthly water temperatures from Keswick to RBDD do not exceed the 61°F threshold during any month and water year type during the November through May rearing period (Tables 0.3-6 through O.3-9). The mean monthly water temperatures for Hamilton City do not exceed the 64°F threshold for the middle Sacramento River during any of the months, but the mean monthly water temperatures for May exceed the middle river threshold at Knights Landing in all water year types under both alternatives. However, there are no meaningful differences between the Alternative 1 and No Action Alternative temperatures at Knights Landing (Table O.3-10). These results indicate that water temperature conditions would too warm for juvenile Spring-Run Chinook Salmon rearing and emigrating in the middle Sacramento River during May. It should be noted that May is the last month during spring or summer that Spring-Run Chinook Salmon juveniles are found in the middle river, and it is likely that when water temperatures are too high they emigrate to the ocean before May. It should be noted that early emigration could have other adverse effects.

The flow and water temperature effects resulting from Alternative 1 would have a less-than-significant effect relative to the No Action Alternative on juvenile Spring-Run Chinook Salmon in the Sacramento River.

Adult Upstream Migration and Holding

Spring-Run Chinook Salmon adults enter the Sacramento River from the Delta as early as January and make their way to the upper Sacramento River beginning in February, where they hold until ready to spawn in late summer and early fall (Windell et al. 2017). Adults may continue migrating upstream until

August, and holding continues until October when spawning is complete. There are no flow or temperature requirements for the middle Sacramento River designed to protect fish. Lower flow in the Sacramento River relative to flow from the lower Yolo and Sutter bypasses and agricultural drains may affect navigation cues and straying of Spring-Run adults into canals and behind weirs, increasing their stranding risk. Once the adults reach holding habitat in the upper Sacramento River, they are more directly affected by Shasta and Keswick reservoir operations designed to preserve cold water for the Winter-Run and Spring-Run spawning and incubation periods.

During the January through August period of adult Winter-Run immigration, the mean monthly CalSim II flows under Alternative 1 at Keswick, RBDD, Hamilton City, and Wilkins Slough would generally be similar to or greater than those under the No Action Alternative, except during July of dry and critically dry water years (Tables O.3-5 and O.3-12 through O.3-14). However, the mean July flows under both alternatives would remain high enough (>5,000 cfs) to allow upstream passage. During the holding period, September flow would be much lower under Alternative 1 than under the No Action Alternative (Tables O.3-5 and O.3-12; Figure O.3-25), but the mean September Alternative 1 flows at Keswick Dam would not fall below 6,000 cfs over the range of flows for which the alternatives have major flow differences (i.e., upper 50% in Figure O.3-25). A flow of 6,000 cfs would presumably be sufficient to maintain good water quality conditions in the Spring-Run holding habitats. Note that monthly mean flows for these months should reasonably estimate daily mean flows because operations at Shasta and Keswick dams create relatively stable summer and fall flow and water temperature conditions in the upper Sacramento River.

The USEPA (2003) gives 68°F as the critical 7DADM water temperature for Spring-Run Chinook Salmon adults migrating upstream in the Sacramento River and 61°F for adult Spring-Run holding in the upper river. Throughout the January through August period of Spring-Run upstream migration, HEC-5Q water temperatures for Alternative 1 are similar to or slightly lower than those for the No Action Alternative, including greater than 1°F reductions in mean monthly water temperature for June of below normal and dry water years at Knights Landing (Tables O.3-6 through O.3-11). Under both alternatives, the mean monthly water temperatures in the middle Sacramento River (Knights Landing) would be below the 68°F threshold for immigrating adults from December through April, but would exceed the threshold in May of critically dry water years and in June through August of all water year types (Table O.3-11). The high May through August water temperatures would be likely to adversely affect any Spring-Run adults that were migrating upstream in those months. High water temperatures were found to cause adult Spring-Run Chinook Salmon in Butte Creek to terminate their upstream migrations, which made them more susceptible to mortality from rising water temperatures (Mosser et al. 2012). The June temperature reductions under Alternative 1 occur in a range slightly above the 68°F threshold and, therefore, would likely have a beneficial effect on upstream migrating adults. In the upper Sacramento River at Keswick Dam to Balls Ferry, the mean water temperatures under both alternatives would be well below the 61°F threshold for holding adults from February through October (Tables O.3-6-2 through O.3-8). As previously noted, flow below Keswick Dam is relatively stable during the summer and fall months, so monthly mean flows and temperatures are likely to be fairly representative of daily means in those months.

As previously discussed, although the HEC 5Q results show little difference in water temperatures between the No Action Alternative and Alternative 1, the modeling for Alternative 1 does not include the new water temperature management operations and stuctures proposed for Alternative 1. It is expected that, during the May through October period of operation, water temperatures under Alternative 1 would in fact be more protective of Winter-Run Chinook Salmon adults than the No Action Alternative, particularly in the upper Sacramento River.

Therefore, with respect to flow, Alternative 1 is expected to have a less-than-significant effect relative to the No Action Alternative on Spring-Run Chinook Salmon adult migration and holding, and with respect to water temperature, Alternative 1 is expected to have a beneficial effect.

O.3.3.2.4 Central Valley Steelhead

Spawning and Egg Incubation

CV steelhead adults spawn from November through April with peak spawning from January through March. Based on the general timing of hatching and fry emergence, eggs and alevins may occur from November through May. Little is known about steelhead spawning locations in the Sacramento River, but it is generally assumed that spawning occurs primarily between Keswick Dam and RBDD.

CalSim II modeling indicates that mean monthly flows released at Keswick Dam under Alternative 1 would generally be higher than or similar to the flows under the No Action Alternative, except in September and November of above normal and wet years, when Alternative 1 flows would be substantially lower than the No Action Alternative flows (Table O.3-5). These reductions would average approximately 3,000 cfs and 3,500 cfs lower in November for above normal and wet years, respectively, when steelhead are assumed to initiate spawning. Based on PHABSIM results (flow versus weighted usable area [WUA]) developed by the USFWS (2003) for the Sacramento River between Keswick Dam and Battle Creek, lower flows under Alternative 1 would increase the amount of available spawning habitat (as measured by WUA) in above normal and wet years (Figure O.3-31-B). However, higher flows under Alternative 1 in subsequent months (averaging approximately 1,000 cfs to 2,000 cfs higher in December and January of above normal and wet years) would reduce the amount of available spawning habitat in these months relative to the No Action Alternative (Table O.3-5). For example, in wet years, the changes in flow under Alternative 1 would result in an 18% increase in spawning WUA in November, and 7% decrease in December, and a 14% decrease in January. Over all months, average WUA would increase by less than 1% under Alternative 1.

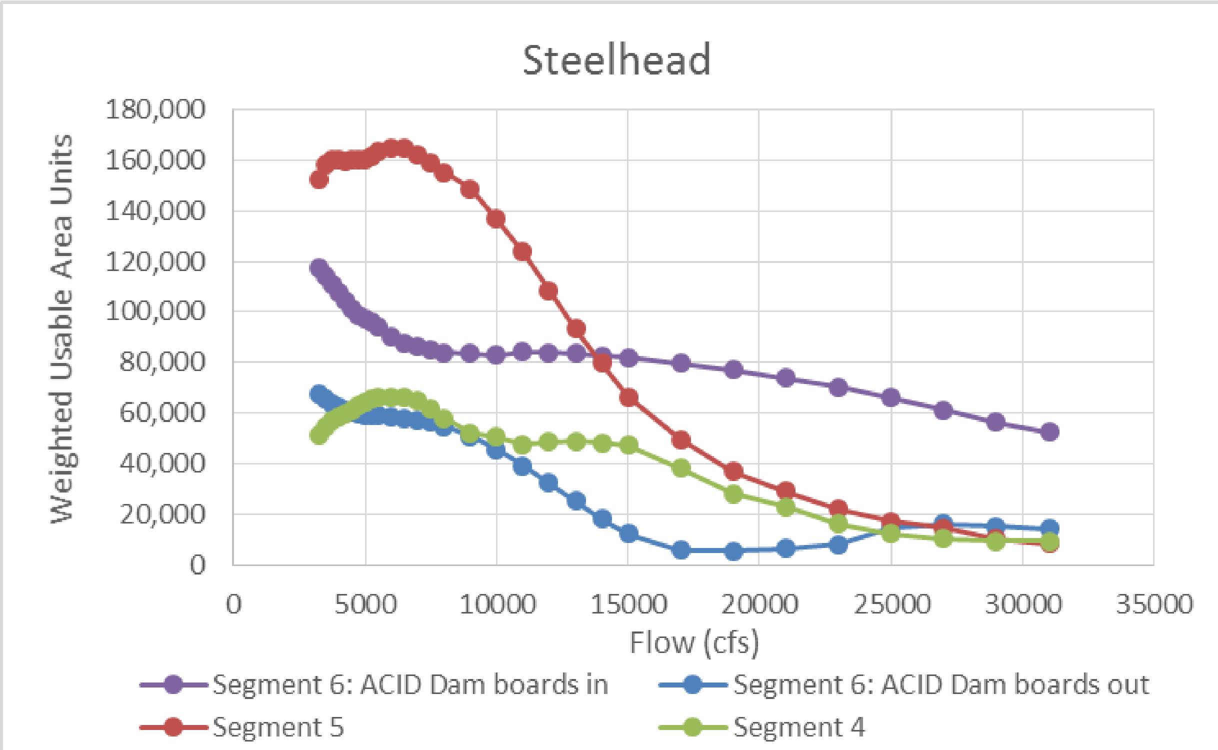


Figure O.3-31-B. Spawning WUA curves for CCV Steelhead in the Sacramento River. Segment 4: Battle Creek to Cow Creek; Segment 5: Cow Creek to the Anderson-Cottonwood Irrigation District (ACID) Dam; Segment 6: ACID to Keswick Dam

No water temperature requirements have been established for steelhead spawning and incubation in the Sacramento River. The USEPA-recommended 7DADM water temperatures is 55°F for salmon and trout spawning and incubation, although 53°F was selected for this analysis based on the review by McCullough et al. (2001); this was considered a more conservative criterion for evaluating the potential for adverse temperature effects based on monthly modeling results. HEC-5Q modeling indicates that the water temperatures in the upper Sacramento River during the steelhead spawning and incubation period (November through May) would be similar under the No Action Alternative and Alternative 1 (Tables O.3-6 through O.3-9). Under both alternatives, the exceedance plots for the upper Sacramento River generally indicate that suitable water temperatures for steelhead spawning and incubation would not occur until December and generally extend to March or April. Therefore, changes in Sacramento River flows and water temperatures under Alternative 1 would have a less-than-significant effect on spawning and incubating steelhead relative to the No Action Alternative.

Juvenile Rearing and Emigration

CV steelhead rear year-round in the Sacramento River, and use the river downstream from spawning areas as both a rearing and migration corridor. The timing of downstream migration is variable but generally peaks in the upper river at RBDD in spring and summer (March through June) and in the lower river at Knights Landing in winter and spring (January thorugh May) (NMFS 2009). The peak migration of yearling and older juveniles through the Delta occurs in March and April (NMFS 2009).

Flow-habitat relationships are not available for steelhead rearing habitat in the Sacramento River. In other assessments (e.g., SacEFT model, ESSA 2011), the PHABSIM results for juvenile Late Fall-Run Chinook Salmon (USFWS 2005) have been used to characterize potential flow effects on steelhead rearing habitat in the upper Sacramento River. Although similarities exist in their early life history and general habitat requirements, the validity of applying the PHABSIM results for Late Fall-Run Chinook Salmon to steelhead is uncertain. As described previously, CalSim II modeling indicates that the largest differences in Sacramento River flows under the No Action Alternative and Alternative 1 would occur in September and November of above normal and wet years, when Alternative 1 flows would be substantially lower than the No Action Alternative flows (Table O.3-5). These reductions would average approximately 4,700 cfs and 5,700 cfs in September and 3,000 cfs and 3,500 cfs in November in above normal and wet years, respectively, increasing the amount of available rearing habitat (as measured by WUA) in these months relative to the No Action Alternative (Figure O.3-40). However, higher flows under Alternative 1 in December (averaging approximately 1,000 cfs to 2,000 cfs higher in above normal and wet years) would reduce the amount of rearing habitat relative to the No Action Alternative (Table O.3-5). For example, in wet years, the changes in flows under Alternative 1 would result in a 30% increase in rearing WUA in September, a 2% increase in October, a 38% increase in November, a 17% decrease in December, and a 1% increase in January. Over all months, average WUA would increase be 11% under Alternative 1.

High summer water temperatures are recognized as a major stressor for Central Valley Steelhead (NMFS 2014a). However, current and proposed operations at Shasta and Keswick Dam to meet water temperature requirements for Winter-Run Chinook Salmon would be expected to maintain suitable rearing temperatures for juvenile steelhead in the upper Sacramento River throughout the summer. This assumption was evaluated for the No Action Alternative and Alternative 1 by comparing modeled summer water temperatures in the Sacramento River to general water temperature criteria for juvenile steelhead. The USEPA-recommended 7DADM water temperature for juvenile salmonids in core rearing areas (upper reaches of natal rivers) is 61°F. Although based on studies of steelhead in the Pacific Northwest, this criterion was considered a reasonable threshold for evaluating the potential for adverse temperature effects based on monthly modeling results. Under both alternatives, HEC-5Q modeling indicates that average water temperatures in the Sacramento River between Keswick Dam and RBDD would be maintained at or below 61°F in all water years except in the summer (July through September) of critical water years (Table O.3-9). However, no major differences would occur in the frequency and magnitude of temperatures above this threshold under these alternatives.

Under the No Action Alternative and Alternative 1, no major differences would occur in the frequency and magnitude of Sacramento River water temperatures during the peak steelhead emigration season (January through May) (Tables O.3-5 through O.3-11). However, monitoring at RBDD indicates that downstream movements of juvenile steelhead (predominantly fry and parr) past RBDD can occur throughout the summer (May through September), extending the distribution of rearing juveniles to the middle Sacramento River. Downstream of RBDD, lower flows in September of above normal and wet years under Alternative 1 are expected to increase the frequency of water temperatures exceeding 61°F relative to the No Action Alternative; HEC-5Q modeling indicates that September water temperatures near Hamilton City would average 3.5°F higher in wet years and 4.6°F higher in above normal years relative to the No Action Alternative (Table O.3-10). Over all years, modeled water temperatures exceeded the 61°F threshold 83% of the time under Alternative 1 compared to 55% of the time under the No Action Alternative (Figure O.3-23). While this represents a potential adverse effect on rearing and emigrating steelhead in the Sacramento River below RBDD, the overall effect on the juvenile steelhead population would be ameliorated by the relatively low numbers of steelhead that emigrate in the lower river in September and the improved habitat conditions that would be expected in the Sacramento River as a result of the additional flow and water temperature management actions (e.g., Shasta Lake Cold Water Pool Management), and other nonflow habitat and facility improvements that are proposed under Alternative 1. Therefore, changes in Sacramento River flows and water temperatures resulting from

Alternative 1 would have a less-than-significant effect on rearing and emigrating steelhead in the Sacramento River relative to the No Action Alternative.

Adult Upstream Migration and Holding

Adult steelhead immigration into Central Valley streams potentially occurs during all months of the year but typically begins in August and continues through March or April (McEwan 2001; NMFS 2014a). In the Sacramento River, adults migrate upstream past RBDD during all months of the year, but primarily during September and October (NMFS 2009). Adults may hold until the spawning season which generally extends from November through April.

Flow thresholds for evaluating immigration and holding conditions for steelhead adults have not been determined for the Sacramento River. A threshold of 3,250 cfs is used in this analysis to evaluate the potential for adverse effects on migrating and holding adults. Flows in the Sacramento River rarely drop below this level, and adults have not been observed to experience passage delays, crowding, or other adverse effects at this flow. Therefore, it represents a reasonable threshold for evaluating the potential for adverse effects on migrating and holding adults. During the August through April immigration and holding period, Shasta and Keswick operations under Alternative 1 would result in lower mean flows in the Sacramento River in September and November of wet and above normal years relative to the No Action Alternative. These reductions would average approximately 4,700 to 5,800 cfs lower in September and 3,000 cfs to 3,500 cfs lower in November depending on the water year (Table O.3-5, O.3-13, and O.3-14). However, CalSim II modeling indicates that a minimum flow of 3,250 cfs would be maintained in September and November (Figures O.3-29 and O.3-32) and throughout the year under both the No Action Alternative and Alternative 1.

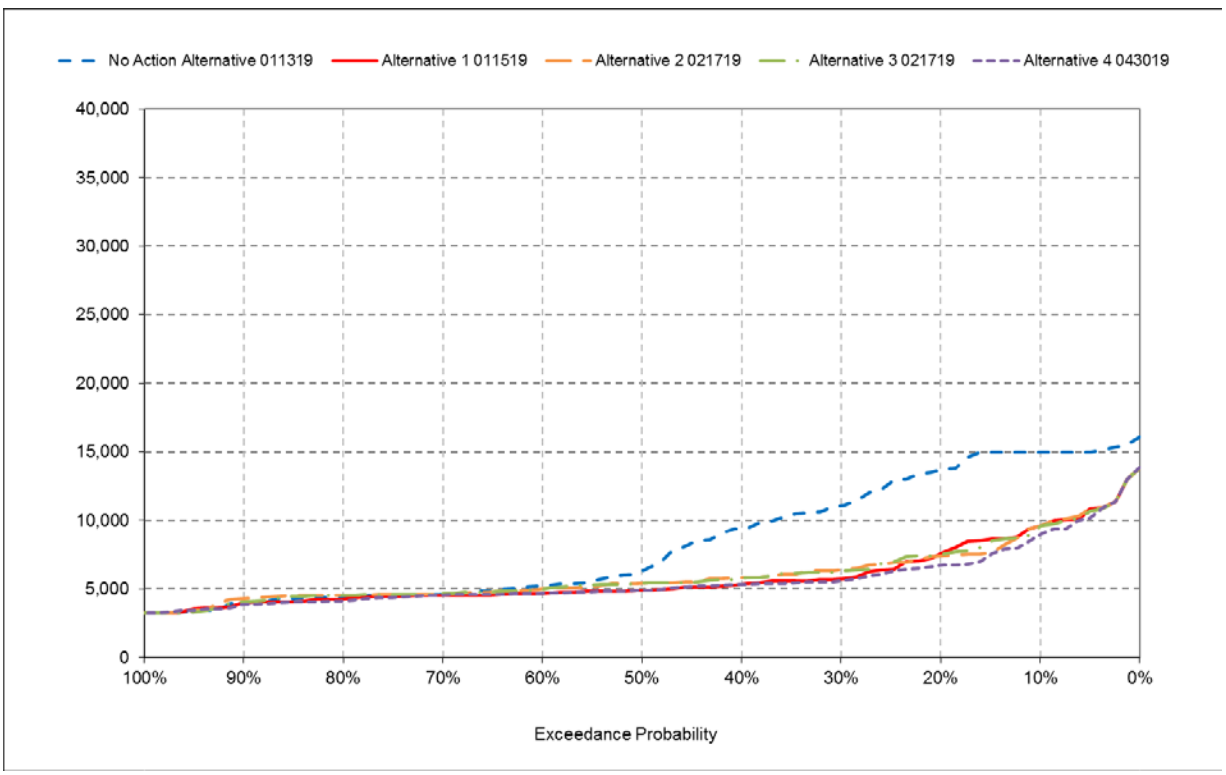


Figure O.3-32. CalSim II Sacramento River Flow at Wilkins Slough under the No Action Alternative, Alternative 1, Alternative 2, Alternative 3, and Alternative 4; September

No water temperature requirements have been established for adult steelhead migration and holding in the Sacramento River (August through April). The USEPA-recommended 7DADM water temperatures is 68°F for migrating adult salmonids and 61°F for holding adults prior to spawning. Although based on studies of steelhead in the Pacific Northwest, this criterion was considered a reasonable threshold for evaluating the potential for adverse temperature effects on migrating and holding adults based on monthly modeling results. Under the No Action Alternative and Alternative 1, no major differences would be expected to occur in the frequency and magnitude of monthly water temperatures exceeding 68°F; for example, at Hamilton City, modeled water temperatures exceeding 68°F would occur in about 7% of the years (critical water years) under both the No Action Alternative and Alternative 1 (Figure O.3-23). Similarly, no major differences would be expected to occur in the exposure of holding adults to potentially stressful water temperatures; for example, at RBDD, modeled water temperatures exceeding 61°F would occur in about 27% of the years under both the No Action Alternative and Alternative 1 (Figure O.3-22). Therefore, changes in Sacramento River flows and water temperaturess associated with Alternative 1 would have a less-than-significant effect on migrating and holding adult steelhead in the Sacramento River relative to the No Action Alternative.

O.3.3.2.5 Southern DPS Green Sturgeon

Spawning and Egg Incubation

Green Sturgeon spawn in deep pools (averaging about 28 feet deep) (NMFS 2018b). Eggs from spawning Southern DPS Green Sturgeon have been found in the middle and upper Sacramento River from the GCID oxbow (River Mile [RM] 207) to Inks Creek (RM 265) and, based on adult sightings and presence of suitable habitat, spawning is believed to extend upstream to the confluence with Cow Creek (RM 277) (Heublein et al. 2017b).

Green Sturgeon spawn primarily from April through July, although they periodically spawn in late summer and fall (as late as October) (Heublein et al. 2009, 2017b, NMFS 2018b). Northern DPS Green Sturgeon eggs hatch about a week after fertilization (at 60ºF), and incubation time of southern DPS Green Sturgeon eggs is assumed to be similar (Heublein et al. 2017b). Because the incubation time for Green Sturgeon is so short, the effects analysis period for incubating eggs is considered to be the same as the spawning period, April through July, occasionally extending to October.

During the April through July Green Sturgeon spawning period, CalSim II estimates of mean monthly flows at RBDD (RM 244) under the No Action Alternative and Alternative 1 range from about 5,000 cfs for April of critically dry water years to about 14,300 cfs in July of Above Normal water years (Table O.3-12). Mean flows during most of this period are moderate (~8,000 cfs to ~12,000 cfs). These flow levels are likely to be suitable for Green Sturgeon spawning and egg incubation, and no adverse effects are expected to result. Differences in flows between Alternative 1 and the No Action Alternative are small in most months, but flows are moderately higher for Alternative 1 in May and June of below normal and dry water years (Table O.3-12). During the August through October period, when Green Sturgeon spawning occurs in occasional years, the flows under both alternatives tend to be lower than those in April through July, but the mean flows would be close to or above 5,000 cfs for all water year types in all three months. Large reductions in mean flows from the No Action Alternative to Alternative 1 are predicted for September of wet and above normal water years and, although the resulting Alternative 1 mean flows are close to or greater than 5,000 cfs, the flow reductions are so large (42 and 49%, respectively) that conditions for Green Sturgeon spawning and egg incubation are likely to be adversely affected (Table O.3-12). However, September spawning occurs only sporadically, so any effect on the Green Sturgeon population would be minor (NMFS 2018b). Therefore, the September flow reductions are expected to have a minor adverse impact on Green Sturgeon.

Critical water temperatures thresholds have been determined for Northern DPS Green Sturgeon but not for Southern DPS Green Sturgeon, but it is assumed that the temperature tolerances of the two distinct population segments are similar (Heublein et al. 2017b). Based on laboratory studies, Van Eenennaam et al. (2005, cited in Heublein et al. 2017) concluded that the optimal range for normal embryo development of Northern DPS Green Sturgeon is 53 to 64°F, and impaired fitness occurs below 52°F and above 71°F.

The spawning and egg incubation water temperature requirements for Green Sturgeon present a potential management conflict with temperature management for Winter-Run Chinook Salmon and other upper Sacramento River salmonid populations. When RBDD, which had prevented Green Sturgeon from spawning further upstream, was decommissioned in 2013, the sturgeon population was able to expand its spawning distribution upstream and, as noted above, their current upstream limit is about at the Cow Creek confluence, which is about 10 river miles downstream of the Clear Creek confluence and a few miles upstream of Balls Ferry. Based on the HEC-5Q modeling, mean water temperatures during the April through July primary spawning period of Green Sturgeon are frequently below the 53 and 52°F lower temperature thresholds for Green Sturgeon egg development at both locations (Tables O.3-7 and O.3-8). At Balls Ferry in July, which is the month of the Green Sturgeon spawning period most likely to be affected by the proposed water temperature management improvements of Alternative 1, the mean monthly water temperatures under the No Action Alternative are below 52 and 53°F in about 10% and 33% of years, respectively (Figure O.3-33). As discussed previously, daily water temperatures are likely to be more variable than monthly mean temperatures, so these percentages probably underestimate the frequency of years with July days falling below the 52°F and 53°F thresholds. These results suggest that further upstream movement of Green Sturgeon spawning may currently be limited by cold water temperatures and that further reductions in temperature to protect salmonids could force the upstream limit of Green Sturgeon spawning downstream.

The HEC-5Q modeling results show little difference in Clear Creek confluence and Balls Ferry mean water temperatures between Alternative 1 and the No Action Alternative during the April through July primary Green Sturgeon spawning and incubation period (Tables O.3-7 and O.3-8, Figure O.3-33). However, as has been discussed, the HEC 5Q modeling for Alternative 1 relies on shutter (TCD) operations quite similar to those of the No Action Alternative and does not include the proposed operational and structural water management improvements that are included in Alternative 1. Consequently, the HEC-5Q results for Alternative 1 may underestimate water temperatures for certain months, particularly in dry and critically dry water years, when the water temperature management improvements would be likely to have their greatest impact. Therefore, Alternative 1 is likely to cause a reduction in water temperatures relative to the No Action Alternative and thereby adversely affect Green Sturgeon spawning and egg incubation.

It should be noted that several factors other than the upstream water temperatures potentially affect the Green Sturgeon spawning distribution, and these complicate assessment of the effects of the reduced water temperatures under Alternative 1. For example, reducing the temperatures of Keswick Dam releases would potentially result in cooler water temperatures at the downstream limit of the Green Sturgeon spawning distribution, where summer/fall water temperatures under the No Action Alternative often exceed the 53°F to 64°F optimal range for Green Sturgeon eggs (Table O.3-11; Figure O.3-34). Cooler downstream temperatures, therefore, could result in a downstream expansion of the spawning distribution and no net loss of spawning habitat availability. Also, the spawning distribution of Green Sturgeon is affected by factors other than water temperature, including availability of spawning habitat elements such as suitable substrates and deep holes. Therefore, although Alternative 1 would potentially reduce availability of suitable spawning habitat for the Green Sturgeon relative to the No Action Alternative, confidence in this conclusion is low because of uncertainty about the effects of other potentially important effects on Green Sturgeon spawning distribution.

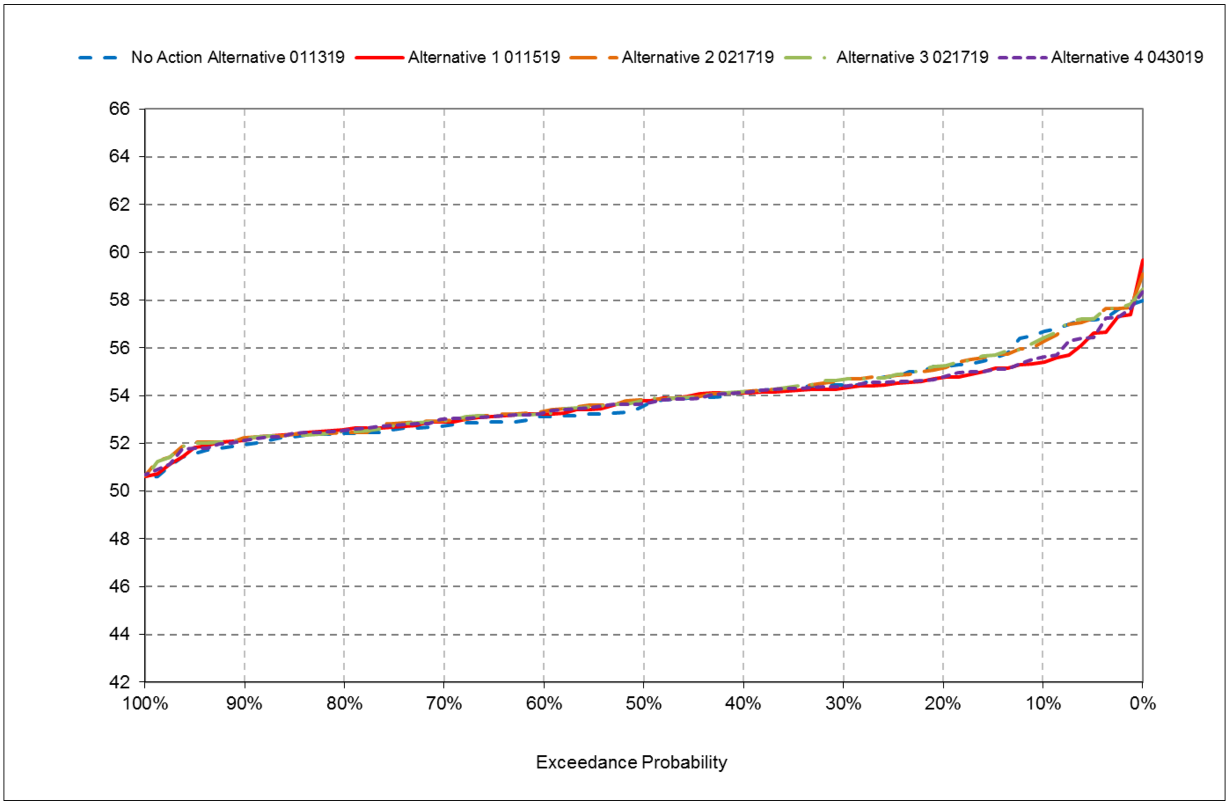


Figure O.3-33. HEC-5Q Sacramento River Water Temperatures at Balls Ferry under the No Action Alternative, Alternative 1, Alternative 2, Alternative 3 and Alternative 4; July

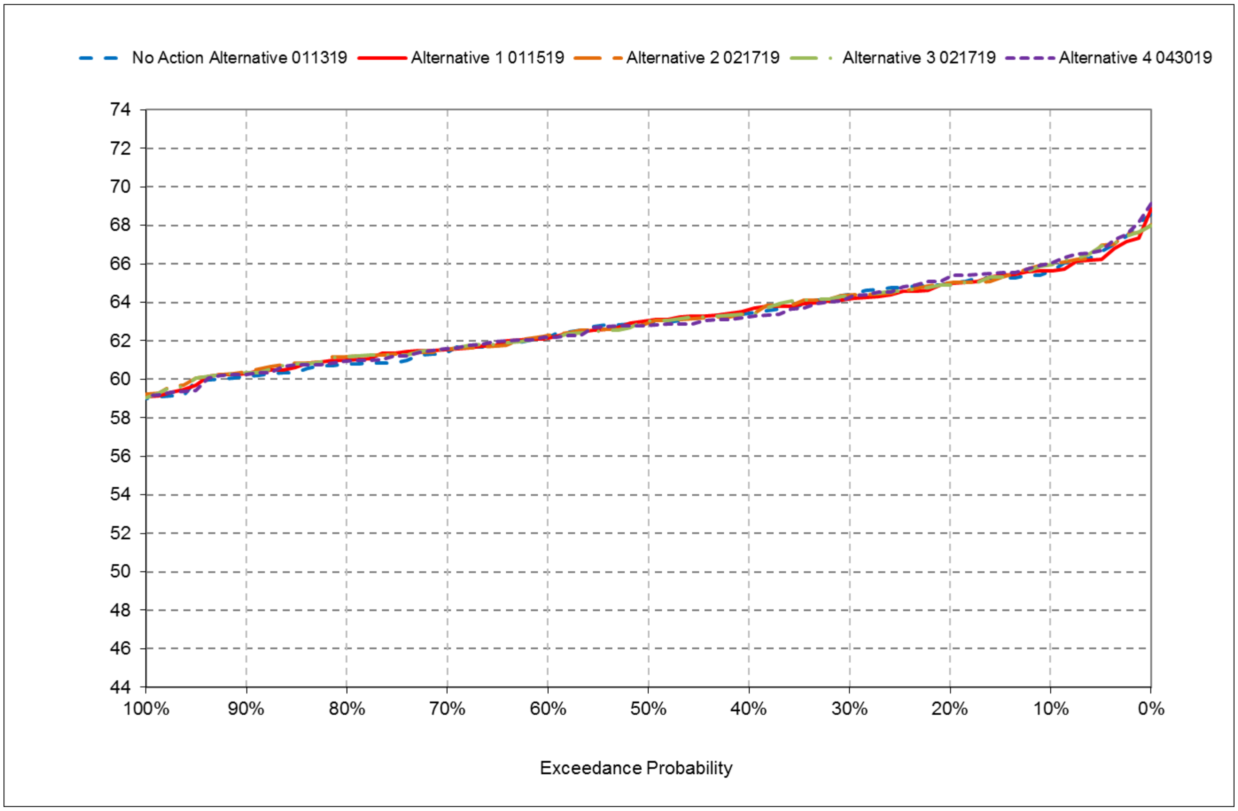


Figure O.3-34. HEC-5Q Sacramento River Water Temperatures at Hamilton CIty under the No Action Alternative, Alternative 1, Alternative 2, Alternative 3, and Alternative 4; July

O.3.3.2.6 Larval and Juvenile Rearing and Emigration

According to field observations, Green Sturgeon larvae begin to disperse from hatching areas at 18 days post hatch (dph), and dispersion is complete at about 35 dph (Poytress et al. 2011, cited in Heublein et al. 2017b). They begin exogenous feeding at about 15 dph. The Green Sturgeon spawning period is from April through July, so the larval period is considered to be April through September. The downstream distribution of Green Sturgeon larvae in the Sacramento River is uncertain, but is estimated to extend to the Colusa area, at RM 157 (Heublein et al. 2017b). The upstream limit is the Cow Creek confluence.

The Green Sturgeon juvenile stage begins when metamorphosis of the larva is complete, typically at about 45 dph and about 75 mm in length (Heublein et al. 2017b). It is likely that juveniles rear near spawning habitat for a few months or more before migrating to the Delta (Heublein et al. 2017b). The juveniles rear in the Sacramento River from about May through December (NMFS 2017b, *Appendix B*). During most of this period, the juveniles are likely to be found anywhere from the upstream spawning habitat near the Cow Creek confluence to the Delta.

The effects of flow on Green Sturgeon larvae and juveniles are poorly understood. There appears to be a positive relationship between annual outflow and abundance in rotary screw traps at RBDD of Green Sturgeon larvae and juveniles (Heublein et al. 2017a *SAIL model*). Also, there is a positive correlation between mean daily freshwater outflow (April to July) and white sturgeon year class strength (CDFG 1992 and USFWS 1995, cited in NMFS 2018b). These relationships may result from flows transporting larvae to areas with greater food availability, dispersing larvae over a wider area, and/or enhancing nutrient availability to the Sacramento River and Delta/Estuary.

CalSim modeling for the Sacramento River at RBDD indicates that mean monthly flows during the April through September period of larval rearing are generally similar between the No Action Alternative and Alternative 1 except, as described previously, for moderately higher mean flows in May and June of the drier water year types under Alternative 1 and much higher flow during September of wet and above normal water years under the No Action Alternative (Table O.3-12). The September reductions in flow from the No Action Alternative to Alternative 1 would potentially affect Green Sturgeon larvae adversely because, as discussed above, there appears to be a positive relationship between annual outflow and abundance of Green Sturgeon larvae and juveniles, but this conclusion is highly uncertain.

CalSim modeling for the Sacramento River at Hamilton City indicates that mean monthly flows during the period of juvenile rearing and emigration, May through December, are generally similar between the No Action Alternative and Alternative 1 except, as described previously, for much higher flows under the No Action Alternative during September and November of wet and above normal water years, resulting from Fall X2 releases (Table O.3-13). These reductions in flow could adversely affect Green Sturgeon juveniles under Alternative 1 because, as discussed above, there appears to be a positive relationship between annual outflow and abundance of Green Sturgeon. There are moderate increases in mean flow from No Action Alternative to Alternative 1 in December, May and June, but these increases are much smaller than the reductions in September and November (Table O.3-13).

Critical water temperatures thresholds have been determined for Northern DPS Green Sturgeon but not for Southern DPS Green Sturgeon, but it is assumed that the temperature tolerances of the two distinct population segments are similar (Heublein et al. 2017b). Based on laboratory studies, Van Eenennaam et al. (2005 cited in Heublein et al. 2017b) concluded that 63°F to 68°F is optimal water temperature range for growth and survival of Green Sturgeon larvae. This temperature range exceeds the upper limit of optimal temperatures for Green Sturgeon eggs (63°F), so there is no overlap in optimal conditions for eggs and larvae. In another laboratory study, Mayfield and Cech (2004 cited in Heublein et al. 2017b) concluded that 59°F to 66°F is the optimal range of water temperatures for growth of juvenile sturgeon. This temperature range overlaps the optimal range temperature ranges for Green Sturgeon eggs (53°F to 63°F) and larvae (63°F to 68°F).

There are few notable differences in the HEC-5Q mean monthly water temperature estimates at RBDD or Hamilton City between the No Action Alternative and Alternative 1 during the Green Sturgeon larval and juvenile rearing and emigration period in any month, except for September (Tables O.3-9 and O.3-10). During over half of the years in September, the Alternative 1 water temperature at RBDD is greater than the No Action Alternative temperature, with a maximum difference of about 3°F (Figure O.3-22). Over the range of years for which there are temperature differences, the water temperatures of both the No Action Alternative and Alternative 1 are under the 63°F lower limit of the optimal range for larvae. However, the Alternative 1 water temperatures are closer to the optimal range and therefore would potentially provide more favorable conditions for larval growth and survival. For the juveniles at RBDD, the September water temperatures under the No Action Alternative are below the 59°F lower limit of the optimal temperature range in about half of the years, and under Alternative 1 they are below the optimal range in about a third of the years (Figure O.3-22). The September HEC-5Q temperature estimates for Hamilton City also fall within or are closer to the optimal ranges of Green Sturgeon larvae and juveniles in more years under the Alternative 1 than the No Action Alternative (Table O.3-10; Figure O.3-23).

The CalSim II flow results indicate that Alternative 1 would have a less-than-signficant impact on rearing larval and juvenile southern DPS Green Sturgeon relative to the No Action Alternative, and the HEC-5Q water temperature modeling results indicate that Alternative 1 would provide a minor potential benefit to rearing larval and juvenile Green Sturgeon relative to the No Action Alternative.

O.3.3.2.7 Adult Upstream Migration and Holding

Green Sturgeon adults enter the Sacramento River from the Delta as early as February and ultimately make their way upstream to spawn in deep pools from the GCID oxbow (near Hamilton City) to the Cow Creek confluence (Heublein et al. 2017b). Elevated flows during the late winter and early spring months may provide an important cue for spawning Green Sturgeon adults to initiate their upstream migrations (Heublein et al. 2009; NMFS 2018). Green Sturgeon spawn in most years from April through July, but spawn in occasional years as late as October. After spawning, the adults hold in the river for varying amounts of time, but typically emigrate back to the San Francisco Estuary and the ocean from about October through December (Heublein et al. 2017b).

Flows during the February through December period of Green Sturgeon immigration, spawning and holding would generally be similar between Alternative 1 and the No Action Alternative at RBDD, Hamilton City, and Wilkins Slough (Tables O.3-12 through O.3-14). Exceptions include moderately higher mean monthly flows under Alternative 1 at both locations during February, March, May, June, and December of various water year types and substantially lower flows under Alternative 1 during September and November. All of the more notable flow differences occur within a range of river flows (~5,000 cfs to 15,000 cfs) not expected to substantially affect upstream passage of migrating Green sturgeon, but the September and November flow reductions under Alternative 1 at Hamilton City and RBDD could result in reduced habitat quality in holding pool habitats, adversely affecting holding adults.

The USEPA (2003) gives 61°F as the critical 7DADM water temperature for Green Sturgeon adults holding in the Sacramento River. The water temperature upper limit for of spawning adults is assumed to be similar to that for incubating eggs, 63°F. In addition, assuming that adults are at least as tolerant to warm temperatures as juveniles, the upper limit for mean monthly water temperatures of migrating adults, whether immigrating or emigrating, is treated as 66°F.

There are few major differences in mean monthly water temperatures between the No Action Alternative and Alternative 1 in the Sacramento River at Knights Landing during the February through April period that most adult Green Sturgeon migrate upstream or during the later months (through December) when the sturgeon migrate downstream after spawning (Table O.3-11). However, large differences occur in September of wet and above normal water years, when monthly mean water temperatures under Alternative 1 are higher than those under the No Action Alternative by over 4°F. The means exceed the 66°F threshold for migrating Green Sturgeon adults in both water year types under Alternative 1 and in neither water year type under the No Action Alternative. The mean monthly water temperatures at Knights Landing also exceed the 66°F threshold under both alternatives during June through August of all water year types and May of all but wet years (Table O.3-11). Adults migrating downstream from May through September would potentially be adversely affected by the high water temperatures. However, adults migrating upstream would be less affected because most upstream immigration occurs before late spring (Heublein et al. 2009), when water temperatures are below the 66°F threshold.

During the May through December spawning and post-spawn holding period for Green Sturgeon, the HEC-5Q mean monthly water temperatures at Hamilton City, which is located in the most downstream, warmest section of the Green Sturgeon spawning reach, are generally similar between the No Action Alternative and Alternative 1, except for higher temperatures under Alternative 1 in September, as discussed above for Knights Landing (Table O.3-10). The mean monthly water temperatures during the hottest months of this period, July through September, range from 59°F to over 68°F (both in September). The temperatures frequently exceed the 63°F threshold for spawning adults and the 61°F threshold for holding adults during these months. During September, the mean water temperatures exceed the 63 and 61°F thresholds more often under Alternative 1 than under the No Action Alternative. Under Alternative

1, the temperatures exceeds the 63 and 61°F thresholds 66% and 82% of years, respectively, and under the No Action Alternative they exceed the thresholds 49% and 55% of years (Figure O.3-23). September water temperatures are cooler at RBDD and there is no difference at this location between Alternative 1 and the No Action Alternative in the frequency of the threshold exceedances (Figure O.3-22). During October through December, the mean monthly water temperatures stay well below both thresholds in every water year type, except in October of critically dry water years.

The CalSim II modeling results indicate that for adult southen DPS Green Sturgeon holding in September or November, reduced flows under Alternative 1 would have a potentially significant adverse impact on holding habitat relative to the No Action Alternative. However, it is more difficult to draw conclusiongs about the water temperature results. As previoulsy indicated, the HEC-5Q modeling for Alternative 1 does not include many of the proposed water temperature management improvements that would be included in Alternative 1 and, therefore, likely overestimates summer and fall water temperatures that would result from this alternative. Therefore, although the HEC-5Q modeling results indicate that the water temperatures for September of wet and above normal water years would more often exceed the 66, 63 and 61°F thresholds for migrating, spawning and holding adult Green Sturgeon under Alternative 1 than under the No Action Alternative, it is likely that this would not occur, or would occur less frequently, under full implementation of Alternative 1 with all of its operational and structural improvements for facilitating coldwater pool storage. In conclusion, although the HEC-5Q model results for adult Green Sturgeon migrating, spawning and holding during September near Hamilton City indicate that water temperatures under Alternative 1 would have a significant adverse impact relative to the No Action Alternative, the expected water temperature management improvements under Alternative 1, which are only partially represented in the HEC-5Q results, are expected to improve water temperatures for Green Sturgeon. The relative magnitude of the adverse effects indicated by the HEC-5Q modeling versus the expected benefits obtained from the water temperature management improvements is unknown, which makes any conclusion about the true effect of Alternative 1 highly uncertain.

O.3.3.2.8 Fall-Run Chinook Salmon

Spawning and Egg/Alevin Incubation

Fall-Run Chinook Salmon migrate upstream past RBDD on the Sacramento River between July and December, typically spawning in upstream reaches from October through January, with a peak in October and November. Eggs and alevins are present from October through April. The primary spawning area used by Fall-Run Chinook Salmon in the Sacramento River is the area from Keswick Dam downstream to RBDD. Spawning densities for all Chinook Salmon runs are highest in this reach, but the distribution of spawning fall-run generally extends farther downstream and includes spawning areas below RBDD (Gard 2013).

CalSim II modeling indicates that mean monthly flows released at Keswick Dam under Alternative 1 would generally be higher than or similar to the flows under the No Action Alternative, except in September and November of above normal and wet years, when Alternative 1 flows would be substantially lower than the No Action Alternative flows (Table O.3-5). These reductions would average approximately 3,000 cfs and 3,500 cfs lower in November for above normal and wet years, respectively, when Fall-Run Chinook Salmon are spawing and eggs and alevins are present. Based on PHABSIM results (flow-habitat relationships) developed by the USFWS (2003) for the Sacramento River between Keswick Dam and Battle Creek, lower flows under Alternative 1 would increase the amount of available spawning habitat (as measured by weighted usable area) in above normal and wet years (Figure O.3-35). However, higher flows under Alternative 1 in subsequent months (averaging approximately 1,000 cfs to 2,000 cfs higher in December and January of above normal and wet years) would reduce the amount of available spawning habitat in these months relative to the No Action Alternative (Table O.3-5). In wet years, for example, the changes in flow under Alternative 1 would result in an 80% increase in spawning WUA in November, a 26% decrease in December, and a 7% decrease in January. Consequently, changes in flows under Alternative 1 would have both positive and negative effects on the availability of spawning habitat relative to the No Action Alternative.

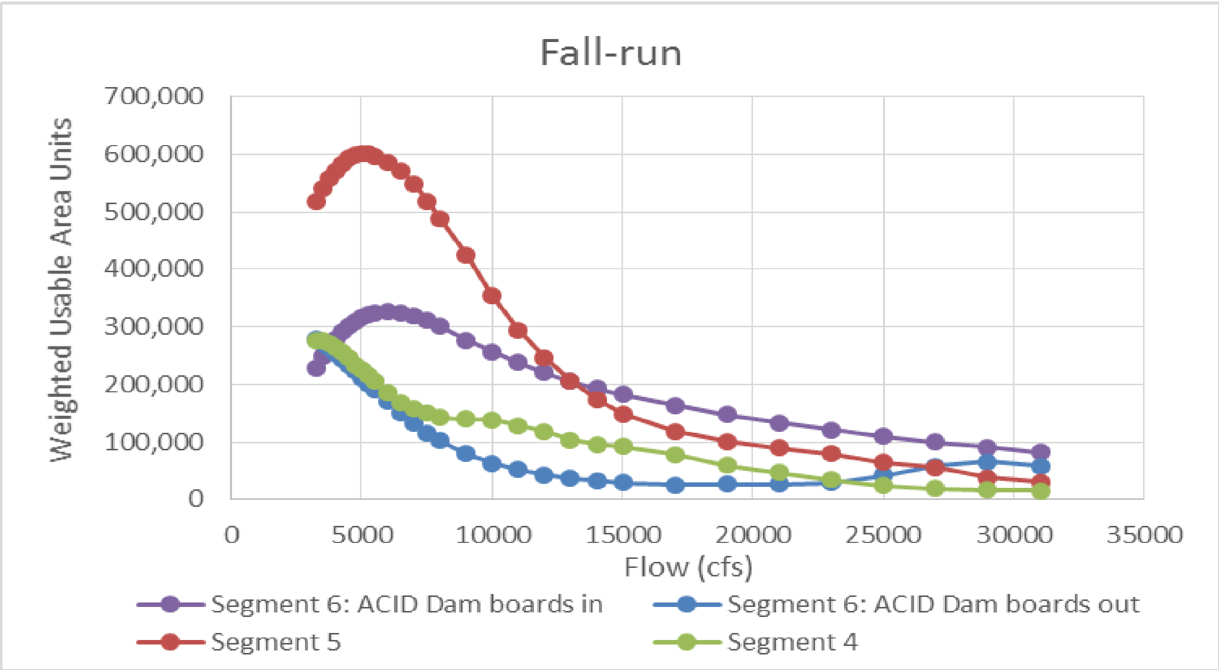


Figure O.3-35. Spawning WUA Curves for Fall-Run Chinook Salmon in the Sacramento River. Segment 4: Battle Creek to Cow Creek; Segment 5: Cow Creek to the Anderson-Cottonwood Irrigation District (ACID) Dam; Segment 6: ACID to Keswick Dam

HEC-5Q modeling indicates that Alternative 1 would improve water temperatures for Fall-Run Chinook Salmon spawning and incubation during the peak spawning months (October and November) relative to the No Action Alternative; for example, in October, modeled mean monthly temperatures at Keswick Dam are predicted to be below the 53.5°F threshold (Martin et al. 2017; Anderson 2018) in approximately 70% of years under Alternative 1 compared to less than 20% of the years under the No Action Alternative (Figure O.3-18; Table O.3-6). Under both alternatives, water temperatures in the upper Sacramento River during the remainder of the Fall-Run Chinook Salmon spawning and incubation period would be similar and within suitable ranges for spawning and incubation through March or April (Tables O.3-6 through O.3-9). Therefore, reductions in water temperatures in the upper Sacramento River under Alternative 1 in October and November would have beneficial effects on Fall-Run Chinook Salmon relative to the No Action Alternative. Other actions that would be expected to improve habitat conditions for spawning adults, eggs, and alevins include proposed operational and structural modifications at Shasta Dam as well as spawning habitat restoration actions (e.g., spawning gravel placement) that are currently proposed as part of Alternative 1. Spawning and rearing habitat restoration are proposed programmatic measures that are not certain to be included in Alternative 1. Overall, improved habitat conditions during the peak spawning months under Alternative 1 would be expected to substantially offset potential reductions in spawning habitat availability associated with higher flows later in the season. Therefore, changes in Sacramento River flows and water temperaturess resulting from Alternative 1 would have a less-than-significant effect on Fall-Run Chinook Salmon spawning and incubation in the Sacramento River relative to the No Action Alternative.

Juvenile Rearing and Emigration

Fall-Run Chinook Salmon juveniles rear in the Sacramento River primarily from December through May. Following emergence, juveniles rear for variable lengths of time in the Sacramento River before entering the Delta and estuary, and may emigate as fry, parr, or smolts. The timing of emigration is variable but generally peaks in the upper river from January through April and in the lower river from January thorugh May (NMFS 2009).

During the primary rearing period (December through May), CalSim II modeling indicates that Sacramento River flows under Alternative 1 would generally be higher than or similar to the flows under the No Action Alternative (Table O.3-5). Based on PHABSIM results (flow-habitat relationships) for fry (<60 mm) and juvenile (≥60 mm) Chinook Salmon developed by the USFWS (2005) for the Sacramento River between Keswick Dam and Battle Creek, higher flows under Alternative 1 would reduce the amount of available rearing habitat (as measured by weighted usable area). (Figures O.3-36 and O.3-37). The largest flow increases would occur in the winter of wet, above normal, and below normal water years, potentially affecting fry habitat (Table O.3-5). In wet years, for example, an increase in flow of approximately 2,100 cfs in December (on average) corresponds to a 7% decrease in available fry rearing habitat (as measured by WUA). In spring, the largest flow reductions would occur in above normal and below normal water years. In below normal water years, for example, an increase in flow of approximately 1,000 cfs in May (on average) corresponds to an 8% decrease in juvenile rearing WUA. While this represents a potential adverse effect on rearing habitat capacity.

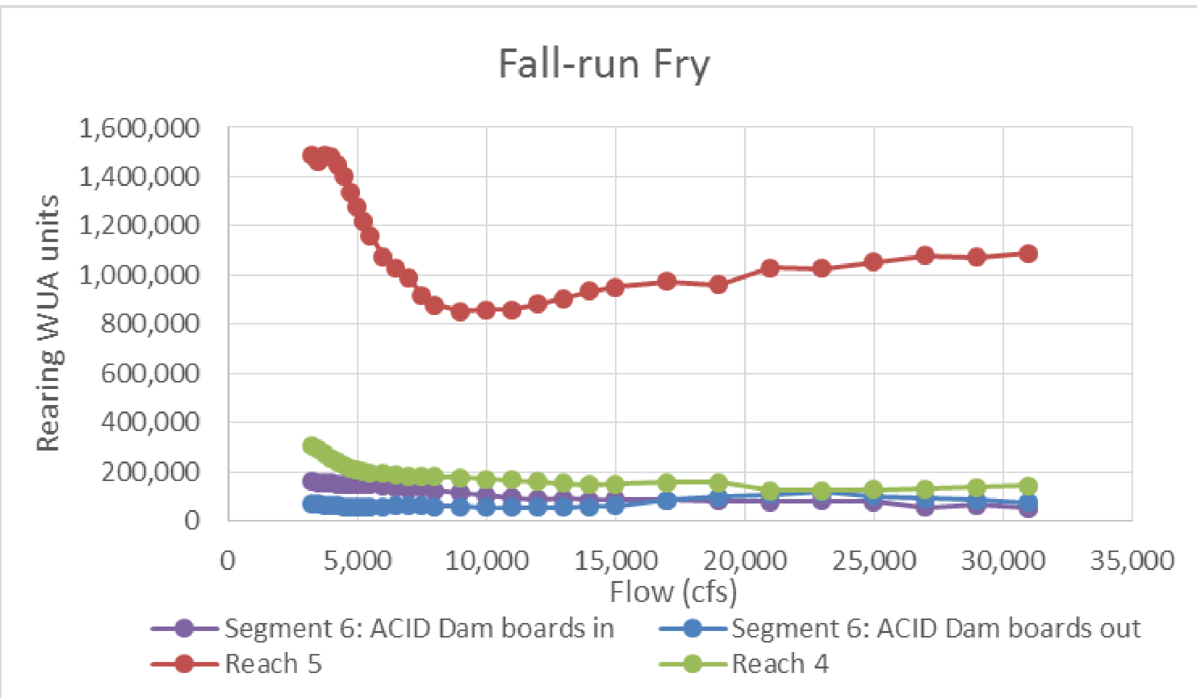


Figure O.3-36. Fry Rearing WUA Curves for Fall-Run Chinook Salmon in the Sacramento River. Segment 4: Battle Creek to Cow Creek; Segment 5: Cow Creek to the Anderson-Cottonwood Irrigation District (ACID) Dam; Segment 6: ACID to Keswick Dam

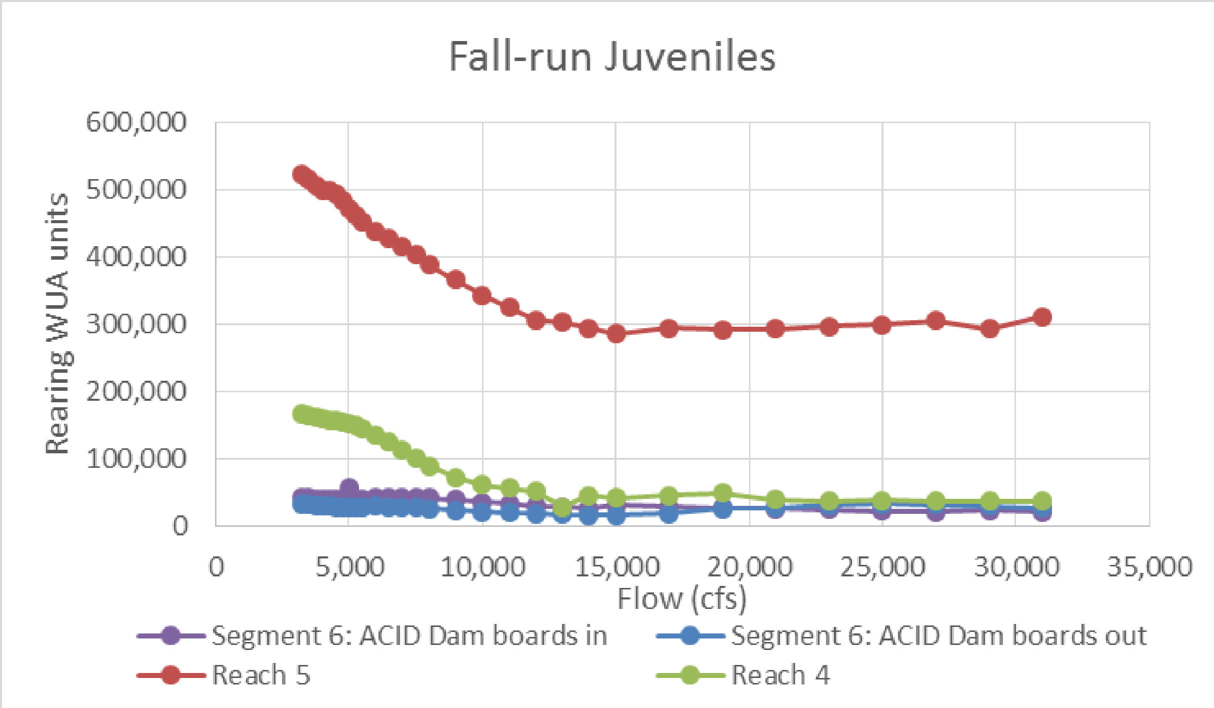


Figure O.3-37. Juvenile Rearing WUA Curves for Fall-Run Chinook Salmon in the Sacramento River. Segment 4: Battle Creek to Cow Creek; Segment 5: Cow Creek to the Anderson-Cottonwood Irrigation District (ACID) Dam; Segment 6: ACID to Keswick Dam

The USEPA-recommended 7DADM water temperatures for juvenile salmonids is 61°F in core rearing areas (upper reaches of natal rivers) and 64°F in non-core areas (lower reaches). Although based on studies of salmonids in the Pacific Northwest, this criterion was considered a reasonable threshold for evaluating the potential for adverse temperature effects based on monthly modeling results. Under both the No Action Alternative and Alternative 1, HEC-5Q estimates of mean monthly water temperatures from Keswick to RBDD do not exceed the 61°F threshold during any month or water year type during the primary Fall-Run Chinook Salmon rearing and emigration period (December through May) (Tables O.3-6 through O.3-9). Farther downstream, the 64°F threshold would be exceeded in the lower river (Knights Landing) in May under both alternatives but there would be no major differences between the alternatives in the frequency and magnitude of water temperatures above this threshold (Table O.3-10). Therefore, changes in Sacramento River flows and water temperatures resulting from Alternative 1 would have a less-than-significant effect on rearing and emigrating juvenile Fall-Run Chinook Salmon in the Sacramento River relative to the No Action Alternative.

Adult Upstream Migration and Holding

Fall-Run Chinook Salmon migrate upstream past RBDD on the Sacramento River between July and December. Adults may hold until the spawning season, which occurs primarily from October through January.

During the July through December migration period, CALSIM II modeling indicates that mean monthly flows under Alternative 1 at Keswick, RBDD, Hamilton City, and Wilkins Slough would be substantially lower in September and November of wet and above normal water years than those under the No Action Alternative (Tables O.3-5 and O.3-12 through O.3-14). However, mean monthly flows would be maintained at a minimum of 3,250 under both alternatives, and would not differ substantially in frequency and magnitude between the alternatives until flows exceed approximately 5,000 cfs (Figures O.3-32 and O.3-29). Within the range of flows in which major differences in flows would occur (>5,000 cfs), no adverse effects on migrating or holding adults would be expected; flows of this magnitude would presumably be sufficient to maintain suitable flow and water quality conditions for migrating and holding adults under both alternatives.

No water temperature requirements have been established for adult Fall-Run Chinook Salmon migration and holding in the Sacramento River. The USEPA-recommended 7DADM water temperatures is 68°F for migrating adult salmonids and 61°F for holding adults prior to spawning. Under the No Action Alternative and Alternative 1, no major differences would be expected to occur in the frequency and magnitude of monthly water temperatures exceeding 68°F; for example, at Hamilton City, modeled water temperatures in September exceeded 68°F in about 8% of the years under both the No Action Alternative and Alternative 1 (Figure O.3-23). Similarly, no major differences would be expected to occur in the exposure of holding adults to potentially stressful water temperatures; for example, at RBDD, modeled water temperatures in September exceeded 61°F in about 27% of the years under both the No Action Alternative and Alternative 1 (Figure O.3-22). As previously discussed, the modeling for Alternative 1 does not include many of the new water temperature management actions proposed for Alternative 1, and therefore does not include the potentially beneficial effects of these actions on pre-spawning Fall-Run Chinook Salmon, particularly in the upper Sacramento River. Therefore, changes in Sacramento River flows and water temperaturess associated with Alternative 1 would have a less-than-significant effect on migrating and holding adult Fall-Run Chinook Salmon in the Sacramento River relative to the No Action Alternative.

O.3.3.2.9 Late Fall-Run Chinook Salmon

Spawning and Egg/Alevin Incubation

In the Sacramento River, adult Late Fall-Run Chinook Salmon spawn primarily from December through April, and eggs and alevins are present in the gravel from December through June. Most adults spawn upstream of Red Bluff Diversion Dam, with the majority spawning between Keswick Dam and the ACID Dam.

During the primary Late Fall-Run Chinook Salmon spawning and incubation period (December thorugh April), CalSim II modeling indicates that mean monthly flows at Keswick Dam under Alternative 1 would generally be higher than or similar to the flows under the No Action Alternative (Table O.3-5). Flow increases of greatest magnitude are expected to occur in wet, above normal, and below normal years, ranging from approximately 1,000 cfs to 2,000 cfs (on average) from December through February. Based on PHABSIM results (flow-habitat relationships) developed by the USFWS for the Sacramento River between Keswick Dam and Battle Creek (USFWS 2003a), higher flows under Alternative 1 would reduce the amount of available spawning habitat (as measured by WUA) (Figure O.3-38). For example, on average, spawning habitat WUA would be reduced by 18% in December and 7% in January in wet years, and percent reductions in WUA in above normal and below normal years would generally be within this range from December thorugh February. Consequently, relative to the No Action Alternative, changes in flows under Alternative 1 would have negative effects on the availability of spawning habitat for Late Fall-Run Chinook Salmon.

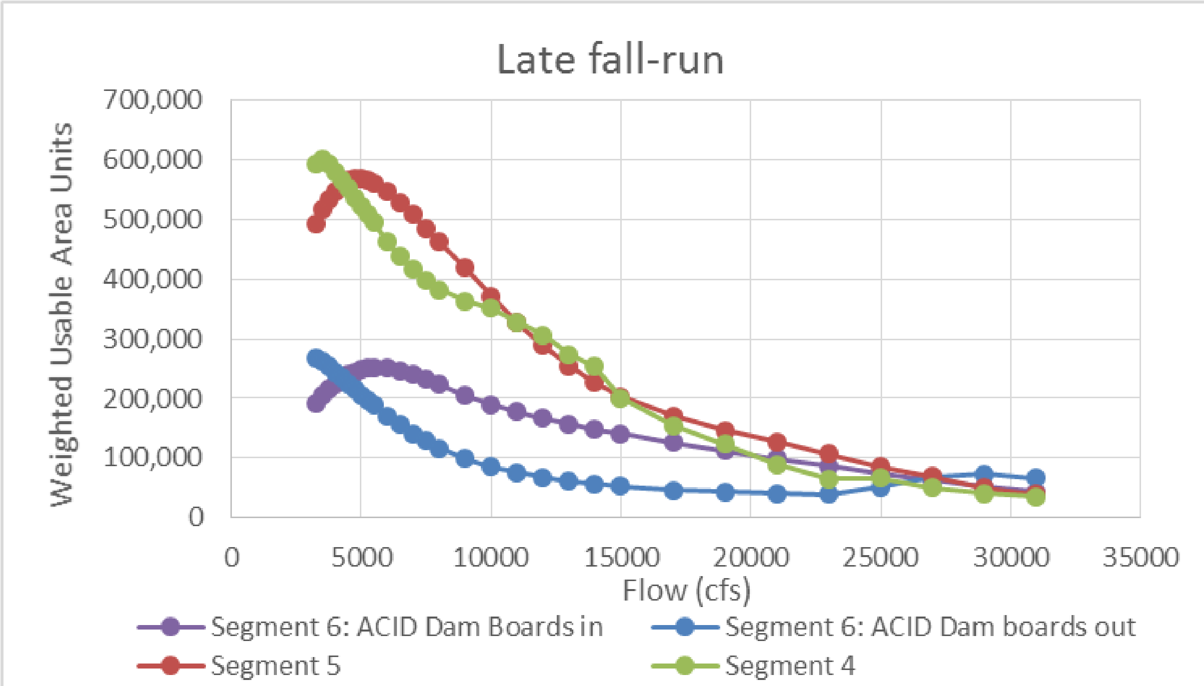


Figure O.3-38. Spawning WUA Curves for Late Fall-Run Chinook Salmon in the Sacramento River. Segment 4: Battle Creek to Cow Creek; Segment 5: Cow Creek to the Anderson-Cottonwood Irrigation District (ACID) Dam; Segment 6: ACID to Keswick Dam

HEC-5Q modeling indicates that water temperatures in the upper Sacramento River during the Late Fall-Run Chinook Salmon spawning and incubation period (December through June) would be similar under the No Action Alternative and Alternative 1 (Tables O.3-9 through O.3-9). Under both alternatives, water temperatures in the Sacramento River would be maintained below 53.5°F from Keswick Dam to the Clear Creek confluence through June of most years (Table O.3-7). As previously discussed, the modeling for Alternative 1 does not include many of the new water temperature management actions proposed for Alternative 1, and therefore does not include the potentially beneficial effects of these actions on Late Fall-Run Chinook Salmon, especially for eggs and alevins that may be present in the gravel through June. Other actions that would be expected to improve habitat conditions for spawning adults, eggs, and alevins include proposed operational and structural modifications at Shasta Dam as well as spawning habitat restoration actions (e.g., spawning gravel placement) that are proposed as part of Alternative 1. These actions would potentially improve the quantity and quality of spawning habitat for Late Fall-Run Chinook Salmon, and potentially offset reductions in the amount of available habitat predicted by the flow-habitat relationships. Therefore, the potential negative effects of higher flows on available spawning and incubation habitat for Late Fall-Run Chinook Salmon spawning and incubation would likely be less-than-significant.

Juvenile Rearing and Emigration

Late fall–run Chinook Salmon fry generally emerge from March through June, and juveniles rear in the Sacramento River through the summer before emigrating at a relatively large size (150- to 170-mm fork length) primarily from November through May.

CalSim II modeling indicates that Sacramento River flows under Alternative 1 would generally be higher than or similar to the flows under the No Action Alternative during early rearing period (March through

August) but would be substantially lower in September and November of wet and above normal water years (Table O.3-5). Based on PHABSIM results (flow-habitat relationships) for juvenile (≥60 mm) Late Fall-Run Chinook Salmon developed by the USFWS for the Sacramento River between Keswick Dam and Battle Creek (USFWS 2005), generally higher flows during spring and summer would reduce the amount of available fry rearing habitat (Figures O.3-39 and O.3-40). For example, in below normal water years, modeled monthly flows from March through June under Alternative 1 ranged from approximately 400 cfs to 1,300 cfs higher (on average) than those under the No Action Alternative (Table O.3-5), corresponding to 2% to 9% reductions in available fry rearing habitat in the upper Sacramento River (as measured by WUA). However, in wet years, flow reductions of approximately 5,700 cfs in September and 3,500 cfs in November (on average) correspond to a 36% and 33% increase, respectively, in juvenile rearing habitat in those months. Although reductions in fry habitat in the spring and summer represent a potential adverse effect on rearing habitat capacity, the proposed habitat restoration actions in the Sacramento River under Alternative 1 (e.g., side channel and floodplain creation) are expected to increase the quantity and quality of rearing habitat and potentially expand the availability of habitat under the higher spring and summer flows.

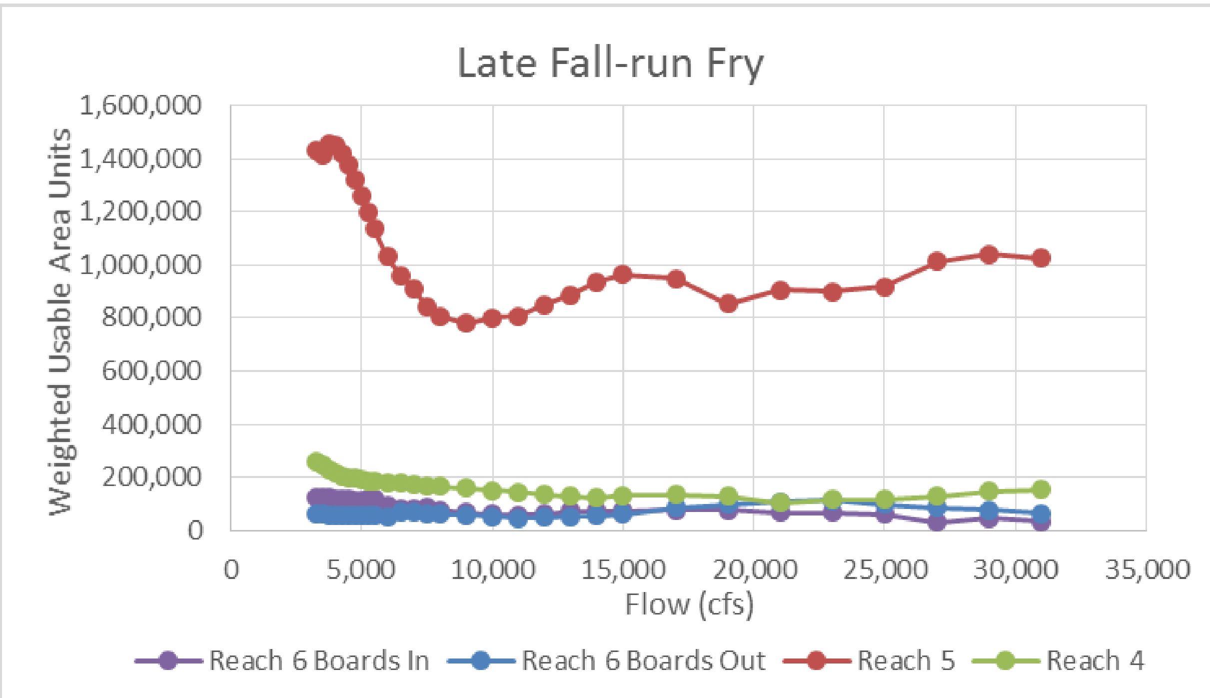


Figure O.3-39. Fry Rearing WUA Curves for Late Fall-Run Chinook Salmon in the Sacramento River. Segment 4: Battle Creek to Cow Creek; Segment 5: Cow Creek to the Anderson-Cottonwood Irrigation District (ACID) Dam; Segment 6: ACID to Keswick Dam

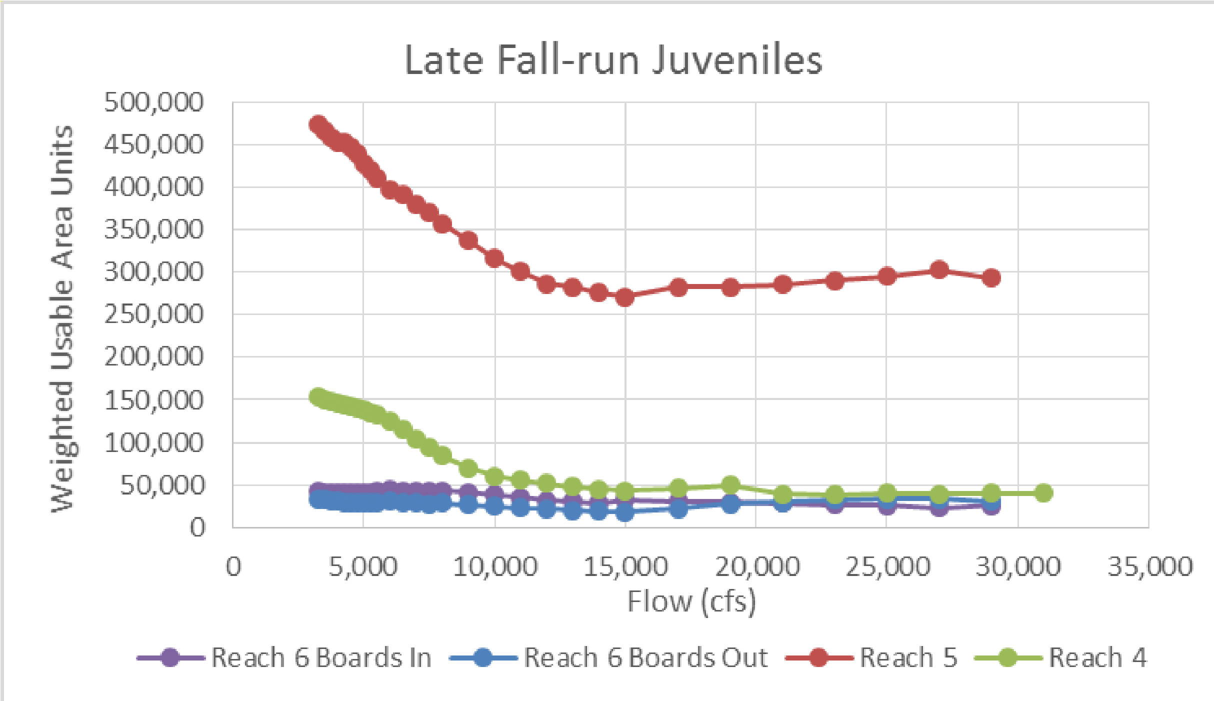


Figure O.3-40. Juvenile Rearing WUA Curves for Late Fall-Run Chinook Salmon in the Sacramento River. Segment 4: Battle Creek to Cow Creek; Segment 5: Cow Creek to the Anderson-Cottonwood Irrigation District (ACID) Dam; Segment 6: ACID to Keswick Dam

Current and proposed operations at Shasta and Keswick Dam to meet water temperature requirements for Winter-Run Chinook Salmon would be expected to maintain suitable rearing temperatures for juvenile Late Fall-Run Chinook Salmon in the upper Sacramento River through the summer. In the upper Sacramento River, monthly water temperatures exceeding the USEPA-recommended 7DADM water temperature for core rearing areas (61°F) would be limited to the summer of critical water years under both alternatives (Tables O.3-6 through O.3-9), and there would be no major differences in the frequency and magnitude of water temperatures above this threshold between the two alternatives (Figure O.3-22). Similarly, during the primary Late Fall-Run Chinook Salmon emigration period (November through May), monthly water temperatures exceeding the USEPA-recommended 7DADM water temperature for non-core rearing areas (64°F) would occur in the lower river (Knights Landing) in May under both alternatives but there would be no major differences in the frequency and magnitude of water temperatures above this threshold (Figure O.3-41). Therefore, changes in Sacramento River flows and water temperatures resulting from Alternative 1 would have a less-than-significant effect on rearing and emigrating juvenile Late Fall-Run Chinook Salmon in the Sacramento River relative to the No Action Alternative.

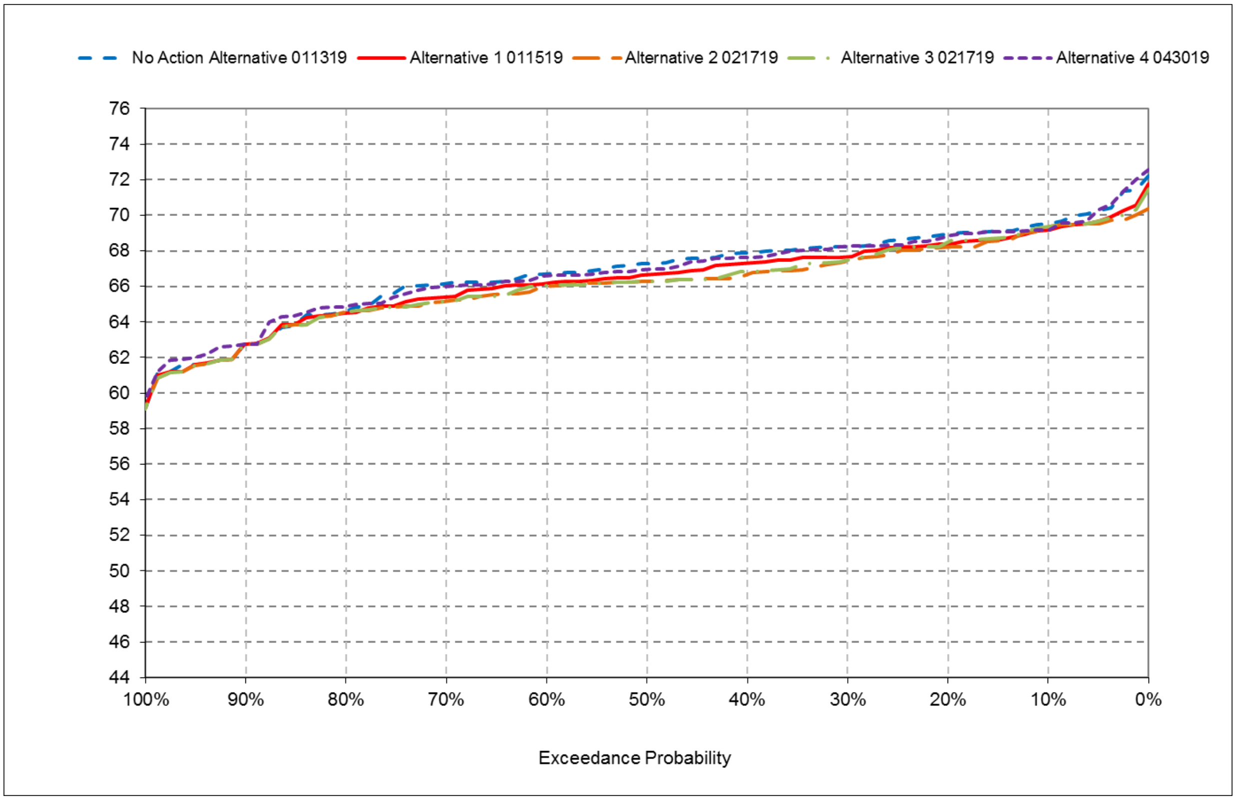


Figure O.3-41. HEC-5Q Sacramento River Water Temperatures at Knights Landing under the No Action Alternative, Alternative 1, Alternative 2, Alternative 3, and Alternative 4; May

Adult Upstream Migration and Holding

In the Sacramento River, adult Late Fall-Run Chinook Salmon migrate from October through April, with a peak during January through March (NMFS 2009). Adults hold for 1 to 3 months prior to spawning, which occurs primarily from December through April.

During the October through April migration and holding period, CALSIM II modeling indicates that mean monthly flows under Alternative 1 at Keswick, RBDD, Hamilton City, and Wilkins Slough would be substantially lower in November of wet and above normal water years than those under the No Action Alternative (Tables O.3-5 and O.3-12 through O.3-14). However, mean monthly flows would be maintained at a minimum of 3,250 under both alternatives, and would not differ substantially in frequency and magnitude until flows exceed approximately 5,000 cfs (Figures O.3-29). Within the range of flows, no adverse effects on migrating or holding adults would be expected; flows of this magnitude would presumably be sufficient to maintain suitable flow and water quality conditions for migrating and holding adults under both alternatives.

HEC-5Q modeling indicates that water temperatures in the Sacramento River during the Late Fall-Run Chinook Salmon migration and holding period (October through April) would be similar under the No Action Alternative and Alternative 1 (Tables O.3-6 through O.3-9). Under both alternatives, water temperatures in the lower Sacramento River would be maintained below the USEPA-recommended 7DADM water temperatures for migrating adult salmonids (68°F) throughout the migration period (Table O.3-11). In the upper Sacramento River, monthly water temperatures exceeding the USEPA-recommended 7DADM water temperature for holding adults (61°F) would be limited to October of critical water years under both alternatives (Tables O.3-6 through O.3-9), and there would be no major differences between the alternatives in the frequency and magnitude of water temperatures above this threshold (Figure O.3-42). Therefore, changes in Sacramento River flows and water temperaturess associated with Alternative 1 would have a less-than-significant effect on migrating and holding adult Late Fall-Run Chinook Salmon in the Sacramento River relative to the No Action Alternative.

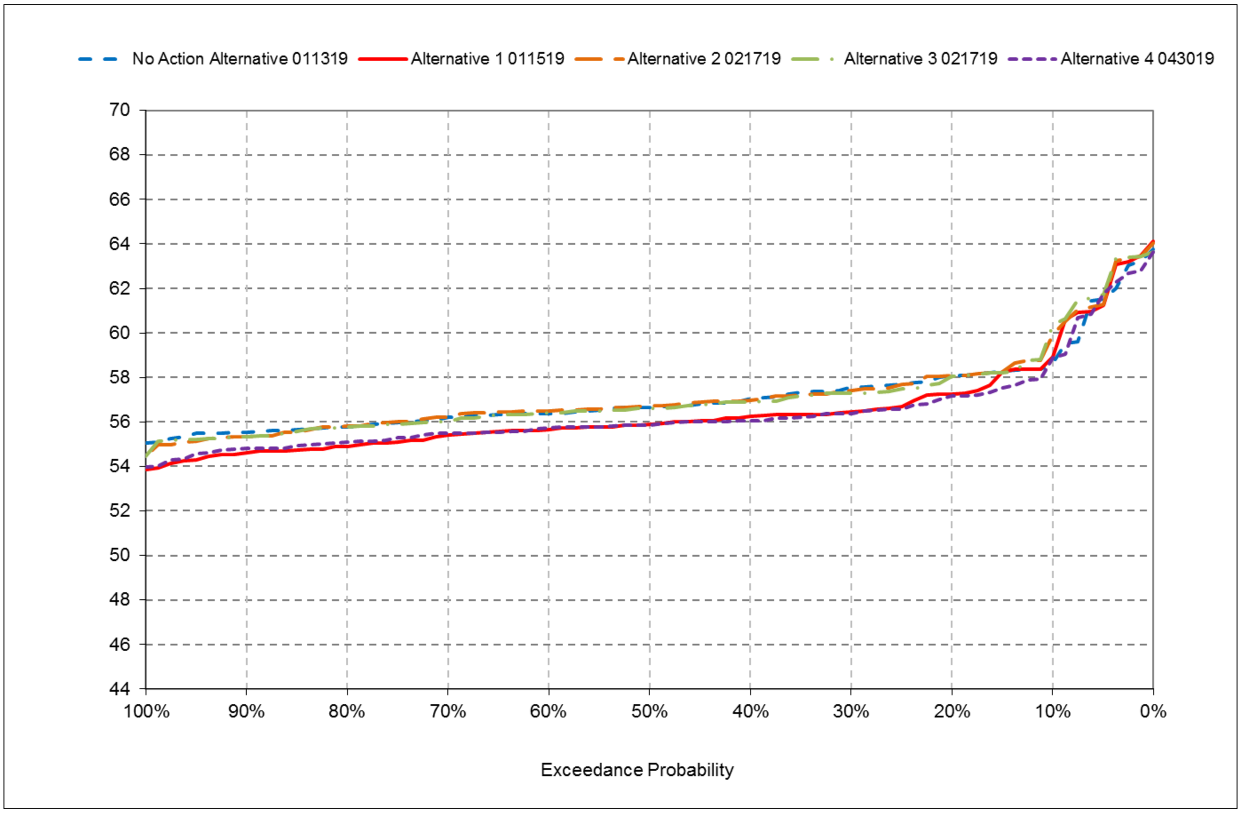


Figure O.3-42. HEC-5Q Sacramento River Water Temperatures at Red Bluff Diversion Dam under the No Action Alternative, Alternative 1, Alternative 2, Alternative 3, and Alternative 4; October

O.3.3.2.10 <u>White Sturgeon</u>

Spawning and Egg Incubation

Elevated flows during late winter and early spring may provide an important cue for spawning White Sturgeon adults to initiate their upstream spawning migrations (Heublein et al. 2017). Spawning occurs in deep water in the middle and lower Sacramento River from Verona (RM 80) to just upstream of Colusa (~RM 156) from late February to early June, but primarily during March and April, (Moyle et al. 2015; Heublein et al. 2017). The adults typically return promptly to the Delta/Estuary after spawning. The eggs hatch about a week after fertilization (Heublein et al. 2017). Because the incubation time for White Sturgeon is so short, the peak effects-analysis period for incubating eggs is considered to be March and April.

During the March and April spawning and egg incubation period of White Sturgeon, CalSim II estimates of mean monthly flows at Wilkins Slough (RM 117) under the No Action Alternative and Alternative 1 range from about 5,200 cfs for April of critically dry water years to about 17,800 cfs for March of wet water years (Table O.3-14). These flow levels are likely to be adequate for White Sturgeon spawning and egg incubation, so no adverse effects are expected to result. Differences in flows between Alternative 1 and the No Action Alternative are small in both months, but flows are moderately higher for Alternative 1 in March of below normal and critically dry water years (Table O.3-14). Therefore, it is concluded that Alternative 1 would have no flow effects on White Sturgeon eggs and embryos relative to the No Action Alternative.

Based on presence of eggs or larvae, White Sturgeon have been found to spawn at water temperatures from 46 to 73°F, with peak spawning occurring around 57°F (Heublein et al. 2017). Laboratory studies indicate that the optimal range for normal embryo development of White Sturgeon is 57 to 63°F (Wang et al. 1985, cited in Heublien et al. 2017). Mortality increased as temperature increased until it reached 68°F, which was lethal to all the embryos. However, viable White Sturgeon embryos have been collected in the field in water temperatures above 68°F (Heublein et al. 2017).

The HEC-5Q water temperature modeling results for March and April indicated that mean monthly water temperatures at Knights Landing were well below the 63°F threshold for optimal temperatures, except in April of critically dry water years (Table O.3-11). As noted earlier, the mean monthly water temperatures for the water year types combine water temperatures for many years and therefore mask individual year variations. The monthly means for individual years show that April water temperatures exceed the 63°F threshold in 15% of years, but lie below the 68°F lethal temperature in all years (Figure O.3-43). There are no appreciable differences in water temperatures between Alternative 1 and No Action Alternative in March or April (Table O.3-11; Figure O.3-43). During June, the warmest month of the full spawning and egg incubation period, the mean monthly water temperatures are predicted to exceed the 68°F lethal temperature in all water year types, but the water temperatures are lower for Alternative 1 than for the No Action Alternative, especially in drier water years (Table O.3-11). Therefore, it is concluded that Alternative 1 would have no water temperature effects on White Sturgeon eggs and embryos relative to the No Action Alternative.

Larval and Juvenile Rearing and Emigration

The White Sturgeon juvenile stage begins when metamorphosis of the larva is complete, typically at about 45 dph (Heublein et al. 2017). Therefore, since the White Sturgeon spawn primarily in March and April, the larval period is considered to be March through June. The larvae are distributed from upstream spawning habitats downstream to the western Delta.

Laboratory studies indicate that White Sturgeon larvae have high growth rates at 68°F, but outside of controlled laboratory conditions, suitable water temperatures may be less than 61°F (Heublein et al. 2017). During the March through June larval period, water temperature modeling indicates that water temperatures frequently exceed these water temperature thresholds at Knights Landing under the No Action Alternative and Alternative 1 (Table O.3-11), especially, as noted above, in June. Such high levels of temperature threshold exceedances suggest that typical water temperature conditions in the lower Sacramento River may be highly stressful for white sturgeon larvae. In any case, the water temperatures, especially in June, are lower under Alternative 1 than under the No Action Alternative (Table O.3-11).

Juvenile white sturgeon are believed to initiate a secondary dispersal (the primary dispersal occurring at the larval stage) in spring by actively swimming downstream during the night. Dispersal likely lasts several days and covers many miles (Heublein et al. 2017).

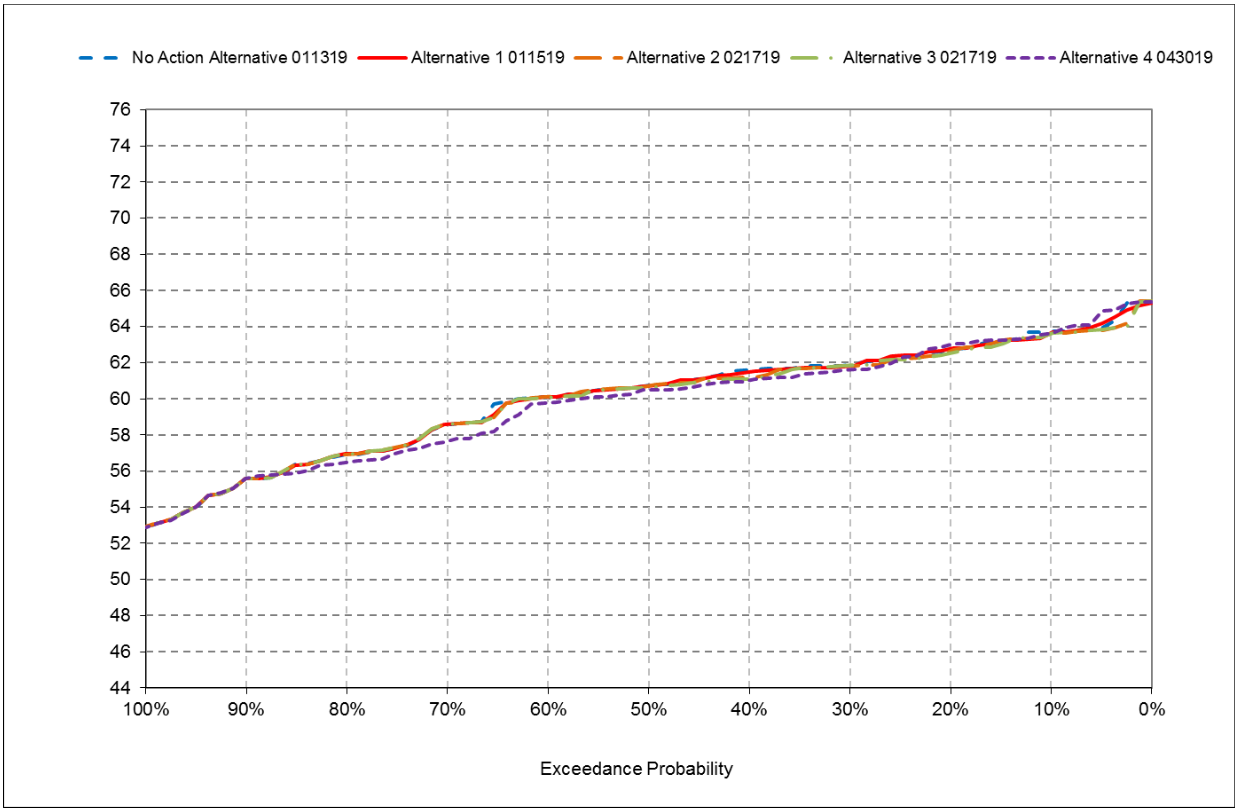
There is a positive correlation between mean daily freshwater outflow (April to July) and white sturgeon year class strength (CDFG 1992 and USFWS 1995, cited in NMFS 2018b). These relationships may result from flows transporting larvae to areas with greater food availability, dispersing larvae over a wider area, and/or enhancing nutrient availability to the Sacramento River and Delta/Estuary. The relationship of White Sturgeon year class recuitemnt and outflow is discussed in more detail in Section 0.3.3.8 Bay-Delta.

During the of White Sturgeon juvenile emigration period, approximately April to July, CalSim II results indicate that flows at Wilkins Slough during May and June would increase with Alternative 1 compared to No Action Alternative, but decrease in July of critically dry years (Table O.3-14). Alternative 1 would have a less-then significant impact on larval and juvenile White Sturgeon.

O.3.3.2.11 Adult Upstream Migration and Holding

As previously noted, White Sturgeon adults to initiate their upstream spawning migrations during late winter and early spring, presumably in response to elevated flows (Heublein et al. 2017). CalSim II flows at Wilkins Slough for December through February are not much different between Alternative 3 and No Action Alternative for all water year types. There are a few months and water year types when flows are higher under Alternative 3, such as December during wet years and January during Above Normal and below normal years. These increased flows would be beneficial for White Sturgeon migration, but all flows are between 7,800 and 19,600 cfs, which are suitable for migration. There are no temperature differences from December through February for Knights Landing. Alternative 3 would have no flow or water temperature effects on White Sturgeon adults.

The CalSim II flow results for Wilkins Slough and the HEC-5Q water temperature results for Knight Landing indicate that Alternative 1 would have a less-than-signficant impact on White Sturgeon relative to the No Action Alternative.



O.3-43. HEC-5Q Sacramento River Water Temperatures at Knights Landing under the No Action Alternative, Alternative 1, Alternative 2, Alternative 3 and Alternative 4; April

O.3.3.2.12 Sacramento Splittail

Sacramento splittail occur in the Sacramento River upstream of the Delta from about December through May. The adults begin moving upstream from the Delta in December and spawn in river-margin and inundated floodplain habitats in February through April (Feyrer et al. 2005, 2006; Sommer et al. 2007; Moyle et al. 2015). The larvae hatch several days after spawning then rear for about a month in habitat similar to the spawning habitat (Moyle et al. 2004). The juveniles also rear upstream and then begin their downstream migration during April and May, as the river level recedes back to the channel (Moyle et al. 2004; Feyrer et al. 2005). Floodplain spawning in wet years overwhelmingly dominates production, but spawning in side channels and channel margins is important during low-flow years when floodplains are not inundated. In the Sacramento River drainage, splittail spawn from Colusa to Knights Landing, but the the most important spawning areas are the inundated floodplains of the Yolo and Sutter bypasses (Feyrer et al. 2005).

High flows benefit adults migrating upstream (Feyrer et al. 2006), and greatly enhance spawning and rearing habitat for larvae and early juveniles (Crain et al. 2004). Mean monthly flows at Wilkins Slough during January through March of wet and above normal water years consistently equal or exceed 17,000 cfs under both alternatives (Table O.3-14). Such flows would be high enough to produce moderate side channel and floodplain inundation along reaches of the Sacramento River not constrained by levees, but they would not be high enough to overtop the bypass weirs and flood the bypasses, although some flooding of the bypasses occurs from local streams. As noted earlier, the mean monthly flows for the water year types combine flows for many years and therefore mask individual year variations. Figure O.3-44 shows the expected mean February flows for each year of the CalSim II record. About 15% of the years have mean February flows greater than 22,500 cfs, which is the approximate flow at which the Tisdale Weir, the first of the Sacramento River flood relief weirs that spills, begins to spill into the Sutter Bypass (DWR 2010b). In any case, differences between Alternative 1 and the No Action Alternative in flows at Wilkins Slough during December through May are relatively minor, and generally result from higher flow under the Alternative 1 (Table O.3-14; Figure O.3-44). Furthermore, as previously noted, the highest flows, which cause substantial flooding on the Yolo and Sutter bypasses, are flood flows, which are not affected by routine project operations. It is concluded that Alternative 1 would have no flow effects on Sacramento Splittail relative to the No Action Alternative.

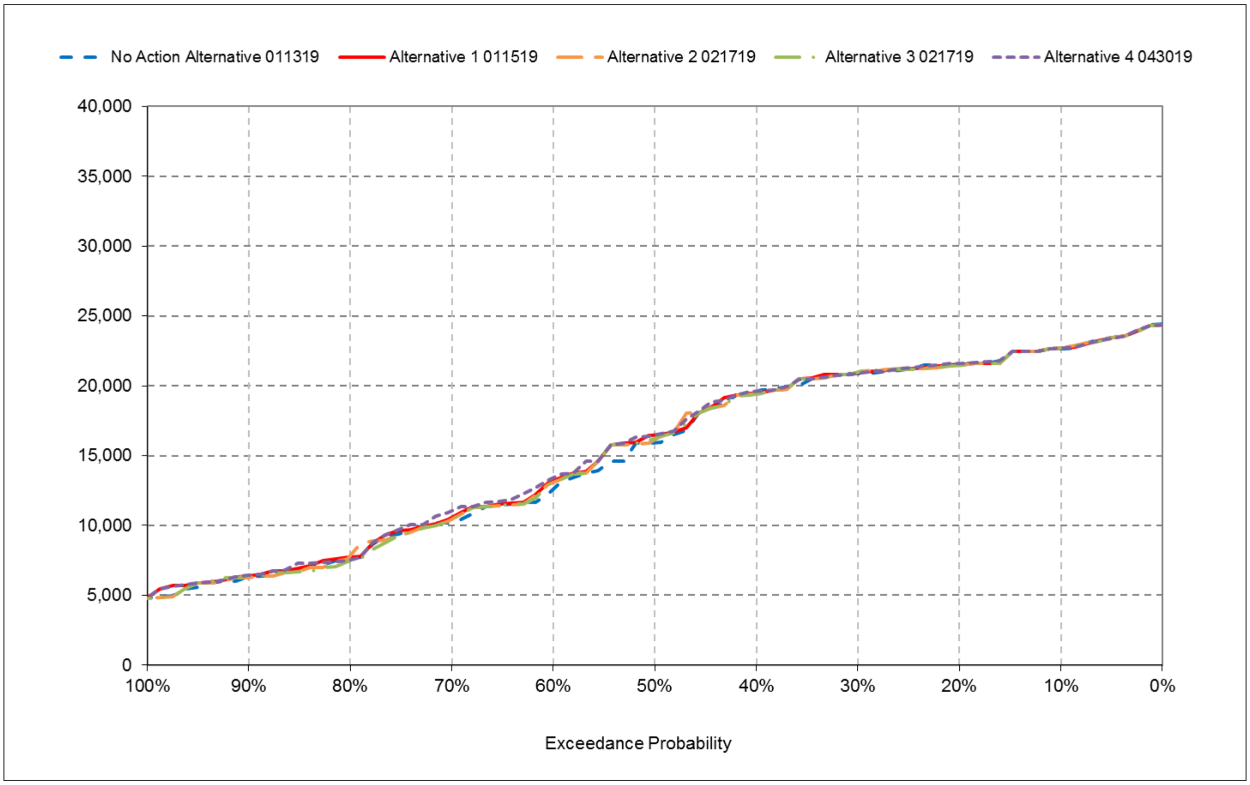


Figure O.3-44. CalSim II Sacramento River Flow at Wilkins Slough under the No Action Alternative, Alternative 1, Alternative 2, Alternative 3 and Alternative 4; February

Preferred water temperature for Sacramento splittail ranges from about 66°F for adults to about 75°F for juveniles, and the "upper limit of safe temperatures" ranges from about 75°F for adults and 81°F for juveniles (Young and Cech 1996). Mean monthly water temperatures during December through May at Knights Landing, which is at the approximate downstream limit of splittail spawning in the Sacramento River, range up to 68°F under both alternatives in May of critically dry water years (Table O.3-11). Although the monthly mean water temperatures underestimate the daily means, it is likely that the daily means infrequently exceed the 75°F threshold for adults. In any case, there are no meaningful water temperature differences between the alternatives at Knights Landing during the December through May period that Sacramento Splittial occupy the river upstream of the Delta (Table O.3-11). There is evidence that some juvenile splittail remain in the Sacramento River well upstream of the Delta through the entire year (Feyrer et al. 2005), but summer water temperatures in the more upstream locations where they have been found are considerably cooler than those at Knights Landing (compare Tables O.3-10 and O.3-11). Therefore, Alternative 1 is considered to have no water temperature effects on splittail relative to the No Action Alternative.

The CalSim II flow results for Wilkins Slough and the HEC-5Q water temperature results for Knight Landing indicate that Alternative 1 would have a less-than-signficant impact on Sacramento Splittail relative to the No Action Alternative.

O.3.3.2.13 Pacific Lamprey

Sacramento River Pacific Lamprey adults enter the Sacramento River from the Delta primarily during about March through June and hold in the river for about a year prior to spawning (Moyle et al. 2015). Spawning occurs in gravel redds in the upper river from March through July. The eggs and pro-larvae incubate for about 1 to 1.5 months. After the larvae (ammocoetes) emerge, they drift downstream and burrow into fine sediments primarily in off-channels habitats, where they rear (Schultz et al. 2014; Moyle et al. 2015). After 5 or more years, the ammocoetes metamorphose to the macropthalmia (juvenile) stage and migrate downstream to the Delta and ocean, typically migrating from March through June during pulse flow events (Moyle et al. 2015).

River flow potentially affects survival of Pacific Lamprey eggs and larvae, and migratory habitat of the juveniles and adults. Pacific lamprey build their spawning redds in shallow water (about 0.5 to 3.5 feet) (Gunckel et al. 2009; Schultz et al. 2014; Moyle et al. 2015), so reductions in water level can dewater the redds. The larvae select habitats, often off-channel, with fine sediments, low flow velocity, and shallow depths (~1 ft), so they are vulnerable to stranding by reductions in water level. Migrations of the juveniles and adults may be triggered by surges in flow (Moyle et al. 2015).

The types of variations in flow that potentially affect Pacific Lamprey, as described above, often occur on a time scale of hours or days, and therefore may not be detectable using the CalSim II monthly time-step modeling results. However, the CalSim II results mostly show little difference in Sacramento River flow between the No Action Alternative and Alternative 1, so there is no reason to expect much difference in short period flow fluctuations between the alternatives. The biggest differences in monthly mean flows occur in September and November of wet and above normal water years, when flows are lower under Alternative 1 than the No Action Alternative because Alternative 1 operations do not include releases for Fall X2 flows (Table O.3-12; Figures O.3-25 and O.3-28). Pacific lamprey are generally done spawning by late July and the prelarvae have finished emerging from their redds by early September. In contrast, the larvae are present in the river yearround and so could be vulnerable to flow reductions during September and November. However, water levels during these months are generally relatively stable because they are largely determined by Shasta and Keswick dam releases rather than runoff and because, especially under Alternative 1, maintaining stable water levels during the fall is an important objective of Shasta Dam operations to avoid dewatering Winter-Run and Spring-Run Chinook Salmon redds. The adults and juveniles carry out their migrations primarily during March through June. CalSim II modeling flow results for these months are generally higher under Alternative 1 than under the No Action Alternative, particularly for the drier water year types (Table O.3-13 and O.3-14). Therefore, Alternative 1 and the No Action Alternative are expected to similarly affect Pacific Lamprey with respect to flow in the Sacramento River.

Laboratory studies conducted on Columbia River Pacific Lamprey indicated that survival of incubating eggs and pre-larvae and of young larvae was greatest at a water temperature of 64°F and lowest at the highest water temperature included in the study, 72°F (Meeuwig et al. 2005). Young larvae showed six times as many developmental abnormalities at 72°F as at the other test temperatures. HEC-5Q modeling results indicate that mean monthly water temperatures in the Sacramento River between Keswick and RDBB during the March through August spawning and egg/prelarvae incubation period would be consistently below 64°F, with minor differences between the alternatives (Tables O.3-6 through O.3-9). During September, when Pacific Lamprey larvae would be present in the river, mean water temperatures would exceed the 64°F optimal temperature at RBDD in critically dry water years. September has the highest water temperatures of the year upstream of RBDD. Mean September water temperatures at RBDD for individual years exceed 64°F in about 7% of years for both alternatives, but are below 72°F for all years (Figure O.3-22). The downstream distribution of Pacific Lamprey larvae is uncertain, but if the larvae drift well downstream of RBDD or enter the Sacramento River from downstream tributaries, they would be subject to higher water temperatures, especially during July and August. However, there are few differences between July and August water temperatures at the lower temperature modeling sites (Table O.3-10 and O.3-11; Figure O.3-45). There are no biologically meaningful differences in water temperature conditions for Pacific Lamprey between the No Action Alternative and Alternative 1.

The CalSim II flow results and the HEC-5Q water temperature results indicate that Alternative 1 would have a less-than-signficant impact on Pacific Lamprey relative to the No Action Alternative.

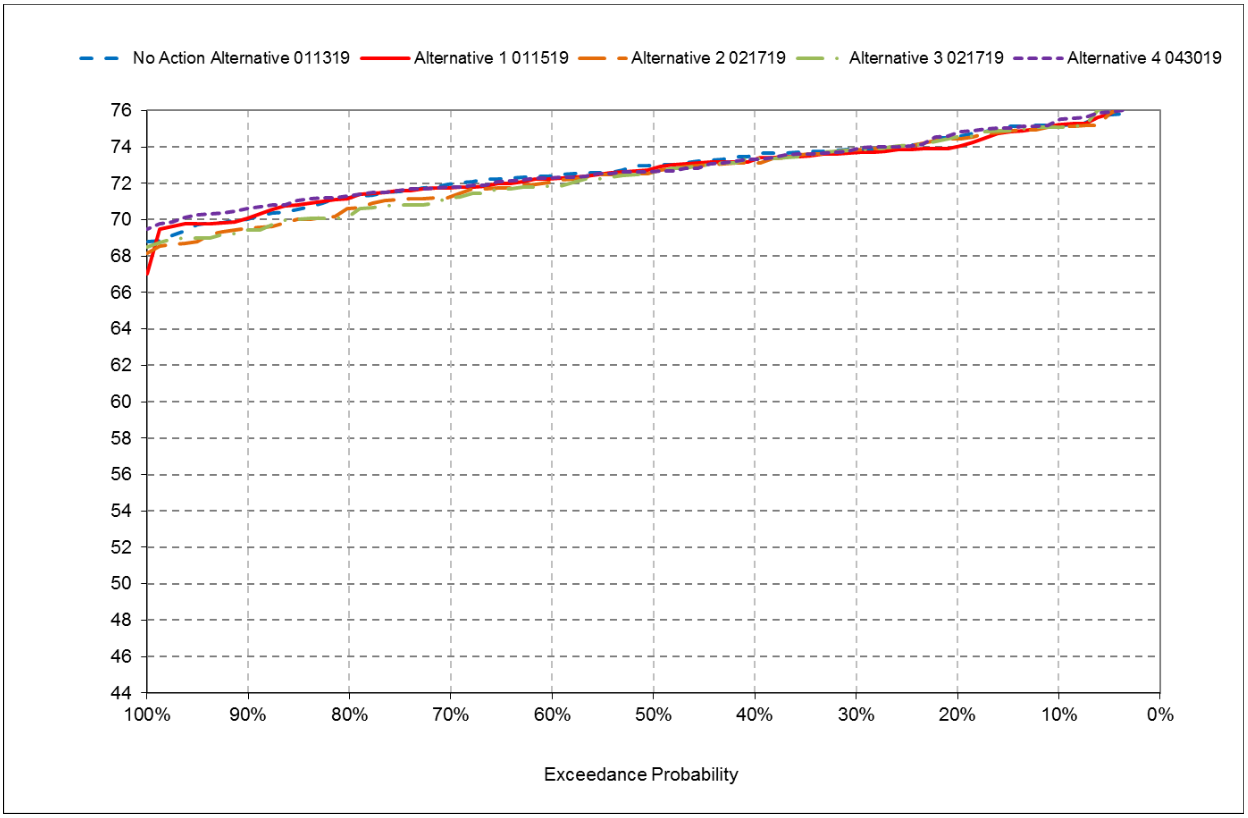


Figure O.3-45. HEC-5Q Sacramento River Water Temperatures at Knights Landing under the No Action Alternative, Alternative 1, Alternative 2, Alternative 3 and Alternative 4; August

O.3.3.2.14 <u>River Lamprey</u>

River Lamprey life history is poorly known, especially in California (Moyle et al. 2015). The adults migrate from the ocean to spawning areas during the fall and late winter (Beamish 1980). Spawning is believed to occur from February through May in small tributary streams (Moyle 2002). The redds are built at the upstream end of small riffles (Moyle 2002). After the larvae (ammocoetes) emerge, they drift downstream and burrow into sediments in pools or side channels where they rear. After several years, the larvae metamorphose in late July and the juvenile (macrothalmia) migrate downstream in the following year from May to July (Moyle 2002).

River flow potentially affects survival of River Lamprey eggs and larvae, and migratory habitat of the juveniles and adults. River lamprey build their spawning redds in shallow water (Moyle et al. 2015), so reductions in water level can dewater the redds. Assuming River Lamprey larvae habitat requirements are similar to those of Pacific Lamprey, the larvae select habitats, often off-channel, with low flow velocity and shallow depths, so they are vulnerable to stranding by reductions in water level.

The types of variations in flow likely to cause redd dewatering and stranding of larvae often occur on a time scale of hours or days and, therefore, may not be detectable using the CalSim II monthly time-step modeling results. However, the CalSim II results mostly show little difference in Sacramento River flow between the No Action Alternative and Alternative 1, so there is no reason to expect much difference in short period flow fluctuations between the alternatives. The biggest differences in monthly mean flows occur in September and November of wet and above normal water years, when flows are lower under Alternative 1 than the No Action Alternative because Alternative 1 operations do not include releases for Fall X2 flows (Table O.3-12; Figures O.3-25 and O.3-28). River lamprey are generally done spawning by May and, assuming their incubation times are similar to those of Pacific Lamprey, the prelarvae complete their emergence from redds by June or July. In contrast, the larvae are present in the river yearround and so could be vulnerable to flow reductions during September and November. However, water levels during these months are generally relatively stable because they are largely determined by Shasta and Keswick dam releases rather than runoff and because, especially under Alternative 1, maintaining stable water levels during the fall is an important objective of Shasta Dam operations to avoid dewatering Winter-Run and Spring-Run Chinook Salmon redds.

The juveniles carry out their migrations during May through July. CalSim II modeling flow results for May and June are generally higher under Alternative 1 than under the No Action Alternative, particularly for the drier water year types, but flows for July are lower (Tables O.3-13 and O.3-14). The adults migrate upstream primarily in the fall and winter and could be adversely affected by the reductions in flow under Alternative 1 relative to the No Action Alternative during September and November (Tables O.3-13 and O.3-14), but little is know about flow needs of migrating adult River Lamprey. Overall, Alternative 1 and the No Action Alternative are expected to similarly affect River Lamprey with respect to flow in the Sacramento River.

The water temperature requirements of River Lamprey have not been studied, but they are assumed to be similar to those of Columbia River Pacific Lamprey as follows: 1) 64°F for maximum survival of eggs and prelavae and 72°F for minimum survival of eggs and prelavae, for the water temperatures included in the study, and 2) below 64°F for fewest developmental abnormalities of young larvae (Meeuwig et al. 2005). HEC-5Q modeling results indicate that mean monthly water temperatures in the Sacramento River between Keswick and RDBB during the February through May spawning and egg/prelarvae incubation period would be consistently below 64°F, with minor differences between the alternatives (Tables O.3-6 through O.3-9). It should be noted that River Lamprey are believed to spawn in tributary streams rather than the mainstem, but this is uncertain (Moyle et al. 2015). During September, when River Lamprey larvae would be present in the river, mean water temperatures would exceed the 64°F optimal temperature at RBDD in critically dry water years. September has the highest water temperatures of the year upstream of RBDD. Mean September water temperatures at RBDD for individual years exceed 64°F in about 7% of years for both alternatives, but are below 72°F for all years (Figure O.3-22). The downstream distribution of River Lamprey larvae is uncertain, but if the larvae drift well downstream of RBDD or enter the Sacramento River from downstream tributaries, they would subject to higher water temperatures, especially during July and August. However, there are few differences between July and August water temperatures at the lower temperature modeling sites (Table O.3-10 and O.3-11; Figure O.3-45). There are no biologically meaningful differences in water temperature conditions for River Lamprey between the No Action Alternative and Alternative 1.

The CalSim II flow results and the HEC-5Q water temperature results indicate that Alternative 1 would have a less-than-signficant impact on River Lamprey relative to the No Action Alternative.

O.3.3.2.15 Hardhead

Hardhead are believed to spawn in riffles, runs, and heads of pools, primarily during April and May (Moyle et al. 2015). Most spawning probably occurs in tributaries rather then in the Sacramento River mainstem (Moyle et al. 2015). Larvae and juveniles likely inhabit stream margins with abundant cover, and move into deeper habitats as they grow larger. Adults occupy the deepest part of pools. Juvenile and adult Hardhead are present in the Sacramento River yearround. They tend to prefer water temperatures near 67°F (Thompson et al. 2012), but have been captured at RBDD, where water temperatures are generally much cooler (USFWS 2002) (Table O.3-9).

Spawning success of Hardhead in the lower Tuolumne River is highest when there are higher flows during in April and May (Brown and Ford 2002), which is likely true for the Sacramento River Hardhead as well. The CalSim II results indicate that monthly mean flow would be moderately higher under Alternative 1 than under the No Action Alternative during the April and May peak spawning months (Tables O.3-5, O.3-12 and O.3-13). During most of the other months, flows would generally be similar between Alternative 1 and the No Action Alternative, but they would be lower under Alternative 1 in July of critically dry water years and September and October of wet and above normal water years. The large flow reductions in September and October would likely have little effect on hardhead because they are predicted for wet and above normal years, when flows are generally high, and because by September and October, hardhead hatched in the spring would be well developed and have gravitated to deeper water. The flow reduction in July of critically dry water years would be more likely to adversely affect young hardhead. On balance, the flow effects of Alternative 1 are not expected to substantially affect hardhead.

Hardhead juveniles and adults performed well in laboratory tests at water temperatures from about 61 to 70°F (Thompson et al. 2012). They consistently preferred a mean water temperature of 67°F and avoided temperatures above about 79°F. HEC-5Q modeling results indicate that mean monthly water temperatures in the Sacramento River would be below 79°F at all locations under both alternatives (Tables O.3-6 through O.3-9). There would be only minor differences in mean water temperatures between the alternatives, except for moderate increases under Alternative 1 during September of wet and above normal water years. However, these mean water temperatures would be only slightly warmer than the Hardhead preferred temperature, and only at Knights Landing (Table O.3-11). There are no biologically meaningful differences in water temperature conditions for Hardhead between the No Action Alternative and Alternative 1.

The CalSim II flow results and the HEC-5Q water temperature results indicate that Alternative 1 would have a less-than-signficant impact on Hardhead relative to the No Action Alternative.

O.3.3.2.16 Central California Roach

California Roach primarily inhabitat small tributary streams, although they may occur in backwaters with dense riparian cover along the main rivers (Baumsteiger and Moyle 2019). Roach are adaptable fish, with a broad range of habitat types and temperature tolerances (Moyle 2002). Given that most Central California Roach inhabit tributary streams rather than the mainstem Sacramento River and given its wide range of habitats and suitable temperatures, it is unlikely that flow or water temparture conditions under Alternative 1 would adversely affect California Roach. Therefore, Alternative 1 is expected to have no impact on Central California Roach relative to the No Action Alternative.

O.3.3.2.17 Striped Bass

Striped Bass spawn in the Sacramento River primarily between about Verona (RM 78) and Wilkins Slough (RM 121) during April through June (Moyle 2002). No spawning occurs until water temperature reaches 57 degrees Fahernheit (Moyle 2002). When river flows are high, the water takes longer to warm, so spawning takes place further upriver because Striped Bass migrate upstream while waiting for temperatures to rise. It also takes place later in the year. The eggs are free-floating and negatively buoyant and hatch in about two days after spawning (at 66 degrees Fahernheit) as they drift downstream. Low flows can result in eggs settling on the bottom, which they cannot survive for long. The larvae may inhabit shallow, open water of the lower river from April to mid-June and then are carried by flows to the Delta and Suisun Bay (Stevens 1966; Moyle 2002).

Other than for spawning, Striped Bass in the San Francisco Estuary primarily reside in the Delta and bays, with ocean foraging in occasional years. Adult striped bass are found in the upper Sacramento River at RBDD and upstream, primarily from late spring through early fall, where they forage heavily on juvenile salmon and other fish (Tucker et al. 1998).

High flows in April through June benefit striped bass eggs because they help prevent them from settling to the river bottom. High flows likely also accelerate transport of Striped Bass larvae to their nursery habitats in the Delta and Suisun Bay (Moyle 2002). CalSim II flow results for Wilkins Slough indicate that mean monthly flow during April through June under Alternative 1 would be similar to or higher than flow under the No Action Alternative, especially in May and June of drier water years, which would potentially benefit conditions for eggs and larvae drifting downstream (Table O.3-14). The greatest reductions in flow resulting from Alternative 1 would occur in September and November of wet and above normal water years and in July of critically dry water years. Adult Striped Bass may reside throughout the Sacramento River in July and September (Tucker et al. 1998). However, although the Alternative 1 mean monthly flows are reduced from the No Action Alternative flows, they remain close to or well above 5,000 cfs (Table O.3-12 through O.3-14), which is likely adequate for foraging Striped Bass.

Optimal spawning temperatures for Striped Bass are 59 to 68 degrees Fahernheit and spawning ceases at about 70 degrees Fahernheit (Moyle 2002). The eggs can withstand temperatures of about 54 to 75 degrees Fahernheit, with the optimum being about 64 degrees Fahernheit (Emmett et al. 1991). Larvae tolerate temperatures of 50 to 77 degrees Fahernheit, but optimal temperatures for survival are 59 to 72 degrees Fahernheit (Emmett et al. 1991). Striped Bass adults and juveniles are tolerant of a wide range and rapid swings of water temperatures. The adults appear to prefer water temperatures ranging from about 68 to 75 degrees Fahernheit (Emmett et al., 1991) and juveniles prefer rearing temperatures of 61 to 66 degrees Fahernheit (Hasler 1988). Adults are under stress at temperatures over 77 degrees Fahernheit, and temperatures over 86 degrees Fahernheit are lethal (Moyle 2002).

HEC-5Q modeling results indicate that mean monthly water temperatures in the Sacramento River at Knights Landing during the April through June spawning period would be within the optimal range for spawning in April of all but wet years and in May of all but critically dry years, but would be above the optimal range in June during all water year types (Table O.3-11). The mean monthly temperatures would be below the optimal range for adults during April and May of all water year types, except critically dry years in May, but would be within this range in all water year types in June. The temperatures would be acceptable for eggs and optimal for larvae throughout the spawning period (Table O.3-11). Juvenile striped bass generally do not occur in the Sacramento River upstream of the Delta. The adults, as noted earlier, may forage in the river upstream to and above RBDD from about May through early October. Mean monthly water temperatures at RBDD throughout this period would be well below the optimal range for adults (Table O.3-9).

The largest difference in water temperatures between the No Action Alternative and Alternative 1 at Knights Landing during the Striped Bass spawning season are moderate reductions in June of below normal and dry water years (Table O.3-11). With these reductions, water temperatures under Alternative 1 would be closer to the optimal range for spawning than those under the No Action Alternative, providing a minor benefit. The largest temperature differences at any time of year are substantial increases under Alternative 1 for September of wet and above normal water years. These increases would be potentially beneficial for foraging Striped Bass adults because the No Action Alternative water temperatures for these months and water year types would be well below the optimal range for adults throughout the river (Tables O.3-9 through O.3-11).

The CalSim II flow results and the HEC-5Q water temperature results indicate that Alternative 1, with regard to flow and water temperature, would have a less-than-signficant impact on Striped Bass relative to the No Action Alternative.

O.3.3.2.18 American Shad

American shad migrate upstream in the Sacramento River starting in March, and typically spawn from April to June. Water temperature influences the timing of runs, with peak runs and spawning usually occurring at water temperatures of 62°F to 75°F (Moyle 2002). Shad eggs drift downstream from spawning areas and hatch in 8 to 12 days at 52°F to 59°F, 6 to 8 days at 63°F, and 3 days at 75°F (MacKenzie et al. 1985). However, more rapid development at higher temperatures appears to be associated with lower survival rates of embryos (Moyle 2002). Larval shad are planktonic for about 4 weeks, after which they metamorphose to actively swimming juveniles. Juveniles spend the next several months in freshwater, and seem to prefer temperatures of 63°F to 77°F. In the Sacramento River, summer rearing habitat occurs in the main river from Colusa to the north Delta (Stevens et al. 1987). As the season progresses, juvenile shad move downstream and enter salt water primarily during September through November (Moyle 2002). In general, variations in river discharge and temperature during early larval development are considered important regulators of year-class strength and recruitment of American shad (Hinrichsen et al. 2013). Although the importance of various potential mechanisms is unknown, the abundance of juvenile American shad in the Sacramento-San Joaquin Delta has been shown to be positively correlated with freshwater inflow during the April through June spawning and nursery periods (Stevens et al. 1987, Kimmerer 2002, Kimmerer et al. 2009).

During the spawning and larval rearing period (April through June), CalSim II modeling results indicates that average monthly flows in May and June under Alternative 1 would be higher than those under the No Action Alternative, which may have positive effects on spawning and early rearing success of American shad (Table O.3-14). In addition, with higher flows under Alternative 1, HEC-5Q modeling results indicate that mean monthly temperatures in the lower Sacramento River (Knights Landing) during May and June would be lower on average, which may improve water temperatures for developing embryos and larvae (see the ROC LTO BA). The largest differences in flows and water temperatures in the Sacramento River under Alternative 1 and the No Action Alternative would occur in September of wet and above normal water years (Table O.3-11 and O.3-14). However, the importance of river inflows and river temperatures for juvenile shad in September is unknown. Correlations between Delta inflows and abundance of juvenile shad have been demonstrated for the months of April through August, with the highest correlations in April through June, suggesting that the principal factors influencing abundance occur during periods of larval dispersal and transport. Sacramento River flows and temperatures under Alternative 2 appear to have minor benefits to American Shad relative to the No Action Alternative, but because the potential effects are highly uncertain, Alternative 2 is considered to have a less-than-significant effect on American Shad.

O.3.3.2.19 Largemouth Bass

Largemouth bass are warmwater fish species that are adapted to shallow, low-velocity, and relatively clear waters with aquatic vegetation and other forms of cover (e.g., logs, brush, and debris) (Stuber et al. 1982). Consequently, they are most abundant in ponds, lakes, reservoirs, sloughs, and river backwaters that support other warmwater fish species (Moyle 2002). While populations of largemouth bass have expanded in the Delta in recent decades (Brown and Michniuk 2007), the Sacramento River above the Delta generally provides poor habitat conditions for largemouth bass because of large seasonal flow fluctuations, relatively cold water, and lack of suitable nesting and rearing habitat. Consequently, largemouth bass populations in the Sacramento River above the Delta are largely dependent on upstream sources, including reservoirs, floodplain ponds and sloughs, and irrigation canals that provide suitable conditions for spawning and rearing during the late spring and summer months.

Largemouth bass spawning activity typically starts in April when water temperatures reach 59 to 61°F, and continues through June (Moyle 2002). Optimal temperatures for successful spawning and incubation are 68 to 70°F, although spawning is generally observed over a range of 55 to 79°F (Stuber et al. 1982). Nests (shallow depressions in sand, gravel, or debris-littered bottoms) are constructed by males, typically at a depth of about 3 feet, and defended from other bass and potential predators (Brown et al. 2009a; Moyle 2002). Eggs hatch in 2 to 7 days and sac fry usually spend 5 to 8 days in the nest until they begin actively feeding (Moyle 2002). Largemouth bass fry feed mainly on zooplankton and other small invertebrates, while juveniles and adults feed increasingly on larger invertebrates and fish as they grow (Stuber et al. 1982). Optimal temperatures for growth of juvenile and adult bass range from 77 to 86°F although growth will occur over a much wider range (50 to 95°F (Moyle 2002).

The CALSIM II and HEC-5Q modeling results for Alternative 1 indicate that Sacramento River flows would be higher and water temperatures would be lower in May and June relative to the No Action Alternative, potentially affecting largemouth bass spawning and incubation (Tables O.3-11 and O.3-14). However, based on modeled mean monthly water temperatures in the lower Sacramento River at Knights Landing, no substantial changes would be expected to occur in the frequency of suitable water temperatures for spawning and incubation (Figures O.3-41 and O.3-91). The relatively large changes in flows and water temperatures in September and November of wet and above normal years under Alternative 1 (Tables O.3-11 and O.3-14) could also affect habitat conditions for juvenile and adult bass, but water temperatures would remain below optimum levels for growth under both alternatives. Consequently, the generally poor habitat conditions for largemouth bass in the Sacramento River under the No Action Alternative would persist under Alternative 1. Therefore, changes in Sacramento River flows and water temperatures associated with Alternative 1 would have a less-than-significant effect on largemouth bass in the Sacramento River relative to the No Action Alternative.

O.3.3.2.20 Smallmouth Bass

Smallmouth Bass prefer large, clear lakes and streams and rivers with abundant cover and cool (68 to 80°F) summer temperatures (Moyle 2002). The optimal temperature range for spawning is 55 to 70°F (Brown et al. 2009b) and the optimal for adult growth is approximately 77 to 80°F, but rapid growth has been seen in the wild at temperatures as high as 84°F providing prey is abundant (Moyle 2002). Young-of-year Smallmouth Bass will select temperatures as high as 84 to 87°F. Populations are rarely established in water temperatures that do not exceed 66°F in summer for extended periods, and most smallmouth populations in California are present where summer temperatures are typically 69 to 71°F. In northern California reservoirs most spawning takes place in May and June, but spawning in streams may occur into July, depending on flows and temperatures. Males start making nest depressions when water temperatures reach 55to 61°F. The nests are typically built at depths of about 3 to 8 feet (Brown et al. 2009). In streams, nesting and reproduction can be disrupted by flow reductions that lead to nest dewatering or elevated flows that wash embryos and fry out of nests or lower water temperatures excessively (Graham and Orth 1986; Lukas and Orth 1995).

CalSim II results for Wilkins Slough flow for Alternative 1 compared to No Action Alternative during the spawning season May through July indicate increased flow during May and June of all of the water year types and reduced flow in July, especially in critically dry water years (Table O.3-14). Higher flows could adversely affect embryos and fry by washing them out of the nests, but it is unknown what magnitude of flows would cause washouts.

HEC-5Q monthly mean water temperatures at Hamilton City consistently fall within the the 55 to 70°F optimal spawning range during the spawning season of May through July under both Alternative 1 and the No Action Alternative (Table O.3-10). At Knights Landing, however, the temperatures fall within the optimal range during May of all water year types, but only during June of below normal water years and July of above normal years (Table O.3-11). The water temperatures under Alternative 1 are generally similar or moderately lower than those under the No Action Alternative. The monthly mean summer water temperatures at Hamilton City consistently fall below the 66°F threshold that has been found to be a minimum for Smallmouth Bass to establish populations in California (Moyle 2002), except for critically dry water years in August and September (Table O.3-10). At Knights Landing, however, the 66°F threshold is exceeded in all summer months and water year types except September of wet and above normal years under the No Action Alternative (Table O.3-11). Note that the large wet-and-Above-Normal-year September water temperature increases under Alternative 1 result in water temperatures exceeding the threshold, which may benefit Smallmouth Bass. The mean water temperatures are consistently well below the optimal range for adult growth, 77 to 80°F, at both locations.

The CalSim II flow and HEC-5Q water temperature results indicate that Alternative 1 would have a less-than-significant impact on Smallmouth Bass relative to the No Action Alternative with regard to flow and water temperature.

O.3.3.2.21 Spotted Bass

Spotted Bass inhabit streams and reservoirs and prefer moderate-size, clear, low-gradient sections of rivers and reservoirs (McKechnie 1966). They prefer pool habitat and slower, more turbid water than Smallmouth Bass but faster water than Largemouth Bass (Moyle 2002). Their summer water temperature preference is 75 to 87°F (Moyle 2002). In streams, nests are constructed in low-current areas on bottoms ranging from debris to gravel (Moyle 2002). Spawning depths are deeper than those of Largemouth Bass (Aasen and Henry 1981). They spawn in late spring when water temperatures rise to 59°F to 64°F (Aasen and Henry 1981; Howland 1931). Spawning continues through late May and early June, until temperatures reach 71-73°F.

During the spring (April through June) spawning season, CalSim II results for Wilkins Slough monthly mean flows under Alternative 1 are mostly higher than the No Action Alternative flows during May and June, and are mostly similar in April (Table O.3-14). Higher flows could adversely affect embryos and fry by dewtering nests or washing them out of the nests, but it is unknown what magnitude of flows would have these effects.

HEC-5Q monthyly mean water temperatures at Knights Landing during the spawning season of April through June would be within the 59 - 64°F spawning range in April under Alternative 1 and the No Action Alternative, but would exceed the range in May and June under both alternatives. The preferred summer water temperatures range of 75 to 87°F would be available only in critically dry years, especially in August, under both Alternative 1 and the No Action Alternative (Table O.3-11).

The CalSim II flow results and the HEC-5Q water temperature results indicate that Alternative 1, with regard to flow and water temperature, would have a less-than-significant impact on Spotted Bass relative to the No Action Alternative.

Potential changes to aquatic resources in the Sacramento River from Shasta cold water pool management

As described above in the introduction to *Potential changes to aquatic resources in the Sacramento River from seasonal operations*, water temperature management during summer and fall under Alternative 1 would be based in large part on the Shasta Cold Water Pool Management. The management decisions in a given year are tied to Shasta Reservoir coldwater pool storage on May 1, combined with summer and fall storage predictions from water temperature modeling. In years with high May 1 coldwater pool storage (> 2.8 MAF), operators would manage temperature releases to maintain a water temperature of 53.5°F in the Sacramento River upstream of the Clear Creek confluence (CCR) beginning when real-time monitoring indicated that the Winter-Run Chinook Salmon population had begun spawning and ending October 31, or when fry had emerged from an estimated 95% of the Winter-Run redds, whichever was earlier. In years with an intermediate level of May 1 cold water storage, the coldwater pool is generally insufficient to maintain 53.5°F at CCR through October, so operations would target developmental-stage-specific requirements of Winter-Run eggs and alevins, maintaining the 53.5°F threshold only for the period when the most temperature-sensitive developmental stage would be present. This period would be estimated from modeling using the new analytical tools discussed above (Martin et al. 2017; Anderson 2018). The duration of the 53.5°F protection period would be adjusted in proportion to the available coldwater pool on May 1. In years with low May 1 coldwater pool storage (e.g., <2.3 MAF), the temperature maintained at CCR would be gradually increased up to 56°F as necessary to conserve remaining coldwater pool through the period of Winter-Run egg and alevin incubation. Operators would minimize adverse effects of the higher water temperatures to the greatest extent possible, as determined by the latest egg mortality models, real-time monitoring, and current and expected future cold water availability. Finally, if operators could no longer maintain 56°F at CCR, they would operate to a less than optimal duration and temperature target, which would be determined in real-time with technical assistance from NMFS and USFWS. Reclamation would regularly evalute the performance of the coldwater pool management by monitoring egg to fry survival in the river and compare actual survival levels with those expected from modeling. If actual mortality was greater than expected, Reclamation would work with the SRTTG to develop alternative protective strategies and measures for the early life stages. More detailed description of this component is provided in Section 4.3.1.3, *Cold Water Pool Management*. Management of the Shasta coldwater pool under the No Action Alternative is guided by RPAs I.2.1 to I.2.4 of NMFS's 2009 Biological Opinion. Comparisons of the effects of water temperature on focal fish species under Alternative 1 vs. the No Action Alternative are provided above in *Potential changes to aquatic resources in the Sacramento River from seasonal operations* under the species specific discussions of effects. Alternative 1 has a potentially signficant impact of elevated temperature on southern dps Green Sturgeon adults relative to the No Action Alternative (see *Southern DPS Green Sturgeon* section above), but this impact results from the cessation of Delta Fall X2 flows under Alternative 1 rather than Shasta coldwater pool management. Alternative 1 is expected to benefit Winter-Run Chinook Salmon and Spring-Run Chinook Salmon with respect to coldwater pool management relative to the No Action Alternative, and is considered to have a less-than-signficant impact on the other focal fish species.

Potential changes to aquatic resources in the Sacramento River from spring pulse flows

Under Alternative 1, Reclamation would make a spring pulse flow release of up to 150 TAF in coordination with the Upper Sacramento scheduling team when the projected total May 1 Shasta Reservoir indicates a likelihood of sufficient cold water to support summer coldwater pool management through the summer and fall. Reclamation would not make a spring pulse flow release if the release would reduce the coldwater pool such that summer Shasta temperature management drops into a Tier 4 schedule (see Section 4.3.1.3, *Cold Water Pool Management*) or would interfere with the ability to meet other anticipated demands on the reservoir. The pulse flow release would be made in March, April, or May, but only one pulse flow would occur during this period (up to 150 TAF total).

Pulse flows serve two major functions for anadromous fish species: 1) for emigrating larvae and/or juveniles they trigger emigration and reduce exposure to predation and other stressors and 2) for immigrating adults they improve conditions by enhancing environmental cues that trigger migration and improve homing fidelity. Additional potential benefits include dispersal of larvae and juvenile, passage improvements for emigrating juveniles and immigrating adults, enhancement of rearing and migratory habitat conditions, and reduced water temperatures and increased dissolved oxygen in redds. The most important potential adverse effect of the spring pulse flows is that they potentially increase the risk of exhausting the coldwater pool in Shasta Reservoir while sensitive life stages of Winter-Run and other species remain in the river and before air temperatures have cooled. The effect of the spring pulse flow release action on the focal fish species depends largely on the the degree to which the pulse flow period overlaps the period of juvenile emigration or adult immigration in the Sacramento River. Spring-Run Chinook Salmon would potentially benefit the most from spring pulse flows because the period of juvenile and smolt emigration and the period of adult immigration both overlap the spring pulse flow period of March through May. Spring-Run juveniles and smolts emigrate primarily in December and again during the spring and the adults immigrate during January through August (for timing of life stages see discussions above for individual species in *Potential changes to aquatic resources in the Sacramento River from seasonal operations.*). No other species or run overlaps the spring pulse flow period in both their emigration and immigration periods, but most overlap in one or the other period. Other species or runs that would potentially benefit because their periods of emigration substantantially overlap with the spring pulse flow period include Fall-Run Chinook Salmon, Late fall-run Chinook Salmon, and Central Valley Steelhead. Species that would potentially benefit because their adult immigration periods overlap with the spring pulse flow period include Winter-Run Chinook Salmon and Green Sturgeon. Under the No Action Alternative there are no spring pulse flows; therefore, the overall population-level effects of Alternative 1 are expected to be beneficial relative to the No Action Alternative.

Potential changes to aquatic resources in the Sacramento River from fall and winter refill and redd maintenance

Under Alternative 1, Reclamation would, in the fall, seek to balance higher flow releases to maintain cold water temperatures and to avoid dewatering Winter-Run redds with lower flow releases to rebuild storage needed for cold water releases through the subsequent summer and early fall. Maintaining releases to keep late spawning Winter-Run redds underwater carries the risk of depleting storage needed for effective temperature management in a subsequent year. If, based on their analysis, Reclamation determines releases need to be reduced to rebuild storage, targets for winter base flows (December 1 through the end of February) would be set in October based on Shasta Reservoir end-of-September storage and the current hydrology, after accounting for Winter-Run redd stranding. Table O.3-14a shows examples of possible Keswick releases based on Shasta Reservoir storage condition; these would be refined through future modeling efforts as part of the seasonal operations planning. The *Fall and Winter Refill and Redd Maintenance* and *Spring Pulse Flow* actions have in common an objective to balance flow needs for fish in one season (fall and spring, respectively) with cold water temperature needs in another season (summer and early fall).

Table O.3-14a. Keswick Dam Release Schedule for End-of-September Storage (Preliminary Estimates)

Keswick Release	Shasta End-of-September Storage
3,250 cfs	≤ 2.2 MAF
4,000 cfs	≤ 2.8 MAF
4,500 cfs	≤ 3.2 MAF
5,000 cfs	> 3.2 MAF

The Fall and Winter Refill and Redd Maintenance action would provide the greatest potential benefit to Winter-Run and Spring-Run Chinook Salmon, both of which have redds present in the upper Sacramento River during the fall period when redds are at risk of being dewatered by flow reductions and both have incubating eggs and alevins present in the upper river during the summer and early fall that are vulnerable to inadequate cold water releases. Under the No Action Alternative, efforts are generally implemented to balance fall and winter refill with redd maintenance (NMFS 2009; RPA Action I.2.2), but further measures are considered necessary to achieve adequate protection of the coldwater pool and of salmon redds ; therefore, the overall population-level effects of Alternative 1 are expected to be positive relative to the No Action Alternative.

Potential changes to aquatic resources in the Sacramento River from rice decomposition smoothing

Under Alternative 1, following the emergence of Winter-Run Chinook Salmon fry and prior to spawning of the majority of Fall-Run Chinook Salmon, upstream Sacramento Valley CVP contractors and Sacramento River Settlement Contractors would work to synchronize their diversions to lower peak rice decomposition water demand, resulting in lower Sacramento River flow in late October and early November. With the lower flows, Fall-Run Chinook Salmon would be less likely to spawn in shallow areas that would be subject to dewatering during winter base flows. However, Winter-Run and Spring-Run Chinook Salmon spawn before the proposed river flow lowering would take place, making their redds susceptible to dewatering. Therefore, the potential benefits of this action, reduced dewatering of fall-run redds and greater Shasta storage refill, must be balanced against the potential impacts, dewatering of Spring-Run redds, which spawn during August through October, and dewatering of Winter-Run redds, which spawn from May through August. Under the No Action Alternative, there is no rice decomposition smoothing; therefore, Alternative 1 would increase the risk of dewatering of Spring-Run and Winter-Run redds, while reducing the risk of dewatering fall-run redds and the risk of conserving too little storage for protection of Winter-Run eggs in the following summer. Spring-Run Chinook Salmon and Winter-Run Chinook Salmon are federally listed species, but Fall-Run Chinook Salmon is not. On balance, this action is expected to benefit Fall-Run Chinook Salmon and have a less-than-significant impact on other focal species.

Potential changes to aquatic resources in the Sacramento River from spring management of spawning locations

Under Alternative 1, Reclamation would coordinate with NMFS to conduct experiments to test two complementary hypotheses: 1) releasing colder water to the Sacramento River earlier in the year induces earlier spawning and 2) releasing colder water to the Sacramento River later in the year, i.e., keeping April to May Sacramento River temperatures warmer, induces later spawning. To avoid risking temperature stress to Winter-Run and Spring-Run Chinook Salmon in the summer and/or fall, the experiments would be run during years with high May storage and a large coldwater pool. Under these conditions, the action would have no adverse impact, and would potentially benefit both salmon runs by contributing to better temperature management of Shasta Reservoir. This action is not included under the

No Action Alternative; therefore, Alternative 1 is considered to benefit Winter-Run and Spring-Run Chinook Salmon with regard to this action.

O.3.3.3 *Clear Creek*

O.3.3.3.1 Whiskeytown Reservoir Operations

Reclamation operates Whiskeytown Lake to (1) regulate inflows for power generation and recreation; (2) support upper Sacramento River temperature objectives; and (3) provide releases to Clear Creek.

Trinity River exports are first conveyed through Carr Powerplant before being released into Whiskeytown Lake. From Whiskeytown Lake, the water either continues to flow into Spring Creek Powerplant, ultimately outflowing into the Sacramento River below Keswick Dam, or is released from Whiskeytown Lake into Clear Creek. Although Whiskeytown Lake is primarily used as a conveyance system for cross-basin transfers, operations at both Carr and Spring Creek powerplants are done in a manner to maintain specified elevations for seasonal recreation support.

Whiskeytown Lake is annually drawn down by approximately 35 TAF during November through April to regulate flows for winter and spring flood management. Heavy rainfall events occasionally result in spillway discharges to Clear Creek. Operations at Whiskeytown Lake during flood conditions are complicated by its operational relationship with the Trinity River, the Sacramento River, and Clear Creek. On occasion, imports of the Trinity River water to Whiskeytown Lake may be suspended to avoid aggravating high flow conditions in the Sacramento Basin. Joint temperature control objectives similarly interact among the Trinity River, Clear Creek, and the Sacramento River. Two temperature curtains in Whiskeytown Lake were installed to pass cold water through the bottom layer of the reservoir and limit warming from Carr Powerplant to Clear Creek or Spring Creek Powerplant.

Under Alternative 1, Whiskeytown Lake operations would be similar to those described for the No Action Alternative with minor changes to accommodate Clear Creek flow measures. Spring Creek Debris Dam operations and the Clear Creek Restoration Program would continue under Alternative 1 as described in the No Action Alternative.

Under Alternative 1, flows from Whiskeytown Dam to Clear Creek would be managed to achieve minimum base flow of 150 cfs year-round in all water year types except critically dry water year types (compared to minimum base flows of 50 cfs to 100 cfs under the No Action Alternative), downstream water rights, 1963 Reclamation proposal to USFWS and NPS, predetermined CVPIA 3406(b)(2) flows. Channel maintenance flows of 10 TAF would occur, unless flood control operations provide similar releases, using the river release outlets, in all but dry and critically dry years or pulse flows released from Whiskeytown Dam. Pulse flows of 10 TAF would occur using the river release in all but critically dry years.

Model output for Whiskeytown Lake predicts that compared to the No Action Alternative, minimum reservoir volumes would be lower under Alternative 1 from March to July (Figure O.3-46, Table O.3-15) during all water year types. During these five months, water surface elevations would be lower under Alternative 1 compared to the No Action Alternative. In all other months, Whiskeytown Lake storage volume under Alternative 1 would be within 0.1 TAF of the No Action Alternative.

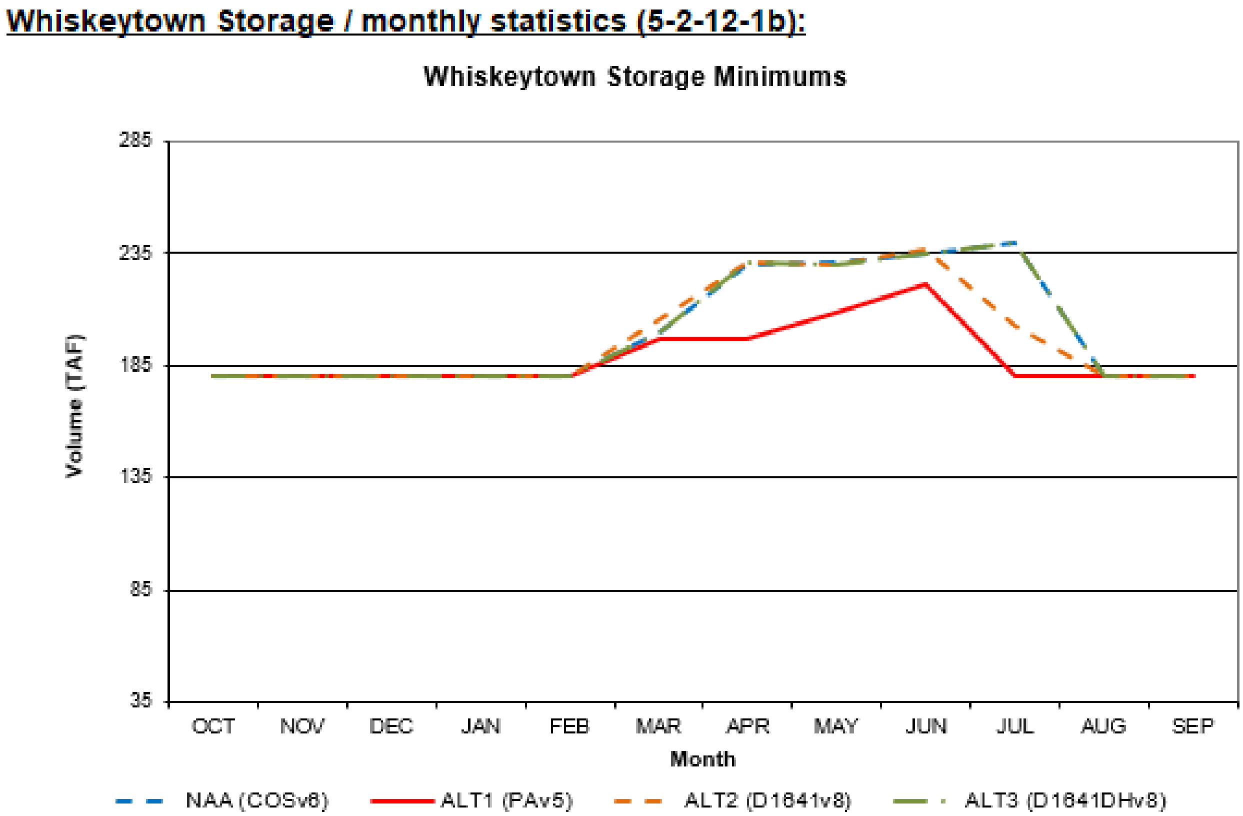


Figure O.3-46. Modeled Whiskeytown Lake Monthly Minimum Storage Volume under the No Action Alternative, Alternative 1, Alternative 2, and Alternative 3 during All Water Year Types

Table O.3-15. Modeled Differences in Whiskeytown Lake Monthly Minimum Storage Volumes from March to July during All Water Year Types under Alternative 1 relative to the No Action Alternative

Month	Change in Volume from No Action Alternative (TAF)
March	-2.2
April	-2.2
May	-22.4
June	-13.5
July	-59.8

Full pool elevation of Whiskeytown Lake is 1,210 feet above sea level, representing a capacity of 241 TAF. The upper outlet is located at 1,110 feet, and the lower outlet is at 985 feet. At full pool, the historic mouths of tributary creeks (Whiskey Creek, Grizzly Creek, Clear Creek, Boulder Creek, Dry Creek, and Brandy Creek) are under water. The proposed additional seasonal draw-downs from March through July under Alternative 1 could cause bank and bed erosion in newly exposed areas of tributary stream mouths where they are devoid of stabilizing riparian vegetation. This scour could cause channel incision (i.e., down-cutting) and result in increased lake water turbidity. Channel incision can create erosional nick points that propagate upstream until they encounter scour-resistant grade-controlling materials such as bedrock, at which point a cascade can form. However, annual minimum storage volume is not expected to change under this alternative. The additional draw-downs therefore represent a change in timing and duration of lower water surface elevation, not a new type or mechanism of disturbance, and channel incision may have already occurred and stabilized as a result of past operations.

Potential changes to aquatic resources in Clear Creek from seasonal variation in water surface elevation

Hardhead

Hardhead migrate from the reservoir into tributaries in April and May to spawn upstream of Whiskeytown Lake. The timing of the increased draw-downs from March through July under Alternative 1 could affect Hardhead if the lower water surface elevations expose any previously submerged cascades at tributary mouths or create new ones. No such cascades have been documented, but if they are present or created by tributary incision at low water, they could present barriers to migration that would prevent reservoir-dwelling adult Hardhead from spawning in tributary streams. Alternately, depending on the locations of any migration barriers and the longitudinal gradient profile of tributaries, lower reservoir water levels could potentially expose more usable stream habitat for Hardhead, benefiting adults and juveniles.

Hardhead are not a cold-water species, so drawing additional cold water from the bottom layers of the reservoir would not be expected to affect them directly. Hardhead have shown sensitivity to high sediment loads (Gard 2002), so increased reservoir turbidity due to varial zone erosion during draw-down periods could reduce suitability of reservoir and downstream waters for Hardhead persistence.

The increased annual variations in reservoir water surface elevation under Alternative 1 compared to the No Action Alternative could cause Hardhead to be affected by reducing habitat connectivity and increasing water turbidity. However, under Alternative 1, the largest changes to storage volume and water surface elevation in Whiskeytown Lake would occur in July, after Hardhead upstream migration and spawning are likely to be complete.

Other Fish Species

Central California Roach are not likely to be affected by changes in reservoir operations because, although they are found in upstream tributaries, they do not reside in Whiskeytown Lake, having likely been extirpated from the reach after the reservoir was originally filled in 1963. Future operations of Whiskeytown Dam under Alternative 1 are therefore unlikely to affect either individuals or populations.

Increased annual variations in reservoir water surface elevation under Alternative 1 compared to the No Action Alternative could cause varying effects to stocked and introduced nonnative game species in Whiskeytown Lake. Stocked species would not be expected to be affected by changes in reservoir operations. Rainbow Trout, Brown Trout, Kokanee Salmon, and Brook Trout typically spawn in tributary streams, but they are capable of spawning in lakes if they are unable to access moving water. Whiskeytown Lake Kokanee spawn in the fall, a period when no differences in water levels are expected under Alternative 1 compared to the No Action Alternative. Pond species such as Largemouth Bass, Smallmouth Bass, Spotted Bass, Bluegill, Black Crappie, Channel Catfish, and Brown Bullhead are able to tolerate a wide range of conditions, but the basses and panfish spawn in relatively shallow lake areas when water warms to at least 50°F in late spring or summer, which may put some of their nests at risk of being dewatered. However, these species have rapid reproductive rates which can enable them to recover from episodic recruitment failures.

O.3.3.3.2 Clear Creek Flows

Under Alternative 1, Reclamation proposes to release Clear Creek flows in accordance with the 1960 MOA with CDFW, and the April 15, 2002 SWRCB permit, which established minimum flows to be released to Clear Creek at Whiskeytown Dam. Reclamation proposes a base flow in Clear Creek of 200 cfs from October to May and 150 cfs from June to September in all year types except critical; in critically dry years, Clear Creek base flows may be reduced below 150 cfs based on available water from Trinity Reservoir. These minimum base flows are greater than those under the No Action Alternative, where minimum base flows from January through October are 50 cfs during normal years and 30 cfs during critically dry years, and 100 cfs from November through December in normal water year types, and 30 cfs to 70 cfs in critically dry water year types based on downstream water rights, 1963 Reclamation proposal to USFWS and NPS, predetermined CVPIA 3406(b)(2) flows, and NMFS BO Action I.1.1 (Table O.3-16).

Table O.3-16. Minimum Flows at Whiskeytown Dam for Normal and Critically Dry Water Year Types

Period	No Action Alternative Normal Year (cfs)	No Action Alternative Critically Dry Year (cfs)	Alternative 1[1]
Jan to May	50	30	200
June to Sept	50	30	150
Oct	50	30	200
Nov to Dec	100	70	200

[1] All but critically dry water year types. During critically dry water year types, Clear Creek base flows may be reduced below 150 cfs based on available water from Trinity Reservoir

Reclamation also proposes creating pulse flows for both channel maintenance and spring attraction flows. Under Alternative 1, Reclamation would release 10 TAF, with daily releases up to the safe release capacity (approximately 900 cfs), from Whiskeytown Reservoir for channel maintenance flows in all but dry and critically dry water year types. In the event of a storm resulting in a Whiskeytown Gloryhole spill of at least 3,000 cfs for 3 days, Reclamation would reduce the channel maintenance flow volume for the year or following year by 5 TAF; if 2 spills meeting this criterion occur in a single year, additional channel maintenance flows would not be required. For spring attraction pulse flows, Reclamation would release 10 TAF, with daily releases up to the safe release capacity (approximately 900 cfs), in all but critically dry water year types. During critically dry water year types, Reclamation would release one spring attraction flow up to the safe release capacity for up to 3 days and would not release any channel maintenance flows. Under the No Action Alternative, channel maintenance flows occur only during flood operations at Whiskeytown and spring attraction flows are provided by two pulse flows in Clear Creek in May and June of at least 600 cfs for at least 3 days for each pulse per year.

Modeling results indicate that differences in average Clear Creek flow between Alternative 1 and the No Action Alternative are minor (Figure O.3-47), with flows increasing slightly under Alternative 1 compared to the No Action Alternative in dry and critically dry water year types (Figure O.3-48). Although Clear Creek flow is similar under Alternative 1 and the No Action Alternative, the average flow fails to reach the minimum instream flow requirements of Alternative 1 except from January to February and from April to June, whereas the flow requirements under the No Action Alternative are met in all months.

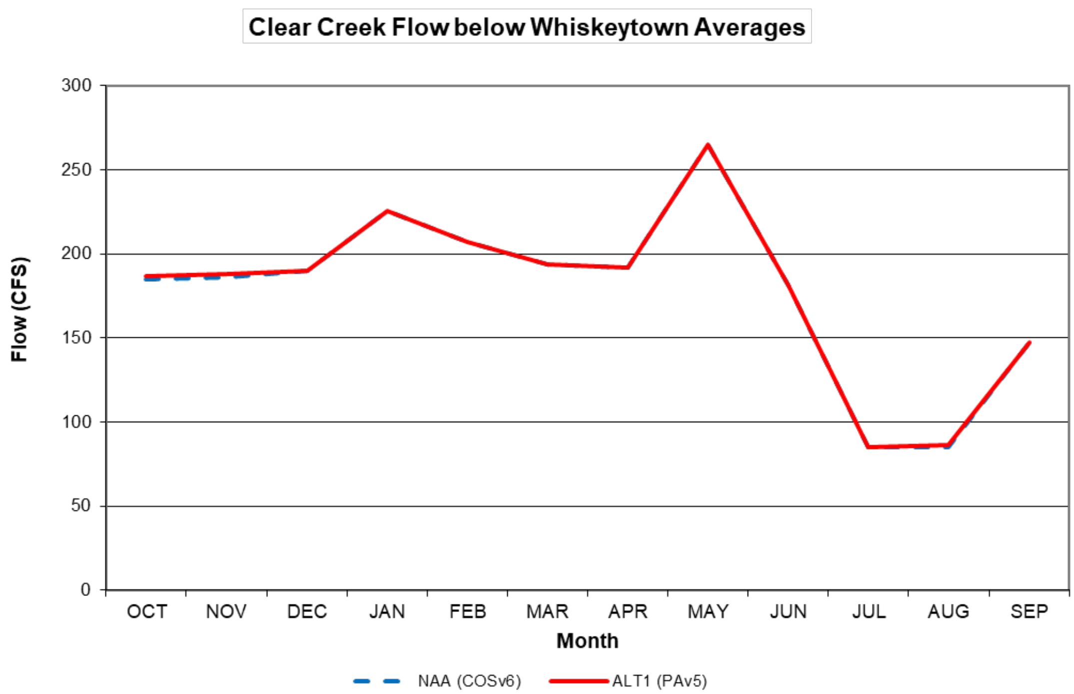


Figure O.3-47. Average Annual Flow in Clear Creek below Whiskeytown Dam for the No Action Alternative and Alternative 1 (40-30-30 Index)

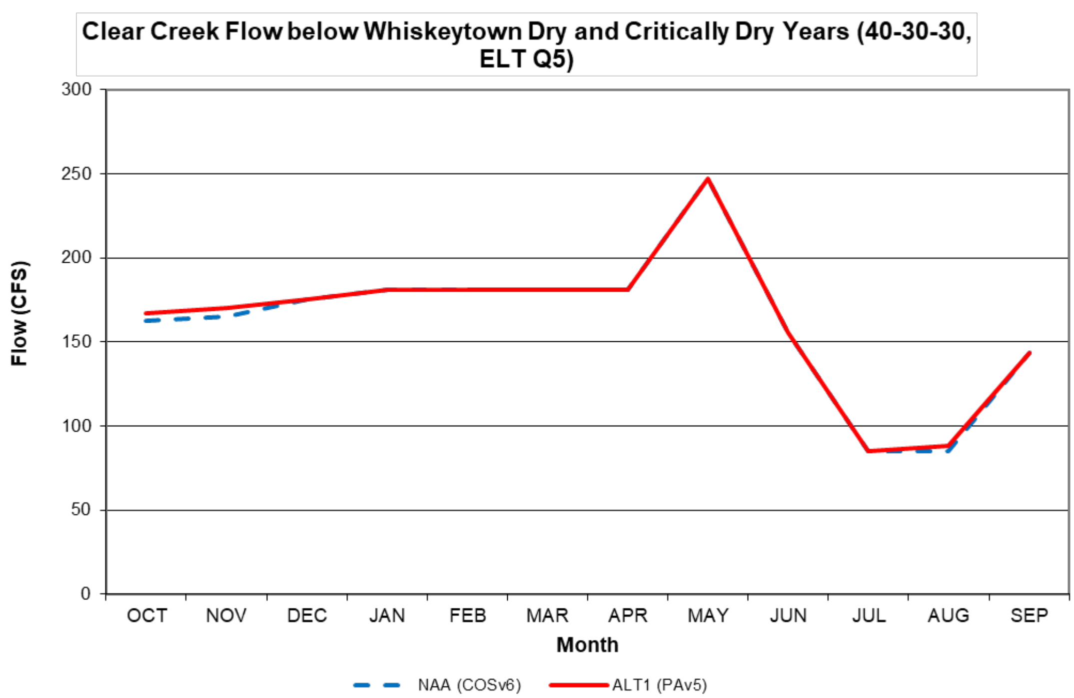


Figure O.3-48. Average Annual Flow in Clear Creek below Whiskeytown Dam for the No Action Alternative and Alternative 1 during Dry and Critically Dry Water Years (40-30-30 Index)

Under Alternative 1, Clear Creek base flows may be reduced below 150 cfs in critically dry years based on available water from Trinity Reservoir. During critically dry years, flows would be below Alternative 1 minimum instream flow requirements from June through November; during much of this period Alternative 1 flows would be slightly greater than No Action Alternative flows (Figure O.3-49).

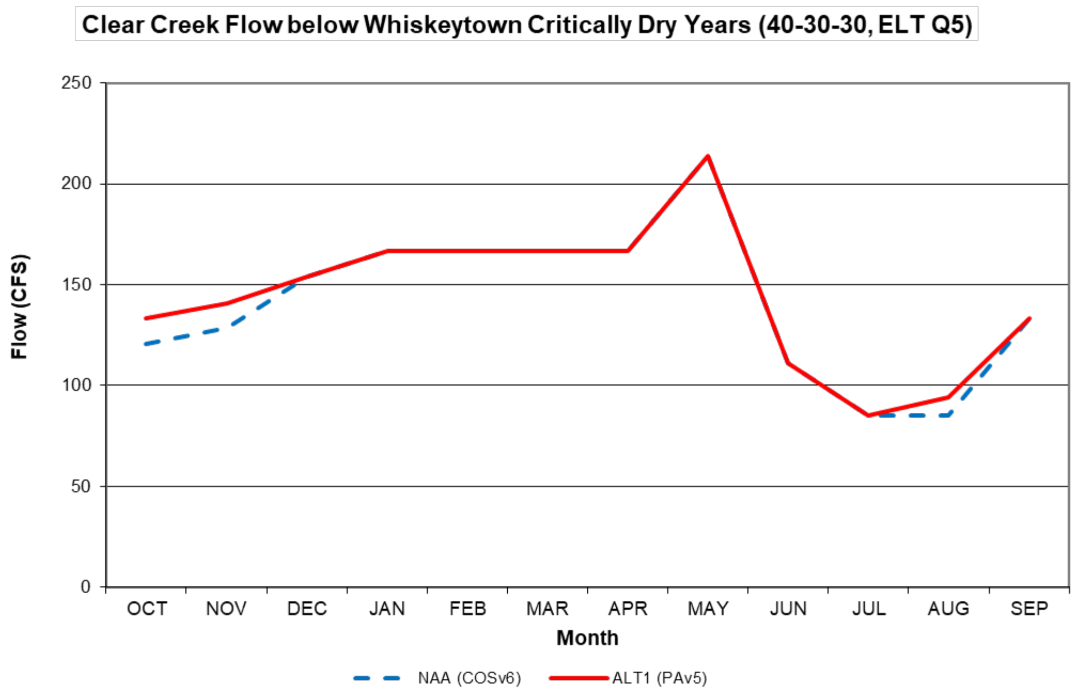


Figure O.3-49. Average Monthly Flow in Clear Creek below Whiskeytown Dam for the No Action Alternative and Alternative 1 during Critically Dry Water Years (40-30-30 Index)

Potential changes to aquatic resources in Clear Creek from variation in flow

Spring-Run Chinook Salmon

Under Alternative 1, base flows in Clear Creek downstream of Whiskeytown Dam would increase by approximately 7% compared to the flows under the No Action Alternative during the period of August to November in critically dry water years (Index 40-30-30, Figure O.3-49); flows are similar between Alternative 1 and the No Action Alternative in all other months and water years. These changes in flow would coincide with the seasonal occurrence of various life stages of Spring-Run Chinook Salmon in Clear Creek including holding adults (May to August), eggs and fry (September to October), and rearing and outmigrating juveniles (November to May). Increased flows during critically dry years would benefit adults and juveniles by increasing pool connectivity and available habitat. Increased flow would also lower temperatures and increase DO, benefiting eggs, fry, and juveniles.

Alternative 1 also allows for greater flexibility in the timing of channel maintenance and pulse flows, so releases could be scheduled in a manner beneficial to various life stages of Spring-Run Chinook Salmon based on their seasonal occurrence in Clear Creek. Relative to the No Action Alternative, Alternative 1 would potentially benefit Spring-Run Chinook Salmon in Clear Creek.

Fall-Run Chinook Salmon

Under Alternative 1, base flows in Clear Creek downstream of Whiskeytown Dam would increase by approximately 7% compared to the flows under the No Action Alternative during the period of August to November in critically dry water years (Index 40-30-30, Figure O.3-49); flows are similar between Alternative 1 and the No Action Alternative in all other months and water years. These changes in flow would coincide with the seasonal occurrence of various life stages of Fall-Run Chinook Salmon in Clear Creek including spawning adults (late-September to December) and eggs and fry (October to April). Increased flows during critically dry years would benefit adults by increasing pool connectivity and spawning habitat. Increased flow would also lower temperatures and increase DO, benefiting eggs and fry.

Alternative 1 allows for greater flexibility in the timing of channel maintenance and pulse flows, so releases could be scheduled in a manner beneficial to various life stages of Fall-Run Chinook Salmon based on their seasonal occurrence in Clear Creek. Relative to the No Action Alternative, Alternative 1 would potentially benefit Fall-Run Chinook Salmon.

Central Valley Steelhead

Under Alternative 1, base flows in Clear Creek downstream of Whiskeytown Dam would increase by approximately 7% compared to the flows under the No Action Alternative during the period of August to November in critically dry water years (Index 40-30-30, Figure O.3-49); flows are similar between Alternative 1 and the No Action Alternative in all other months and water years. These changes in flow would coincide with the seasonal occurrence of California Central Valley DPS Steelhead adult migration (September to October). Increased flows during critically dry years would benefit migrating adult Steelhead by increasing pool connectivity, reducing water temperatures, and increasing foraging habitat and shelter.

Alternative 1 allows for greater flexibility in the timing of channel maintenance and pulse flows, so releases could be scheduled in a manner beneficial to various life stages of California Central Valley DPS Steelhead based on their seasonal occurrence in Clear Creek. Relative to the No Action Alternative, Alternative 1 would potentially benefit California Central Valley DPS Steelhead.

Pacific Lamprey

Under Alternative 1, base flows in Clear Creek downstream of Whiskeytown Dam would increase by approximately 7% compared to the flows under the No Action Alternative during the period of August to November in critically dry water years (Index 40-30-30, Figure O.3-49); flows are similar between Alternative 1 and the No Action Alternative in all other months and water years. These changes in flow would coincide with the seasonal occurrence of various life stages of Pacific Lamprey in Clear Creek, including holding adults (year-round), ammocoetes (year-round), and outmigrating adults (peak early winter to spring). Increased flows during critically dry years would benefit these life stages by increasing pool connectivity, reducing water temperatures, and increasing foraging habitat and shelter.

Alternative 1 allows for greater flexibility in the timing of channel maintenance and pulse flows, so releases could be scheduled in a manner beneficial to various life stages of Pacific Lamprey based on their seasonal occurrence in Clear Creek. Relative to the No Action Alternative, Alternative 1 would potentially benefit Pacific Lamprey.

Potential changes to aquatic resources in Clear Creek from variation in water temperature

Water temperature objectives under Alternative 1 would be similar to those required under the No Action Alternative, with the exception of dry and critically dry water year types when it might not be possible for Reclamation to meet these temperature requirements. In these water year types Reclamation would operate as close to these temperatures as possible.

Modeling results indicate that average water temperatures in Clear Creek above the Sacramento River would be nearly identical under the No Action Alternative and Alternative 1 (Figure O.3-50); however, maximum temperatures do differ between the two scenarios (Figure O.3-51). Under the No Action Alternative, modeled maximum water temperatures exceed those under Alternative 1 in October by up to 7°F, but modeled maximum water temperature under Alternative 1 exceed those under the No Action Alternative by approximately 1°F in September (Figure O.3-51).

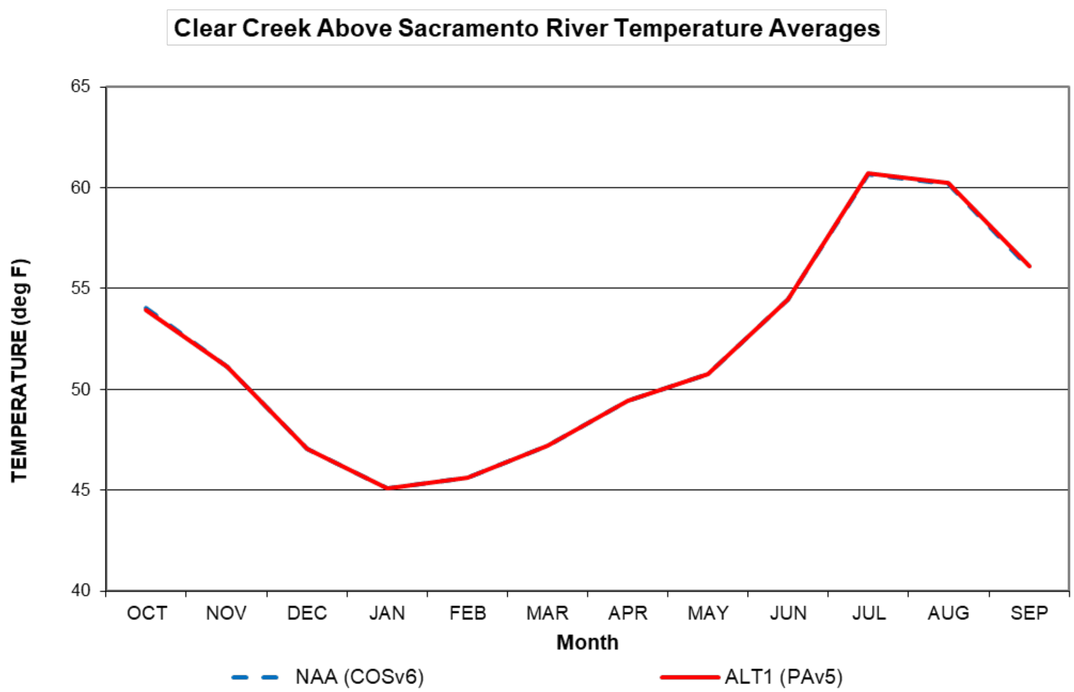


Figure O.3-50. Average Monthly Water Temperatures in Clear Creek above the Sacramento River for the No Action Alternative and Alternative 1

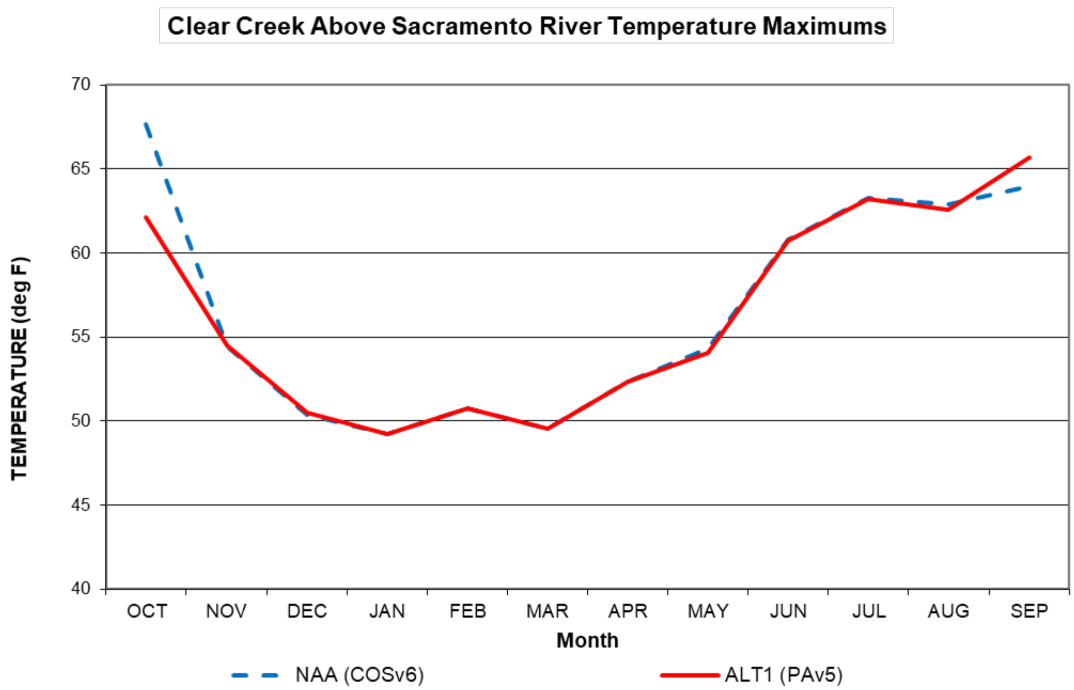


Figure O.3-51. Maximum Modeled Water Temperatures in Clear Creek above the Sacramento River under the No Action Alternative and Alternative 1

Table O.3-17. Water Temperatures Suitable for Spring-Run and Fall-Run Chinook Salmon, Central Valley Steelhead, and Pacific Lamprey by Life Stage

Life Stage	Peak Occurrence	Optimal	Suboptimal	Stress-inducing
Spring-Run Chinook Salmon				
Eggs to fry	September to October	< 54°F	54°F to 58°F	> 58°F
Rearing to out-migrating	November to May	< 60°F	60°F to 65°F	> 65°F
Migrating adults	March to June	< 56°F	56°F to 65°F	> 65°F
Adult holding	May to August	< 60.8°F	60.8°F to 66.2°F	> 66.2°F
Fall-Run Chinook Salmon				
Eggs to fry	October to April	48.2°F to 55.4°F	55.4°F to 62.6°F	> 62.6°F
Rearing to out-migrating	April to June	55.4°F to 68°F	68°F to 75.2°F	> 75.2°F
Migrating adults	June to April	50°F to 68°F	68°F to 69.8°F	> 69.8°F
Central Valley Steelhead				
Eggs to fry	January	46°F to 52°F	52°F to 55°F	> 55°F
Rearing to out-migrating	January to May	< 65°F	65°F to 68°F	> 68°F
Migrating adults	September to October	< 52°F	52°F to 70°F	> 70°F
Adult holding	December to March	< 60.8°F	60.8°F to 66.2°F	> 66.2°F

Sources: NMFS 2016a; Stillwater Sciences 2006; CDFG 2012a, 2012b.

Spring-Run Chinook Salmon

Effects of water temperature on Spring-Run Chinook Salmon have been heavily studied, resulting in an understanding of the optimal (beneficial), suboptimal, and stress-inducing (adverse) temperature ranges for each life stage during its period of peak abundance in Clear Creek (Table O.3-17).

On average, modeled Alternative 1 and No Action Alternative water temperatures are essentially identical (Figure O.3-50), so no difference in effects of water temperature on Spring-Run Chinook Salmon is generally expected. Maximum temperatures under the No Action Alternative, however, reach higher levels in October but lower levels in September than they do under Alternative 1 (Figure O.3-51). Spring-Run Chinook eggs and fry are present during this period (Table O.3-17) and would be exposed to the possible adverse effects of elevated water temperature, including effects of physiologic stress such as slower growth rates and an inability to satisfy metabolic demand (Stillwater Sciences 2006; Martin et al. 2017). Maximum water temperatures under both scenarios exceed stress-inducing levels for Spring-Run Chinook eggs and fry in September and October, but maximum water temperatures under the No Action Alternative remain stress-inducing for a longer period (Figure O.3-51). Minimal difference in effects of water temperature on Spring-Run Chinook Salmon is expected between Alternative 1 and the No Action Alternative, but since temperatures remain at stress-inducing levels longer under the No Action Alternative, there is potential for beneficial effects on eggs and fry under Alternative 1 when temperatures reach their maximum levels.

Fall-Run Chinook Salmon

Effects of water temperature on Fall-Run Chinook Salmon have been heavily studied, resulting in an understanding of the optimal (beneficial), suboptimal, and stress-inducing (adverse) temperature ranges for each life stage during its period of peak abundance in Clear Creek (Table O.3-17).

On average, modeled Alternative 1 and No Action Alternative water temperatures are essentially identical (Figure O.3-50), so no difference in effects of water temperature on Fall-Run Chinook Salmon is generally expected. Maximum temperatures under the No Action Alternative, however, reach higher levels in October but lower levels in September than they do under Alternative 1 (Figure O.3-51). Fall-Run Chinook eggs and fry are present during October (Table O.3-17) and would be exposed to the possible adverse effects of elevated water temperature, including effects of physiologic stress such as slower growth rates and an inability to satisfy metabolic demand (Stillwater Sciences 2006; Martin et al. 2017). Maximum water temperatures under the No Action Alternative remain at stress-inducing levels for a longer period (Figure O.3-51). Under Alternative 1, therefore, minimal difference in effects of water temperature on Fall-Run Chinook Salmon is expected, but there is potential for beneficial effects on eggs and fry when temperatures reach their maximum levels.

Central Valley Steelhead

Effects of water temperature on Central Valley Steelhead have been heavily studied, resulting in an understanding of the optimal (beneficial), suboptimal, and stress-inducing (adverse) temperature ranges for each life stage during its period of peak abundance in Clear Creek (Table O.3-17).

On average, modeled Alternative 1 and No Action Alternative water temperatures are essentially identical (Figure O.3-50), so no difference in effects of water temperature on Central Valley Steelhead is generally expected. Maximum temperatures under the No Action Alternative, however, reach higher levels in October and lower levels in September than they do under Alternative 1 (Figure O.3-51). Migrating adult Steelhead are present during this period (Table O.3-17) and would be exposed to the possible adverse effects of elevated water temperature, including effects of physiologic stress such as an inability to satisfy metabolic demand (Stillwater Sciences 2006; Martin et al. 2017). Maximum water temperatures under both scenarios remain at suboptimal levels for migrating adult Steelhead throughout their September to October period of peak occurrence (Figure O.3-49). Under Alternative 1, therefore, minimal difference in effects of water temperature on Central Valley Steelhead is expected.

Pacific Lamprey

Pacific Lamprey temperature tolerance has been less studied than that of salmonids. Periods of life stage occurrence and associated temperatures for Pacific Lamprey are provided in Table O.3-18.

Table O.3-18. Summary Table of Water Temperatures Suitable for Pacific Lamprey by Life Stage

Life Stage	Peak Occurrence	Temperature Range
Ammocoetes	Year-round	< 82°F [1]
Spawning	January to May	50°F to 64°F, peak 57°F to 59°F
Adult out-migration	Early winter to spring	<68°F

Source: Stillwater Sciences 2014.
[1] Temperature of 82°F is lethal to ammocoetes of four North American species of lamprey; however, it is uncertain if Pacific Lampreys have similar tolerances.

On average, modeled Alternative 1 and No Action Alternative water temperatures are essentially identical, so no difference in effects of water temperature on Pacific Lamprey is generally expected. Maximum temperatures under the No Action Alternative, however, reach higher levels in October and lower levels in September than they do under Alternative 1 (Figure O.3-51). Pacific Lamprey ammocoetes are present during this period (Table O.3-18) and would be exposed to the possible adverse effects of elevated water temperature, including effects of physiologic stress such as slower growth rates and an inability to satisfy metabolic demand (Stillwater Sciences 2006; Martin et al. 2017). Maximum water temperatures under both scenarios remain at suitable levels for Pacific Lamprey ammocoetes year-round (Figure O.3-49). Under Alternative 1, therefore, minimal difference in effects of water temperature on Central Valley Steelhead is expected.

O.3.3.3.3 Spring Creek Debris Dam

Under Alternative 1 Reclamation proposes to implement the interim operation while a revised MOU is developed by Reclamation, CDFW, SWRGB, and EPA. This interim operation includes more stringent water quality criteria based on criteria for the protection of aquatic life in the upper Sacramento River as described in the Water Quality Control Plan for the Sacramento River and San Joaquin River Basins (Basin Plan) (SWRCB 1998), and the California Toxics Rule (CTR) (provided in SWRCB 2003). The point of compliance is below Keswick Dam, and sets a maximum concentration for acute exposure of 5.6 µg/L (dissolved copper) and 16 µg/L (dissolved zinc). Maximum concentration for chronic exposure are set at 4.1 µg/L (dissolved copper) and 54 µg/L (dissolved zinc).

Potential changes to aquatic resources due to Spring Creek Debris Dam operations

The most recent five-year review of the project (EPA 2018: i) found that there has been a significant decrease in total copper and total zinc measured at lower Spring Creek. This is largely a result of operational remedies (see description of remedies under NAA) implemented in an effort to comply with the Basin Plan standards in the Sacramento River below Keswick Dam and objectives laid out in applicable RODs. Between 2012 and 2017, the range of total copper and zinc concentrations measured at lower Spring Creek decreased to approximately 50 µg/L to 150 µg/L and 90 µg/L to 800 µg/L, respectively. Water quality below Keswick Dam has likewise shown dramatic improvement. The prescribed remedies are effectively protecting the Sacramento River as important fish habitat and there has been a 97% reduction in heavy metals downstream of Keswick Dam, eliminating fish kills and greatly improving water quality downstream (CVRWQCB 2002: 23). This trend of decreasing copper and zinc contamination in affected waters as a result of SCDD operational remedies will be reinforced under Alternative 1 through adherence to applicable water quality objectives under the Basin Plan at the compliance point below Keswick Dam. As a result, fisheries resources, including Central Valley Steelhead, Green sturgeon, and all runs of Chinook Salmon, in affected reaches of the upper Sacramento River would be exposed to improved water quality, leading to potential individual and population-level benefits.

O.3.3.3.4 Clear Creek Restoration Program

The Clear Creek Restoration Program is being implemented under both Alternative 1 and the No Action Alternative. Therefore, Alternative 1 and the No Action Alternative are likely to have similar effects on aquatic resources.

O.3.3.4 *Feather River*

O.3.3.4.1 FERC Project #2100-134

DWR, under Alternative 1, would operate Oroville Dam consistent with the NMFS, USFWS, and CDFW environmental requirements applicable for the current Oroville Complex FERC License (FERC Project #2100-134). Reclamation would operate Oroville Dam with minimum flows of 700 cfs to 800 cfs below the Thermalito Diversion Dam in the low flow channel (2006 Settlement Agreement), 750 cfs to 1,700 cfs below the Thermalito Afterbay outlet (1983 DWR-CDFG Agreement), and the DFG/DWR operation objective of 2,800 cfs at the mouth of the Feather River from April through September, with options to vary flow depending on year types. Reclamation would also operate Oroville Dam to meet minimum instream flow requirements below the Thermalito Afterbay outlet in the HFC of 1,000 cfs to 1,700 cfs depending on the time of year and the preceding April to July unimpaired runoff (Table O.3-19).

Under the No Action Alternative, DWR would operate Oroville Dam in accordance with ongoing management policies, criteria, and regulations, including water right permits and licenses issued by the SWRCB and operational requirements of the 2008 USFWS BO and the 2009 NMFS BO. Under the No Action Alternative, DWR typically releases water from Lake Oroville to meet the requirements of instream flows and D-1641.

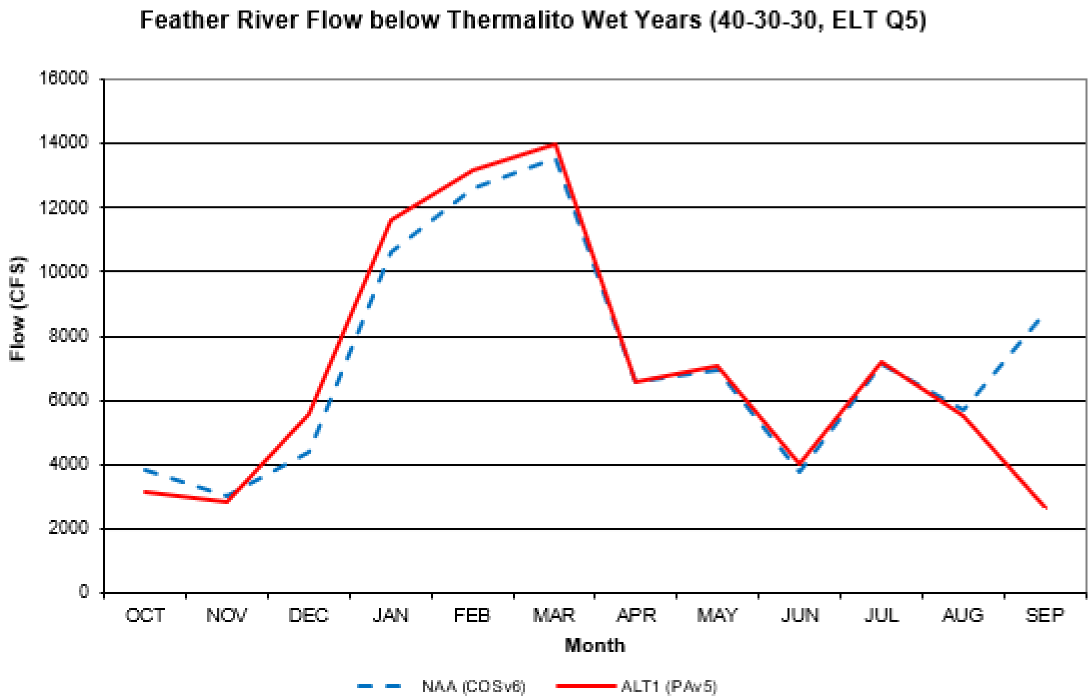
Table O.3-19. Feather River HFC Minimum Instream Flow Requirements

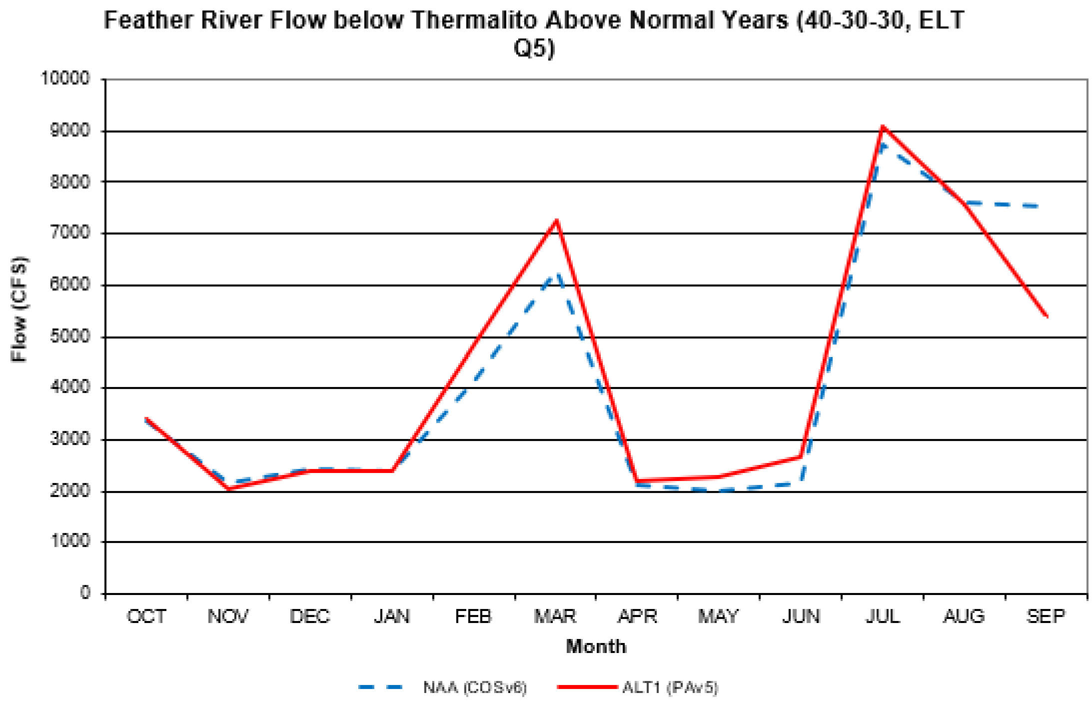
Preceding April to July Unimpaired Runoff (Percent of Normal)	Oct to Feb Minimum Instream Flow (cfs)	March Minimum Instream Flow (cfs)	April to Sept Minimum Instream Flow (cfs)
55% or greater	1,700	1,700	1,000
Less than 55%	1,200	1,000	1,000

Potential changes to aquatic resources in the Feather River due to seasonal variation in flow

CalSim II model output shows that Feather River flows under Alternative 1 and the No Action Alternative would comply with Feather River HFC minimum instream flow requirements during all months in wet, above normal, and below normal water years. In dry years where the preceding April to

July unimpaired runoff is less than 55% of normal, Alternative 1 and the No Action Alternative would comply with minimum instream flow requirements in the HFC; however, where the preceding April to July unimpaired runoff is greater than 55% of normal, Alternative 1 would not comply with minimum instream flow requirements from October through March (Table O.3-19 and Figure O.3-52). In critically dry years where the preceding April to July runoff is greater than 55% of normal, Alternative 1 and the No Action Alternative would not comply with minimum instream flows from October to March; however, where the preceding April to July runoff is less than 55% of normal, Alternative 1 and the No Action Alternative would only not comply with minimum instream flow requirements in the HFC in November (Table O.3-19 and Figure O.3-52).




Feather River Flow below Thermalito Above Normal Years (40-30-30, ELT Q5)
Flow (CFS)
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
OCT
NOV
DEC
JAN
FEB
MAR
APR
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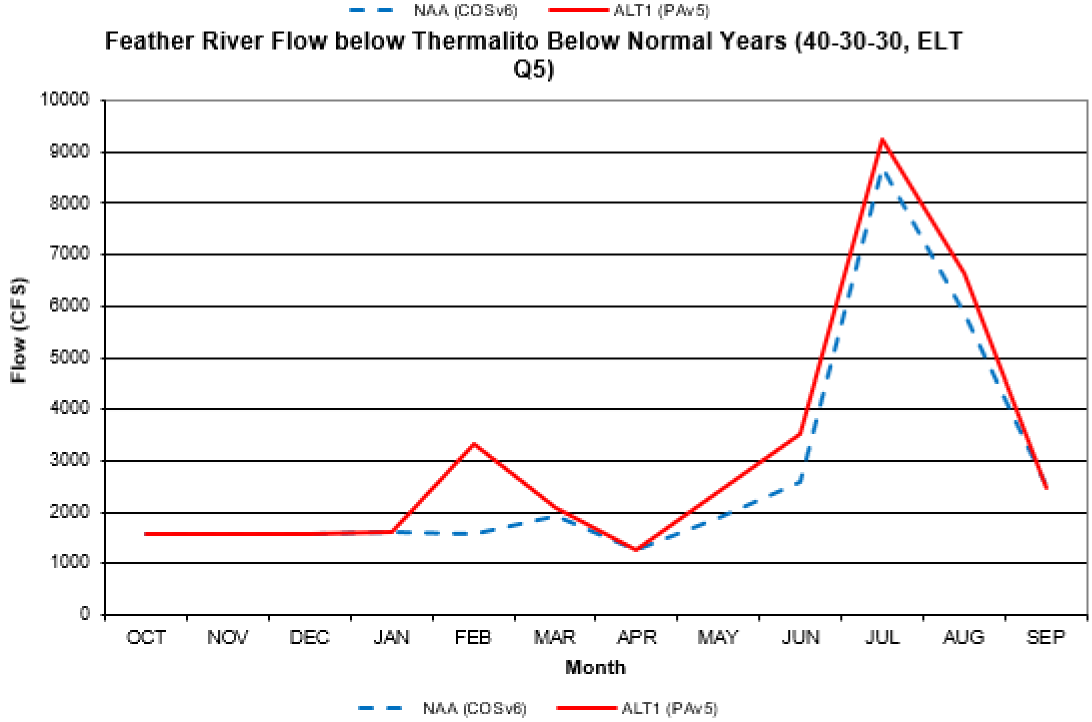
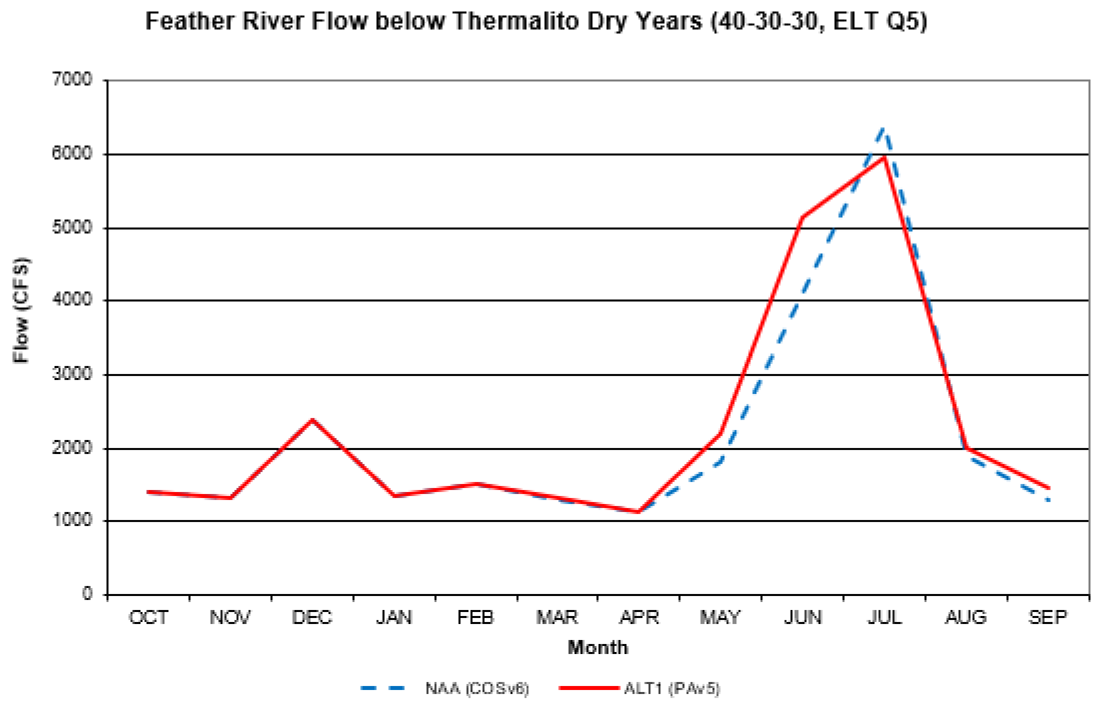
NAA (COSv6)
ALT1 (PAv5)


Feather River Flow below Thermalito Below Normal Years (40-30-30, ELT Q5)
Flow (CFS)
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
Month
NAA (COSv6)
ALT1 (PAv5)



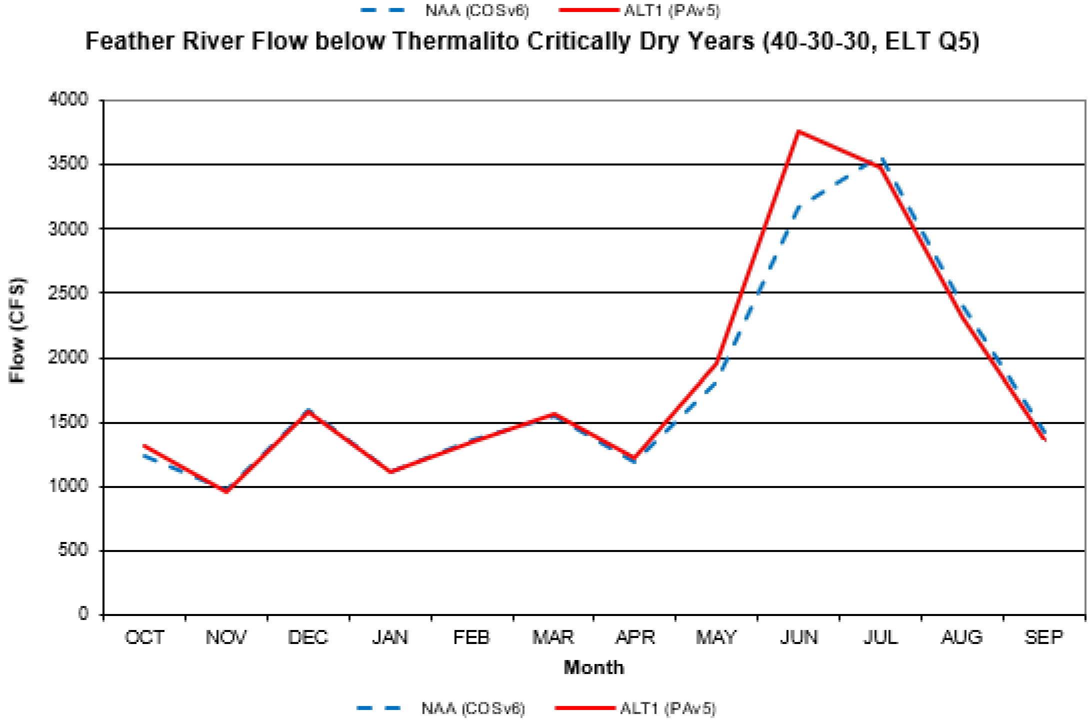


Figure O.3-52. CalSim II Estimates of Feather River Long-Term Average Flow below Thermalito, All Scenarios in Wet, Above Normal, Below Normal, Dry, and Critically Dry Water Years

Overall, simulated flows under the Alternative 1 and No Action Alternative scenarios are similar, but flows under the No Action Alternative are higher in September of wet and above normal years, and flows under Alternative 1 are slightly higher from April through June of above normal, below normal, dry, and critically dry water years and much higher in February of below normal years (Figure O.3-52).

Winter-Run Chinook Salmon

Winter-Run Chinook are not likely to be affected by changes in flow under Alternative 1 compared to the No Action Alternative due to their limited distribution in the Feather River.

Spring-Run Chinook Salmon

Spring-Run Chinook Salmon would be exposed to the effects of Alternative 1 based on their seasonal occurrence in the Feather River, minimum instream flow requirements in the HFC, and compliance with D-1641. Eggs and emerging fry of Spring-Run Chinook Salmon may occur in the Feather River from September through February (NMFS 2016a); juvenile Spring-Run Chinook Salmon occur in the Feather River year-round, with peak abundance from November through May; and adult Spring-Run Chinook Salmon peak in abundance in the Feather River from March through June. All life stages would thus be exposed to the effects of Alternative 1.

Spring-Run Chinook Salmon eggs and emerging fry would benefit from increased Alternative 1 flows, leading to increased dissolved oxygen in February of below normal years when Alternative 1 flows are significantly higher than No Action Alternative flows (Figure O.3-52). Juvenile Spring-Run Chinook Salmon would also benefit from increased Alternative 1 flows relative to No Action Alternative flows from November through March of wet years, January through April of above normal years, and February of below normal years when the increased flows result in increased rearing and foraging habitat and higher dissolved oxygencontent (Figure O.3-52). Adult Spring-Run Chinook Salmon would benefit from increased Alternative 1 flows relative to No Action Alternative flows from April through June of below normal, dry, and critically dry years due to the resulting increased attraction flows and holding habitat (Figure O.3-52). Because Spring-Run Chinook Salmon benefit from increased Alternative 1 flows relative to No Action Alternative flows during key months of all life stages and because Alternative 1 flows do not comply with minimum instream flow requirements only in dry and critically dry years (Table O.3-19, Figure O.3-52), flow-related actions under Alternative 1 would have beneficial effects on Spring-Run Chinook Salmon.

Fall-Run Chinook Salmon

Fall-Run Chinook Salmon would be exposed to the effects of Alternative 1 based on their seasonal occurrence in the Feather River, minimum instream flow requirements in the HFC, and compliance with D-1641. Fall-Run Chinook Salmon occur in the Feather River year-round, with eggs and emerging fry occurring between January and April; juveniles out-migrating year-round with peaks from January to April and August to November; and holding and migrating adults occurring between April and July (NMFS 2016a). All life stages would thus be exposed to the effects of Alternative 1.

Fall-Run Chinook Salmon eggs and emerging fry would benefit from the increased dissolved oxygendue to higher Alternative 1 flows from January to April of wet and above normal years and in February of below normal years (Figure O.3-52). Juvenile Fall-Run Chinook Salmon would benefit from increased Alternative 1 flows relative to No Action Alternative flows from January to April of wet and above normal years and in February of below normal years when increased flows result in increased rearing and foraging habitat, and higher dissolved oxygencontent (Figure O.3-52). Migrating adult Fall-Run Chinook Salmon would benefit from increased Alternative 1 flows relative to No Action Alternative flows from April to July of below normal, dry, and critically dry years due to increased attraction flows and holding habitat (Figure O.3-52). Because Fall-Run Chinook Salmon benefit from increased Alternative 1 flows relative to No Action Alternative flows during key months of all life stages and because Alternative 1 flows do not comply with minimum instream flow requirements only in dry and critically dry years

(Table O.3-19, Figure O.3-52), flow-related actions under Alternative 1 would have beneficial effects on Fall-Run Chinook Salmon.

Central Valley Steelhead

Central Valley Steelhead would be exposed to the effects of Alternative 1 based on their seasonal occurrence in the Feather River, minimum instream flow requirements in the HFC, and compliance with D-1641. Central Valley Steelhead eggs and fry occur in the Feather River from December to May; rearing juveniles occur year-round and out-migrate from January to May; peak adult migration occurs in September and October; and adult holding occurs from December to March (NMFS 2016a).

Alternative 1 flows can affect Central Valley Steelhead by influencing water temperature, DO, sedimentation, substrate composition, habitat, food availability, predation, entrainment and stranding risk, habitat availability, and migration cues. Differences in flow under Alternative 1 and the No Action Alternative are minimal during the January to May period in which Central Valley Steelhead juveniles are out-migrating in all but below normal water years, when Alternative 1 flows are considerably higher than No Action Alternative flows from mid-January through mid-March (Figure O.3-52). The increased flow under Alternative 1 during mid-January through mid-March of below normal years can benefit juveniles via increased rearing and foraging habitat and higher dissolved oxygencontent. The same is true for the December to May period in which Central Valley Steelhead eggs and fry are present in the Feather River. During the September and October adult peak migration period, No Action Alternative flows are higher than Alternative 1 flows in September of wet and above normal water years, which could create higher levels of flow attraction (Figure O.3-52); there are minimal differences during all other water years. During adult holding from December to March, differences between Alternative 1 and No Action Alternative flows are minimal except for in February of below normal water years when increased flows could increase available habitat (Figure O.3-52). Because Central Valley Steelhead benefit from increased Alternative 1 flows relative to No Action Alternative flows during key months of all life stages and because Alternative 1 flows do not comply with minimum instream flow requirements only in dry and critically dry years (Table O.3-19, Figure O.3-52), flow-related actions under Alternative 1 may have beneficial effects on Central Valley Steelhead.

North American Green Sturgeon

North American Green Sturgeon would be exposed to the effects of Alternative 1 based on their seasonal occurrence in the Feather River, minimum instream flow requirements in the HFC, and compliance with D-1641. Green Sturgeon eggs and larvae occur in the Feather River from March to July; larvae and juveniles occur from April to August; subadults occur year-round; and adults occur from March to August (NMFS 2016a).

Differences in flow under Alternative 1 and the No Action Alternative are minimal during all water years in the March to August period in which Green Sturgeon eggs, larvae, juveniles, and adults occur in the Feather River. Because subadults occur year-round, only subadults would be exposed to the larger differences between Alternative 1 and No Action Alternative flows; exposure would occur in February of below normal water years when Alternative 1 flows are greater than they are under the No Action Alternative and in September of above normal and wet water years when No Action Alternative flows are greater than flows under Alternative 1 (Figure O.3-52). Because flow differences between Alternative 1 and the No Action Alternative during key periods of Green Sturgeon presence in the Feather River are minimal and flows below the minimum instream flow requirements occur only in dry and critically dry years (Table O.3-19, Figure O.3-52), flow-related actions under Alternative 1 are not anticipated to substantially affect North American Green Sturgeon.

Potential changes to aquatic resources in the Feather River due to changes in water temperature from differences in flow

Water flow, combined with other environmental drivers, has the potential to affect aspects of water quality such as temperature. Water temperature has the potential to influence the condition and survival of fish species during all stages of their life cycle. Optimal water temperatures can facilitate physiological responses that range from faster growth rates to a heightened immune system, leading to a higher likelihood of survival. In contrast, effects of elevated water temperatures include an inability to satisfy metabolic demand and acute to chronic physiological stress, eventually leading to mortality (Stillwater Sciences 2006; Martin et al. 2017).

HEC-5Q/RecTemp modeling results provide predictions of water temperature at multiple locations in the Feather River HFC from below the Thermalito Afterbay to the mouth of the Feather River. Average water temperatures in the Feather River HFC at Gridley Bridge follow a seasonal pattern where they increase to a high point around 72°F in July or August and decrease to a low point around 47°F in January (Figure O.3-53). Flow releases from Oroville facilities influence Feather River water temperature primarily in summer and fall when these releases can help to lessen water temperatures when air temperatures and solar radiation levels are at their highest. Average water temperatures in the Feather River do not change substantially between water year type in winter, but water temperatures can reach levels up to 4°F warmer (approximately 75°F) in critically dry years than in wet years (approximately 71°F) (Figure O.3-54).

Alternative 1 was designed to follow flow regulation procedures similar to procedures under the No Action Alternative as a way to minimize potential adverse temperature-related effects on various fish species in the Feather River. Certain water temperature objectives were developed to aid the development of Alternative 1 operations (Table O.3-20).

Table O.3-20. Maximum Daily Mean Water Temperature Objectives for the Feather River HFC

Period	**Temperature (°F)**
January 1 to March 31	56
April 1 to 30	61
May 1 to 15	64
May 16 to 31	64
June 1 to August 31	64
September 1 to 8	61
September 9 to 30	61
October 1 to 31	60
November 1 to December 31	56

Source: NMFS 2016a.

Modeled average water temperatures under both Alternative 1 and the No Action Alternative (Figure O.3-53) exceed the daily average water temperature objectives of 64°F from June 1 to August 31 and 61°F from September 1 to 30 (Table O.3-20). There is, therefore, potential for adverse temperature-related effects on Feather River anadromous fish species, although the presence and magnitude of these effects would vary between the different species and life stages. In particular, these modeled average temperatures would reach suboptimal or stress-inducing levels for Spring-Run Chinook eggs, fry, and adults, migrating Central Valley Steelhead, and Green Sturgeon eggs, fry, and post-spawn adults.

Modeling results indicate that water temperatures under Alternative 1 operations would be similar to temperatures under the No Action Alternative for much of the year (Figures O.3-53 and O.3-54). In August and September, though, the water in the Feather River HFC at Gridley Bridge would reach temperatures, on average, up to 1°F warmer than under the No Action Alternative (Figure O.3-53). The most pronounced difference in August and September water temperatures between Alternative 1 and No Action Alternative scenarios would occur in wet years when this temperature difference could reach as much as 3°F, whereas no difference is projected in drier water years (Figure O.3-54). In dry water years, a small difference in water temperature between Alternative 1 and No Action Alternative scenarios would occur instead in June, when Alternative 1 water temperatures would surpass No Action Alternative temperatures by approximately 1°F (Figure O.3-54). These differences in water temperature between Alternative 1 and the No Action Alternative would therefore occur in summer months when water temperatures are higher (> 60°F) and more likely to lead to physiological stress and mortality. The effects of water temperature on fish in the Feather River vary among species and life stages; however, water temperatures under the No Action Alternative and Alternative 1 scenarios would surpass suboptimal levels for Chinook Salmon between 58°F and 75.2°F, for Steelhead between 55°F and 70°F, and for Green Sturgeon between 66°F and 70°F (Table O.3-21).

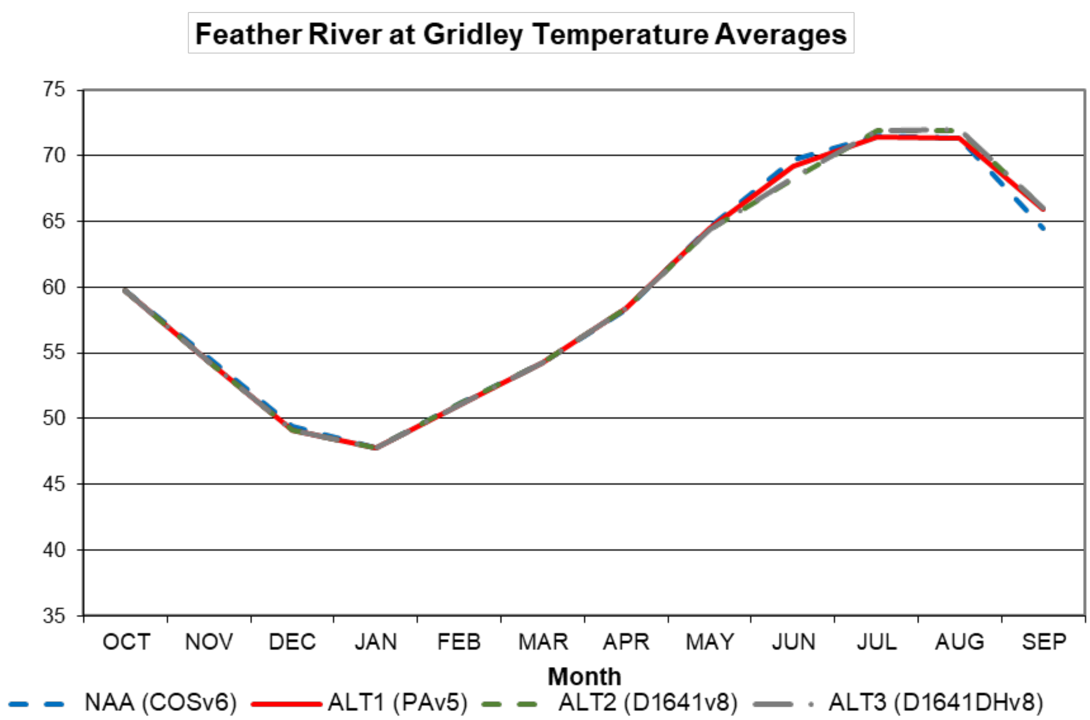


Figure O.3-53. RecTemp Average Feather River Water Temperatures at Gridley Bridge under the No Action Alternative, Alternative 1, Alternative 2, and Alternative 3 Scenarios

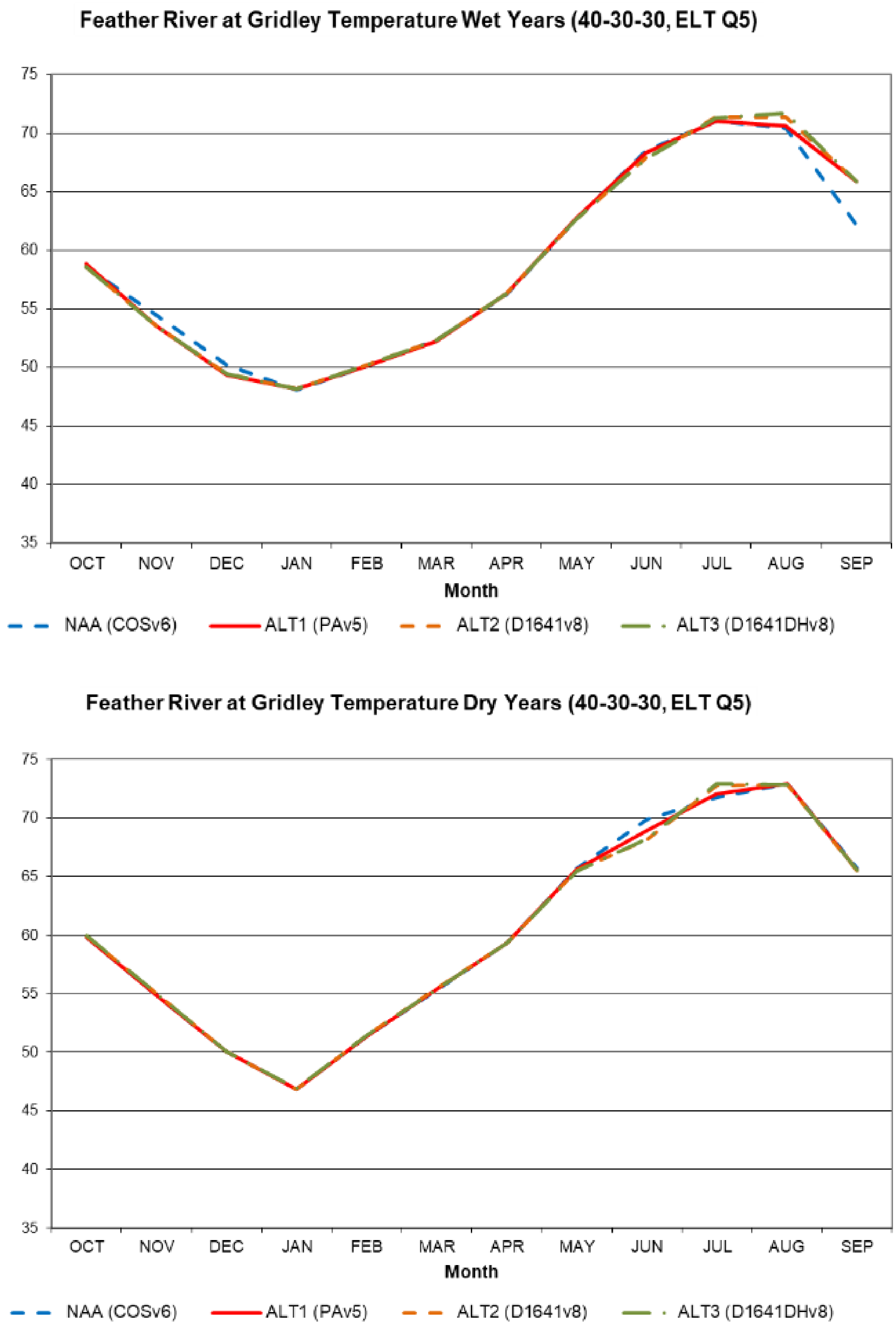


Figure O.3-54. RecTemp Average Estimated Feather River Water Temperatures at Gridley Bridge in Wet and Dry Water Year Types under the No Action Alternative, Alternative 1, Alternative 2, and Alternative 3 Scenarios

Table O.3-21. Water Temperatures Suitable for Spring-Run and Fall-Run Chinook Salmon, Central Valley Steelhead, and Green Sturgeon by Life Stage

Life Stage	Peak Occurrence	Optimal	Suboptimal	Stress-inducing
Spring-Run Chinook Salmon				
Eggs to fry	September to October	< 54°F	54°F to 58°F	> 58°F
Rearing to out-migrating	November to May	< 60°F	60°F to 65°F	> 65°F
Migrating adults	March to June	< 56°F	56°F to 65°F	> 65°F
Adult holding	May to August	< 60.8°F	60.8°F to 66.2°F	> 66.2°F
Fall-Run Chinook Salmon				
Eggs to fry	October to April	48.2°F to 55.4°F	55.4°F to 62.6°F	> 62.6°F
Rearing to out-migrating	April to June	55.4°F to 68°F	68°F to 75.2°F	> 75.2°F
Migrating adults	June to April	50°F to 68°F	68°F to 69.8°F	> 69.8°F
Central Valley Steelhead				
Eggs to fry	January	46°F to 52°F	52°F to 55°F	> 55°F
Rearing to out-migrating	January to May	< 65°F	65°F to 68°F	> 68°F
Migrating adults	September to October	< 52°F	52°F to 70°F	> 70°F
Adult holding	December to March	< 60.8°F	60.8°F to 66.2°F	> 66.2°F
Green Sturgeon				
Eggs to fry	May to July	53°F to 65°F	65°F to 66°F	> 66°F
Rearing to out-migrating	May to October	58°F to 66°F	66°F to 69°F	> 69°F
Migrating adults	March to May	53°F to 64°F	64°F to 66°F	> 66°F
Post-spawn adults	March to August	46°F to 68°F	68°F to 70°F	>70°F

Sources: NMFS 2016a; Stillwater Sciences 2006; CDFG 2012a, 2012b.

Winter-Run Chinook Salmon

Winter-Run Chinook are not likely to be affected by changes in flow under Alternative 1 compared to the No Action Alternative due to their limited distribution in the Feather River.

Spring-Run Chinook Salmon

Effects of water temperature on Spring-Run Chinook have been heavily studied in the Feather River, resulting in an understanding of the optimal (beneficial), suboptimal, and stress-inducing (adverse) temperature ranges for each life stage during its period of peak abundance (Table O.3-21).

A difference in water temperature between Alternative 1 and No Action Alternative scenarios during the peak occurrence period for Spring-Run Chinook eggs and emerging fry would occur in in September of wet water years when temperatures under Alternative 1 flows could be up to 3°F higher than temperatures under No Action Alternative flows (Figure O.3-54 and Table O.3-21). This would result in potentially adverse effects from the slightly higher water temperatures under Alternative 1 than under the No Action Alternative, yet water temperatures under both scenarios would fall in the stress-inducing range for this life stage (Table O.3-21). During the peak abundance period of juvenile Spring-Run Chinook (November to May), there is no projected difference between water temperatures under Alternative 1 and the No Action Alternative (Figure O.3-53 and Table O.3-21). For the majority of the peak occurrence range for migrating and holding adults, there is no difference in water temperature between Alternative 1 and the No Action Alternative (Figure O.3-53 and Table O.3-21); in June of dry water years, however, water temperatures under Alternative 1 could be up to 1°F lower than under the No Action Alternative (Figure O.3-54). The effect on adult Spring-Run Chinook would likely be negligible because modeled water temperatures would cross the threshold for stress-inducing temperatures under both Alternative 1 and the No Action Alternative for both life stages (Figure O.3-54 and Table O.3-21).

Alternative 1 therefore has the potential for slightly adverse water temperature-related effects on eggs and fry but very slightly beneficial effects on adults, so its overall effect on Spring-Run Chinook relative to the No Action Alternative is negligible.

Fall-Run Chinook Salmon

Effects of water temperature on Fall-Run Chinook have been heavily studied in the Feather River, resulting in an understanding of the optimal (beneficial), suboptimal, and stress-inducing (adverse) temperature ranges for each life stage (Table O.3-21).

Fall-Run Chinook eggs and fry are present in the Feather River between October and April when there is no projected difference between water temperatures under Alternative 1 and the No Action Alternative (Figure O.3-53 and Table O.3-21). In June of dry water years, water temperatures under Alternative 1 could be up to 1°F lower than under the No Action Alternative, possibly affecting juvenile and migrating adult Fall-Run Chinook (Figure O.3-54). The effect of the June temperature difference would be beneficial but could be slightly more pronounced for both juveniles and adults than otherwise expected since water temperatures under Alternative 1 in these years would remain at optimal levels longer, while they would rise to suboptimal levels under No Action Alternative flows (Figure O.3-54 and Table O.3-21). For migrating adults, water temperatures under Alternative 1 would also remain at stress-inducing and then suboptimal levels approximately one month longer than in the No Action Alternative scenario in September of wet water years (Figure O.3-54 and Table O.3-21). The net effect of Alternative 1 water temperatures on migrating adult Fall-Run Chinook relative to the No Action Alternative would be expected to be slightly adverse overall due to the greater magnitude of the water temperature difference between Alternative 1 and the No Action Alternative in September of wetter years relative to the difference in June of drier years but would ultimately depend on the rainfall levels experienced in the watershed.

Alternative 1 therefore has the potential for both slightly beneficial and slightly adverse water temperature-related effects on Fall-Run Chinook relative to the No Action Alternative, so its overall effects would be negligible.

Central Valley Steelhead

Effects of water temperature on Central Valley Steelhead have been heavily studied, resulting in an understanding of the optimal (beneficial), suboptimal, and stress-inducing (adverse) temperature ranges for each life stage during its period of peak abundance (Table O.3-21).

Central Valley Steelhead eggs, fry, juveniles, and holding adults are present in the Feather River in winter and spring months when there is no projected difference between water temperatures under Alternative 1 and the No Action Alternative (Figure O.3-53 and Table O.3-21). Migrating (ocean to river) adult

Steelhead peak in abundance in the Feather River between September and October (Table O.3-21). Modeled water temperatures for Alternative 1 and the No Action Alternative differ in September of wet water years when temperatures under Alternative 1 could be up to 3°F higher than temperatures under No Action Alternative flows (Figure O.3-54), yet water temperatures would remain in the suboptimal range for migrating adults under Alternative 1 and the No Action Alternative (Table O.3-21). Adverse effects of water temperature on this life stage are therefore anticipated to be slightly less severe under the No Action Alternative than under Alternative 1. Alternative 1 therefore has the potential for slightly adverse water temperature-related effects on migrating adults relative to the No Action Alternative.

North American Green Sturgeon

Effects of water temperature on Green Sturgeon have been heavily studied in the Feather River, resulting in an understanding of the optimal (beneficial), suboptimal, and stress-inducing (adverse) temperature ranges for each life stage (Table O.3-21).

Green Sturgeon eggs and emerging fry occur in the Feather River from May to July, rearing and out-migrating juveniles from May to October, and post-spawn adults from March to August (Table O.3-21). All life stages would be exposed to water temperatures up to 1°F lower under Alternative 1 than under the No Action Alternative in June of dry water years (Figure O.3-54), yet modeled water temperatures are above the threshold for stress-inducing temperatures for eggs and fry under both Alternative 1 and the No Action Alternative (Table O.3-21). For juveniles and post-spawn adults, though, water temperatures would rise to stress-inducing and suboptimal levels, respectively, later in June under Alternative 1 than under the No Action Alternative (Table O.3-21). Juvenile Green Sturgeon are also present in the Feather River during September when, in wet water years, water temperatures under Alternative 1 flows could be up to 3°F higher than temperatures under No Action Alternative flows (Figure O.3-54 and Table O.3-21). Water temperatures in wet water years would drop from stress-inducing levels for juveniles to suboptimal levels and again to optimal levels later in the month under Alternative 1 than under the No Action Alternative (Figure O.3-54, Table O.3-21). The effects of water temperature on juvenile Green Sturgeon under Alternative 1 would then be dependent on water year types with slightly beneficial effects in dry water years and slightly adverse effects in wet water years, so the net effect would be negligible. Migrating (ocean to river) adult Green Sturgeon reach the Feather River between March and May and do not experience any temperature differences between Alternative 1 and the No Action Alternative.

Alternative 1 therefore has the potential for slightly adverse water temperature-related effects on juveniles in wet water years but very slightly beneficial effects on eggs, fry, juveniles, and post-spawn adults in dry water years, so its overall effect on North American Green Sturgeon relative to the No Action Alternative is minor and dependent on annual rainfall totals.

O.3.3.5 *American River*

Potential changes to aquatic resources in the American River from flood control

Flood control would be similar under Alternative 1, compared to the No Action Alternative and would include following the USACE Water Control Manual, with the addition of working with the American River Stakeholders to define the “planning minimum”, an appropriate amount of storage in Folsom Reservoir that represents the lower bound for typical forecasting processes at the end of calendar year. The objective of the planning minimum is to preserve storage to protect against future drought conditions and to facilitate the development of the coldwater pool when possible. The objective of incorporating the planning minimum into the forecasting process is to provide releases of salmonid-suitable temperatures to the lower American River and reliable deliveries to American River water agencies. Analysis of Folsom

Storage indicates that under average conditions, there would be little difference in flood control storage under Alternative 1, compared to the No Action Alternative (Figure O.3-55). Flood control storage would be slightly greater in dry years (Figure O.3-56), and the same in wet years (Figure O.3-57), compared to the No Action Alternative.

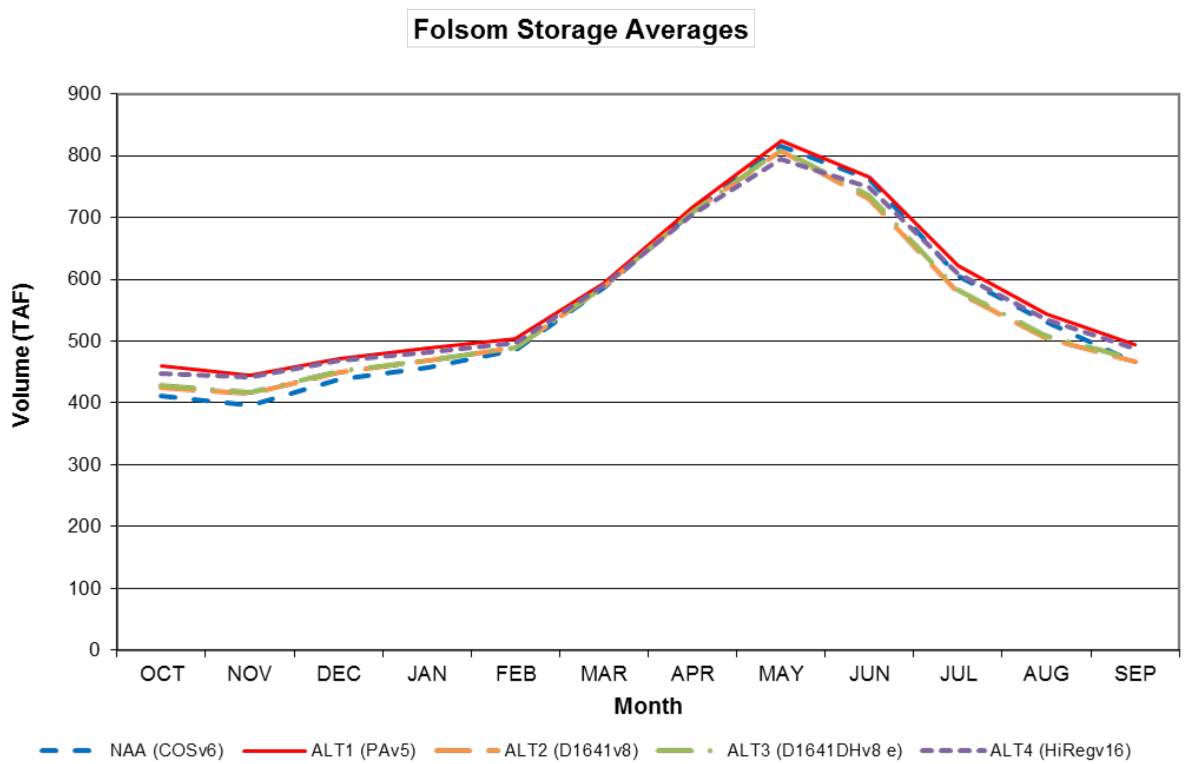


Figure O.3-55. Folsom Reservoir Storage under Average Conditions

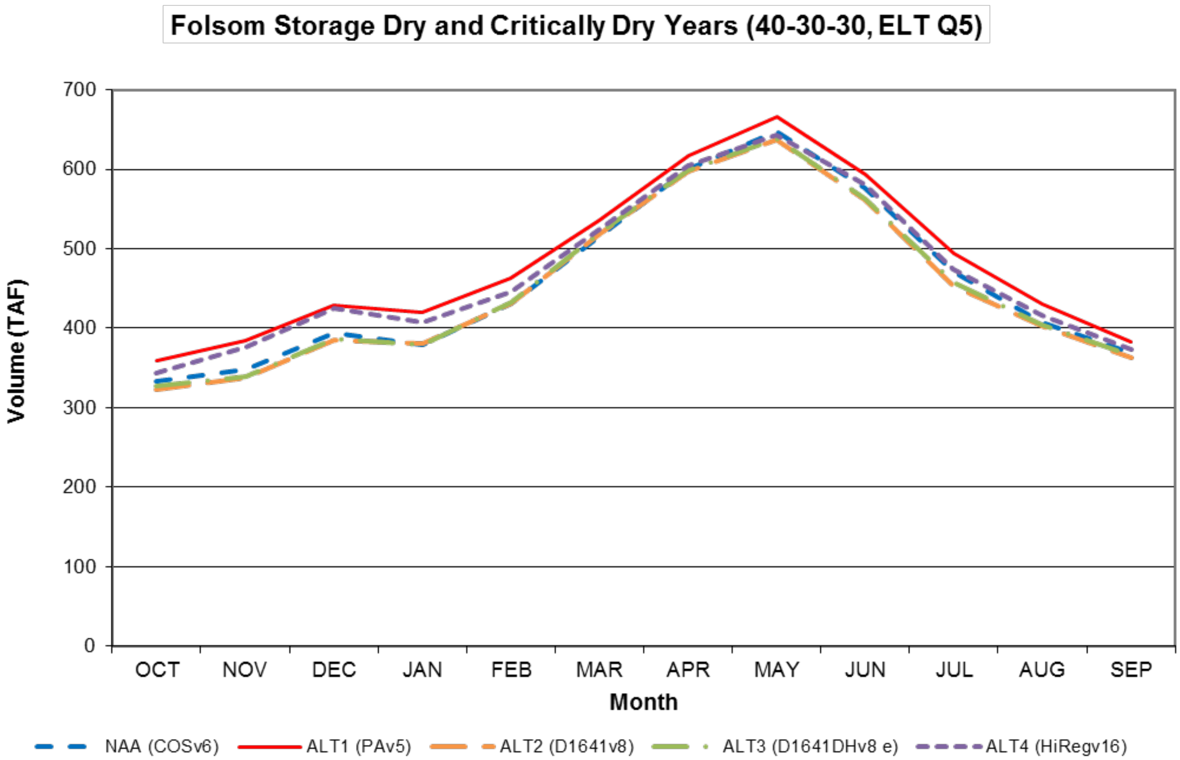


Figure O.3-56. Folsom Reservoir Storage in Dry and Critically Dry Years

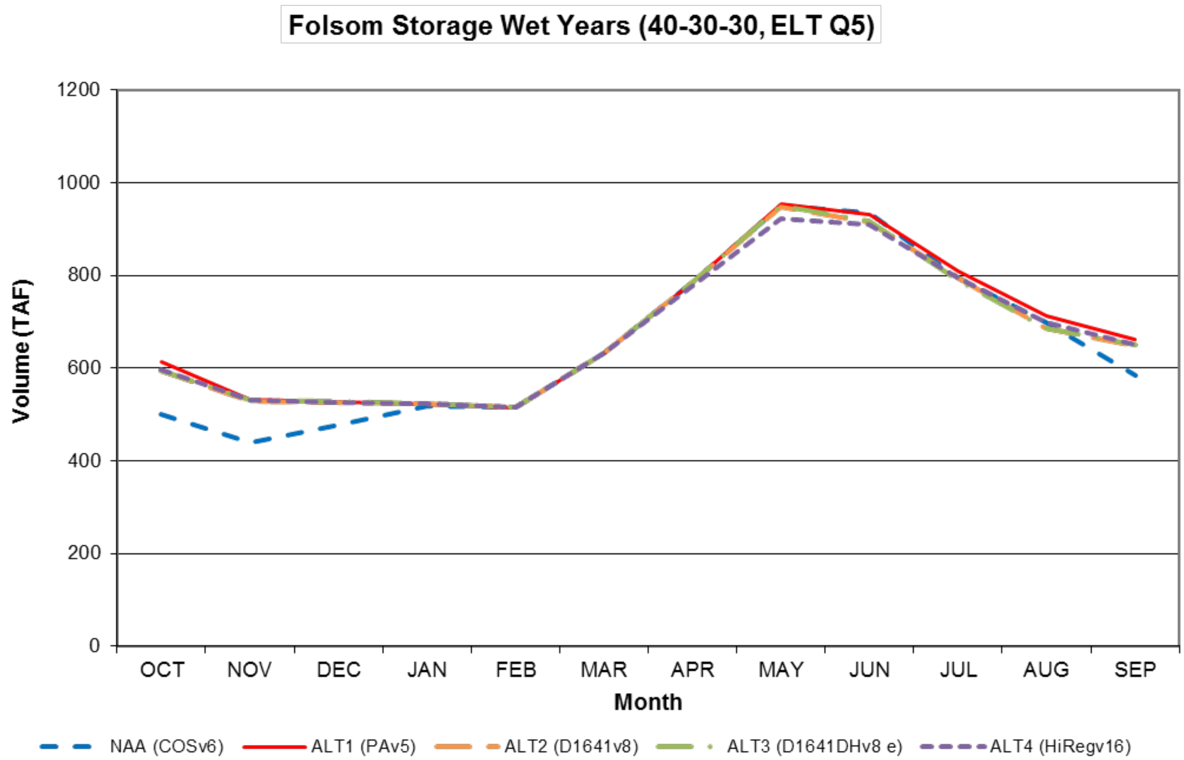


Figure O.3-57. Folsom Reservoir Storage in Wet Water Years

Potential changes to aquatic resources from Folsom Reservoir operations in the American River to meet Delta salinity requirements

Folsom Reservoir operations to address Delta water quality requirements under D-1641 would not change under Alternative 1, compared to the No Action Alternative. Folsom Reservoir flow requirements includes releases to meet Delta standards under D-1641, as needed. Since Folsom Reservoir is the closest reservoir to the Delta, releases from Folsom can more quickly address Delta water quality requirements. Releases to address Delta water quality objectives would be conducted, as needed, in coordination with the American River stakeholders. Releases to address Delta water quality objectives would improve water quality conditions, and thus habitat conditions for fish and other aquatic species in the Delta when hydrologic conditions are negatively affecting salinity levels.

Potential changes to aquatic resources from flows in the American River

Flow objectives for Alternative 1 are similar to the objectives for the No Action Alternative with the intent of providing suitable conditions for Fall Chinook and Steelhead. Flows under Alternative 1 are according to the 2017 Flow Management Standard, where additional flow measures include minimizing releases above 4,000 cfs during sensitive life stages, redd dewatering protective measures in January through May (holding releases relatively constant), providing spring pulse flows, and continued summer releases for instream temperature control. Although these objectives result additional flow measures, the modeling indicates that overall change to flows in the American River below Nimbus Dam are minor, and that instream flows during critically dry periods for Fall Chinook Salmon and Steelhead are driven more by hydrologic conditions (wet versus dry years) than the operations to meet objectives.

Flows in the American River below Nimbus Dam would be similar throughout the year under Alternative 1 with relatively minor differences in average flows (Figure O.3-58) and in wet years (Figure O.3-59), under Alternative 1 compared to the No Action Alternative. In dry and critically dry years, flows would be similar under Alternative 1 and the No Action Alternative, with some differences in the late winter/early spring months and in the summer months, (Figure O.3-60). Flows would be higher in February through March, slightly lower in July, and higher in August and September.

Changes to minimum flows in the American River below Nimbus Dam would be more evident in low water years, with lower minimum flows in October through January, higher minimum flows in February and March, and higher flows in July through September compared to the No Action Alternative (Figure O.3-60).

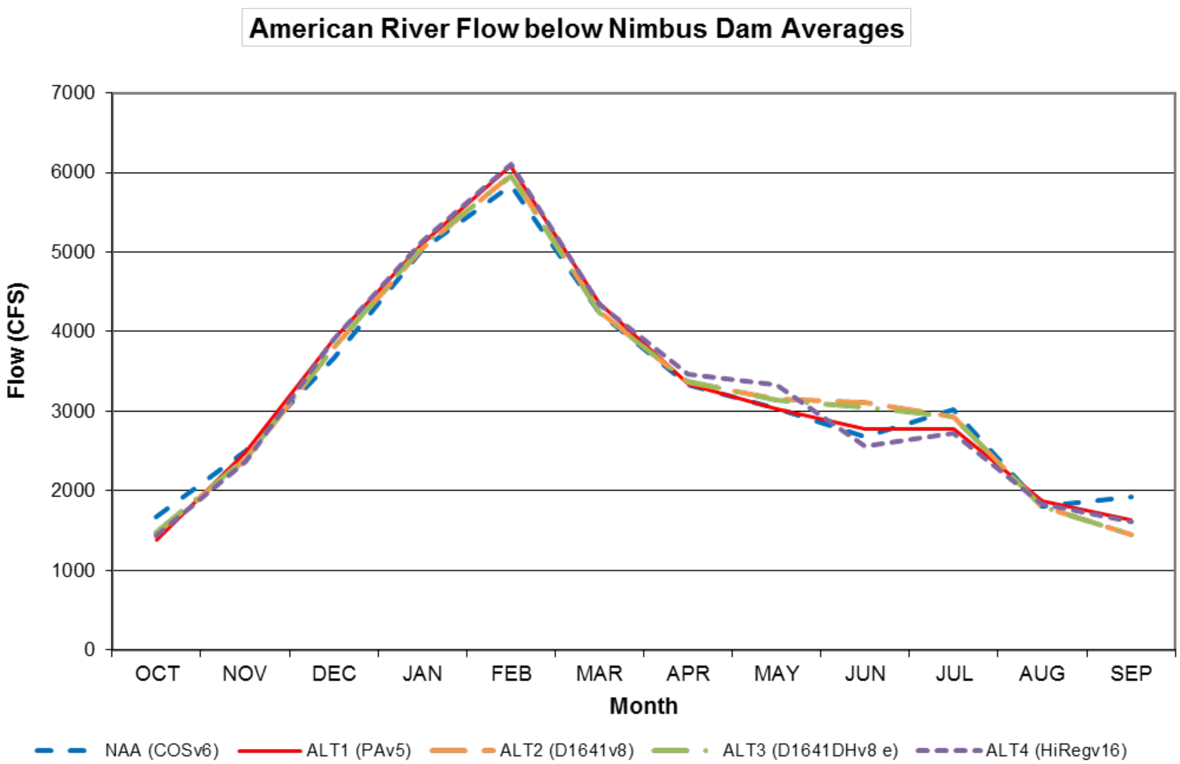


Figure O.3-58. Average Flows in the American River below Nimbus Dam at Watt Avenue

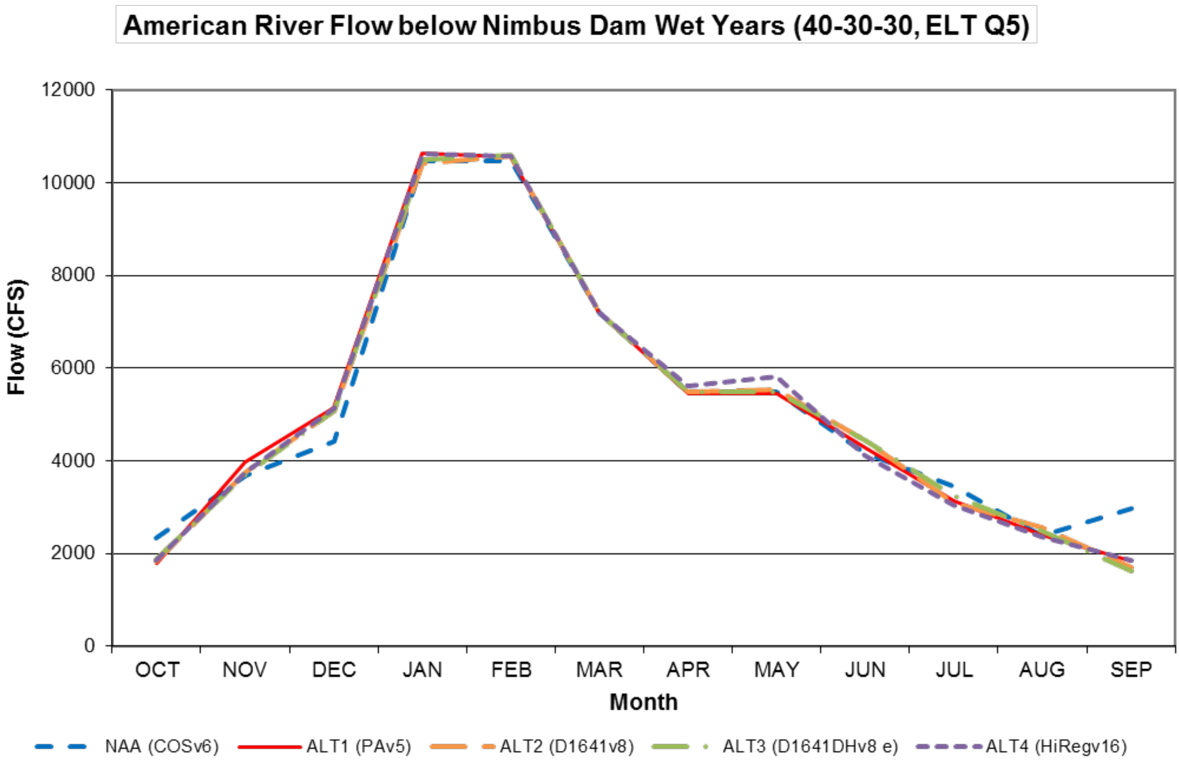


Figure O.3-59. Flows in the American River below Nimbus Dam in Wet Water Years

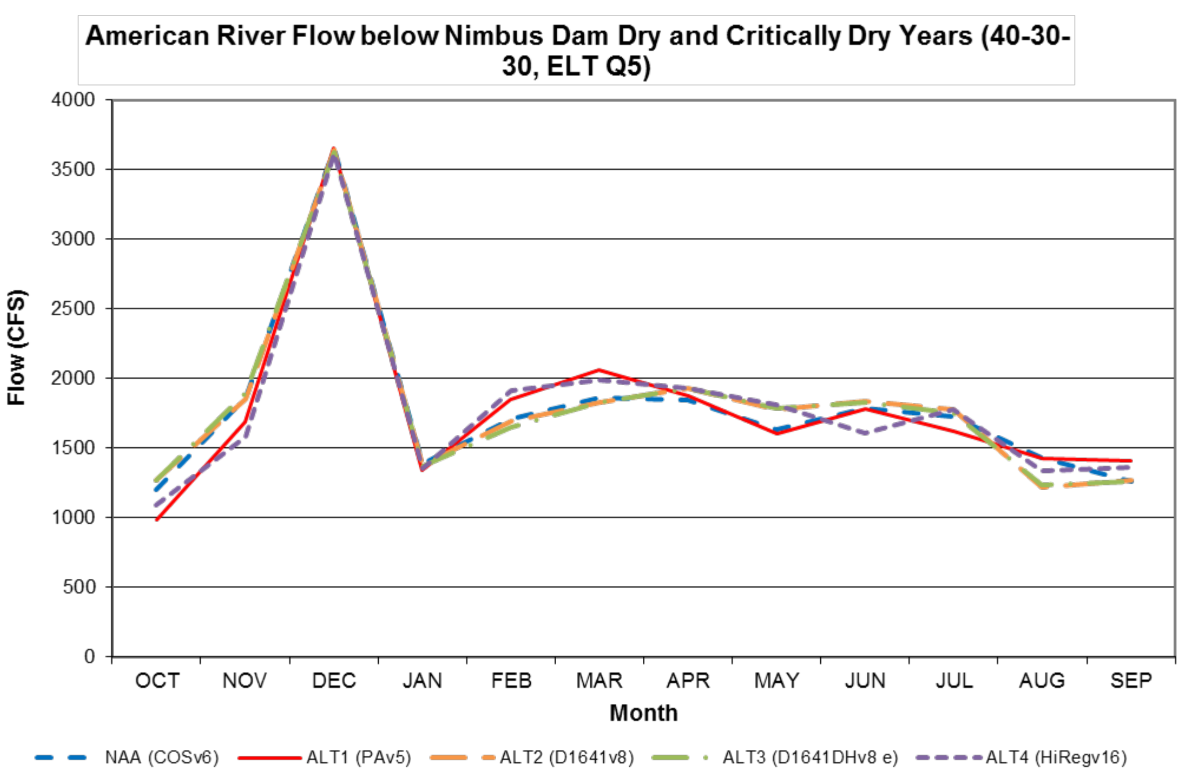


Figure O.3-60. Flows in the American River below Nimbus Dam in Dry and Critically Dry Years

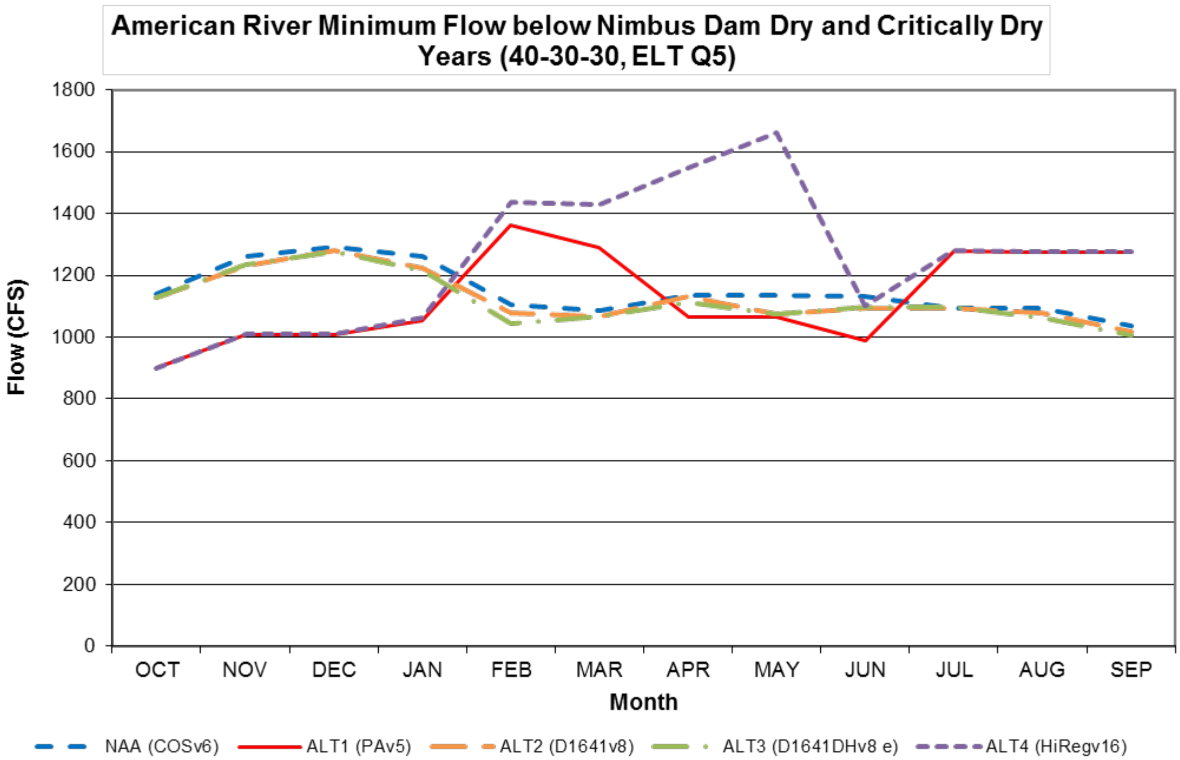


Figure O.3-61. Minimum Flows in the American River below Nimbus Dam in Dry and Critically Dry Years

Potential changes to aquatic resources in the American River due to changes in water temperature

The water temperature objectives for Alternative 1 are similar the objectives for the No Action Alternative. The objectives address the needs for Steelhead incubation and rearing during the late spring and summer, and for fall–run Chinook Salmon spawning and incubation starting in late October or early November. Specific additional objectives for Alternative 1 are to maintain a daily average water temperature of 65°F (or other temperature as determined by the temperature modeling) or lower at Watt Avenue Bridge from May 15 through October 31, to provide suitable conditions for juvenile Steelhead rearing in the lower American River, and to provide cold water for Fall-Run Chinook Salmon spawning. In addition, the proposed alternative shutter configurations at Folsom Dam to allow temperature flexibility as part of adaptive management may provide for additional improved water temperatures.

Average water temperatures are similar throughout the year in the lower American River under Alternative 1, compared to the No Action Alternative (Figure O.3-62). Differences in water temperatures are more a function of hydrologic conditions than operations to meet objectives, wither lower summer high temperatures wet years (Figure O.3-63) than in dry years (Figure O.3-64). Maximum water temperatures are lower for Alternative 1 in summer months in comparison to the No Action Alternative and the other action alternatives, which would beneficially affect fishery resources (Figure O.3-65).

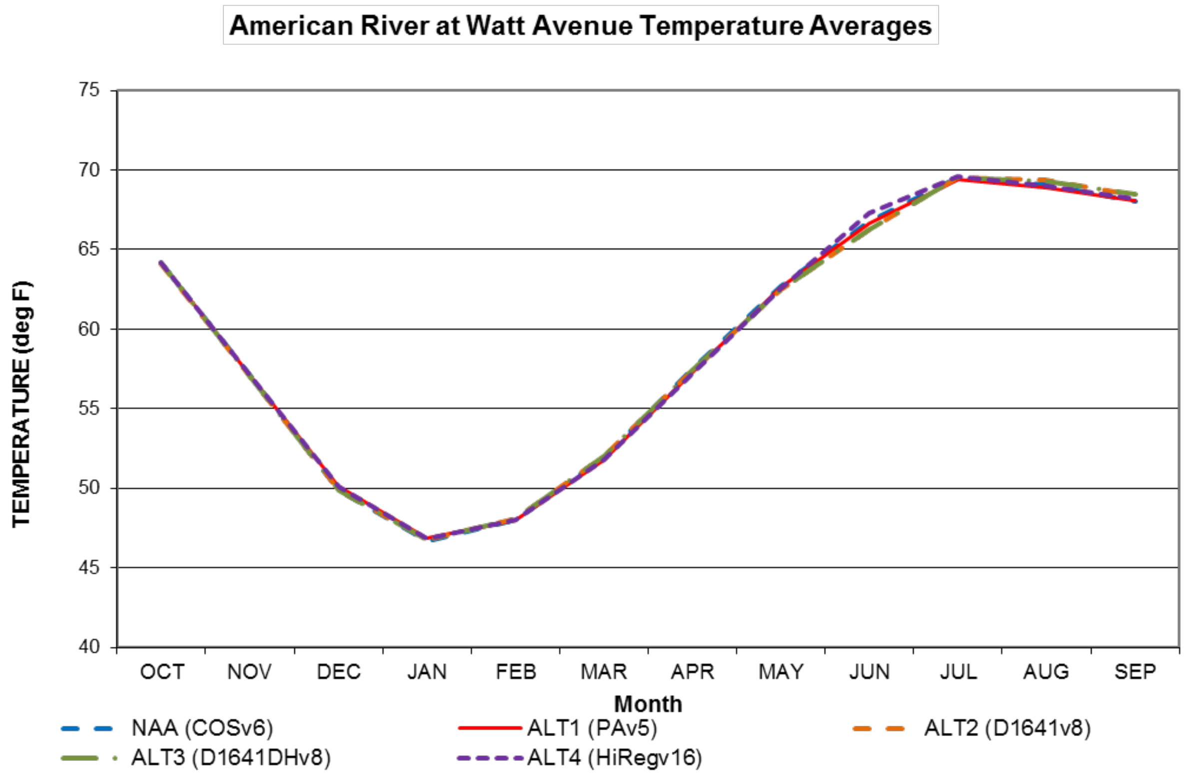


Figure O.3-62. Average Temperatures at Watt Avenue on the American River

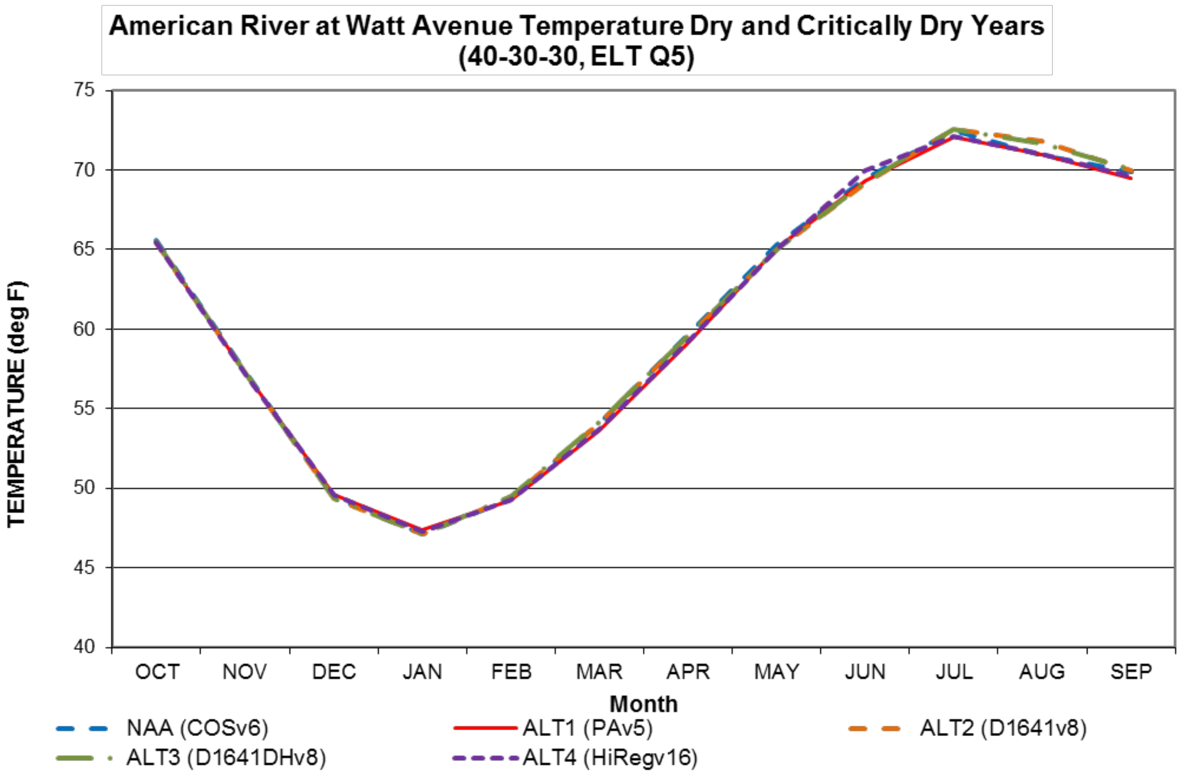


Figure O.3-63. Average Temperatures at Watt Avenue on the American River in Dry and Critically Dry Years

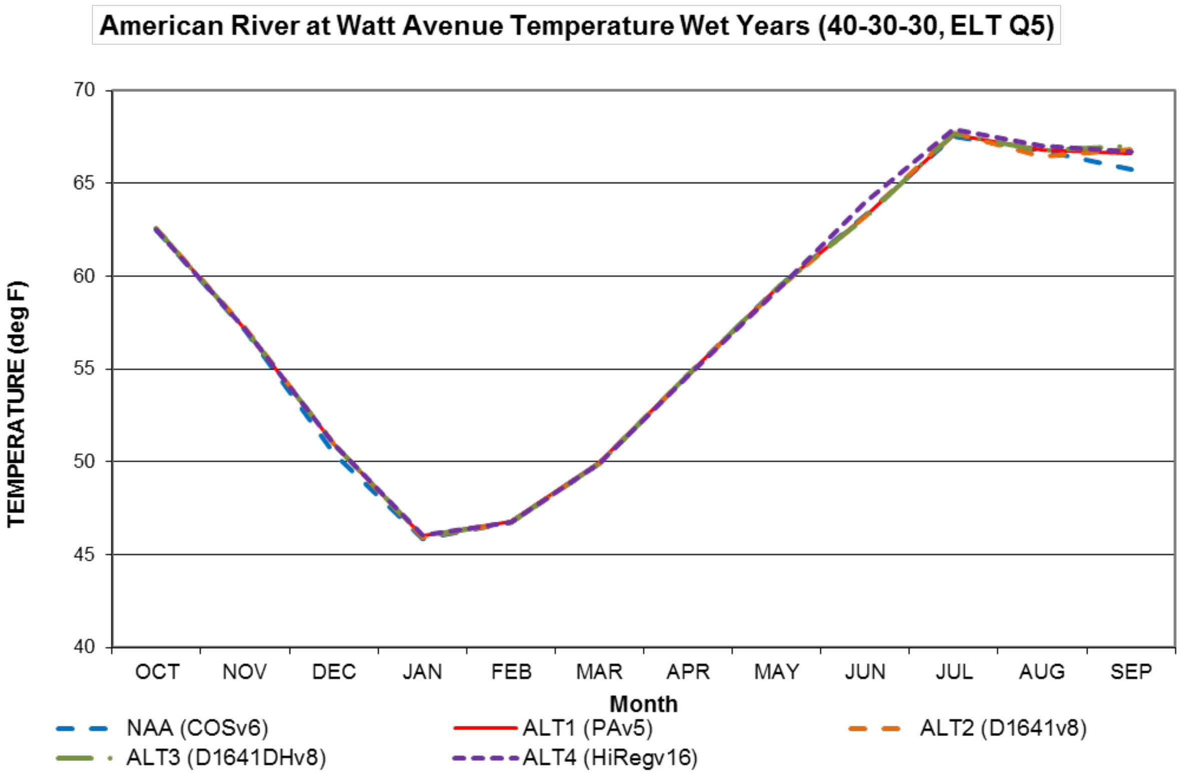


Figure O.3-64. Average Temperatures at Watt Avenue on the American River

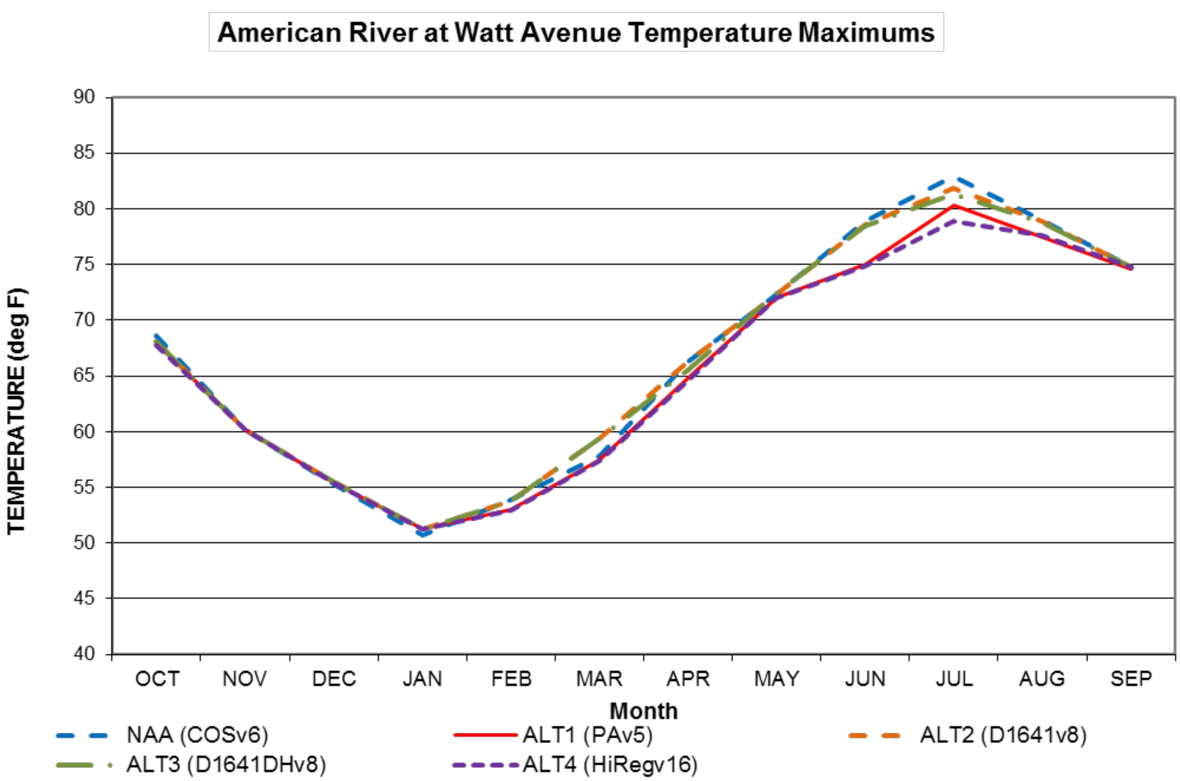


Figure O.3-65. Maximum Temperatures at Watt Avenue on the American River

Potential changes to aquatic resources in the American River from habitat restoration

Habitat for Chinook Salmon and Steelhead in the lower American River would be improved under Alternative 1, compared to the No Action Alternative. Alternative 1 includes implementation of spawning and rearing habitat projects in the American River and its tributaries. This action will likely result in long-term improvements to the habitat and conditions for Fall-Run Chinook Salmon, Steelhead, and other aquatic inhabitants. The spawning and rearing habitat projects would result in increased total spawning habitat area, increased and improved side channel habitat, improved intragravel incubation conditions, increased and improved total rearing habitat area, improved overall habitat complexity, and cover and refugia.

O.3.3.6 *Stanislaus River*

Potential changes to aquatic resources in the Stanislaus River due to changes in flow

Reclamation has several control points in the Stanislaus River to measure flow. Those control points are located at Goodwin Dam (below) and at mouth of Stanislaus River. Additionally, storage and releases are factored in at New Melones Reservoir.

Under Alternative 1, Reclamation would operate New Melones Reservoir (as measured at Goodwin Dam) in accordance with a Stepped Release Plan (SRP) that varies by hydrologic conditions/water year type as shown in Table O.3-22. The SRP would be implemented similarly to current operations under the 2009 BO RPA Action III.1.3 with a default daily hydrograph, and the ability to shape monthly and seasonal flow volumes to meet specific biological objectives. The SRP would be a sustainable operation on the Stanislaus River that strives to meet requirements for fish flows, temperature, water quality, dissolved oxygen, and water deliveries.

Table O.3-22. New Melones Stepped Release Plan—Annual Releases by Water Year Type

Water Year Type	Annual Release (TAF)
Critically Dry	184.3
Dry	233.3
Below Normal	344.6
Above Normal	344.6
Wet	476.3

Below Goodwin Dam

Under Alternative 1, flows are generally lower when compared to the No Action Alternative (Figures O.3-66 and O3-67.); however, the overall change to flows below Goodwin Dam are minor. Central Valley Steelhead, Fall- /Late Fall-Run Chinook Salmon, and Spring-Run Chinook Salmon would experience minor effects associated with the minor decrease in average flows. Flows under Alternative 1 are generally better for salmonids as water operations are similar to the No Action Alternative.

Additionally, under Alternative 1, spawning and rearing habitat restoration are proposed to offset effects related to changes in flow. Restoration activities for spawning and rearing habitat would yield immediate benefits. Existing riparian vegetation would be increased with the creation of side-channel habitat, providing instream object cover and overhanging object cover; new shaded riverine habitat; and additional area for food source. The creation of the side-channel and floodplain rearing habitat would also increase the aquatic habitat complexity and diversity within the Stanislaus River and provide additional predator escape cover. The habitat restoration would result in increased survival of juvenile salmonids in the Stanislaus River.

Mouth of Stanislaus River

Flows at the mouth of the Stanislaus River under Alternative 1 are similar to the below Goodwin Dam control point (Figures O.3-68 and O.3-69). Effects to salmonids are similar to those described above due to water operations being similar to the No Action Alternative.

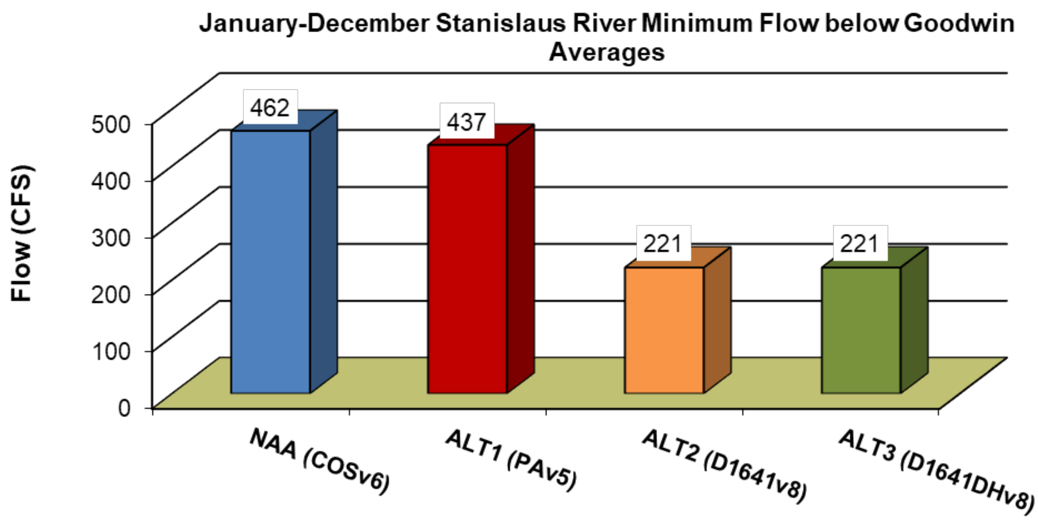


Figure O.3-66. Annual Average Minimum Flow below Goodwin Dam for Each Action Alternative

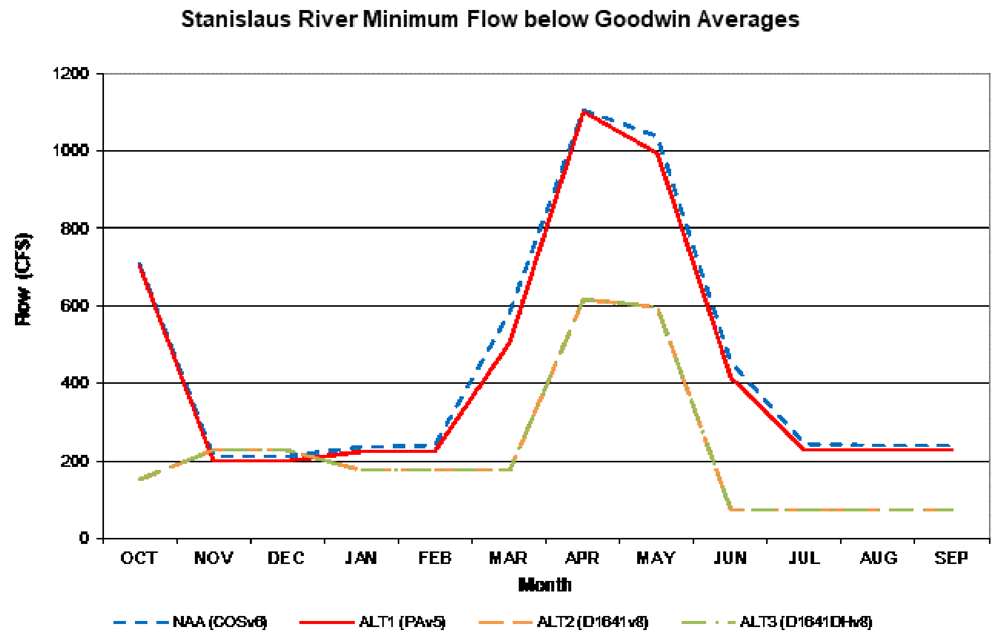


Figure O.3-67. Stanislaus River Average Minimum Flow below Goodwin Dam

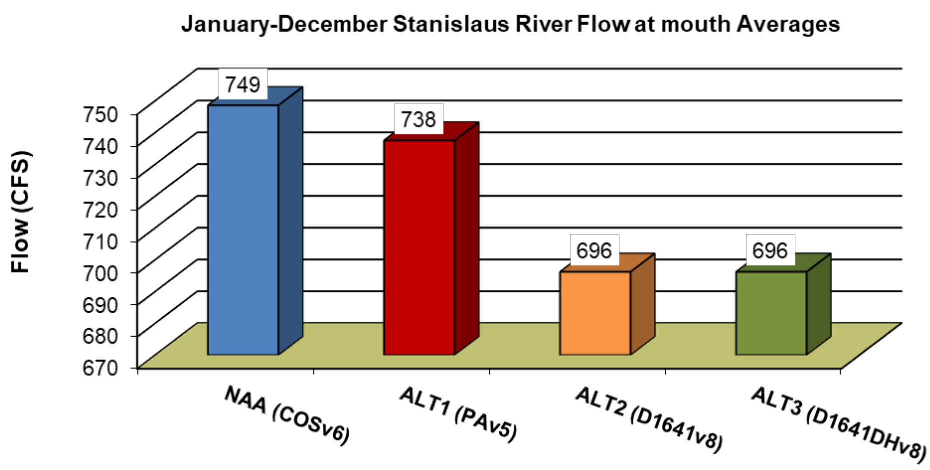


Figure O.3-68. Average Annual Flow at the Mouth of the Stanislaus River

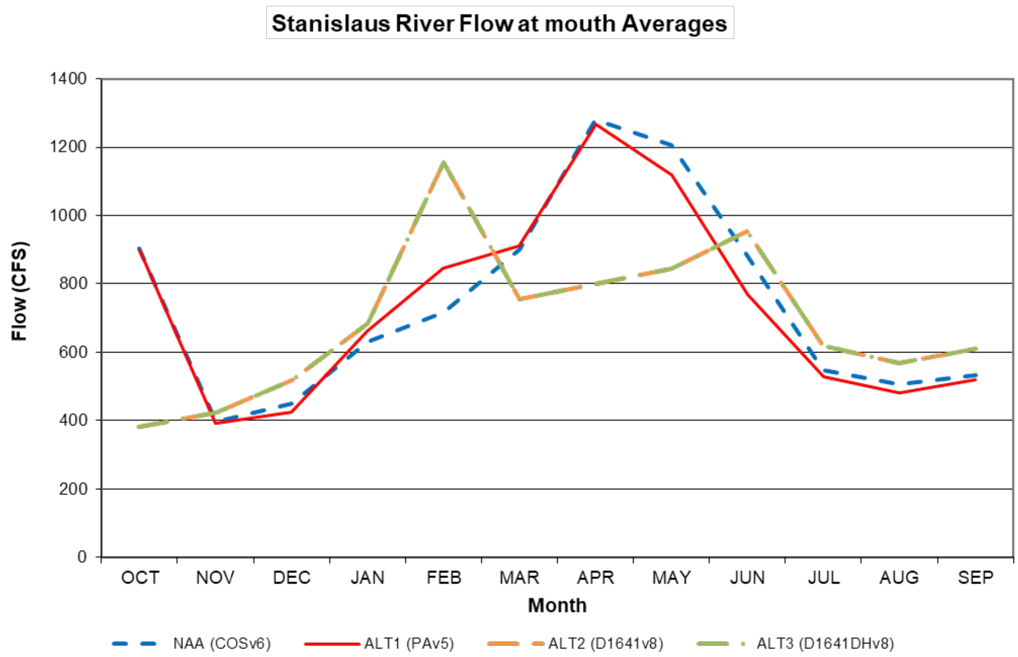


Figure O.3-69. Average Monthly Flow at the Mouth of the Stanislaus River

Potential changes to aquatic resources in the Stanislaus River due to changes in water temperature

Under Alternative 1, Reclamation proposes to implement the New Melones SSRP to create a sustainable operation on the Stanislaus River that strives to meet requirements for fish flows, temperature, water quality, dissolved oxygen, and water deliveries. Managing the cold water at New Melones with the SRP will benefit Central Valley Steelhead, as well as aide in Reclamation meeting the temperature objects for the restoration of Central Valley Chinook Salmon. The temperature targets are include in Table O.3-23**.**

Table O.3-23. Temperature Objectives for the Restoration of Central Valley Chinook Salmon

Monthly Water Temperature Objectives for the San Joaquin River Restoration Program

Spring-Run and Fall-Run Chinook Salmon

Life Stage	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec
Adult Migration			Optimal: ≤59°F (15°C) Critical: 62.6 – 68°F (17 – 20°C) Lethal: >68°F (20°C)									
Adult Holding (Spring-Run Only)				Optimal: ≤55°F (13°C) Critical: 62.6 – 68°F (17 – 20°C) Lethal: >68°F (20°C)								
Spawning								Optimal: ≤57°F (13.9°C) Critical: 60 – 62.6°F (15.5 – 17°C) Lethal: 62.6°F or greater (17°C)				
Incubation and Emergence								Optimal: ≤55°F (13°C) Critical: 58 – 60°F (14.4 – 15.6°C) Lethal: >60°F (15.6°C)				
In-River Fry/Juvenile	Optimal: ≤60°F (15.6°C), young of year rearing; ≤62.6°F (18°C), late season rearing (primarily spring-run) Critical: 64.4 – 70°F (18-21.1°C) Lethal: >75 °F (23.9°C), prolonged exposure											
Floodplain Rearing*	Optimal: 55 – 68°F (13 – 20°C), unlimited food supply											
Outmigration	Optimal: ≤60°F (15.6°C) Critical: 64.4 – 70°F (18 – 21.1°C) Lethal: >75°F (23.9°C), prolonged exposure											

Sources: EPA 2003, Rich 2007, Pagliughi 2008, Gordus 2009

Note:

* Floodplain rearing temperatures represent growth maximizing temperatures based on floodplain condition. No critical or lethal temperatures are cited assuming fish have volitional access and egress from floodplain habitat to avoid unsuitable conditions.

Shaded box indicates life stage is present Key:

°F = degrees Fahrenheit

°C = degrees Celsius

Source: Conceptual Models of Stressors and Limiting Factors for San Joaquin River Chinook Salmon

As described earlier, Reclamation would implement the New Melones SRP similar to current operations with a default daily hydrograph, and the ability to shape monthly and seasonal flow volumes to meet specific biological objectives. The default daily hydrograph is the same as prescribed under current operations (No Action Alternative) for critically dry, dry, and below normal water year types; above normal and wet year types follow daily hydrographs for below normal and above normal year types respectively. As a result, flows would be reduced in above normal and wet year types. The difference between Alternative 1 and the No Action Alternative during above normal years and wet years, where the minimum release requirement for wetter year types is reduced from No Action Alternative to promote storage for potential future droughts and preserve coldwater pool, leads to improved coldwater pool performance in droughts, benefitting salmonid eggs.

The SRP under Alternative 1 would provide coldwater pool performance in droughts, but would reduce flow releases in above normal and wet years. This could result in less inundated rearing habitat, lower out-migration flows, and potentially warmer temperatures in some years, affecting rearing of outmigrating juvenile salmonids.

Under Alternative 1, storage at New Melones Dam is increased in comparison to No Action Alternative (Figures O.3-101 and O.3-102). The overall average increase in TAF benefits salmonids in the Stanislaus River by increasing coldwater pool available for flow management through warmer months. Recognizing that there is no ability for Reclamation to release water from different depths at New Melones, increased water depth above the static intake structure would function like a thermal cap, keeping the water below cooler. More cold water in New Melones Reservoir may lower water temperatures downstream of Goodwin Dam, even at relatively lower flow magnitudes, which would benefit salmonids in all life stages in the lower Stanislaus River.

Potential change to aquatic resources in the Stanislaus River due to changes to dissolved oxygen

Current operations are required to meet a year-round dissolved oxygen minimum of 7 mg/L, from June 1 to September 30 in the Stanislaus River at Ripon to protect salmon, Steelhead, and trout in the river (CDFW 2018a). Under Alternative 1, Reclamation proposes to move the compliance location to Orange Blossom Bridge, where the species are primarily located at that time of year (June through September). Without Alternative 1, there would be no water temperature management. Therefore, the proposed temperature compliance point is beneficial to the species, because the majority of salmonid eggs, alevin and/or fry are found in locations where summer dissolved oxygen levels would be expected to be maintained at or near 7 mg/L. However, based on the typical seasonal occurrence of this life stage in the river (July to October), adult migrating salmonids would be expected to be exposed to the effects of the relaxation of dissolved oxygen requirements at Ripon. During low flow periods in the Stanislaus River there could be delay of adults migrating up the Stanislaus River if dissolved oxygen is too low.

O.3.3.7 *San Joaquin River*

Effects would be expected to be similar under Alternative 1 to the potential effects as previously described for the No Action Alternative. A full description of potential effects are described in Section O.3.2.7.

O.3.3.8 *Bay-Delta*

O.3.3.8.1 <u>Delta Smelt</u>

Potential changes to Delta Smelt due to seasonal operations

Seasonal operations under Alternative 1 would change the frequency of the low salinity zone being located within the productive habitat of Suisun Marsh and bay during some seasons, relative to the No Action Alternative. As described in more detail in the ROC LTO BA, seasonal operations have the potential to affect various habitat attributes hypothesized to be important to Delta Smelt, including predation risk, food availability, harmful algal blooms, and size and location of the low salinity zone. These are discussed in turn in the paragraphs below.

As described in the ROC LTO BA, flows entering the Delta have the potential to affect Delta Smelt predation risk through effects on sediment delivery and turbidity. There would be expected to be little difference in this habitat attribute between Alternative 1 and the No Action Alternative given the similarity in CalSim-modeled flows in the Sacramento River at Rio Vista (e.g., Appendix E, Attachment 3-2, Figures 32-9 through 32-14), particularly during the high-flow portion of the year when most sediment is delivered to the Delta. As described in the ROC LTO BA, predation risk on Delta Smelt eggs/larvae is hypothesized to largely be a result of Silversides, and Silverside abundance is negatively correlated with June–September Delta inflow and March–May south Delta exports. Under Alternative 1, March–May south Delta exports would be greater compared to the No Action Alternative (Appendix E, Attachment 3-3, Figures 53-12 through 53-14), which would tend to suggest the potential for lower abundance of Silversides under Alternative 1 compared to the No Action Alternative. In contrast, June–September Delta inflow (Freeport + Vernalis + Yolo + Mokelumne flows) under Alternative 1 is generally similar to the No Action Alternative, except for September in wet and above normal years when the inclusion of the USFWS (2008) BO RPA for fall X2 under the No Action Alternative results in greater Freeport flow and therefore total inflow compared to Alternative 1 (Appendix E, Attachment 3-2, Figures 29-15 through 29-18), potentially resulting in greater abundance of Silversides under Alternative 1 compared to the No Action Alternative. The extent to which the opposing effects of differences in exports and inflow could affect Silverside abundance under Alternative 1 is uncertain, particularly given that the relationships are correlations and do not necessarily imply causality and require further investigation (Reclamation 2019). As discussed in the ROC LTO BA, predation risk for subadult Delta Smelt could increase under Alternative 1 relative to the No Action Alternative as a result of less overlap of the low salinity zone with more turbid areas (see additional discussion regarding area and extent of the low salinity zone below), but seasonal operations would not be expected to affect temperature to the point that predation risk is influenced by Alternative 1 (which is true for all Delta Smelt life stages). The ROC LTO BA summarizes studies suggesting that the age-0 abundance of another Delta Smelt predator, Striped Bass, is positively correlated to fall Delta outflow (negative correlation with X2), but a potential reduction in Striped Bass abundance because of less fall outflow under Alternative 1 compared to the No Action Alternative is uncertain because of the relatively low correspondence between abundance trends for age 0 and age 1 Striped Bass and apparent density dependence between ages 1 and 2.

Various aspects of seasonal operations have the potential to affect Delta Smelt food availability. For adult Delta Smelt, flooding of Yolo Bypass in winter/spring could affect food availability (Reclamation 20198). However, CalSim modeling suggests little difference in Yolo Bypass flows between Alternative 1 and the No Action Alternative (Appendix E, Attachment 3-2, Figures 25-6 through 25-18). For larval Delta Smelt, the ROC LTO BA (notes a positive correlation between spring Delta outflow and the Delta Smelt zooplankton prey *Eurytemora affinis* (i.e., a negative correlation with March to May X2). CalSim modeling indicates that there would be somewhat less spring Delta outflow under Alternative 1 compared to the No Action Alternative and therefore somewhat greater X2 (see Appendix E, Attachment 3-2, Figures 41-12 through 41-14; Attachment 3-7, Figures 45-9 through 45-11 of the ROC LTO BA), with the potential effect of reducing *E. affinis* abundance under Alternative 1 compared to the No Action Alternative. As noted in the ROC LTO BA, there is uncertainty in the predictive relationship between X2 and *E. affinis* abundance, and Alternative 1 includes completion of the remainder of the 8,000 acres of restoration to offset potentially negative effects on Delta Smelt prey, as well as other potentially beneficial actions for Delta Smelt food availability as described elsewhere in this analysis (see sections discussing *Potential changes to Delta Smelt from food subsidies (Sacramento Deepwater Ship Channel Food Study; North Delta Food Subsidies/Colusa Basin Drain Study; Suisun Marsh Roaring River Distribution System Food Subsidies Study*). For Delta Smelt juveniles in summer/early fall (July–September), the ROC LTO BA noted the positive correlation between Delta outflow and the subsidy of the Delta Smelt zooplankton prey *Pseudodiaptomus forbesi* to the low salinity zone, with flows in the lower San Joaquin River potentially being of importance given the higher density of *P. forbesi* there. DSM2-HYDRO modeling suggests that the percentage of years with net negative lower San Joaquin River flows would be similar in July (~32% for Alternative 1 vs. ~37% for No Action Alternative) and August (~60% for Alternative 1 vs. 58% for No Action Alternative) (Figures O.3-70 and O.3-71), whereas in September, the frequency of net negative flows would be greater under Alternative 1 (51% of years) than the No Action Alternative (35% of years) (Figure O.3-72); therefore there may be less potential for transport of *P. forbesi* to the low salinity zone under Alternative 1 compared to the No Action Alternative in September. As previously noted, various potentially beneficial actions are included in Alternative 1 to provide benefit to Delta Smelt food availability, thereby potentially offsetting this potentially negative effect. For subadult Delta Smelt in fall (September–December), the ROC LTO BA notes that while the same *P. forbesi* subsidy effect would apply as discussed for juvenile Delta Smelt, there was no evidence for a correlation between overall calanoid copepod zooplankton prey and Delta outflow (X2) based on a recent analysis, so the negative effects under Alternative 1 relative to No Action Alternative may be limited to *P. forbesi* subsidy during September.

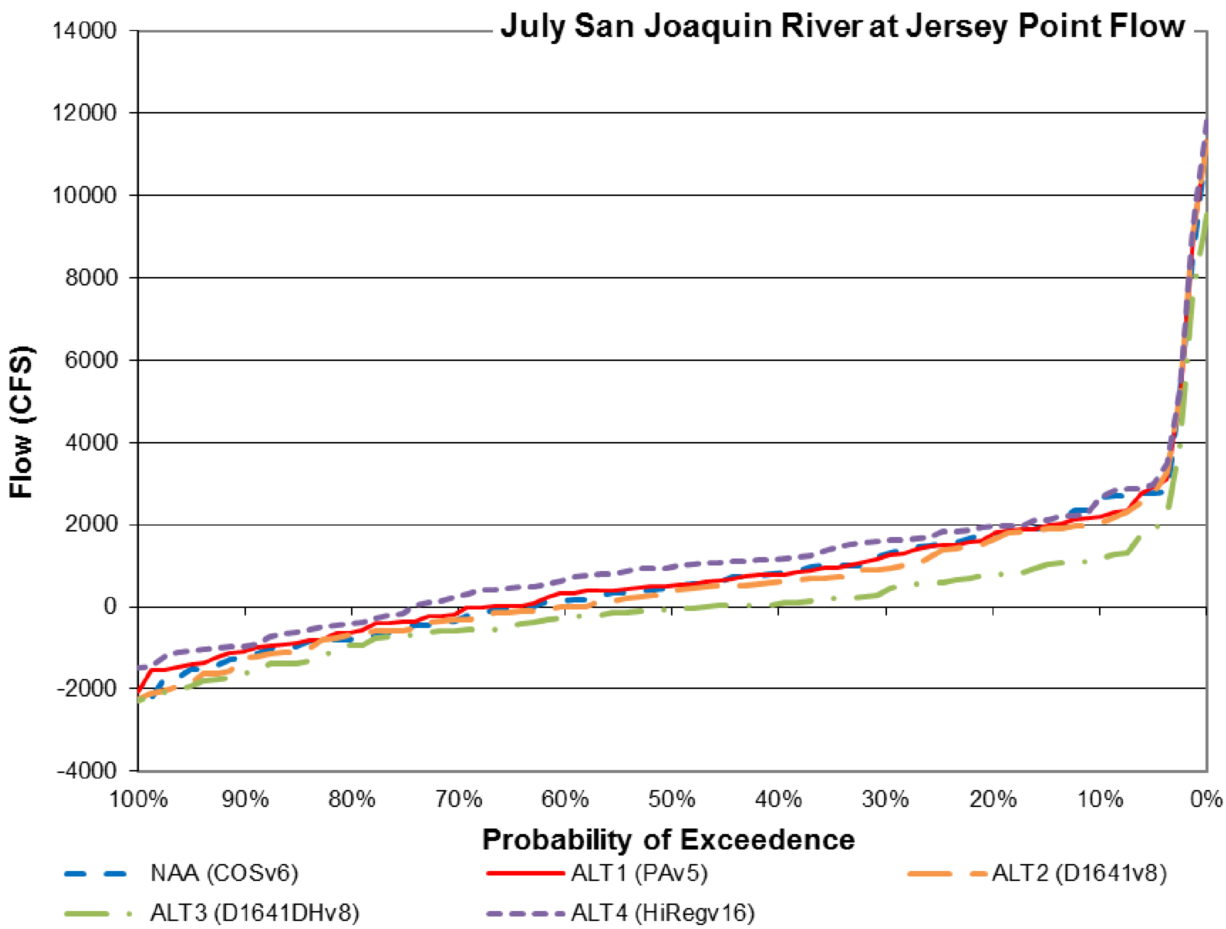


Figure O.3-70. DSM2-HYDRO-Modeled Probability of Exceedance of San Joaquin River Flow at Jersey Point, July

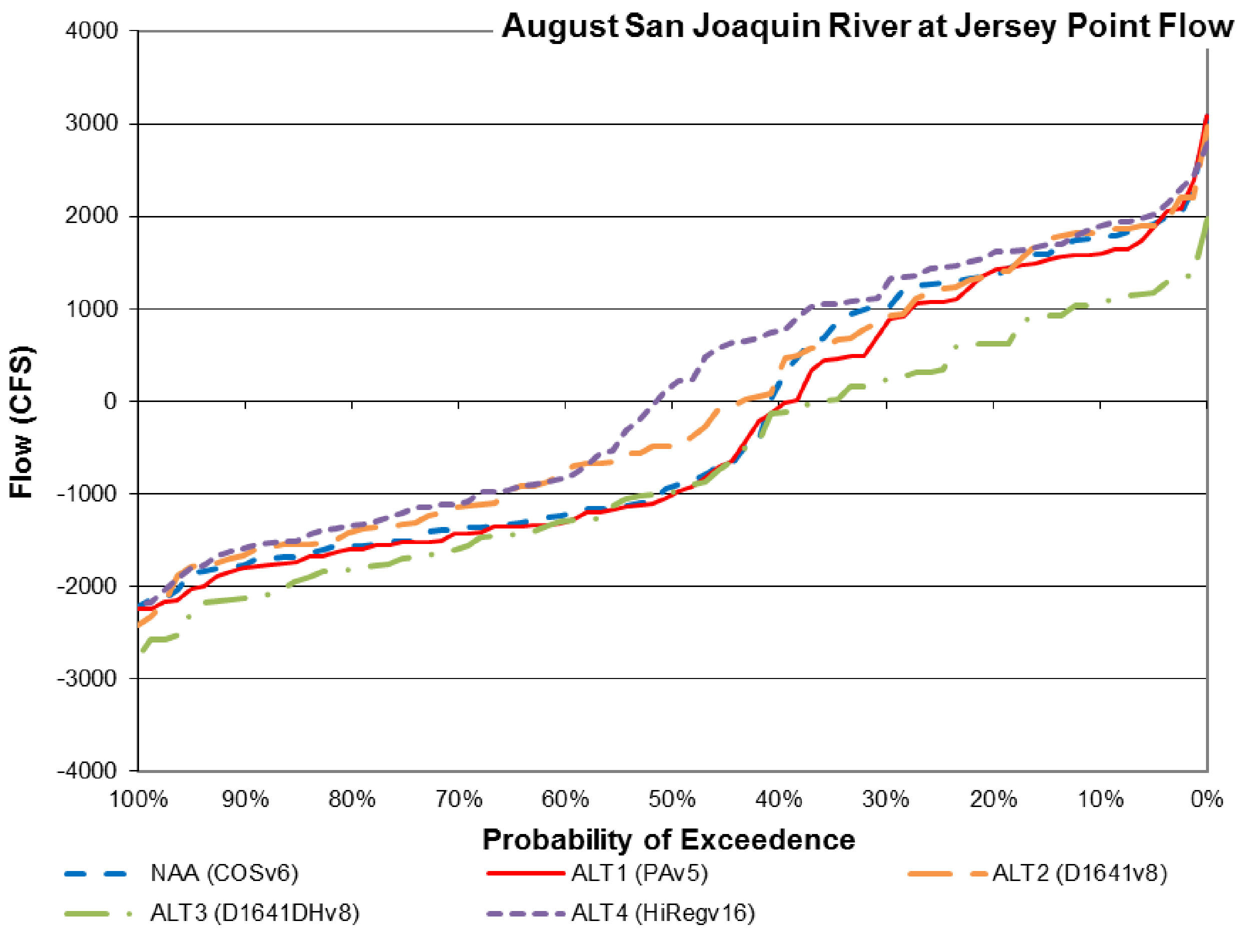


Figure O.3-71. DSM2-HYDRO-Modeled Probability of Exceedance of San Joaquin River Flow at Jersey Point, August

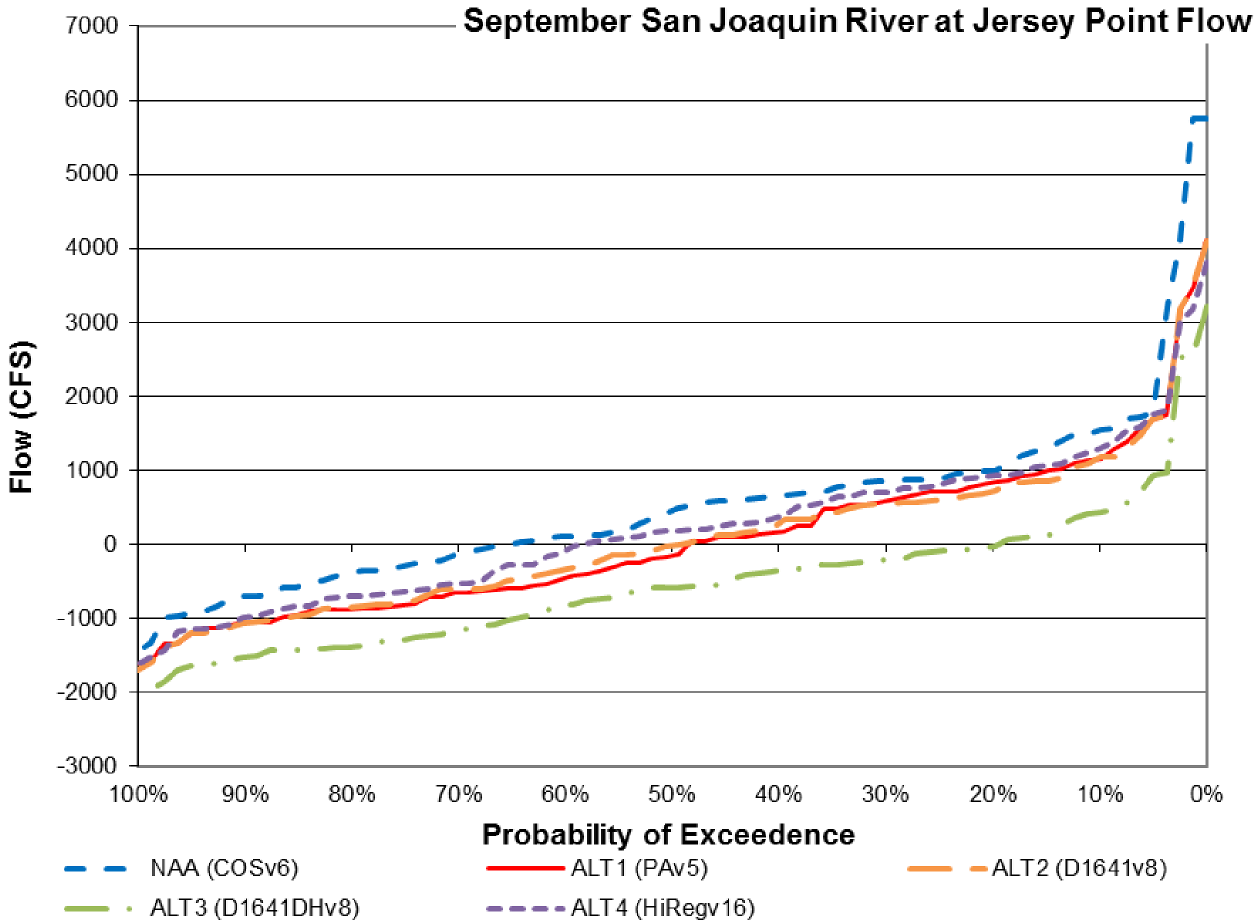


Figure O.3-72. DSM2-HYDRO-Modeled Probability of Exceedance of San Joaquin River Flow at Jersey Point, September

As described in the ROC LTO BA, the size and location of the low salinity zone is hypothesized to affect subadult Delta Smelt abundance, survival, and growth, although evidence is mixed and additional investigations are thought to be needed to provide further support. On the basis of modeled X2, Alternative 1 would be expected to appreciably reduce the size of the low salinity zone in September–November of wet and above normal years compared to the No Action Alternative, as a result of Alternative 1 not including the USFWS (2008) BO RPA fall X2 action: applying the methods from the ROC LTO BA, the area of the low salinity zone would be similar under Alternative 1 and the No Action Alternative in critical, dry, and below normal years (i.e., ~50–100% exceedance), whereas in above normal (~30–50% exceedance) and in particular wet years (i.e., ~0–30% exceedance) the area of the low salinity zone would be considerably lower under Alternative 1 compared to the No Action Alternative (Figures O.3-73, O.3-74, and O.3-75). As discussed in the ROC LTO BA, the percentage of time that X2 is ≥ 85 km is an indicator of how often the low salinity zone rearing habitat is outside of Suisun Bay, important Delta Smelt rearing habitat. Modeling suggests that in June–August, there would be little difference between Alternative 1 and the No Action Alternative in the percentage of time that X2 is ≥ 85 km, whereas in September–December, X2 would be ≥ 85 km considerably more of the time under Alternative 1 than the No Action Alternative (Figure O.3-76). Collectively, modeling of the area of low salinity zone habitat and the percentage of years with X2 ≥ 85 km thus suggest the potential for negative effects to Delta Smelt juveniles/subadults under Alternative 1 relative to the No Action Alternative, based on the hypothesized importance of these factors. However, the Delta Smelt Habitat conservation measure analyzed below in *Potential changes to Delta Smelt from actions for Delta Smelt summer-fall habitat* would aim to meet several environmental and biological goals for Delta Smelt. The modeling discussed herein does not include representation of habitat operations components. In addition, to the extent that tidal restoration (i.e., the completion of the remaining acreage as part of 8,000 acres of tidal habitat restoration) provides new low salinity zone habitat that is occupied by rearing Delta Smelt, this could provide some offsetting of potential reductions in the size and area of the low salinity zone resulting from operations.

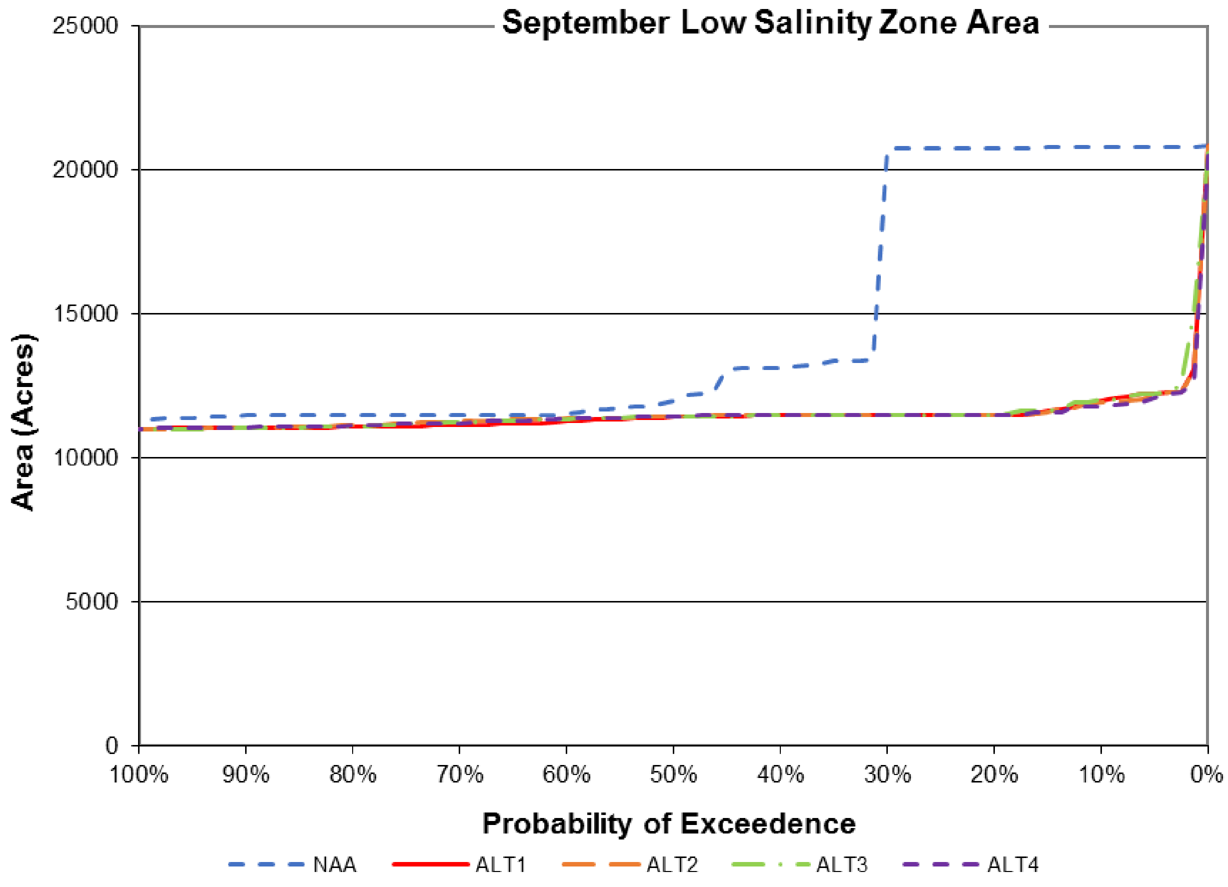


Figure O.3-73. Low Salinity Zone Area Estimated from CalSim X2, September

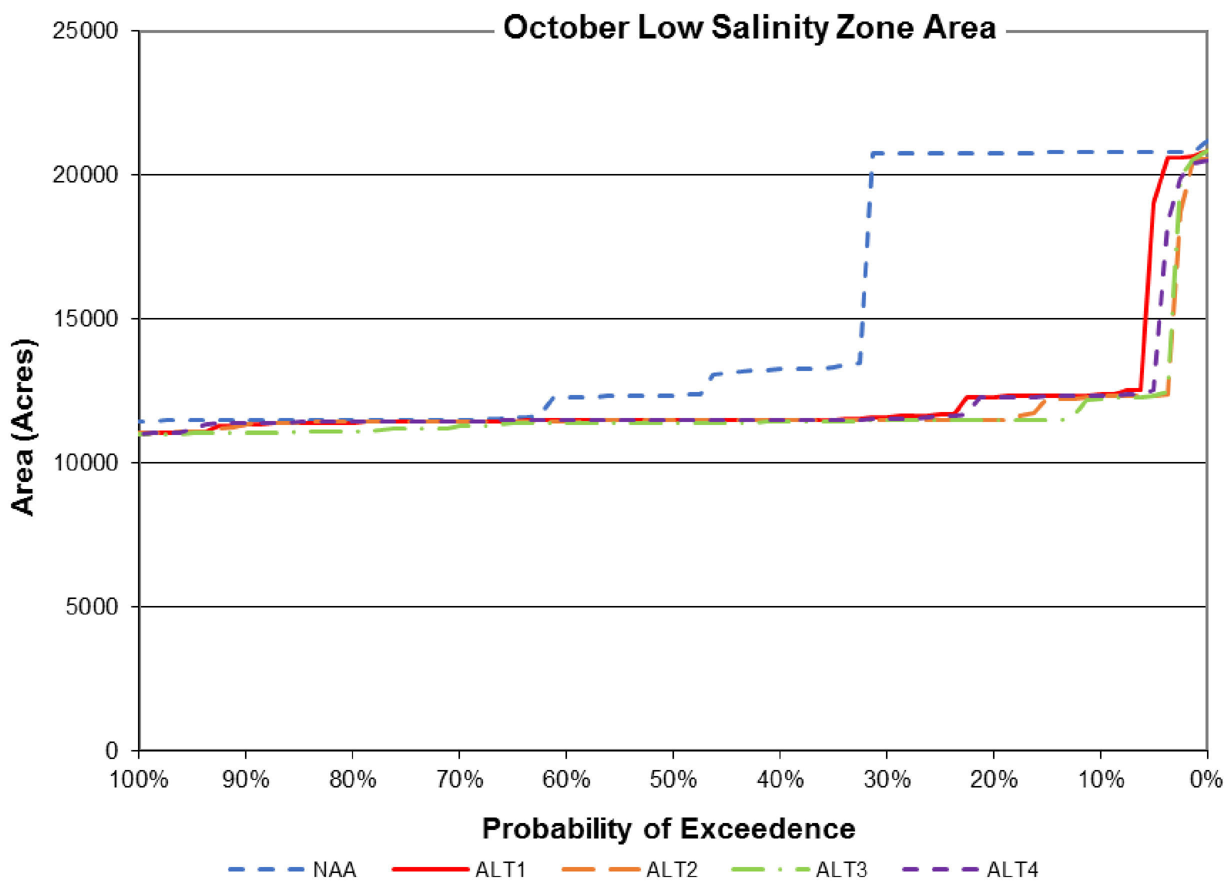


Figure O.3-74. Low Salinity Zone Area Estimated from CalSim X2, October

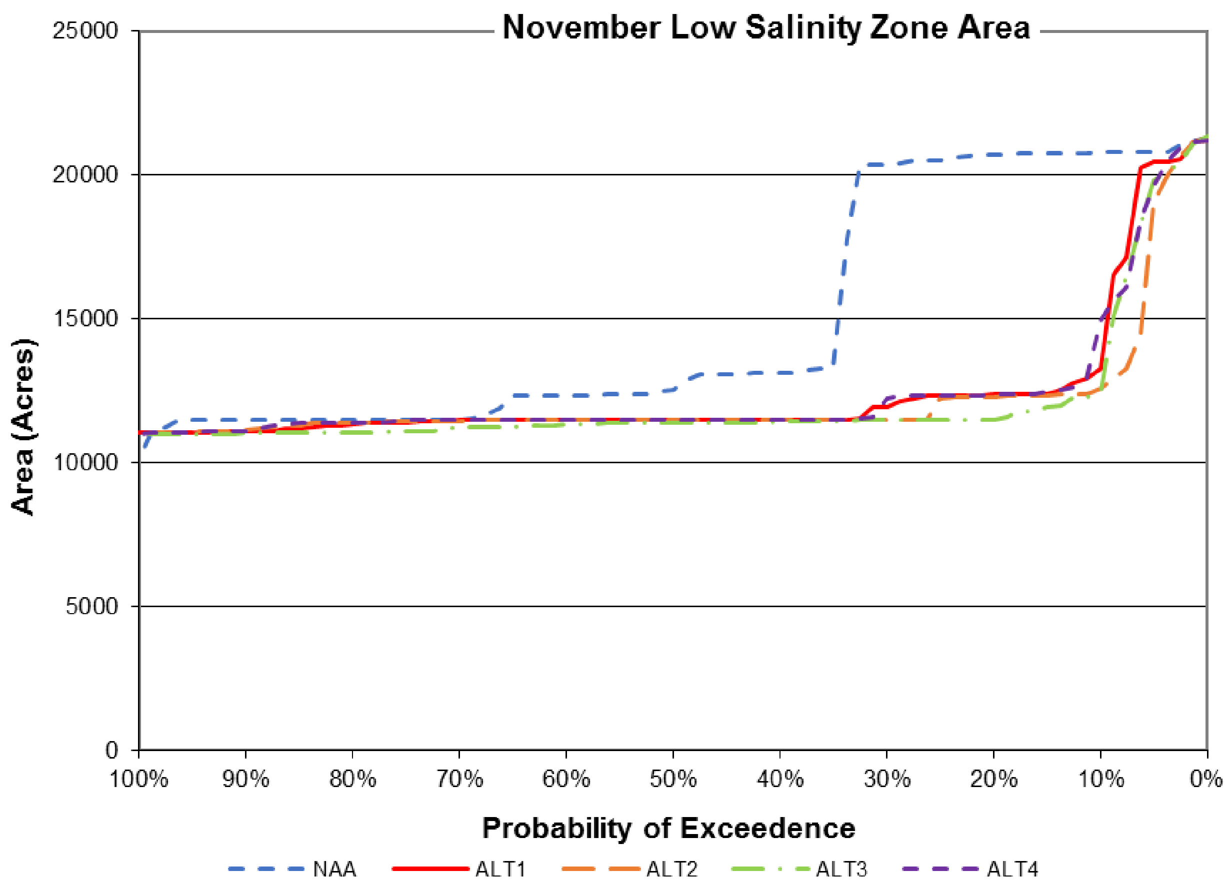


Figure O.3-75. Low Salinity Zone Area Estimated from CalSim X2, November

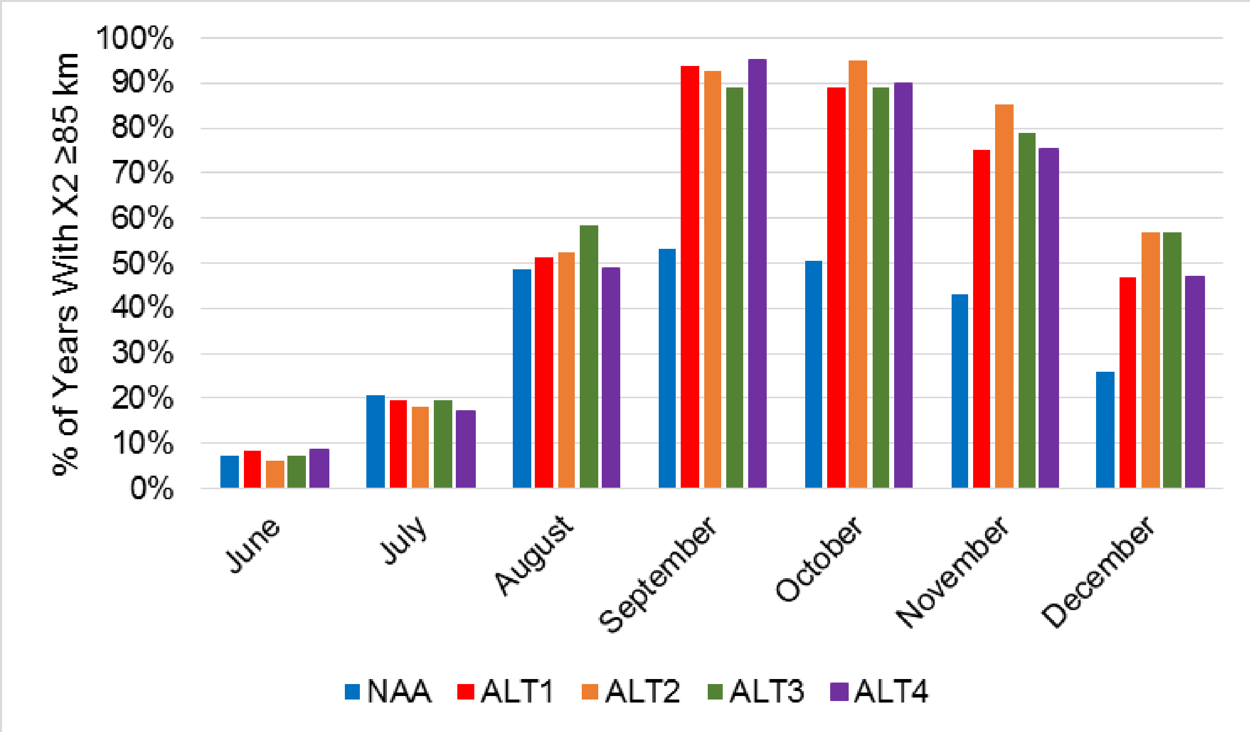


Figure O.3-76. Percentage of Years with Mean X2 ≥ 85 km, June–December

As discussed in the ROC LTO BA, water operations potentially could affect harmful algal blooms (*Microcystis*) and therefore Delta Smelt or Delta Smelt prey. However, as shown in the ROC LTO BA, there is little difference in modeled velocity (a potential indicator of harmful algal bloom disruption) between Alternative 1 (represented by the PA scenario) and the No Action Alternative (represented by the COS scenario) (see Figures 5.16-19 through 5.16-26 of the ROC LTO BA). This suggests that there would be little difference in harmful algal bloom potential between Alternative 1 and the No Action Alternative.

Potential changes to Delta Smelt due to OMR management

As described in more detail in the analysis of OMR Management in the ROC LTO BA, Delta Smelt entrainment risk is a function of water diversions, hydrology, and turbidity. During the main period of adult Delta Smelt entrainment risk (December–March), CalSim modeling suggests that OMR flows would generally be similar or slightly lower under Alternative 1 compared to the No Action Alternative (see Appendix F, Attachment 3-2, Figures 40-9 through 40-12 of the ROC LTO BA). In March–June, the larval/early juvenile Delta Smelt entrainment risk period, the modeled OMR flows suggest that the difference between Alternative 1 and the No Action Alternative would be greater. However, Alternative 1 includes protective criteria as described in more detail in Section 4.3.6.5, *OMR Management* of Appendix D. These criteria, including real-time adjustments to operations in response to physical and biological criteria, would be expected to limit entrainment risk of Delta Smelt from Alternative 1.

Potential changes to Delta Smelt due to changes in Delta Cross Channel operations

As noted in the ROC LTO BA, it is unknown what if any direct impacts occur to Delta Smelt from opening or closing the DCC gates, and there is limited occurrence of Delta Smelt near the DCC. DCC operations under Alternative 1 would differ somewhat compared to the No Action Alternative (Section 4.3.6.1, *Delta Cross Channel* of Appendix D), although the extent to which this would give effects on Delta Smelt is unclear; factors such as entrainment risk in the south Delta would be considered when operating the DCC, to limit potential negative effects.

Potential changes in Delta Smelt survival related to the Temporary Barriers Project

Under Alternative 1, potential effects of the three south Delta agricultural barriers on Delta Smelt would be expected to be similar to the effects under the No Action Alternative (i.e., near-field predation and potential effects on transport of *P. forbesi* to the low salinity zone; see also ROC LTO BA). Relative to the No Action Alternative, Alternative 1 would not include the spring HOR barrier, so any effects (near-field predation, far-field hydraulic effects) that would occur under the No Action Alternative would not occur under Alternative 1. However, given the low presence of Delta Smelt near the HOR barrier and the fact that far-field hydraulic effects would be factored into entrainment risk as part of OMR management, there may be little difference in effects to Delta Smelt between the No Action Alternative and Alternative 1.

Potential changes to Delta Smelt from Contra Costa Water District operations

Contra Costa Water District operations would not differ between Alternative 1 and the No Action Alternative, so the effects to Delta Smelt would be expected to be similar under Alternative 1 as the No Action Alternative, i.e., negligible entrainment and hydrodynamic effects (Reclamation 2019).

Potential changes to Delta Smelt from North Bay Aqueduct operations

North Bay Aqueduct Barker Slough Pumping Plant operations would not differ between Alternative 1 and the No Action Alternative, so the effects to Delta Smelt would be expected to be similar under Alternative 1 as the No Action Alternative, i.e., potential entrainment, impingement, near-field predation, and entrainment of Delta Smelt food, which could have limited effects on Delta Smelt given low occurrence in the vicinity of the Barker Slough Pumping Plant (Reclamation 2019). Alternative 1 also includes sediment removal with a suction dredge that could entrain Delta Smelt individuals occurring near the suction dredging. In addition, aquatic weed removal with a grappling system could disturb Delta Smelt occurring near the removal; given the lack of Delta Smelt association with vegetation (Ferrari et al. 2014), Delta Smelt would not be expected to be occurring close to vegetation removal. At the broader scale, effects from both sediment removal and aquatic weed removal in any case would be expected to be limited given the low occurrence in the vicinity of the Barker Slough Pumping Plant, as previously noted for operational effects.

Potential changes to Delta Smelt from water transfers

Alternative 1 includes an expanded transfer window (July to November) relative to the No Action Alternative (July to September). As described in the ROC LTO BA, the expanded window generally does not overlap the presence of Delta Smelt in the south Delta, but there could be potential exposure of an occasional Delta Smelt to increased pumping from water transfers, resulting in entrainment or predation risk. However, entrainment would be limited as discussed in the analysis of *Potential changes to Delta Smelt due to OMR management*.

Potential changes to Delta Smelt from Clifton Court aquatic weed and algal bloom management

As described in Section 4.3.6.5, *Clifton Court Aquatic Weed and Algal Bloom Management,* of Appendix D, under Alternative 1 Clifton Court aquatic weed removal efforts may be expanded relative to the No

Action Alternative by including additional herbicides and the treatment period. However, given the low occurrence of Delta Smelt during the principal period of application, as well as various protective measures to limit potential effects such as salvage monitoring for presence of listed fishes including Delta Smelt, aquatic weed removal and algal bloom management in Clifton Court would be expected to have minimal effects on Delta Smelt. As discussed in Appendix D, treatment of harmful algal blooms with peroxide-based algaecide is proposed to occur as needed, year-round, but there are no anticipated impacts to fish because the oxidation reaction occurs immediately upon contact with the water, destroying algal cell membranes and chlorophyll, with hydrogen peroxide and oxygen as byproducts.

Potential changes to Delta Smelt due to changes from Tracy and Skinner fish facilities

Tracy and Skinner Fish Facility operations under Alternative 1 would remain largely the same as the No Action Alternative, except for installation of a carbon dioxide injection device to allow remote controlled anesthetization of predators in the secondary channels of the Tracy facility (see Section 4.3.6.6, *Tracy Fish Collection Facility Carbon Dioxide Injection and Release Sites* in Appendix D). As described in the ROC LTO BA, this has the potential to increase salvage efficiency of adult Delta Smelt at the Tracy facility. Such effects would be expected to be limited given that OMR management would be undertaken to limit the potential for occurrence of Delta Smelt in the south Delta.

Potential changes to Delta Smelt due to changes from Suisun Marsh facilities

Aside from changes to Suisun Marsh Salinity Control Gates operations (discussed below in *Potential changes to Delta Smelt from actions for Delta Smelt summer-fall habitat*), project-level operations of the Suisun Marsh facilities would remain the same as the No Action Alternative (there may be changes to RRDS and other facility operations, as part of the food subsidy actions included in Delta Smelt summer-fall habitat operations). The potential effects of the Suisun Marsh facilities on Delta Smelt are described in more detail in the ROC LTO BA, which notes risk from factors such as entrainment is limited.

Potential changes to Delta Smelt from actions for Delta Smelt summer-fall habitat

Alternative 1 includes structured decision making by DWR and Reclamation to identify and use a variety of actions to achieve various environmental and biological goals for Delta Smelt summer-fall habitat (see Section 4.3.6.8, *Delta Smelt Summer-Fall Habitat*, of Appendix D). Summer and fall management of salinity, potentially including operation of the Suisun Marsh Salinity Control Gates for up to 60 days and Delta outflow to maintain contiguous low salinity habitat from Suisun Marsh upstream to the Cache Slough Complex, would aim to improve Delta Smelt food supply and habitat, thereby contributing to the recruitment, growth, and survival of Delta Smelt. Relative to the No Action Alternative, this conservation measure has the potential to improve habitat, from the perspective of salinity-driven conditions, during the summer, whereas in fall there could be a lesser extent of low salinity zone habitat than otherwise would occur under the No Action Alternative with implementation of the USFWS (2008) fall X2 action. However, the extent to which this would be a negative effect may depend on other aspects included in the action, particularly food subsidy actions in the North Delta/Colusa Basin Drain, Sacramento Deepwater Ship Channel, and Suisun Marsh/RRDS (see discussion in *Potential changes to Delta Smelt from food subsidies (Sacramento Deepwater Ship Channel Food Study; North Delta Food Subsidies/ Colusa Basin Drain Study; Suisun Marsh Roaring River Distribution System Food Subsidies Study).* These food subsidy actions may provide Delta Smelt with additional food relative to the No Action Alternative. If the summer-fall Delta Smelt habitat operations action includes operations of the SMSCG or a fall X2 action, the difference in Delta outflow and X2 between Alternative 1 and the No Action Alternative would tend to be less than suggested by the CalSim modeling described above in *Potential changes to Delta Smelt due to seasonal operations.* The CalSim modeling for Alternative 1 **suggests** potential negative effects relative to the No Action Alternative, as previously described in more detail in *Potential changes to Delta Smelt due to seasonal operations*. In years with the summer or fall Delta Smelt habitat operation actions, the potential negative effects would be less than indicated in the Alternative 1 modeling.

Potential changes to Delta Smelt from the San Joaquin Basin Steelhead Telemetry Study

The San Joaquin Steelhead telemetry study would not affect Delta Smelt as it would be primarily in the San Joaquin River upstream of the areas where Delta Smelt occur, and also does not involve trapping or other mechanisms to affect Delta Smelt of any life stage (Reclamation 2019).

Potential changes to Delta Smelt due to reintroduction by the Fish Conservation and Culture Laboratory

Under Alternative 1, development and successful implementation of a supplementation strategy by the Fish Conservation and Culture Laboratory (see Section 4.3.6.11, *Intervention Components,* of Appendix D) would have the potential to benefit Delta Smelt, given the production capacity and apparent low population numbers (Reclamation 2019). Potential negative effects such as propagation and spread of nuisance species are generally similar to those that could occur at the proposed Delta Fish Species Conservation Hatchery (see ROC LTO BA), and would be limited through risk management strategies.

O.3.3.8.2 Longfin Smelt

Potential changes to Longfin Smelt due to seasonal operations

The principal potential effect of seasonal operations on Longfin Smelt would be changes in population abundance as a result of changes in Delta outflow. Several analyses have correlated Longfin Smelt indices of abundance with Delta outflow or X2 as a proxy for Delta outflow (e.g., Kimmerer et al. 2009; Nobriga and Rosenfield 2016). During the December–May period identified as important for Delta outflow by Nobriga and Rosenfield (2016), CalSim modeling suggests that under Alternative 1 Delta outflow would be similar or somewhat greater than No Action Alternative in December, generally similar in January–March, and less by several hundred to several thousand cfs in April and May (Appendix F, Attachment 3-2, Figures 41-9 through 41-14). Under Alternative 1, the negative differences in April/May have the potential to negatively affect Longfin Smelt through reductions in population abundance. However, the magnitude of the difference may be limited because of density-dependent effects (Nobriga and Rosenfield 2016), there is appreciable (several orders of magnitude) variability in the estimates generated by the Nobriga and Rosenfield (2016) model, and other analyses have found stronger correlations with general hydrological conditions rather than Delta outflow specifically (Maunder et al. 2015). As described for the No Action Alternative, completion of the 8,000 acres of tidal habitat restoration would have the potential to provide positive effects to Longfin Smelt larvae in the north Delta and therefore provide some offsetting of potential negative effects from seasonal operations, although this offsetting may be limited because Longfin Smelt would tend to be more downstream of restored areas than Delta Smelt, for which the restoration is primarily intended.

Potential changes to Longfin Smelt due to OMR management

Alternative 1 proposes OMR management focused on federally listed species, although Longfin Smelt could receive some protection from these measures as well. During the December–March period of adult Longfin Smelt vulnerability to south Delta entrainment, CalSim modeling suggests that OMR flows generally would be similar or somewhat less under Alternative 1 compared to the No Action Alternative (Appendix F, Attachment 3-2, Figures 40-9 through 40-12). January–March represents the main period of larval vulnerability to south Delta entrainment, and during this time DSM2-HYDRO modeling of the flow in the lower San Joaquin River at Jersey Point (an indicator of entrainment risk into the south Delta) suggests that south Delta larval entrainment risk would be similar (January and March) or somewhat greater (February) under Alternative 1 compared to the No Action Alternative (Figures O.3-77 through O.3-79). During the principal period of juvenile Longfin Smelt south Delta entrainment vulnerability (April–May), CalSim modeling suggests that OMR flows under Alternative 1 would be appreciably less than under the No Action Alternative, although generally greater than -4,000 cfs (Appendix F, Attachment 3-2, Figures 40-13 and 40-14). Overall, the modeling for Alternative 1 suggests that Longfin Smelt south Delta entrainment risk would be greater than under the No Action Alternative. However, it should be borne in mind that the modeling does not reflect continued adherence to the criteria of the CDFG (2009) SWP ITP, nor to any subsequent ITP that may govern Longfin Smelt south Delta entrainment protection. In addition, while entrainment risk may be relatively greater under Alternative 1 compared to the No Action Alternative, estimates of Longfin Smelt population-level entrainment loss during the D-1641-based regulatory period (i.e., prior to 2007, and what is included under Alternatives 2 and 3) suggest that low percentages (0–3.6%) of Longfin Smelt were lost to entrainment (ICF International 2016, Table 4.2-10 [p. 4-286] and Table 4.2-11 [p. 4-288]). This suggests that Longfin Smelt proportional entrainment loss under Alternative 1 would also be limited.

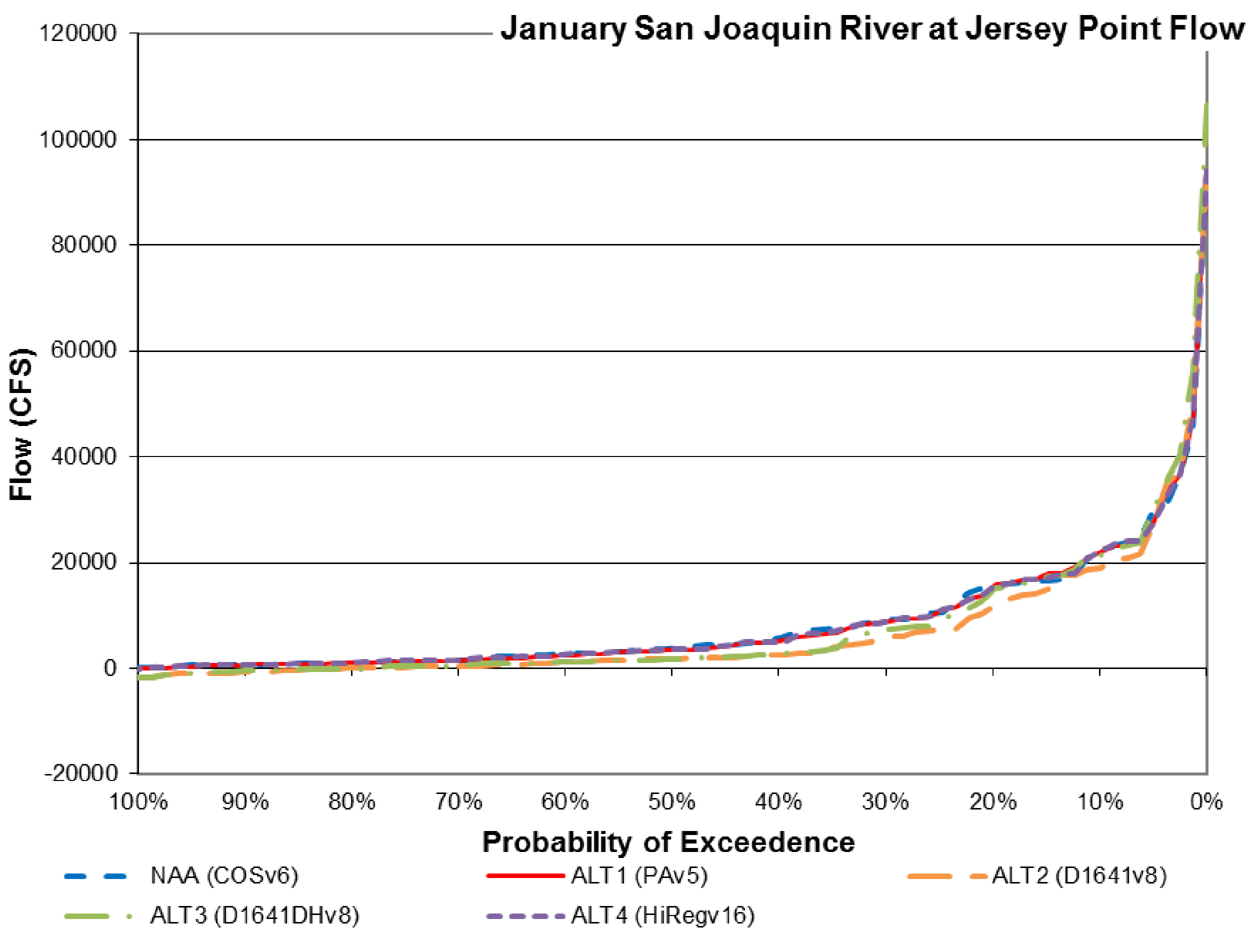


Figure O.3-77. DSM2-HYDRO-Modeled Probability of Exceedance of San Joaquin River Flow at Jersey Point, January

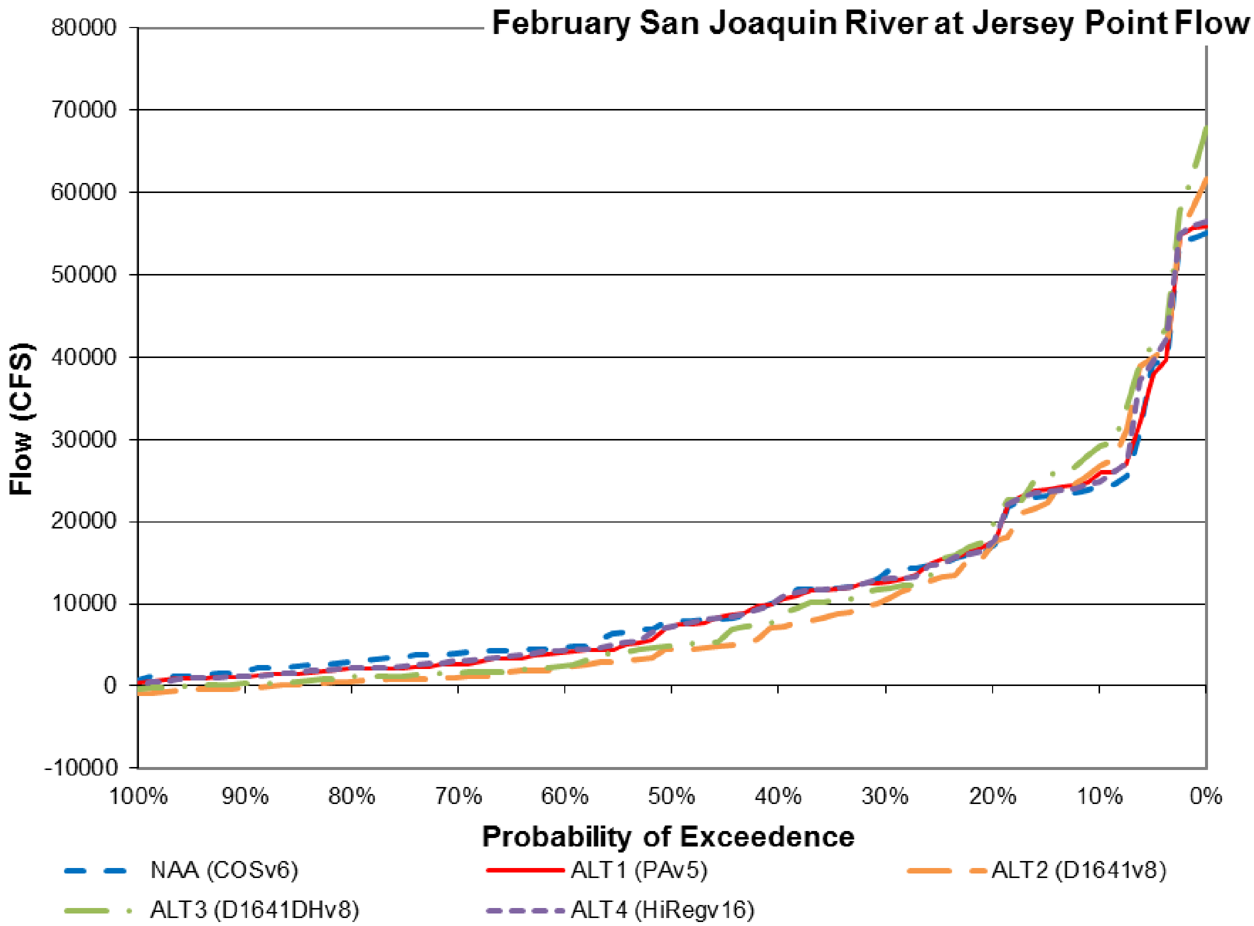


Figure O.3-78. DSM2-HYDRO-Modeled Probability of Exceedance of San Joaquin River Flow at Jersey Point, February

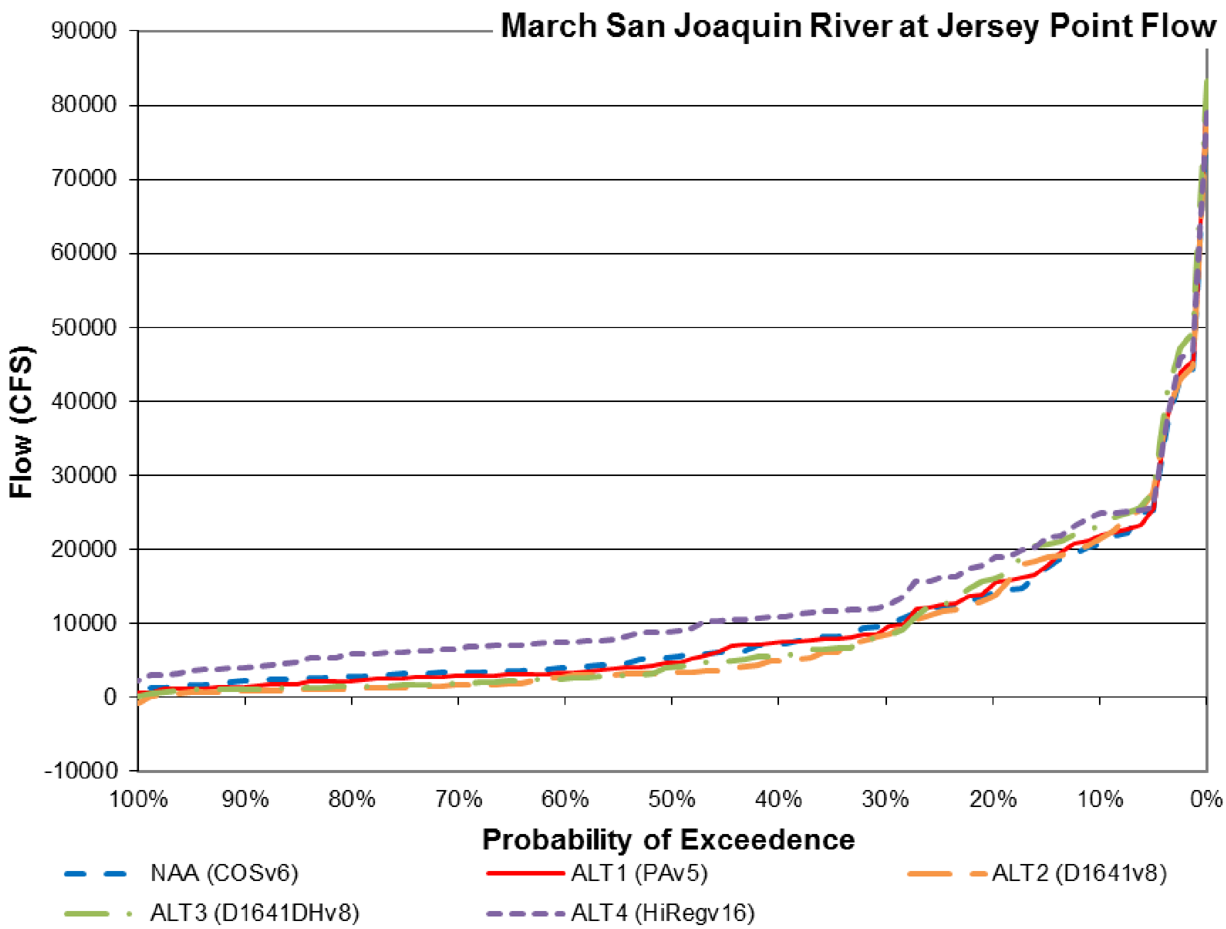


Figure O.3-79. DSM2-HYDRO-Modeled Probability of Exceedance of San Joaquin River Flow at Jersey Point, March

Potential changes to Longfin Smelt due to changes in Delta Cross Channel operations

There may be some differences in DCC operations effects under Alternative 1 relative to the No Action Alternative, although the effects would be expected to be limited given that Longfin Smelt occur downstream of the DCC. Hydrodynamic effects of water operations, including the DCC, e.g., on lower San Joaquin River flows and therefore potential south Delta entrainment risk, were discussed in the analysis of *Potential changes to Longfin Smelt due to OMR management*, which noted the low percentage of Longfin Smelt entrained historically under the D-1641 management framework included in Alternatives 2 and 3.

Potential changes in Longfin Smelt survival related to the Temporary Barriers Project

Although there may be the potential for greater Longfin Smelt occurrence in the south Delta as described under *Potential changes to Longfin Smelt due to OMR management* as a result of lower OMR flows under Alternative 1 compared to the No Action Alternative, and therefore greater potential for negative effects from the Temporary Barriers Project (e.g., near-field predation), the effects would be expected to be limited given the low frequency of occurrence of Longfin Smelt occurring in the south Delta (Merz et al. 2013).

Potential changes to Longfin Smelt from Contra Costa Water District operations

Contra Costa Water District operations under Alternative 1 would not change from the No Action Alternative and therefore would be expected to have similar effects to Longfin Smelt, i.e., negligible entrainment and hydrodynamic effects per analyses undertaken for Delta Smelt (Reclamation 2019).

Potential changes to Longfin Smelt from North Bay Aqueduct operations

There would be expected to be little difference in potential effects on Longfin Smelt from North Bay Aqueduct Operations water operations under Alternative 1 relative to the No Action Alternative, given that operations and protective criteria from the CDFG (2009) ITP (discussed under the No Action Alternative) would not differ. As with Delta Smelt, sediment removal and aquatic weed removal would be expected to have limited effects on Longfin Smelt, particularly in the case of summer and fall aquatic weed removal, given that Longfin Smelt would be expected to be downstream of the Delta at this time.

Potential changes to Longfin Smelt from water transfers

Although Alternative 1 includes an expanded water transfer window (July–November) relative to the No Action Alternative (July–September), this expanded window does not overlap the main period of south Delta entrainment vulnerability for Longfin Smelt (December–May; Grimaldo et al. 2009) and therefore would not be expected to increase south Delta entrainment risk under Alternative 1 relative to the No Action Alternative.

Potential changes to Longfin Smelt from Clifton Court aquatic weed and algal bloom management

Although Clifton Court aquatic weed and algal bloom management under Alternative 1 includes potential additional herbicides and an extended treatment period relative to the No Action Alternative, the timing of the action generally would avoid the main period of Longfin Smelt occurrence in Clifton Court Forebay, resulting in little or no effect to the species, consistent with the No Action Alternative. As previously described for Delta Smelt and as discussed in Appendix D, treatment of harmful algal blooms with peroxide-based algaecide is proposed to occur as needed, year-round, but there are no anticipated impacts to fish because the oxidation reaction occurs immediately upon contact with the water, destroying algal cell membranes and chlorophyll, with hydrogen peroxide and oxygen as byproducts.

Potential changes to Longfin Smelt due to changes from Tracy and Skinner fish facilities

Alternative 1 would include a new carbon dioxide injection device at the Tracy Fish Facility and therefore could have a positive effect on Longfin Smelt salvage efficiency relative to the No Action Alternative in this respect. Given the potential increase in entrainment from seasonal operations (as discussed for Alternative 2), the negative effects from salvage at the Tracy and Skinner fish facilities could outweigh any increases in salvage efficiency at Tracy. However, as previously discussed above in *Potential changes to Longfin Smelt due to OMR management*, the population-level effects may be limited given historically low entrainment loss of Longfin Smelt.

Potential changes to Longfin Smelt due to changes from Suisun Marsh facilities

During the period of Longfin Smelt potential occurrence near the Suisun Marsh facilities (i.e., winter/spring), Suisun Marsh facilities would not be operated differently under Alternative 1 than under the No Action Alternative and therefore the effects such as entrainment (CDFG 2009a) would be expected to be similar to the No Action Alternative.

Potential changes Longfin Smelt from actions for Delta Smelt summer-fall habitat

Delta Smelt habitat operations under Alternative 1 would be focused on the summer/fall period during which Longfin Smelt would not be expected to be affected given general distribution downstream of the potentially affected area.

Potential changes to Longfin Smelt due to the San Joaquin Basin Steelhead Telemetry Study

As discussed for Delta Smelt, the San Joaquin Steelhead telemetry study would not affect Longfin Smelt as it would be primarily in the San Joaquin River upstream of the areas where Longfin Smelt occur, and also does not involve trapping or other mechanisms to affect Longfin Smelt of any life stage.

Potential changes to Longfin Smelt due to the reintroduction by Fish Conservation and Culture Laboratory

Increased abundance of Delta Smelt from reintroduction of Delta Smelt under Alternative 1 potentially could have negative effects on Longfin Smelt if, for example, the rate of hybridization between the species increased from the current low levels (Fisch et al. 2014). There would be expected to be limited effects on Longfin Smelt from reintroduction of Delta Smelt given appropriate risk management strategies such as scaling and adjusting release numbers to optimize production while avoiding significant, density-related interspecific ecological risk (Lessard et al. 2018).

O.3.3.8.3 Sacramento River Winter-Run Chinook Salmon

Potential changes to aquatic resources due to seasonal operations

Rearing Winter-Run Chinook Salmon are present in the Delta between October and May. Key habitat attributes relevant to seasonal operations in the Delta include out-migration cues and entrainment risk.

Hydrodynamic changes associated with river inflows and South Delta exports have been suggested to adversely affect juvenile Chinook Salmon in two distinct ways: 1) “near-field” mortality associated with entrainment to the export facilities, and 2) “far-field” mortality resulting from altered hydrodynamics. Near-field or entrainment effects of proposed seasonal operations can be assessed by examining patterns of proportional population entrainment available from decades of coded wire tag studies (e.g., Zeug and Cavallo 2014). A foundation for assessing far-field effects has been provided by work of the Collaborative Adaptive Management Team’s (CAMT) Salmonid Scoping Team (SST). The SST completed a thorough review of this subject and defined a driver-linkage-outcome (DLO) framework for specifying how water project operations (the “driver”) can influence juvenile salmonid behavior (the “linkage”) and potentially cause changes in survival or routing (the “outcome”). The SST concluded altered “Channel Velocity” and altered “Flow Direction” were the only two hydrodynamic mechanisms by which exports and river inflows could affect juvenile salmonids in the Delta. Figure O.3-80 provides a simplified conceptual model of the DLO defined by the CAMT SST.

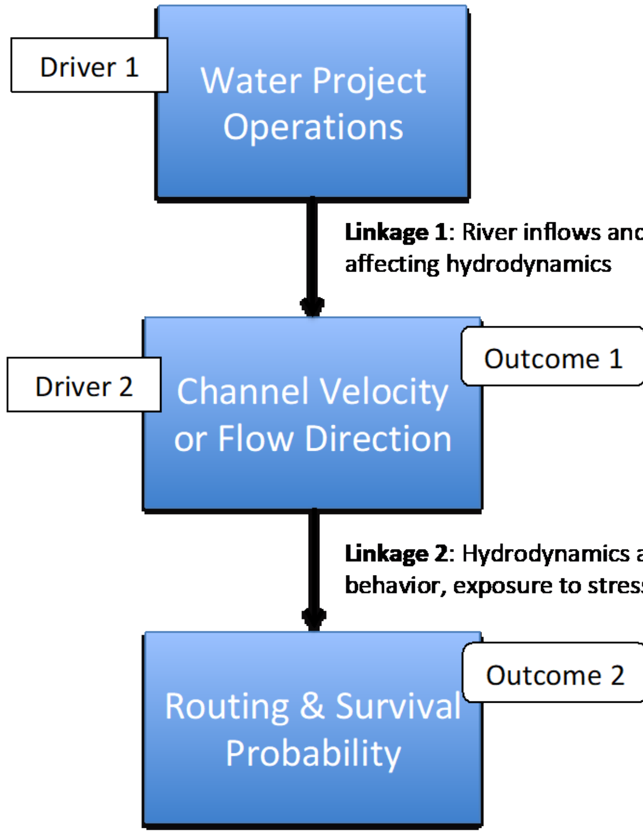


Figure O.3-80. Conceptual Model for Far-Field Effects of Water Project Operations on Juvenile Salmonids in the Delta. This CM is a Simplified Version of the Information Provided by the CAMT SST

In order to assess the potential for water project operations to influence survival and routing, Reclamation and DWR analyzed Delta hydrodynamic conditions by creating maps from DSM2 Hydro modeling. The maps are based on a comparative metric, proportion overlap (more below), to capture channel-level hydrodynamic details as a single number for color-scale mapping of Delta channels.

The objective of the comparative metric is to summarize the water velocity time series for each channel and scenario such the channel-level comparison is captured in a single number. For the proportion overlap metric, kernel density estimates are calculated on each time series. The kernel density estimates represent a non-parametric smoothing of the empirical distribution of time series values. The proportion overlap of two kernel density estimates is calculated with the following steps: 1) calculate the total area under the curve (AUC_t) as the sum of the AUC for each density estimate, 2) calculate the AUC of the overlapping portions (AUC_o) of the two density distributions being compared, and 3) calculate the overlapping proportion of the density distributions as AUC_o/AUC_t. Proportion overlap is naturally bound by zero and one; a value of zero indicates no overlap and a value of one indicates complete overlap. Lower values of proportion overlap identify channels demonstrating larger differences in a scenario comparison.

The proportion overlap metric is best applied over relatively short time periods because seasonal and annual variation in water velocity can overwhelm differences between scenarios. Thus, Reclamation calculated proportion overlap for every DSM2 channel for two seasons (Dec-Feb, Mar-May) in each water year (1922–2003). DSM2 output was excluded from water year 1921 to allow for an extensive burn-in period. The proportion overlap was calculated based on hourly DSM2 output. Because each season was roughly 90 days, each comparison involved roughly 4,300 DSM2 values (2 scenarios * 24 hours * 90 days) for each channel.

Because the proportion overlap was calculated for each channel in each water year, the proportion overlap values were summarized prior to mapping (i.e., not feasible to map proportion overlap for every comparison in every water year). To summarize, the minimum and median proportion overlap for each channel for each water year type for each comparison was found. The minimum values represent the maximum expected effect. The median values represent the average expected effect. Note that the year with the minimum (or median) proportion overlap for one channel might not be the same year as for another channel.

Entrainment

In the December through May period, the average total export rate, under Alternative 1, is slightly higher difference compared to the No Action Alternative. Therefore, slightly higher entrainment is expected compared to the No Action Alternative.

Zeug and Cavallo (2014) analyzed more than 1,000 release groups representing more than 28 million coded wire tagged juvenile fish including Winter-Run, Late Fall-Run and Fall-Run Chinook Salmon. This data represents large release groups of tagged smolts where the number of fish representing each release group lost to entrainment at the export facilities has been estimated. Cavallo (2016) provided a supplemental assessment of Winter-Run Chinook Salmon entrainment risk (building upon Zeug and Cavallo 2014) that showed total CVP and SWP exports described entrainment risk better than OMR or other flow metrics. Entrainment loss results as reported below represents the proportion of coded wire tagged Winter-Run Chinook Salmon released upstream of the Delta which were entrained at South Delta export facilities. This proportion accounts for and includes expansion for sampling effort at the salvage facilities and also prescreen mortality. With total exports of ≤ 6,500 cfs, entrainment loss rates for Winter-Run Chinook Salmon range between 0 and 1.5% (mean 0.1%) (Zeug and Cavallo 2014). With total exports greater than 6,500 cfs, entrainment losses range between 0 and 4% (mean 0.25%) (Zeug and Cavallo 2014). For December through February, Alternative 1 has an average total export rate similar to No Action Alternative (7,813 and 7,617 cfs respectively; Figure O1-1 in Appendix O, Attachment 1, Bay-Delta Aquatics Effects Figures), and will therefore have similar entrainment risk. In the March through June period, total exports for Alternative 1 increase entrainment risk relative to No Action Alternative (5,916 vs. 4,164 cfs, respectively; Figure O1-2 in Appendix O, Attachment 1), but entrainment losses should average 0.1% and not exceed 1.5%. While entrainment risk will increase under Alternative 1, compared to the No Action Alternative, Alternative 1 includes restrictions to OMR (-3,500 cfs and -2,500 cfs) when cumulative salvage of any species reaches 50% of the salvage threshold. CalSim modeling incorporates an assumption for this cumulative salvage restriction.

Routing

Routing of juvenile Chinook Salmon into alternative migration routes is closely related to hydrodynamics (Perry et al. 2015; Cavallo et al. 2015; Steel et al. 2012). Changes to hydrodynamics in Delta channels resulting from Alternative 1 were evaluated using DSM2. Juvenile Winter-Run Chinook Salmon are present in the Sacramento River at Sherwood Harbor upstream of the first distributary junctions between November and March with peak abundance in February and March (Reclamation 2019).

In the December to February period, velocity overlap between Alternative 1 and No Action Alternative in the Sacramento River main stem between the Sutter-Steamboat and DCC/Georgiana Slough Junctions, was more than 75% in critically dry, dry, below normal and above normal years (Figure O1-3 in

Appendix O, Attachment 1). In wet years, velocity overlap in this reach was ≈50%. Velocities were higher under Alternative 1 in all water year types in December through February indicating routing into the interior Delta would be lower relative to No Action Alternative (Perry et al. 2015 described for the December to February period (Figure O1-11 in Appendix O, Attachment 1). During the March to May period, velocity overlap between No Action Alternative and Alternative 1 was >75% in all water year types (Figure O1-4 in Appendix O, Attachment 1).

Abundance of juvenile Winter-Run Chinook Salmon at Chipps Island peaks in March and April but fish are collected between December and May (Reclamation 2019). During this time period, Winter-Run Chinook Salmon originating from the Sacramento River that enter the interior Delta via Georgiana Slough and the Delta Cross Channel can potentially be exposed to hydrodynamic effects associated with the CVP and SWP that could affect routing. Once these fish arrive at the junction of the Mokelumne River and the San Joaquin River, they can move south toward the export facilities or west toward the ocean. In the December to February period analysis of DSM2 data indicates that there is little change to velocities in the region of the junction of the Mokelumne and San Joaquin Rivers between Alternative 1 and the No Action Alternative (Figure O1-5 in Appendix O, Attachment 1). Similar results were obtained when comparing Alternative1 to the No Action Alternative in the March to May period (Figure O1-6 in Appendix O, Attachment 1).

Through-Delta Survival

Perry et al. (2018) found that the effect of flow on survival is not uniform throughout the Delta. Relationships between flow and survival were significant only in reaches where flow changes from bi-directional to unidirectional when discharge increases. This study was performed with hatchery-origin Late Fall-Run and there is uncertainty regarding the applicability of those results to Winter-Run. However, this study represents the best information avaiable on survival of juvneile Chinook Salmon in the Delta.

To examine potential effects of Alternative 1, changes in velocity distributions were examined for the Sacramento River at Walnut Grove and Steamboat Slough which are both in this “transitional” region. During the December to February period at Walnut Grove, there are higher velocities under Alternative 1 than the No Action Alternative in wet, above normal, below normal and dry years. Velocities were lower in critically dry years but overlap was high (>95%) Figure O1-7 in Appendix O, Attachment 1). At Steamboat Slough in the December to February period velocities were higher under Alternative 1 relative to the No Action Alternative in all but critically dry water years (Figure O1-8 in Appendix O, Attachment 1). In the March through May period at Walnut Grove, when Alternative 1 was compared to the No Action Alternative, velocity overlap ranged from 78.5-92.5% with higher velocities under Alternative 1 (Figure O1-9 in Appendix O, Attachment 1). Velocity overlap at Steamboat Slough in the March through May period ranged from 82.2% to 95.0% with higher velocities under Alternative 1 (Figure O1-10 in Appendix O, Attachment 1).

Overall, Alternative 1 results in higher velocities in the Delta in the spring than under No Action Alternative, during the outmigrating juvenile time period. Survival probabilities are non-linear; however, the higher discharge at Freeport in the spring under Alternative 1 results in higher survival in the transition reaches. Higher flows also lead to lower probability of routing into the interior Delta, which has the lowest survival probability regardless of flow.

Potential changes to aquatic resources due to OMR management

See section on seasonal operations above, which integrate OMR management.

Potential changes to aquatic resources due to Delta Cross Channel operations

Under Alternative 1, the DCC may be closed for up to 45 days from November through January for fishery protection purposes. From February 1 through May 20, the gates are closed for fishery protection purposes. The gates may also be closed for 14 days from May 21 through June 15 for fishery protection purposes. The peak migration of juvenile Winter-Run Chinook Salmon in the Sacramento River at Sherwood Harbor, which is near the DCC, occurs from February through March (Reclamation 2019). Therefore, the DCC is closed for the majority of the juvenile Winter-Run Chinook Salmon migration period in the Sacramento River and as such the proportion of juvenile Winter-Run Chinook Salmon exposed to an open DCC would be negligible. Juvenile Chinook Salmon entrained into an open DCC and transported to the interior Delta have reduced survival (Perry et al. 2010; Perry et al. 2018).

Potential changes to aquatic resources due to the Temporary Barriers Project

Juvenile Winter-Run Chinook Salmon are not expected to co-occur in space or time with the agricultural barriers indicating no potential impacts.

Potential changes to aquatic resources due to Contra Costa Water District operations

CCWD's operations in Alternative 1 are consistent with the operational criteria specified in separate biological opinions and permits that govern operations at CCWD's intakes and Los Vaqueros Reservoir (NMFS 1993, 2007, 2010, 2017; CDFG 1994; CDFG 2009a) and remain unchanged from the No Action Alternative.

The Contra Costa Canal Rock Slough Intake is located on a dead-end slough, far from the main migratory route for Winter-Run Chinook Salmon (NMFS 2017c), approximately 18 miles from the Sacramento River via the shortest route. Designated critical habitat for Winter-Run Chinook Salmon does not occur within Rock Slough, but is present further to the north in the Delta (NMFS 2017c, 2014). Salmonids are expected to avoid the area of the Rock Slough Intake during certain times of the year based on historical water temperatures.

Fish monitoring prior to the construction of the Rock Slough Fish Screen (RSFS) indicates the timing and magnitude of Winter-Run Chinook Salmon presence near the Rock Slough Intake. Since 1994, fish monitoring has been conducted by CDFW and CCWD consistent with the separate biological opinions and permits that govern CCWD's operations. From 1994 through 1999, CDFW conducted fish monitoring at the Rock Slough Intake and in the Contra Costa Canal up to the first pumping plant. Over this 6-year period, CDFW captured a total of 13 juvenile Winter-Run Chinook Salmon from January through May (CDFG 2002c; NMFS 2017c). From 1999 to 2009, the 11 years prior to construction of the RSFS, CCWD's Fish Monitoring Program collected no juvenile or adult Winter-Run Chinook Salmon at the Rock Slough Headworks (Reclamation 2016; NMFS 2017c).

Since construction of the RSFS, operation of the hydraulic rake cleaning system has been shown to trap and kill adult Chinook Salmon and other non-listed fish (Reclamation 2016). From 2011–2018, 47 Salmon were recovered at the RSFS (Reclamation 2016, Appendix A; Tenera Environmental 2018a), but none of the captured fish were identified as Winter-Run Chinook Salmon (NMFS 2017c).

NMFS issued a biological opinion in 2017 (NMFS 2017c) that considered improvements to the RSFS facility including the hydraulic rake cleaning system, operations and maintenance (O&M) of the RSFS and associated appurtenances, and administrative actions such as the transfer of O&M activities from

Reclamation to CCWD. NMFS determined that the O&M of RSFS may result in the incidental take of juvenile Winter-Run Chinook Salmon and provided an incidental take limit based upon the number of listed fish collected in the pre and post-construction RSFS monitoring (NMFS 2017c). The incidental take provided in NMFS 2017c is five juvenile Winter-Run Chinook Salmon per year.

CCWD’s Fish Monitoring Program also samples behind the fish screens at CCWD’s other south Delta intakes. Since the intakes have been in operation, CCWD’s Fish Monitoring Program has never collected Winter-Run Chinook Salmon at CCWD’s Old River Intake or Middle River Intake (CCWD 2019).

CCWD’s operations, including operation of the Rock Slough, Old River, and Middle River intakes and Los Vaqueros Reservoir, are simulated in the CalSim model. Thus, CalSim results discussed throughout this appendix include the effects of CCWD’s operations in combination with all other water diversions and reservoir operations. A further analysis was undertaken to isolate the maximum possible effects of CCWD’s operations on Delta hydrodynamics by determining the effect that CCWD pumping at maximum capacity would have on Delta channel water velocity. Results of this analysis are shown below; in all cases the maximum possible effect of CCWD's operations is de minimis.

Due to the location of the Rock Slough Intake near the end of a dead-end slough, far from the main migratory routes, juvenile Winter-Run Chinook Salmon are not likely to be in the vicinity of the Rock Slough Intake. However, according to NMFS (2017), juvenile Salmon can be “drawn” into the south Delta under reverse flows and high CVP and SWP pumping rates. One indicator of reverse flows is the net flow in Old and Middle Rivers (OMR). Rock Slough Intake is located on Rock Slough, approximately 3.5 miles west of the junction of Rock Slough and Old River, which is over 12 river miles north of the gates to the SWP Clifton Court Forebay. Given its location, the Rock Slough Intake does not affect OMR, and any effect that diversions at Rock Slough Intake would have in the Old and Middle River corridor would be to increase the northerly (positive) flow away from the Banks and Jones Pumping Plants.

However, diversions at the Rock Slough Intake could affect flows in the San Joaquin River at Jersey Point, which is approximately 14 river miles from the Rock Slough Intake (via the shortest route through Franks Tract). Mean velocity in a river channel can be calculated by dividing the flow rate by the cross-sectional area of the channel. The maximum effect of Rock Slough diversions on the channel velocity would be the maximum diversion rate (350 cfs) divided by the minimum cross-sectional area of the channel. This calculation assumes that all water diverted at Rock Slough comes from the San Joaquin River at Jersey Point, which is a conservative assumption (i.e., overestimates the effect on velocity). The cross-sectional area of the San Joaquin River at Jersey Point is approximately 60,500 square feet (sf), but varies depending on the tidal stage from approximately 56,000 sf (at low tide and low San Joaquin River flow) to 68,000 sf (at high tide and high San Joaquin River flow) as shown in Figure O.3-81.

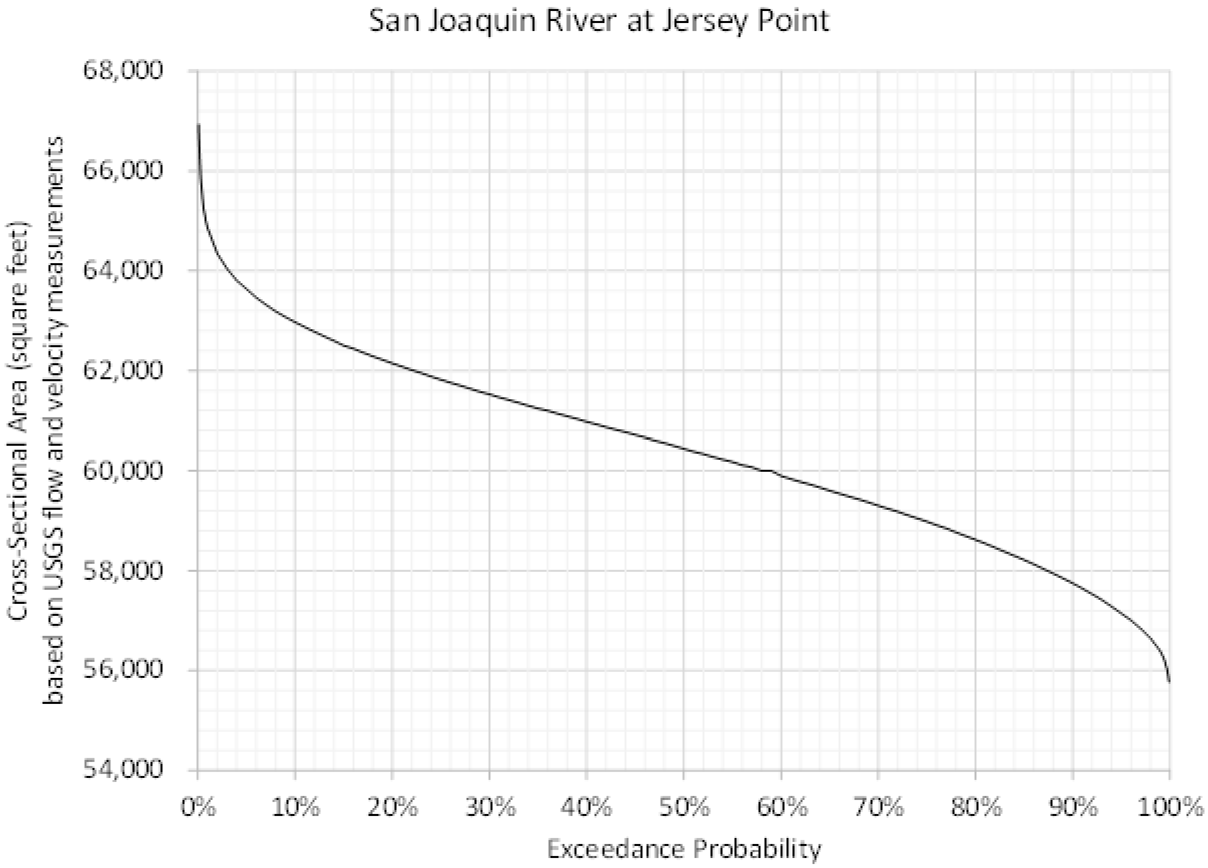


Figure O.3-81. Cross-Sectional Area of the San Joaquin River at Jersey Point (Station: 11337190) Calculated from USGS Measurements of Flow and Velocity every 15 Minutes for Water Years 2014 through 2018

The maximum effect of water diversions at Rock Slough Intake on velocity in the San Joaquin River at Jersey Point is calculated as 350 cfs divided by 56,000 square feet; resulting in 0.00625 feet per second (ft/sec). For comparison, the velocity threshold for design of fish screens to prevent impingement of salmonids is 0.33 ft/sec, which is 50 times the maximum possible contribution from Rock Slough diversions. Furthermore, the actual effect is likely to be much lower than 0.00625 ft/sec because the water diverted at the Rock Slough Intake does not all come from the San Joaquin River west of Jersey Point.

Recognizing that CCWD owns and operates two additional intakes in the south Delta, the combined effect of all three intakes is examined. CCWD's Old River Intake and Middle River Intake have a physical capacity of 250 cfs at each intake. If CCWD were to divert at all three intakes at the maximum capacity at the same time, total CCWD diversions would be 850 cfs. The corresponding effect on velocity in the San Joaquin River at Jersey Point would be 0.015 ft/sec. The velocity threshold used to protect salmonids from diversions in the vicinity of fish screens (0.33 ft/sec) is over 21 times greater than the maximum possible contribution from CCWD's combined physical capacity. The water diversions at the Rock Slough Intake when combined with diversions at CCWD's Old River Intake and Middle River Intake have a negligible effect on velocity along the migratory path for juvenile Winter-Run Chinook Salmon and are not likely to affect the movement of juvenile salmonids.

Nonetheless, even extremely small changes in velocity can affect the movement of neutrally buoyant

particles such as phytoplankton. To examine the effect on neutrally buoyant particles, the distance that a particle would travel due to the maximum permitted Rock Slough diversions over the course of a day is calculated. A change in velocity of 0.00625 ft/sec could move a neutrally buoyant particle approximately 540 ft over the course of the day (0.00625 ft/sec * 86,400 sec/day). For comparison, the tidal excursion on the San Joaquin River at Jersey Point during a flood tide (i.e., the distance a particle will travel tidally upstream during a flood tide) is about 34,000 ft on average (or 6.4 miles), which is about 63 times the distance that diversions at Rock Slough could move a particle at the same location over the course of a full day. Therefore, the maximum possible contribution of diversions at Rock Slough on movement of neutrally buoyant particles such as phytoplankton is not significant in comparison to the tidal excursion and mixing at this location.

In summary, CCWD's operations under Alternative 1 would remain consistent with the operational criteria specified in separate biological opinions and permits that govern operations at CCWD's intakes and Los Vaqueros Reservoir, and as shown above, the effect of CCWD's operations on Delta hydrodynamics is negligible.

Potential changes to aquatic resources due to North Bay Aqueduct operations

Alternative 1 includes the North Bay Aqueduct (NBA) intake in the North Delta and operation of the Barker Slough Pumping Plant. Listed salmonids may be present in the waterways adjacent to the Barker Slough Pumping Plant (monitoring data is available at https://www.wildlife.ca.gov/Regions/3). There should be no discernable effect to the Winter-Run Chinook Salmon due to the operations of the Barker Slough Pumping Facility. This is due to the infrequent presence of Winter-Run Chinook Salmon in the monitoring surveys indicating a low risk of entrainment. Further, Barker Slough Pumping Facility fish screens are designed to protect juvenile salmonids per NMFS criteria and should prevent entrainment while greatly minimizing any impingement of fish against the screen.

Alternative 1 also includes sediment removal with a suction dredge that could entrain Winter Run individuals occurring near the suction dredging. In addition, aquatic weed removal with a grappling system could disturb Winter Run occurring near the removal. The low occurrence of Chinook Salmon in monitoring efforts suggest that any potantil imacts from sediment and aquatic weed removal would be limited.

Potential changes to aquatic resources due to water transfers

Under Alternative 1, Reclamation is extending the water transfer window until November, from the current July through September window. This extension could result in increased flows entering the Delta and increased pumping at Jones and Banks Pumping Plants.

Egg, alevin, and fry lifestages of Winter-Run Chinook Salmon do not occur in the Delta, and therefore would not be affected by this action. Winter-Run Chinook Salmon juveniles enter the Delta starting in December, and therefore would be unlikely to be exposed to increased pumping of water transfers through November. Adults returning from the ocean could possibly be in the Delta in July; however, they are strong swimmers, large fish that can avoid predators, and are unlikely to have impacts associated with direct entrainment of the pumping plants.

Potential changes to aquatic resources from Clifton Court aquatic weed removal

Few if any juvenile Winter-Run Chinook Salmon would be expected to be exposed to the Clifton Court Forebay Aquatic Weed Control Program. Juvenile Winter-Run Chinook Salmon are present in the Delta between December and May with a peak in March and April (Reclamation 2019). The application of aquatic herbicide to the waters of CCF will occur between 28 June and 31 August 31, when tempertures exceed 25 ˚C, or when no protective actions have been triggered. Thus, the probability of exposing Winter-Run Chinook Salmon to the herbicide is very low. Based on typical water temperatures in the vicinity of the salvage facilities during this period, the water temperatures would be incompatible with salmonid life history preferences, generally exceeding 70°F by mid-June. Mechanical harvesting would occur on an as-needed basis and, therefore, Winter-Run Chinook Salmon could be exposed to this action, if entrained into the CCF.

As discussed in Appendix D, treatment of harmful algal blooms with peroxide-based algaecide is proposed to occur as needed, year-round, but there are no anticipated impacts to fish because the oxidation reaction occurs immediately upon contact with the water, destroying algal cell membranes and chlorophyll, with hydrogen peroxide and oxygen as byproducts.

Potential changes to aquatic resources due to changes from Tracy and Skinner Fish Facility improvements

A small proportion of juvenile Winter-Run Chinook Salmon are expected to be exposed to the Tracy Fish Facility (Zeug and Cavallo 2014). However, for fish that arrive at the facility, the proposed improvements are likely to increase survival through the facility. Winter-Run Chinook Salmon adults would not be expected to be exposed to the effects of construction of the carbon dioxide injection device proposed for the Tracy Fish Facility, based on the timing of in-water construction (August to October) and the typical seasonal occurrence of this life stage in the Delta (Reclamation 2019).

Few if any juvenile Winter-Run Chinook Salmon would be expected to be exposed to construction of the carbon dioxide injection device proposed for the Tracy Fish Facility Improvements based on lack of observed salvage during the August to October in-water work window (see Figures F.2.7, F.2.8, and F.2.9 in Appendix F, *Juvenile Salmonid Monitoring, Sampling, and Salvage Summary from SacPAS*, from the ROC LTO BA). However, a few early migrants could occur during the in-water work window based on occurrence in the north Delta (see Figures WR_Seines and WR_Sherwood in Appendix F of the ROC LTO BA).

To the extent that the construction affects the ability of juvenile Winter-Run Chinook Salmon to be efficiently salvaged (as part of the entrainment risk habitat attribute in the SAIL conceptual model; Figure 5.6-44), there could be a minor effect to a small number of individuals, although risk would be minimized through appropriate mitigation measures for aquatic resources (Appendix E, *Mitigation Measures*). There is low potential exposure because of the in-water work window, the application of mitigation measures, and the small scale of the in-water construction.

Skinner Fish Facility improvements from predator control efforts to reduce predation on listed fishes following entrainment into CCF could reduce pre-screen loss of juvenile Chinook Salmon entrained into CCF. It is important to note that only small proportions of Winter-Run Chinook Salmon are lost at the SWP (Zeug and Cavallo 2014).

Potential changes to aquatic resources due to changes from Suisun Marsh facilities

Operation of the SMSCG from October through May to meet salinity standards set by the State Water Resources Control Board and Suisun Marsh Preservation Agreement provides water quality benefits to Winter-Run Chinook Salmon habitat. This beneficial operation coincides with downstream migration of juvenile Winter-Run Chinook Salmon (Reclamation 2019). Montezuma Slough provides an alternative route to their primary migration corridor through Suisun Bay. No data are available to estimate the abundance of juvenile Winter-Run Chinook Salmon in Montezuma Slough thus, the proportion of the total run utilizing this route is unknown. Winter-Run Chinook Salmon typically migrate through the estuary several months before spawning, but an extended delay in the estuary may affect their ability to access their natal spawning streams. Winter-Run Chinook Salmon generally utilize high stream flow conditions to assist their upstream migration. Rapid upstream movement may be needed to take advantage of a short duration high stream flow event, particular in dry years when high flow events may be uncommon. NMFS (2009) determined that operation of the SWSCG is unlikely to impede migration of juvenile salmonids or produce conditions that support unusually high numbers of predators.

As described by NMFS (2009: 437-438), the Roaring River Distribution System (RRDS)'s water intake (eight 60-inch-diameter culverts) is equipped with fish screens (3/32-inch opening, or 2.4 mm) operated to maintain screen approach velocity of 0.7 ft/s, so that juvenile Winter-Run Chinook Salmon would be excluded from entrainment.

The Morrow Island Distribution System (MIDS) diverts water from Goodyear Slough through three 48-inch diameter culverts during high tide. Although the MIDS intakes do not currently have fish screens, its unlikely juvenile Winter-Run Chinook Salmon will be entrained into the water distribution system, since Winter-Run Chinook Salmon have not be caught in past surveys. Also, the large size and better swimming ability of juvenile listed salmonids in the Delta allow these fish to avoid entrainment at MIDS. In addition, the location of the MIDS intake on Goodyear Slough further reduces the risk of entrainment. Goodyear Slough is not a migratory corridor Winter-Run Chinook Salmon.

Goodyear Slough Outfall improves water circulation in the marsh. This structure consists of four 48-inch diameter culverts with flap gates designed to drain water from the southern end of Goodyear Slough into Suisun Bay. On flood tides, the gates reduce the amount of tidal inflow into Goodyear Slough. Due to its location and design, Winter-Run Chinook Salmon are not likely to encounter this structure or be negatively affected by its operation. Improved water circulation by the operation of the Goodyear Slough Outfall likely benefits juvenile Winter-Run Chinook Salmon in Suisun Marsh by improving water quality and increasing foraging opportunities.

Potential changes to aquatic resources from actions for Delta Smelt summer-fall habitat

No Winter-Run Chinook Salmon are detected in the Delta between June and September. Therefore, no effects would occur as a result of the Suisun Marsh Salinity Control Gate operation.

Potential changes to aquatic resources from Clifton Court predator management efforts

Clifton Court predator management efforts could reduce predation on listed fishes following entrainment into CCF, reducing pre-screen loss.

Potential changes to aquatic resources due to the San Joaquin Basin Steelhead Telemetry Study

No effect

Potential changes to aquatic resources due to reintroduction changes from the fish conservation and culture laboratory

Potential changes to aquatic resources from monitoring

No effect

A number of monitoring activities described in the ROC LTO BA (see Appendix C – Real Time Water Operations Charter, in section Routine Operations and Maintenance on CVP Activities) would have the potential to capture Winter-Run Chinook Salmon. Not all the existing IEP monitoring programs that target pelagic fish identify Chinook Salmon race. Of the programs that target and identify Winter-Run Chinook Salmon, collective catches are less than 1% of the Winter-Run JPE (Reclamation 2019). Because such a small percentage of the total JPE is captured in the monitoring programs, the effects of the monitoring programs are not likely to have effects to the Winter-Run Chinook Salmon population. These monitoring programs are important for understanding entry and residence time of Winter-Run Chinook Salmon into the Delta and San Francisco Estuary

O.3.3.8.4 Central Valley Spring-Run Chinook Salmon

Potential changes to aquatic resources due to seasonal operations

Reclamation and DWR propose to operate the C.W. Bill Jones Pumping Plant and the Harvey O. Banks Pumping Plant. These pumping plants affect the hydrodynamics of the south and central Delta resulting in effects to Spring-Run Chinook Salmon entrainment, routing and through Delta survival. Hydrodynamic changes associated with river inflows and South Delta exports have been suggested to negatively impact juvenile Chinook Salmon in two distinct ways: 1) "near-field" mortality associated with entrainment to the export facilities, 2) "far-field" mortality resulting from altered hydrodynamics. See Winter-Run Chinook Salmon effects section for more detail concerning "far-field" and "near-field."

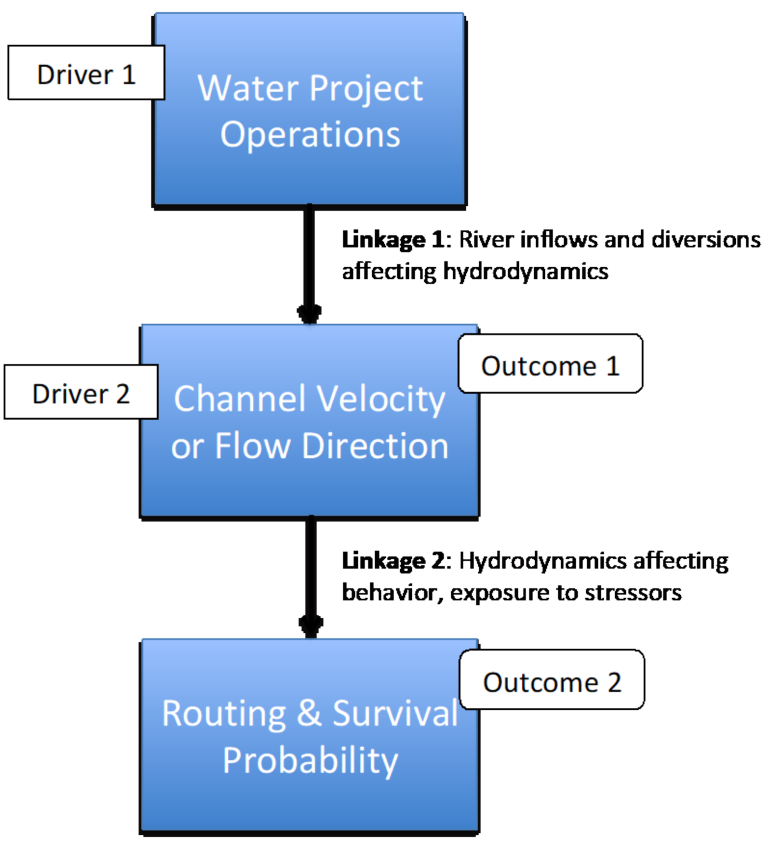


Figure O.3-82. Conceptual Model For Far-Field Effects of Water Project Operations on Juvenile Salmonids in the Delta. This CM Is a Simplified Version of the Information Provided by the CAMT SST

Entrainment

Among 6.8 million tagged natural origin and 2.8 million tagged hatchery origin Spring-Run Chinook Salmon juveniles, entrainment loss averaged less than 0.0005% (Zeug and Cavallo 2014). In the December through February, the average total export rate, under Alternative 1, is slightly higher difference compared to the No Action Alternative (366 cfs; Figure O1-1 in Appendix O, Attachment 1) and will therefore have a similar entrainment risk. Total exports proposed in March-June are 1,752 cfs higher than No Action Alternative (Figure O1-2 in Appendix O, Attachment 1) when juvenile Spring-Run Chinook Salmon are most abundant in the Delta.

Although data for juvenile Spring-Run Chinook Salmon originating from the San Joaquin River are limited, Zeug and Cavallo (2014) analyzed salvage of San Joaquin River-origin Fall-Run juvenile Chinook Salmon that are found in the Delta at a similar time as Spring-Run Chinook Salmon. Salvage of Fall-Run Chinook Salmon originating from the San Joaquin River averaged 1.4% and increased with export rate at the CVP and SWP (Zeug and Cavallo 2014). However, there were few observations at export rates greater than 3,000 cfs. Average mortality at the facilities represents < 5% total juvenile mortality for San Joaquin River-origin populations but can range as high as 17.5% (Zeug and Cavallo 2014).

In the December through February period, Alternative 1 proposes an average total export rate slightly higher than No Action Alternative (196 cfs; Figure O11) and will, therefore, have a similar entrainment risk. Total exports proposed for Alternative 1 in March-June (1,752 cfs higher than No Action Alternative; O1-2 in Appendix O, Attachment 1) when juvenile Spring-Run Chinook Salmon are most abundant in the Delta, will increase entrainment risk relative to No Action Alternative. Recent acoustic studies of juvenile Fall-Run Chinook Salmon in the San Joaquin River revealed that when the Head of Old River Barrier is out, >60% of fish detected at Chipps Island came through CVP, indicating that salvage is a higher survival route than volitional migration.

Routing

As stated in the Sacramento Winter-Run Chinook effects section, routing of juvenile Chinook Salmon into alternative migration routes is closely related to hydrodynamics (Perry et al. 2015; Cavallo et al. 2015; Steel et al. 2012). Juvenile Spring-Run Chinook Salmon are present in the Delta between November and early June with a peak in April (Reclamation 2019). In the December through February period, velocity overlap between Alternative 1 and No Action Alternative in the Sacramento River main stem between the Sutter-Steamboat and DCC/Georgiana Slough Junctions, was >75% in critically dry, dry, below normal and above normal years (Figure O1-3 in Appendix O, Attachment 1). In wet years, velocity overlap in this reach was ≤ 50%. Velocities were higher under Alternative 1 in all water year types indicating routing into the interior Delta would be lower relative to No Action Alternative (Perry et al. 2015). In the March to May period, comparison of Alternative 1 and No Action Alternative revealed similar patterns of velocity overlap as described for the December to February period (Figure O1-4 in Appendix O, Attachment 1) indicating routing into the interior Delta would be lower under Alternative 1 in the March to May period.

Spring-Run Chinook Salmon originating from the Sacramento River that enter the interior Delta via Georgiana Slough and the Delta Cross Channel can be exposed to hydrodynamic project effects that could affect routing. Once these fish arrive at the junction of the Mokelumne River and the San Joaquin River, they can move south toward the export facilities or west toward the ocean. In the December to February period analysis of DSM2 data indicates that there is little change to velocities in the region of the junction of the Mokelumne and San Joaquin Rivers between Alternative 1 and both the No Action Alternative scenarios (Figure O1-5 in Appendix O, Attachment 1). Similar results were obtained when comparing Alternative 1 to No Action Alternative in the March to May period (Figure O1-6 in Appendix O, Attachment 1).

Juvenile Spring-Run Chinook Salmon are present in the Delta between November and early June with a peak in April (Reclamation 2019). Early studies using coded wire tags indicated that survival of San Joaquin River-origin juvenile Chinook Salmon was lower in the Old River Route relative to the San Joaquin main stem (Newman 2008). This finding led to strategies designed to keep larger proportions of fish in the San Joaquin River main stem including the Head of Old River rock barrier and non-physical barriers. Recent studies using acoustic technology have indicated that differences in survival among the two routes are not significant (Buchanan et al. 2013; Buchanan et al. 2018). Thus, fish that enter Old River are unlikely to experience reduced survival.

Spring-Run Chinook Salmon originating from the San Joaquin River that remain in the San Joaquin River main stem at the Head of Old River are exposed to additional junctions that lead into the interior Delta including; Turner Cut, Columbia Cut, Middle River, Old River, Fisherman's Cut and False River. In the December through February period analysis of DSM2 data indicates that there is little change to velocities in the region of the junctions with San Joaquin Rivers between Alternative 1 and No Action Alternative scenarios (Figure O1-5 in Appendix O, Attachment 1). Similar results were obtained when comparing Alternative 1 to No Action Alternative in the March to May period (Figures O1-6 in Appendix O, Attachment 1).

In the December through February period, velocity overlap between Alternative 1 and No Action Alternative at the Head of Old River was high in critically dry water years and moderate in dry, below normal and wet years (Figure O1-5 in Appendix O, Attachment 1). The lowest overlap occurred in above normal years (Figure O1-5 in Appendix O, Attachment 1). In the March to May period, velocity overlap patterns were similar to comparisons in the December through February period (Figure O1-6 in Appendix O, Attachment 1).

Through-Delta Survival

To examine potential effects of Alternative 1, changes in velocity distributions were examined for the Sacramento River at Walnut Grove and Steamboat Slough which are both in this "transitional" region. During the December to February period at Walnut Grove, velocity distributions for Alternative 1 relative to No Action Alternative were most different in wet years (70.9%) with higher velocities in Alternative 1. Velocities were also greater for Alternative 1 relative to No Action Alternative in dry, below normal and above normal years although overlap was greater (≥79%; Figure O1-7 in Appendix O, Attachment 1). In critically dry years, velocity distributions were almost identical (95.4%; Figure O1-7 in Appendix O, Attachment 1). At Steamboat Slough in the December to February period, there was a similar pattern where velocities under Alternative 1 were higher than No Action Alternative in wet, above normal and below normal years and similar in dry and critically dry years (Figure O1-8 in Appendix O, Attachment 1).

In the March through May period at Walnut Grove, velocity overlap between Alternative 1 and No Action Alternative was ≥78% across all water year types with greater velocities under Alternative 1 (Figure O1-9 in Appendix O, Attachment 1). At Steamboat Slough in the March through May period, overlap between

Alternative 1 and No Action Alternative scenarios was high with all values ≥82% and greater velocities under Alternative 1 (Figure O1-10 in Appendix O, Attachment 1).

A recent study by Perry et al. (2018) found that the effect of flow on survival is not uniform throughout the Delta. Relationships between flow and survival were significant only in reaches where flow changes from bi-directional to unidirectional when discharge increases. This study was performed with hatchery-origin Late Fall-Run Chinook Salmon and there is uncertainty regarding the applicability of those results to Spring-Run Chinook Salmon. However, this study represents the best information avaiable on survival of juvneile Chinook Salmon in the Delta.To examine potential effects of Alternative 1, changes in velocity distributions were examined for the San Joaquin River at Highway 4 and the Head of Middle River which are both in the “transitional” region of the San Joaquin River. During the December to February period at the San Joaquin River at Highway 4, velocity distributions for Alternative 1 relative to No Action Alternative exhibited high overlap in all water year types (≥84.3%; Figure O1-11 in Appendix O, Attachment 1). At the Head of Middle River during the December through February period, overlap was high between Alternative 1 and No Action Alternative in critically dry, dry and below normal water years (≥90.1%) and moderate in wet and above normal years (53.6-75.1%; Figure O1-12 in Appendix O, Attachment 1).

In the March to May period in the San Joaquin River at Highway 4, velocity overlap was high between Alternative 1 and No Action Alternative (≥83.2%; Figure O1-13 in Appendix O, Attachment 1). Velocities were lower under Alternative 1 in dry, below normal and wet year and higher in above normal years (Figure O1-23 in Appendix O, Attachment 1). At the Head of Middle River in the March –May period, overlap between Alternative 1 and No Action Alternative was moderate in above normal years (57.7%) and higher in all other water year types ≥ 73% (Figure O1-14 in Appendix O, Attachment 1). In above normal years, velocities were higher under Alternative 1 and lower in all other water year types (Figure O1-14 in Appendix O, Attachment 1).

Potential changes to aquatic resources due to OMR management

See section on seasonal operation above, which integrates OMR management.

Potential changes to aquatic resources due to Delta Cross Channel operations

The Delta Cross Channel may be closed for up to 45 days from November through January for fishery protection purposes. From February 1 through May 20, the gates are closed for fishery protection purposes. Significant amounts of flow and many juvenile Spring-Run Chinook Salmon enter the DCC (when the gates are open) and Georgiana Slough, especially during increased Delta pumping. Mortality of juvenile Salmon entering the central Delta is higher than for those continuing downstream in the Sacramento River. Juvenile Chinook Salmon that are entrained into an open DCC and transported to the interior Delta have reduced survival (Perry et al. 2010) The gates may also be closed for 14 days from May 21 through June 15 for fishery protection purposes. The peak migration of juvenile Spring-Run Chinook Salmon in the Sacramento River past Knights Landing, which is upstream of the DCC, occurs from March-April (Reclamation 2019). Therefore, the DCC is closed to protect the majority of the juvenile Spring-Run Chinook Salmon migration period in the Sacramento River and reduce the proportion of fish exposed to an open DCC.

Potential changes to aquatic resources due to the Temporary Barriers Project

The agricultural barriers at Middle River and Old River near Tracy can begin operating as early as April 15 but the tide gates are tied open from May 16 to May 31. After May 31, the barriers in Middle River, Old River near Tracy, and Grant Line Canal are permitted to be operational until they are completely removed by November 30.

The proportion of juvenile Spring-Run Chinook Salmon exposed to the agricultural barriers (Temporary Barrier Program, TBP) depends on their annual timing of installation and removal. Due to their location, primarily migrants originating from the San Joaquin River would be exposed to the TBP. The peak relative abundance of juvenile Spring-Run Chinook Salmon in the Delta is March and April (Reclamation 2019). If the agricultural barriers are operating as early as April 15 then they have the potential to expose a large proportion of the juvenile Spring-Run Chinook Salmon migrating down the San Joaquin River. When the Head of Old River barrier is not in place, acoustically tagged juvenile Chinook Salmon have demonstrated a high probability of selecting the Old River route (Buchanan 2018), which would expose them to the agricultural barriers. When the agricultural barriers are operating with tidal flap gates down, a significant decline in passage and reach survival of acoustically tagged juvenile Chinook Salmon migrating past the barrier has been observed compared to when the barrier is not present (DWR 2018). When flap gates are tied up, Chinook Salmon passage past the agricultural barrier was improved (DWR 2018). Flap gates tied up on agricultural barriers from May 16 to May 31 would help to reduce the negative effect of the barriers during this period. However, juveniles migrating before or after this period could be exposed to the agricultural barriers with flaps down which apparently decreases passage success and survival (DWR 2018).

Potential changes to aquatic resources due to Contra Costa Water District operations

As discussed in Chapter 3, CCWD’s operations in Alternative 1 are consistent with the operational criteria specified in separate biological opinions and permits that govern operations at CCWD’s intakes and Los Vaqueros Reservoir (NMFS 1993, 2007, 2010, 2017; USFWS 1993a, 1993b, 2000, 2007, 2010, 2017; CDFG 1994, 2009a). Therefore, CCWD’s operations, including operation of the Rock Slough Intake, for Alternative 1 remain unchanged from the current operations.

The Contra Costa Canal Rock Slough Intake is located on a dead-end slough, far from the main migratory route for Central Valley Spring-Run Chinook Salmon (NMFS 2017c), approximately 18 miles from the Sacramento River and 10 miles from the San Joaquin River via the shortest routes. Designated critical habitat for Spring-Run Chinook Salmon does not occur within Rock Slough, but is present further to the north in the Delta (NMFS 2017c, 2014). Salmonids are expected to avoid the area of the Rock Slough Intake during certain times of the year based on historical water temperatures, which range from lows of about 45°F in winter (December and January) to over 70°F beginning in May and continuing to October (Reclamation 2016).

Fish monitoring prior to the construction of the Rock Slough Fish Screen (RSFS) indicates the timing and magnitude of Central Valley Spring-Run Chinook Salmon presence near the Rock Slough Intake. Since 1994, fish monitoring has been conducted by CDFW and CCWD consistent with the separate biological opinions and permits that govern CCWD’s operations. From 1994 through 1999, CDFW conducted fish monitoring at the Rock Slough Intake and in the Contra Costa Canal up to the first pumping plant. Over this 6-year period, CDFW captured a total of 108 juvenile Central Valley Spring-Run Chinook Salmon from March through May (CDFG 2002c; NMFS 2017c). From 1999 to 2009, the 11 years prior to construction of the RSFS, CCWD’s Fish Monitoring Program collected a total of 11 juvenile Central Valley Spring-Run Chinook Salmon from March through May at the Rock Slough Headworks (Reclamation 2016; NMFS 2017c) and 4 juvenile Central Valley Spring-Run at Pumping Plant #1 (CCWD 2019). No adult Spring-Run Chinook Salmon were collected in the vicinity of the Rock Slough Intake from 1994 through 2009 (CDFG 2002c; Reclamation 2016; NMFS 2017c). No juvenile or adult

Central Valley Spring-Run Chinook Salmon have been collected in CCWD's Fish Monitoring Program at the Rock Slough Intake since 2008.

Since construction of the RSFS, operation of the hydraulic rake cleaning system has been shown to trap and kill adult Chinook Salmon and other non-listed fish (Reclamation 2016). From 2011-2018, 47 Salmon were recovered at the RSFS (Reclamation 2016, Appendix A; Tenera Environmental 2018a), but none of the captured fish were identified as Spring-Run Chinook Salmon (NMFS 2017c).

CCWD's Fish Monitoring Program also samples behind the fish screens at CCWD's other south Delta intakes. Since the intakes have been in operation, CCWD's Fish Monitoring Program has never collected at CCWD's Old River Intake or Middle River Intake (CCWD 2019).

CCWD's operations, including operation of the Rock Slough, Old River, and Middle River intakes and Los Vaqueros Reservoir, are simulated in the CalSim model. Thus, CalSim results discussed throughout this appendix include the effects of CCWD's operations in combination with all other water diversions and reservoir operations. A further analysis was undertaken to isolate the maximum possible effects of CCWD's operations on Delta hydrodynamics by determining the effect that CCWD pumping at maximum capacity would have on Delta channel water velocity. Results of this analysis are shown below; in all cases the maximum possible effect of CCWD's operations is de minimis.

Due to the location of the Rock Slough Intake near the end of a dead-end slough, far from the main migratory routes (i.e., 10 miles from the San Joaquin River and 18 miles from the Sacramento River), juvenile Spring-Run Chinook Salmon are not likely to be in the vicinity of the Rock Slough Intake. However, according to NMFS (2017), juvenile Spring-Run Chinook Salmon can be "drawn" into the south Delta under reverse flows and high CVP and SWP pumping rates.

One indicator of reverse flows is the net flow in OMR. Rock Slough Intake is located on Rock Slough, approximately 3.5 miles west of the junction of Rock Slough and Old River, which is over 12 river miles north of the gates to the SWP Clifton Court Forebay. Given its location, the Rock Slough Intake does not affect net reverse flow in OMR, and any effect that diversions at Rock Slough Intake would have in the OMR corridor would be to increase the northerly (positive) flow away from the Banks and Jones Pumping Plants. For juveniles that migrate down the OMR corridor that are not salvaged at TFCF or Skinner Fish Facility, any effect of Rock Slough Intake diversions would be a positive effect on OMR.

For juveniles that migrate down the mainstem of the Sacramento River or the San Joaquin River and for juveniles that were salvaged, trucked, and released in the western Delta, the potential effect of Rock Slough diversions on the net reverse flow in San Joaquin River may be relevant. The effect of water diversions at Rock Slough Intake on the velocity in the San Joaquin River at Jersey Point is presented in the effects analysis for juvenile Winter-Run Chinook Salmon. As detailed in that section, the maximum potential effect of water diversions at Rock Slough Intake (assuming diversions at the maximum permitted capacity of 350 cfs and all water diverted by the Rock Slough Intake comes from the San Joaquin River at Jersey Point) is 0.00625 ft/sec in the San Joaquin River at Jersey Point. For comparison, the velocity threshold for design of fish screens to prevent impingement of salmonids is 0.33 ft/sec, which is 50 times the maximum possible contribution from the Rock Slough diversions.

Recognizing that CCWD owns and operates two additional intakes in the south Delta, we examine the combined effect of all three intakes. CCWD's Old River Intake and Middle River Intake have a physical capacity of 250 cfs at each intake. If CCWD were to divert at all three intakes at the maximum capacity at the same time, total CCWD diversions would be 850 cfs. The corresponding effect on velocity in the San Joaquin River at Jersey Point would be 0.015 ft/sec. The velocity threshold used to protect salmonids from diversions in the vicinity of fish screens (0.33 ft/sec) is over 21 times greater than the maximum possible contribution from CCWD's combined physical capacity. The water diversions at the Rock Slough Intake when combined with diversions at CCWD's Old River Intake and Middle River Intake have a negligible effect on velocity along the migratory path for juvenile Spring-Run Chinook Salmon and are not likely to affect the movement of juvenile salmonids.

Nonetheless, even extremely small changes in velocity can affect the movement of neutrally buoyant particles such as phytoplankton. As shown in the Winter-Run Chinook Salmon section, the diversions at the Rock Slough Intake could move a neutrally buoyant particle in the San Joaquin River at Jersey Point approximately 540 ft over the course of the day. For comparison, the tidal excursion on the San Joaquin River at Jersey Point during a flood tide (i.e., the distance a particle will travel tidally upstream during a flood tide) is about 34,000 ft on average (or 6.4 miles), which is about 63 times the distance that diversions at Rock Slough could move a particle at the same location over the course of a full day. Therefore, the maximum possible contribution of diversions at Rock Slough on movement of neutrally buoyant particles such as phytoplankton is insignificant in comparison to the tidal excursion and mixing at this location.

In summary, CCWD's operations under Alternative 1 would remain consistent with the operational criteria specified in separate biological opinions and permits that govern operations at CCWD's intakes and Los Vaqueros Reservoir, and as shown above, the effect of CCWD's operations on Delta hydrodynamics is negligible.

Potential changes to aquatic resources due to North Bay Aqueduct operations

Alternative 1 includes the North Bay Aqueduct (NBA) intake in the North Delta and operation of the Barker Slough Pumping Plant. Listed salmonids may be present in the waterways adjacent to the Barker Slough Pumping Plant (monitoring data is available at https://www.wildlife.ca.gov/Regions/3). The NBA is located within designated critical habitat for Spring-Run Chinook Salmon. There should be no discernable effect to the Spring-Run Chinook Salmon due to the operations of the Barker Slough Pumping Facility. This is due to the infrequent presence of Spring-Run Chinook Salmon in the monitoring surveys indicating a low risk of entrainment. Further, Barker Slough Pumping Facility fish screens are designed to protect juvenile salmonids per NMFS criteria and should prevent entrainment while greatly minimizing any impingement of fish against the screen.

Alternative 1 also includes sediment removal with a suction dredge that could entrain Spring Run individuals occurring near the suction dredging. In addition, aquatic weed removal with a grappling system could disturb Spring Run occurring near the removal. The low occurrence of Chinook Salmon in monitoring efforts suggest that any potantil imacts from sediment and aquatic weed removal would be limited.

Potential changes to aquatic resources due to water transfers

Under Alternative 1, Reclamation is expanding the transfer window to November from the current July to September. Expanding the transfer window could lead to increased pumping at Jones and Banks Pumping Plants, when capacity is available. The Figures below show when capacity is available under Alternative 1 and the No Action Alternative, in terms of exceedances, years in the model period of record, and average by water year types. These values are total available, and are not filtered for the pattern on which water might be acquired for transfer. The pattern of acquisition could decrease these values, as well as reoperation of storage that might be required, or the water cost of meeting D-1641. Prior estimates indicate that approximately 50% of the capacity in the figures below would be useful for water transfers given these timing and upstream considerations. In addition, a 20-30% surcharge on acquisition might be necessary to accommodate the salinity related inefficiencies that arise in operations. Based on the figures below and these additional estimates, expanding the water transfer window could result in an additional approximately 50 TAF of pumping in most yeartypes. As more stored water is available from CVP and SWP reservoirs to pump in wetter yeartypes, most of the available capacity for transfers is in drier yeartypes (Figures O.3-83 through O.3-85).

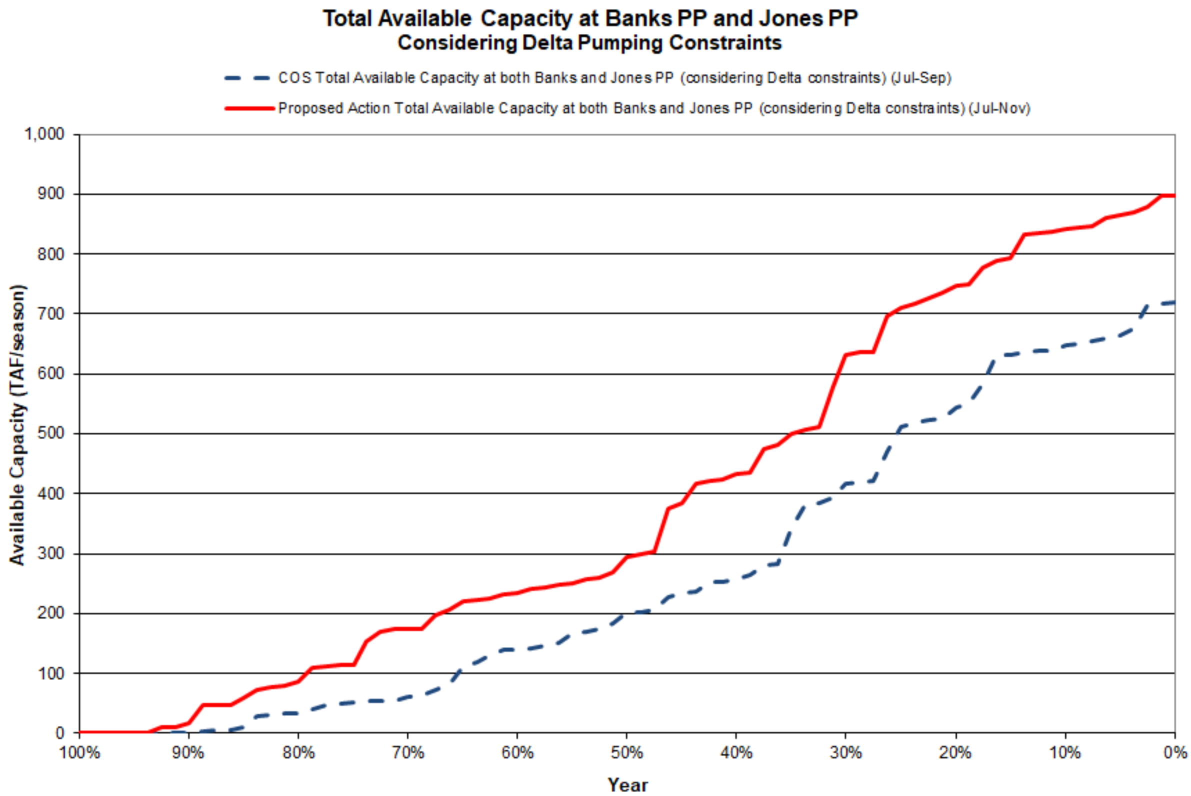


Figure O.3-83. Exceedance of Available Capacity for Transfers at Jones and Banks under the Alternative 1 and No Action Alternative

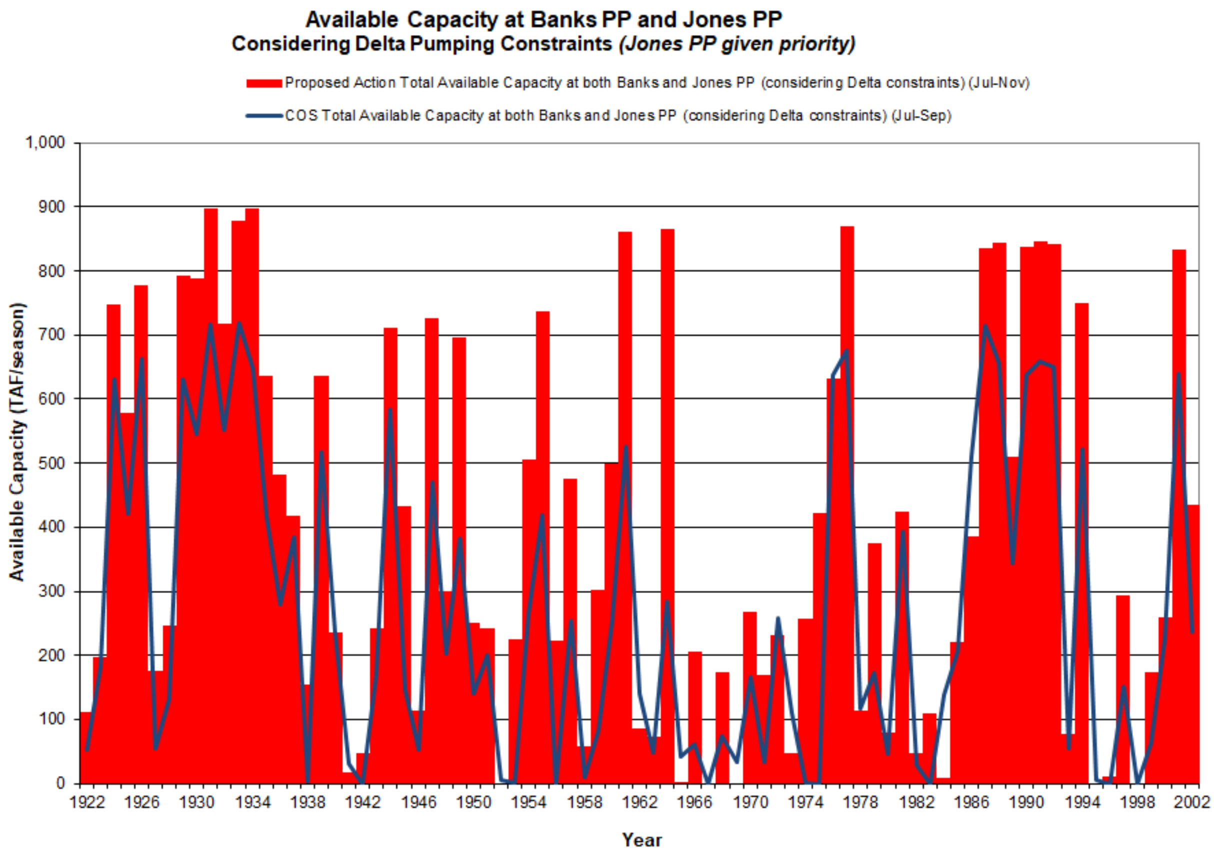


Figure O.3-84. Modeled Annual Maximum Available Capacity for Transfers under Alternative 1 and No Action Alternative, CalSim Period of Record (1922–2003)

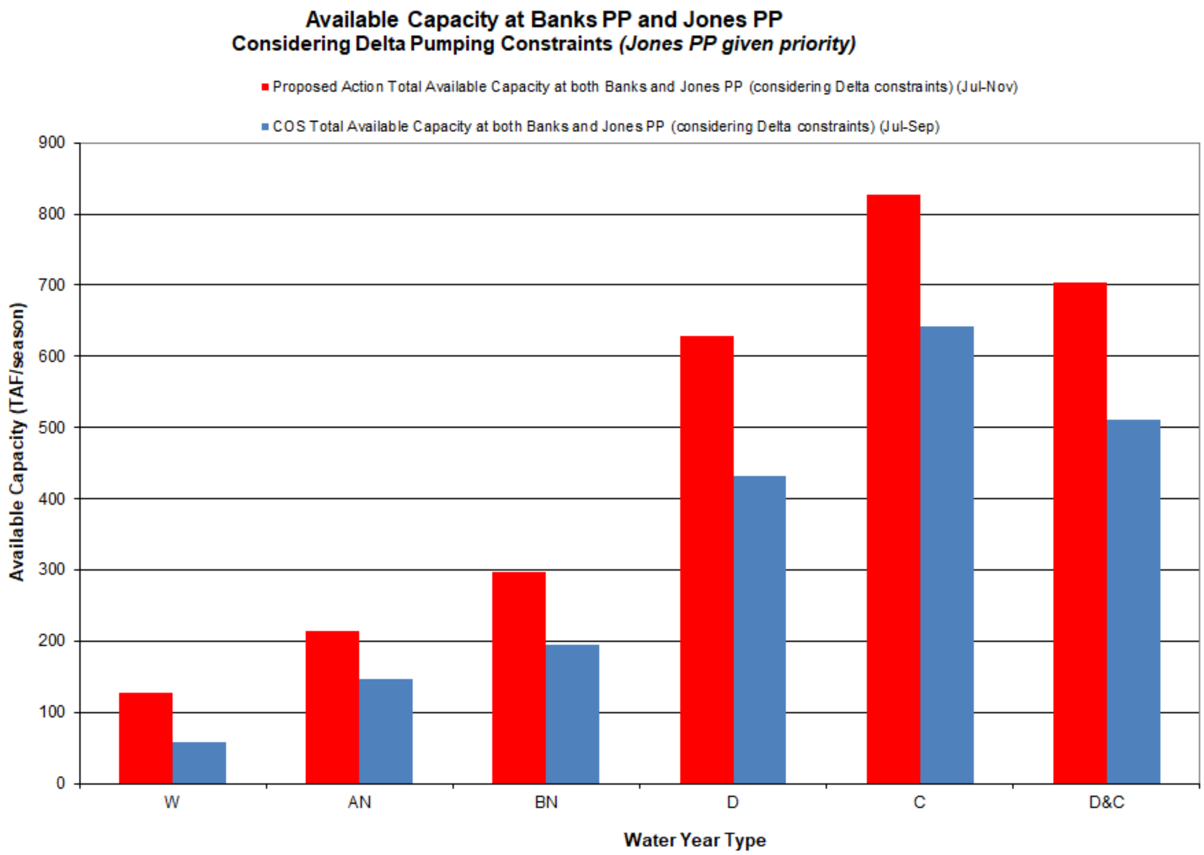


Figure O.3-85. Water Year Type Average Available Capacity at Jones and Banks Pumping Plants

Egg, aelvin, fry, and adult lifestages of Spring-Run Chinook Salmon would not be exposed to the effects of increased water transfers as they do not occur in the Delta during July through November. Juvenile Central Valley Steelhead are detected at Chipps Island between December and July with the highest abundance in March to May (Reclamation 2019). Thus, only the very early or late migrants could potential be exposed to water transfers that occur during this time. These early or late migrant uvenile Spring-Run Chinook Salmon could be exposed to increased effects of entrainment, routing, and decreased Delta survival (see OMR management section) as a result of the expanded water transfer window. Increased flows during conveyance in the Sacramento River could provide small survival benefits to migrating juveniles (Perry et al. 2018).

Potential changes to aquatic resources from Clifton Court aquatic weed removal

Few if any juvenile Spring-Run Chinook Salmon would be expected to be exposed to the Clifton Court Forebay Aquatic Weed Control Program. Juvenile Spring-Run Chinook Salmon are present in the Delta between mid-November and early June with a peak in April (Reclamation 2019). The application of aquatic herbicide to the waters of Clifton Court Forebay will occur during the summer months between 28 June and 31 August. Herbicide application can occur before 28 June if tempertures are ≥ 25˚C but Spring-Run Chinook Salmon are unlikley to be present at these temperature. Thus, the probability of exposing

Spring-Run Chinook Salmon to the herbicide is very low. Based on typical water temperatures in the vicinity of the salvage facilities during this period, the temperatures would be incompatible with salmonid life history preferences, generally exceeding 70°F by mid-June.

As discussed in Appendix D, treatment of harmful algal blooms with peroxide-based algaecide is proposed to occur as needed, year-round, but there are no anticipated impacts to fish because the oxidation reaction occurs immediately upon contact with the water, destroying algal cell membranes and chlorophyll, with hydrogen peroxide and oxygen as byproducts.

Potential changes to aquatic resources due to changes from Tracy and Skinner fish facility improvements

A number of programmatic actions are proposed to improve salvage efficiency of TFCF, including installing a carbon dioxide injection device to allow remote controlled anesthetization of predators in the secondary channels of the Tracy Fish Facility. These actions could potentially benefit juvenile Spring-Run Chinook Salmon through greater salvage efficiency.

Few if any juvenile Spring-Run Chinook Salmon would be expected to be exposed to construction of the CO_2 injection device proposed for the Tracy Fish Facility Improvements, based on lack of observed salvage during the August to October in-water work window (see figures in Appendix F of the ROC LTO BA: WR_salvage_unclipped_date, WR_salvage_clipped_date, and WR_salvage_clipped_CWT_race). Risks to these few individuals would be minimized through appropriate mitigation measures for aquatic resources (Appendix E, *Mitigation Measures*), the selected in-water work window, and the small scale of the in-water construction. For juvenile Spring-Run Chinook Salmon that arrive at the facility, the proposed improvements are likely to increase survival through the facility.

Predator control efforts at Skinner Fish Facility under Alternative 1 to reduce predation on listed fishes following entrainment intopre Clifton Court Forebay could reduce pre-screen loss of juvenile Spring-Run Chinook Salmon entrained into Clifton Court Forebay. A small number of juvenile Spring-Run Chinook Salmon could be impacted by predtor removal activies depending on the technique employed. However, increases in survival may offset any loss due to removal activities.

Potential changes to aquatic resources due to changes from Suisun Marsh facilities

Operation of the SMSCG from October through May to meet salinity standards set by the State Water Resources Control Board and Suisun Marsh Preservation Agreement provides water quality benefits to Spring-Run Chinook Salmon habitat. This beneficial operation coincides with downstream migration of juvenile Spring-Run Chinook Salmon (Reclamation 2019). Montezuma Slough provides an alternative route to their primary migration corridor through Suisun Bay. No data are available to estimate the abundance of juvenile Spring-Run Chinook Salmon in Montezuma Slough thus, the proportion of the total run utilizing this route is unknown. Spring-Run Chinook Salmon typically migrate through the estuary several months before spawning, but an extended delay in the estuary may affect their ability to access their natal spawning streams. Spring-Run Chinook Salmon generally utilize high stream flow conditions during the spring snowmelt to assist their upstream migration. Rapid upstream movement may be needed to take advantage of a short duration high stream flow event, particular in dry years when high flow events may be uncommon. If the destination of a pre-spawning adult Salmon is among the smaller tributaries of the Central Valley, it may be important for migration to be unimpeded, since access to a spawning area could diminish with receding flows. However NMFS (2009) determined that operation of the SWSCG is unlikely to impede migration of juvenile salmonids or produce conditions that support unusually high numbers of predators.

As described by NMFS (2009: 437-438), the Roaring River Distribution System (RRDS)'s water intake (eight 60-inch-diameter culverts) is equipped with fish screens (3/32-inch opening, or 2.4 mm) operated to maintain screen approach velocity of 0.7 ft/s, so that juvenile Spring-Run Chinook Salmon would be excluded from entrainment.

The Morrow Island Distribution System (MIDS) diverts water from Goodyear Slough through three 48-inch diameter culverts during high tide. Although the MIDS intakes do not currently have fish screens, its unlikely juvenile Central Valley Spring-Run Chinook Salmon will be entrained into the water distribution system, since Spring-Run Chinook Salmon have not be caught in past surveys. Also, the large size and better swimming ability of juvenile listed salmonids in the Delta allow these fish to avoid entrainment at MIDS. In addition, the location of the MIDS intake on Goodyear Slough further reduces the risk of entrainment. Goodyear Slough is not a migratory corridor Spring-Run Chinook Salmon.

Goodyear Slough Outfall improves water circulation in the marsh. This structure consists of four 48-inch diameter culverts with flap gates designed to drain water from the southern end of Goodyear Slough into Suisun Bay. On flood tides, the gates reduce the amount of tidal inflow into Goodyear Slough. Due to its location and design, Spring-Run Chinook Salmon are not likely to encounter this structure or be negatively affected by its operation. Improved water circulation by the operation of the Goodyear Slough Outfall likely benefits juvenile Spring-Run Chinook Salmon in Suisun Marsh by improving water quality and increasing foraging opportunities.

Potential changes to aquatic resources from actions for Delta Smelt summer-fall habitat No Spring-Run Chinook Salmon are detected in the Delta between June and September. Therefore, no effects would occur as a result of the Suisun Marsh Salinity Control Gate operation.

Potential changes to aquatic resources from Clifton Court predator management efforts

Predator control efforts at Clifton Court Forebay under Alternative 1 could reduce pre-screen loss of juvenile Spring-Run Chinook Salmon entrained into Clifton Court Forebay. Spring-Run Chinook Salmon are unlikely to be in the area during predator control efforts during the summer in-water work window.

Potential changes to aquatic resources from San Joaquin Basin Steelhead Telemetry Study

Potential changes to aquatic resources due to reintroduction changes from Fish Conservation and Culture Laboratory

Potential changes to aquatic resources from monitoring

Less than 2% of the estimated Spring-Run Chinook Salmon population, as indexed by the Red Bluff Rotary Screw Trap data, is collectively captured by the salmonid monitoring programs that support CVP operations (Reclamation 2019). Because such a small percentage of the estimated Spring-Run Chinook Salmon juvenile production is captured in the monitoring programs, the effects of the monitoring programs are not likely to have effects to the Spring-Run population.

O.3.3.8.5 Central Valley Fall-Run Chinook Salmon

Potential changes to aquatic resources due to seasonal operations

Hydrodynamic changes associated with river inflows and South Delta exports have been hypothesized to adversely affect juvenile Chinook Salmon in two distinct ways: 1) "near-field" mortality associated with entrainment to the export facilities, 2) "far-field" mortality resulting from altered hydrodynamics. Near-field or entrainment effects of proposed seasonal operations can be most appropriately assessed by examining patterns of proportional population entrainment available from decades of coded wire tag studies (e.g., Zeug and Cavallo 2014). A foundation for assessing far-field effects has been provided by work of the Collaborative Adaptive Management Team's (CAMT) Salmonid Scoping Team (SST). The SST completed a thorough review of this subject and defined a driver- linkage-outcome (DLO) framework for specifying how water project operations (the "driver") can influence juvenile salmonid behavior (the "linkage") and potentially cause changes in survival or routing (the "outcome"). The SST concluded altered "Channel Velocity" and altered "Flow Direction" were the only two hydrodynamic mechanisms by which exports and river inflows could affect juvenile salmonids in the Delta. Figure O.3-86 provides a simplified conceptual model of the DLO defined by the CAMT SST.

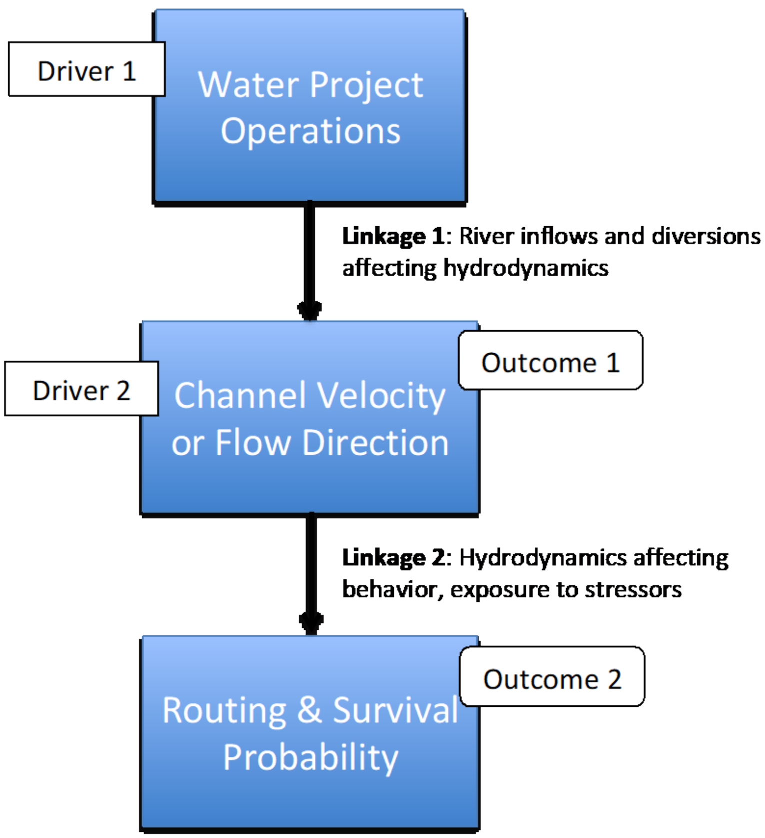


Figure O.3-86. Conceptual Model for Far-Field Effects of Water Project Operations on Juvenile Salmonids in the Delta. This CM Is a Simplified Version of the Information Provided by the CAMT SST

Though many juvenile salmonid tagging studies have been conducted in the Delta, the focus has primarily been on estimating reach survival and routing- not assessing export-related hydrodynamic mechanisms defined by the SST's DLO. In fact, most tagging studies have targeted areas of the Delta where "Channel Velocity" and "Flow Direction" may not be appreciably affected by exports (e.g., Newman and Brandes 2010; Perry et al. 2010; 2012; 2015; Michel et al. 2013).

In order to assess the potential for water project operations to influence survival and routing, we analyzed Delta hydrodynamic conditions by utilizing outputs from DSM2 Hydro modeling. Our analysis of DSM2 output is based on our previous work creating map-based visualizations of spatial hydrodynamic patterns at the scale of the Delta. The map-based approach allows us to identify a ‘footprint’ of the hydrodynamic differences between scenarios. The maps are based on a comparative metric, proportion overlap (more below), to capture channel-level hydrodynamic details as a single number for color-scaled mapping of Delta channels. Our previous work made clear that spatial patterns were more easily discerned by mapping comparative metrics than by mapping descriptive metrics in multiple panels.

The objective of the comparative metric is to summarize the water velocity time series for each channel and scenario such the channel-level comparison is captured in a single number. For the proportion overlap metric, kernel density estimates are calculated on each time series. The kernel density estimates represent a non-parametric smoothing of the empirical distribution of time series values. The proportion overlap of two kernel density estimates is calculated with the following steps: 1) calculate the total area under the curve (AUC_t) as the sum of the AUC for each density estimate, 2) calculate the AUC of the overlapping portions (AUC_o) of the two density distributions being compared, and 3) calculate the overlapping proportion of the density distributions as AUC_o/AUC_t. Proportion overlap is naturally bound by zero and one; a value of zero indicates no overlap and a value of one indicates complete overlap. Lower values of proportion overlap identify channels demonstrating larger differences in a scenario comparison.

The proportion overlap metric is best applied over relatively short time periods because seasonal and annual variation in water velocity can overwhelm differences between scenarios. Thus, we calculated proportion overlap for every DSM2 channel for two seasons (Dec-Feb, May-Mar) in each water year (1922–2003). We excluded DSM2 output from water year 1921 to allow for an extensive burn-in period. We calculated proportion overlap based on hourly DSM2 output. Because each season was roughly 90 days, each comparison involved roughly 4,300 DSM2 values (2 scenarios * 24 hours * 90 days) for each channel.

Because we calculated proportion overlap for each channel in each water year, we summarized the proportion overlap values prior to mapping (i.e., not feasible to map proportion overlap for every comparison in every water year). To summarize, we found the minimum and median proportion overlap for each channel for each water year type for each comparison. The minimum values represent the maximum expected effect. The median values represent the average expected effect. Note that the year with the minimum (or median) proportion overlap for one channel might not be the same year as for another channel.

O.3.3.8.6 Entrainment

Zeug and Cavallo (2014) analyzed > 1000 release groups representing, more than 28 million coded wire tagged juvenile fish including winter, Late Fall-Run and Fall-Run Chinook Salmon. This data is extremely useful because it represents large release groups of tagged smolts where the number of fish representing each release group lost to entrainment at the export facilities has been estimated. Estimating loss from “raw” salvage is problematic because the actual stock or basin of origin is often unknown (e.g., poor performance of length-at-date curves). Furthermore, with “raw” salvage, the number of smolts produced and potentially exposed to entrainment is unknown. The CWT salvage data analyzed by Zeug and Cavallo (2014) overcomes these deficiencies and provides the most appropriate basis for defining stock-specific categories of entrainment risk.

The average proportion Sacramento River-origin Fall-Run Chinook salvaged over a 15-year period was 0.0001 and the proportion of mortality accounted for by entrainment averaged 0.0003 (Zeug and Cavallo 2014). Salvage increased with increasing exports but loss never exceeded 1% regardless of export rate. Late Fall-Run Chinook Salmon juveniles were salvaged at a higher rate than any other race (0.02% of each release group) and entrainment related mortality accounted for almost 1% of total mortality on average (Zeug and Cavallo 2014). Proportional loss of Late-Fall remained low until exports exceeded ~9,000 cfs when proportional loss could approach 8% (Zeug and Cavallo 2014). In the December through February period when Late Fall-Run Chinook Salmon are most abundant, Alternative 1 proposes an average total export rate slightly higher than No Action Alternative (196 cfs; Figure O1-1 in Appendix O, Attachment 1) and will therefore have a similar entrainment risk. Total exports proposed for Alternative 1 in March-June (1,752 cfs higher than No Action Alternative; Figure O1-2 in Appendix O, Attachment 1) when juvenile Fall-Run Chinook Salmon are most abundant in the Delta, will increase entrainment risk relative to No Action Alternative, but entrainment losses for Fall-Run Chinook Salmon will be extremely low. Entrainment risk will also increase for Late Fall-Run Chinook Salmon and losses will likely be higher relative to Fall-Run.

Routing

Routing of juvenile Chinook Salmon into alternative migration routes is closely related to hydrodynamics (Perry et al. 2015; Cavallo et al. 2015; Steel et al. 2012). Changes to hydrodynamics in Delta channels resulting from Alternative 1 were evaluated using DSM2 as described above. Juvenile Fall-Run Chinook Salmon abundance in the Delta is greatest between February and May and Late Fall-Run Chinook Salmon are present in the Delta between November and July with peaks in January through February and April through May (Table FR_1, LFR_1). In the December through February period, velocity overlap between Alternative 1 and No Action Alternative in the Sacramento River main stem between the Sutter-Steamboat and DCC/Georgiana Slough Junctions, was >75% in critically dry, dry, below normal and above normal years (Figure O1-3 in Appendix O, Attachment 1). In wet years, velocity overlap in this reach was ≤ 50%. Velocities were higher under Alternative 1 in all water year types indicating routing into the interior Delta would be lower relative to No Action Alternative (Perry et al. 2015). In the March to May period, comparison of Alternative 1 and No Action Alternative revealed similar patterns of velocity overlap as described for the December through February period (Figure O1-4 in Appendix O, Attachment 1) indicating routing into the interior Delta would be lower under Alternative 1 during March to May.

Fall-Run and Late Fall-Run juveniles originating from the Sacramento River that enter the interior Delta via Georgiana Slough and the Delta Cross Channel can be exposed to hydrodynamic project effects that could affect routing. Once these fish arrive at the junction of the Mokelumne River and the San Joaquin River, they can move south toward the export facilities or west toward the ocean. In the December through February period analysis of DSM2 data indicates that there is little change to velocities in the region of the junction of the Mokelumne and San Joaquin Rivers between Alternative 1 and No Action Alternative scenarios (Figure O1-5 in Appendix O, Attachment 1). Similar results were obtained when comparing Alternative 1 to No Action Alternative in the March to May period (Figure O1-6 in Appendix O, Attachment 1).

O.3.3.8.7 Through-Delta Survival

A recent study by Perry et al. (2018) found that the effect of flow on survival is not uniform throughout the Delta. Relationships between flow and survival were significant only in reaches where flow changes from bi-directional to unidirectional when discharge increases. This study was performed with hatchery-origin Late Fall-Run Chinook Salmon and there is uncertainty regarding the applicability of those results to Fall-Run. However, this study represents the best information avaiable on survival of juvneile Chinook Salmon in the Delta.To examine potential effects of the proposed project, changes in velocity distributions were examined for the Sacramento River at Walnut Grove and Steamboat Slough which are both in this “transitional” region. During the December to February period at Walnut Grove, velocity distributions for Alternative 1 relative to No Action Alternative were most different in wet years (70.9%) with higher velocities in Alternative 1. Velocities were also greater for Alternative 1 relative to No Action Alternative in dry, below normal and above normal years although overlap was greater (≥79%; Figure O1-7 in Appendix O, Attachment 1). In critically dry years, velocity distributions were almost identical (95.4%; Figure O1-7 in Appendix O, Attachment 1). At Steamboat Slough in the December to February period, there was a similar pattern where velocities under Alternative 1 were higher than No Action Alternative in wet, above normal and below normal years and similar in dry and critically dry years (Figure O1-8 in Appendix O, Attachment 1).

In the March through May period at Walnut Grove, velocity overlap between Alternative 1 and No Action Alternative was ≥78% across all water year types with greater velocities under Alternative 1 (Figure O1-9 in Appendix O, Attachment 1). At Steamboat Slough in the March through May period, overlap between Alternative 1 and No Action Alternative scenarios was high with all values ≥82% and greater velocities under Alternative 1 (Figure O1-10 in Appendix O, Attachment 1).

A recent study by Perry et al. (2018) found that the effect of flow on survival is not uniform throughout the Delta. Relationships between flow and survival were significant only in reaches where flow changes from bi-directional to unidirectional when discharge increases. To examine potential effects of Alternative 1, changes in velocity distributions were examined for the San Joaquin River at Highway 4 and the Head of Middle River which are both in the "transitional" region of the San Joaquin River. During the December to February period at the San Joaquin River at Highway 4, velocity distributions for Alternative 1 relative to No Action Alternative exhibited high overlap in all water year types (≥84.3%; Figure O1-11 in Appendix O, Attachment 1). At the Head of Middle River during the December through February period, overlap was high between Alternative 1 and No Action Alternative in critically dry, dry and below normal water years (≥90.1%) and moderate in wet and above normal years (53.6-75.1%; Figure O1-12 in Appendix O, Attachment 1).

In the March to May period in the San Joaquin River at Highway 4, velocity overlap was high between Alternative 1 and No Action Alternative (≥83.2%; Figure O1-13 in Appendix O, Attachment 1). Velocities were lower under Alternative 1 in dry, below normal and wet year and higher in above normal years (Figure O1-23 in Appendix O, Attachment 1). At the Head of Middle River in the March to May period, overlap between Alternative 1 and No Action Alternative was moderate in above normal years (57.7%) and higher in all other water year types ≥ 73% (Figure O1-14 in Appendix O, Attachment 1). In above normal years, velocities were higher under Alternative 1 and lower in all other water year types (Figure O1-14 in Appendix O, Attachment 1).

Potential changes to aquatic resources due to OMR management

See section on seasonal operations, which includes OMR management.

Potential changes to aquatic resources due to Delta Cross Channel operations

The Delta Cross Channel may be closed for up to 45 days from November through January for fishery protection purposes. From February 1 through May 20, the gates are closed for fishery protection purposes. The gates may also be closed for 14 days from May 21 through June 15 for fishery protection purposes. The peak migration of juvenile Fall-Run Chinook Salmon in the Sacramento River past West Sacramento, which is near the DCC, occurs from February through May (Table FR_1). Therefore, the DCC is closed for the majority of the juvenile Fall-Run Chinook Salmon migration period in the Sacramento River and as such the proportion of fish exposed to an open DCC would be low. Juvenile

Fall-Run Chinook Salmon that are entrained into an open DCC and transported to the interior Delta have reduced survival (Perry et al. 2010).

Potential changes to aquatic resources due to the Temporary Barriers Project

The Temporary Barriers Project (TBP) consists of three rock barriers across south Delta channels to improve water levels for agricultural diversions and one rock barrier to improve San Joaquin River salmonid migration in the south Delta. The temporary rock barriers are installed and removed at Middle River near Victoria Canal, Old River near Tracy, Grant Line Canal near Tracy Boulevard Bridge, and the head of Old River. The TBP is operated based on San Joaquin River flow conditions. The agricultural barriers at Middle River and Old River near Tracy can begin operating as early as April 15 but the tide gates are tied open from May 16 to May 31. After May 31, the barriers in Middle River, Old River near Tracy, and Grant Line Canal are permitted to be operational until they are completely removed by November 30. The head of Old River Barrier is only installed from September 16 to November 30 to improve flow and dissolved oxygenconditions in the San Joaquin River for the immigration of adult Fall-Run Chinook Salmon.

The proportion of juvenile Fall-Run Chinook Salmon exposed to the TBP depends on their annual timing of installation and removal. Due to their location, primarily migrants originating from the San Joaquin River would be exposed to the TBP. The peak relative abundance of juvenile Fall-Run Chinook Salmon in the Delta at Mossdale is February through May (seeTable FR_1 of the ROC LTO BA). The Head of Old River Barrier would have no effect on juvenile Fall-Run Chinook Salmon if installed from September 16 to November 30 as juvenile Fall-Run Chinook Salmon are largely absent from this section of the San Joaquin River during this time period (see Table FR_1 of the ROC LTO BA). If the agricultural barriers are operating as early as April 15 then they have the potential to expose a large proportion of the juvenile Fall-Run Chinook Salmon migrating down the San Joaquin River. When the Head of Old River barrier is not in place, acoustically tagged juvenile Chinook Salmon have demonstrated a high probability of selecting the Old River route (Buchanan 2018), which would expose them to the agricultural barriers. When the agricultural barriers are operating with tidal flap gates down, a significant decline in passage and reach survival of acoustically tagged juvenile Chinook Salmon migrating past the barrier has been observed compared to when the barrier is not present (DWR 2018). When flap gates are tied up, Chinook Salmon passage past the agricultural barrier was improved (DWR 2018). Flap gates tied up on agricultural barriers from May 16 to May 31 would help to reduce the negative effect of the barriers during this period. However, juveniles migrating before or after this period could be exposed to the agricultural barriers with flaps down which apparently decreases passage success and survival (DWR 2018). Therefore, the potential negative effects of the agricultural barriers depends on when they are installed and whether the flap gates are down or tied up but overall would be medium to high.

Potential changes to aquatic resources due to Contra Costa Water District operations

As discussed in Chapter 3, CCWD’s operations in Alternative 1 are consistent with the operational criteria specified in separate biological opinions and permits that govern operations at CCWD’s intakes and Los Vaqueros Reservoir (NMFS 1993, 2007, 2010, 2017; USFWS 1993a, 1993b, 2000, 2007, 2010, 2017; CDFG 1994; 2009a). Therefore, CCWD’s operations, including operation of the Rock Slough Intake, under Alternative 1 would remain unchanged from the current operations.

Fish monitoring prior to the construction of the Rock Slough Fish Screen (RSFS) indicates the timing and magnitude of Fall-Run/Late presence near the Rock Slough Intake. From 1999 to 2011, the 11 years prior to construction of the RSFS, CCWD’s Fish Monitoring Program collected 23 juvenile Fall-Run/Late Fall-Run Chinook Salmon at the Rock Slough Headworks and Contra Costa Pumping Plant #1. Since construction of the Rock Slough Fish Screen in 2012, no Fall-Run/Late Fall-Run Chinook Salmon have been collected behind the fish screen. CCWD's Fish Monitoring Program also samples at CCWD's other south Delta intakes. Since the intakes have been in operation, CCWD's Fish Monitoring Program has never collected Fall-Run/Late Fall-Run Chinook Salmon at CCWD's Old River Intake or Middle River Intake (CCWD 2019).

CCWD's operations, including operation of the Rock Slough, Old River, and Middle River intakes and Los Vaqueros Reservoir, are simulated in the CalSim model. Thus, CalSim results discussed throughout this appendix include the effects of CCWD's operations in combination with all other water diversions and reservoir operations. A further analysis was undertaken to isolate the maximum possible effects of CCWD's operations on Delta hydrodynamics by determining the effect that CCWD pumping at maximum capacity would have on Delta channel water velocity. Results of this analysis are shown below; in all cases the maximum possible effect of CCWD's operations is de minimis.

Due to the location of the Rock Slough Intake near the end of a dead-end slough, far from the main migratory routes, juvenile Central Valley Fall-Run /Late Fall-Run Chinook Salmon are not likely to be in the vicinity of the Rock Slough Intake. However, according to NMFS (2017), juvenile Salmon can be "drawn" into the south Delta under reverse flows and high CVP and SWP pumping rates.

One indicator of reverse flows is the net flow in Old and Middle Rivers (OMR). Rock Slough Intake is located on Rock Slough, approximately 3.5 miles west of the junction of Rock Slough and Old River, which is over 12 river miles north of the gates to the SWP Clifton Court Forebay. Given its location, the Rock Slough Intake does not affect net reverse flow in Old and Middle Rivers (OMR), and any effect that diversions at Rock Slough Intake would have in the Old and Middle River corridor would be to increase the northerly (positive) flow away from the Banks and Jones Pumping Plants. For juveniles that migrate down the Old and Middle River corridor that are not salvaged at TFCF or Skinner Fish Facility, any effect of Rock Slough Intake diversions would be a positive effect on OMR.

For juveniles that migrate down the mainstems of the Sacramento River or the San Joaquin River and for juveniles that were salvaged, trucked, and released in the western Delta, the potential effect of Rock Slough diversions on the net reverse flow in San Joaquin River may be relevant. The effect of water diversions at Rock Slough Intake on the velocity in the San Joaquin River at Jersey Point is presented in the effects analysis for juvenile Winter-Run. As detailed in that section, the maximum potential effect of water diversions at Rock Slough Intake (assuming diversions at the maximum permitted capacity of 350 cfs and all water diverted by the Rock Slough Intake comes from the San Joaquin River at Jersey Point) is 0.00625 ft/sec in the San Joaquin River at Jersey Point. For comparison, the velocity threshold for design of fish screens to prevent impingement of salmonids is 0.33 ft/sec, which is 50 times the maximum possible contribution from the Rock Slough diversions.

Recognizing that CCWD owns and operates two additional intakes in the south Delta, we examine the combined effect of all three intakes. CCWD's Old River Intake and Middle River Intake have a physical capacity of 250 cfs at each intake. If CCWD were to divert at all three intakes at the maximum capacity at the same time, total CCWD diversions would be 850 cfs. The corresponding effect on velocity in the San Joaquin River at Jersey Point would be 0.015 ft/sec. The velocity threshold used to protect salmonids from diversions in the vicinity of fish screens (0.33 ft/sec) is over 21 times greater than the maximum possible contribution from CCWD's combined physical capacity. The water diversions at the Rock Slough Intake when combined with diversions at CCWD's Old River Intake and Middle River Intake have a negligible effect on velocity along the migratory path for juvenile Central Valley Fall-Run/Late Fall-Run Chinook Salmon and are not likely to affect the movement of juvenile salmonids.

Nonetheless, even extremely small changes in velocity can affect the movement of neutrally buoyant particles such as phytoplankton. As shown in the Winter-Run Chinook Salmon section, the diversions at the Rock Slough Intake could move a neutrally buoyant particle in the San Joaquin River at Jersey Point approximately 540 ft over the course of the day. For comparison, the tidal excursion on the San Joaquin River at Jersey Point during a flood tide (i.e., the distance a particle will travel tidally upstream during a flood tide) is about 34,000 ft on average (or 6.4 miles), which is about 63 times the distance that diversions at Rock Slough could move a particle at the same location over the course of a full day. Therefore, the maximum possible contribution of diversions at Rock Slough on movement of neutrally buoyant particles such as phytoplankton is not significant in comparison to the tidal excursion and mixing at this location.

In summary, CCWD's operations under Alternative 1 would remain consistent with the operational criteria specified in separate biological opinions and permits that govern operations at CCWD's intakes and Los Vaqueros Reservoir, and as shown above, the effect of CCWD's operations on Delta hydrodynamics is negligible.

Potential changes to aquatic resources due to North Bay Aqueduct operations

Listed salmonids may be present in the waterways adjacent to the Barker Slough Pumping Plant, however several years of monitoring have failed to consistently capture any salmonids during the winter Delta Smelt surveys (1996 to 2004) in Lindsey Slough or Barker Slough. Captures of Chinook Salmon have usually occurred in the months of February and March and typically are only a single fish per net haul (http://www.delta.dfg.ca.goc/data/nba). Most Chinook Salmon captured have come from Miner Slough, which is a direct distributary from the Sacramento River via Steamboat and Sutter Sloughs. Few if any San Joaquin River-origin Fall-Run Chinook Salmon are expected to be exposed to the North Bay aqueduct because it is not on the migration route of this species.

Alternative 1 also includes sediment removal with a suction dredge that could entrain Fall Run individuals occurring near the suction dredging. In addition, aquatic weed removal with a grappling system could disturb Fall Run occurring near the removal. The low occurrence of Chinook Salmon in monitoring efforts suggest that any potantil imacts from sediment and aquatic weed removal would be limited.

Potential changes to aquatic resources due to water transfers

Potential changes to aquatic resources from Clifton Court aquatic weed removal

Potential Effects from Clifton Court Aquatic Weed Removal

Few if any juvenile Fall-Run Chinook Salmon would be expected to be exposed to the Clifton Court Forebay Aquatic Weed Control Program. Juvenile Fall-Run Chinook Salmon are present in the Delta between mid-November and early June with a peak in April (See Table_WR1 of the ROC LTO BA). The application of aquatic herbicide to the waters of Clifton Court Forebay will occur during the summer months between 28 June and 31 August. Treatment could occur before 28 June if tempertures exceed 25 ˚C; however, Fall-Run Chinook Salmon are not expected to occure at that temperature. Thus, the probability of exposing Fall-Run Chinook Salmon to the herbicide is very low. Based on typical water temperatures in the vicinity of the salvage facilities during this period, the temperatures would be incompatible with salmonid life history preferences, generally exceeding 70°F by mid-June. The overall effect of this action is low.

As discussed in Appendix D, treatment of harmful algal blooms with peroxide-based algaecide is proposed to occur as needed, year-round, but there are no anticipated impacts to fish because the oxidation reaction occurs immediately upon contact with the water, destroying algal cell membranes and chlorophyll, with hydrogen peroxide and oxygen as byproducts.

Potential changes to aquatic resources due to changes from Tracy and Skinner fish facility improvements

Although actions at the Tracy facility could positively affect juvenile Fall-Run Chinook Salmon through greater salvage efficiency, only small proportions of Fall-Run Chinook Salmon are lost at the CVP (Zeug and Cavallo 2014).

Skinner Fish Facility improvements from predator control efforts to reduce predation on listed fishes following entrainment into Clifton Court Forebay could reduce pre-screen loss of juvenile Chinook Salmon entrined into Clifton Cout Forebay. However, given that only small proportions of Fall-Run Chinook Salmon are lost at the SWP (Zeug and Cavallo 2014), the population-level positive effect of this action would be low. Larger proportions of Late Fall-Run Chinook Salmon are lost at the facilities and this action would have a larger effect for this run.

Potential changes to aquatic resources due to changes from Suisun Marsh facilities

Operation of the SMSCG from October through May coincides with downstream migration of juvenile Fall-Run Chinook Salmon (Reclamation 2019). NMFS (2009) determined that operation of the SWSCG is unlikely to impede migration of juvenile salmonids or produce conditions that support unusually high numbers of predators.

As described by NMFS (2009: 437-438), the Roaring River Distribution System (RRDS)'s water intake (eight 60-inch-diameter culverts) is equipped with fish screens (3/32-inch opening, or 2.4 mm) operated to maintain screen approach velocity of 0.2 ft/s (for Delta Smelt protection), so that juvenile Fall-Run Chinook Salmon would be excluded from entrainment.

NMFS (2009: 438) considered it unlikely that juvenile Winter-Run Chinook Salmon, would be entrained by the three unscreened 48-inch culverts that form the Morrow Island Distribution System (MIDS) water intake, as a result of their larger size and better swimming ability relative to the size of Fall-Run Chinook Salmon observed to have been entrained (<45 mm), and also because the location of the MIDS intake on Goodyear Slough is not on a migratory corridor for listed juvenile salmonids. Although Fall-Run Chinook Salmon have been entrained at this facility, only a small proportion of total migrants are likely to encounter it.

NMFS (2009: 438) concluded that it would be unlikely that Chinook Salmon would encounter or be negatively affected by the Goodyear Slough outfall given its location and design, which is intended to improve water circulation in Suisun Marsh and therefore was felt by NMFS (2009: 438) to likely be of benefit to juvenile salmonids by improving water quality and increasing foraging opportunities.

Potential changes to aquatic resources from actions for Delta Smelt summer-fall habitat Juvenile Fall-Run Chinook Salmon are abundant in the Delta in December and January and April and May (Reclamation 2019). Late Fall-Run Chinook Salmon are most abundant from January through April. Small fractions of each run could be exposed to Fall Delta Smelt habitat actions. For fish that are exposed, increased turbidity may reduce susceptibility to predation and increase through-Delta survival.

Potential changes to aquatic resources from Clifton Court predator management efforts

Pre-screen survival of juvenile Chinook Salmon has been shown to be low (Gingras 1997) and predation is thought to be a major source of mortality. Analyses by Zeug and Cavallo (2014) indicate that only small proportions of Sacramento River-origin Fall-Run Chinook Salmon arrive at the facilities. However, moderte proportions of San Joaquin River-origin Fall-Run Chinook Salmon arrive at the facilities. For fish that are entrained into Clifton Cout Forebay, predator control may increase pre-screen survival. There is potential for San Joaquin River- and Mokelumne River-origin adult Fall-Run Chinook Salmon to be impacted by predator capture activities. Survival benefits of predator management may offset impacts to the occasional capture of adult Fall-Run. The overall effect of the action is low for Sacramento River-Origin fish and moderte for San Joaquin River and Mokelumne River-origin fish.

Potential changes to aquatic resources due to the San Joaquin Basin steelhead telemetry study

Potential changes to aquatic resources due to reintroduction changes from Fish Conservation and Culture Laboratory

O.3.3.8.8 Central Valley Steelhead

Potential changes to aquatic resources due to seasonal operations

Entrainment

ICF (2018) analyzed salvage of Central Valley Steelhead at the CVP and SWP between 2003 and 2017 and found that salvage increased with export rate and decreased with San Joaquin River flow. Salvage also decreased with OMR flow. However, OMR is a metric comprised of both exports and San Joaquin River flow which complicates attempts to understand individual effects.

In the December through February period, Alternative 1 proposes an average total export rate slightly higher than the No Action Alternative (196 cfs; Figure O1-1 in Appendix O, Attachment 1) and will therefore have a similar entrainment risk. Total exports proposed for Alternative 1 in March-June (1,752 cfs higher than No Action Alternative; Figure O1-2 in Appendix O, Attachment 1) when juvenile Central Valley Steelhead are most abundant in the Delta at Chipps Island (Reclamation 2019), will increase entrainment risk relative to No Action Alternative.

Routing

Routing of juvenile Central Valley Steelhead into alternative migration routes is closely related to hydrodynamics (Perry et al. 2015; Cavallo et al. 2015; Steel et al. 2012). Changes to hydrodynamics in Delta channels resulting from Alternative 1 were evaluated using DSM2. Juvenile Central Valley Steelhead are present in the Sacramento River at Hood upstream of the first distributary junctions between November and early June with peak abundance from February to early June (Reclamation 2019). In the December through February period, velocity overlap between Alternative 1 and No Action Alternative in the Sacramento River main stem between the Sutter-Steamboat and DCC/Georgiana Slough Junctions, was >75% in critically dry, dry, below normal and above normal years (Figure O1-3 in Appendix O, Attachment 1). In wet years, velocity overlap in this reach was ≈ 50%.

In the March to May period Comparison of Alternative 1 and No Action Alternative revealed similar patterns of velocity overlap as described for the December through February period (Figure O1-4 in Appendix O, Attachment 1) indicating routing into the interior Delta would be lower under Alternative 1 during March to May.

Through-Delta Survival

A recent study by Perry et al. (2018) found that the effect of flow on survival is not uniform throughout the Delta. Relationships between flow and survival were significant only in reaches where flow changes from bi-directional to unidirectional when discharge increases. This study was performed with hatchery-origin Late Fall-Run Chinook Salmon and there is uncertainty regarding the applicability of those results to steelhead. However, this study represents the best information avaiable on survival of juvneile salmonids in the Delta.To examine potential effects of Alternative 1, changes in velocity distributions were examined assuming a positive correlation between discharge and mean water column velocity for the Sacramento River at Walnut Grove and Steamboat Slough, which are both in this “transitional” region. During the December to February period at Walnut Grove, velocity distributions for Alternative 1 relative to No Action Alternative were most different in wet years (70.9%) with higher velocities in Alternative 1. Velocities were also greater for Alternative 1 relative to No Action Alternative in dry, below normal and above normal years although overlap was greater (≥79%; Figure O1-7 in Appendix O, Attachment 1). In critically dry years, velocity distributions were almost identical (95.4%; Figure O1-7 in Appendix O, Attachment 1). At Steamboat Slough in the December to February period, there was a similar pattern where velocities under Alternative 1 were higher than No Action Alternative in wet, above normal and below normal years and similar in dry and critically dry years (Figure O1-8 in Appendix O, Attachment 1).

In the March through May period at Walnut Grove, velocity overlap between Alternative 1 and No Action Alternative was ≥78% across all water year types with greater velocities under Alternative 1 (Figure O1-9 in Appendix O, Attachment 1). At Steamboat Slough in the March through May period, overlap between Alternative 1 and No Action Alternative scenarios was high with all values ≥82% and greater velocities under Alternative 1 (Figure O1-10 in Appendix O, Attachment 1).

A recent study by Perry et al. (2018) found that the effect of flow on survival is not uniform throughout the Delta. Relationships between flow and survival were significant only in reaches where flow changes from bi-directional to unidirectional when discharge increases. To examine potential effects of Alternative 1, changes in velocity distributions were examined for the San Joaquin River at Highway 4 and the Head of Middle River which are both in the “transitional” region of the San Joaquin River. During the December to February period at the San Joaquin River at Highway 4, velocity distributions for Alternative 1 relative to No Action Alternative exhibited high overlap in all water year types (≥84.3%; Figure O1-11 in Appendix O, Attachment 1). At the Head of Middle River during the December through February period, overlap was high between Alternative 1 and No Action Alternative in critically dry, dry and below normal water years (≥90.1%) and moderate in wet and above normal years (53.6-75.1%; Figure O1-12 in Appendix O, Attachment 1).

In the March to May period in the San Joaquin River at Highway 4, velocity overlap was high between Alternative 1 and No Action Alternative (≥83.2%; Figure O1-13 in Appendix O, Attachment 1). Velocities were lower under Alternative 1 in dry, below normal and wet year and higher in above normal years (Figure O1-23 in Appendix O, Attachment 1). At the Head of Middle River in the March to May period, overlap between Alternative 1 and No Action Alternative was moderate in above normal years (57.7%) and higher in all other water year types ≥ 73% (Figure O1-14 in Appendix O, Attachment 1). In above normal years, velocities were higher under Alternative 1 and lower in all other water year types (Figure O1-14 in Appendix O, Attachment 1).

Potential changes to aquatic resources due to OMR management

See section on Seasonal Operations, which includes OMR management.

Potential changes to aquatic resources due to Delta Cross Channel operations

Significant flow and many juvenile Central Valley Steelhead enter the central Delta when the DCC gates are open. Mortality of juvenile Central Valley Steelhead entering the central Delta is higher than for those continuing downstream in the Sacramento River. The peak migration of juvenile Central Valley Steelhead in the Sacramento River past Knights Landing, which is upstream of the DCC, occurs from January through February (Reclamation 2019). Therefore under Alternative 1, the continued operation of the DCC to protect the majority of the juvenile Central Valley Steelhead during their migration period in the Sacramento River would reduce the proportion of fish exposed to an open DCC and result in beneficial impacts to this life stage when compared to the No Action Alternative.

Potential changes to aquatic resources due to the Temporary Barriers Project

The Temporary Barriers Project (TBP) consists of three rock barriers across south Delta channels to improve water levels for agricultural diversions and one rock barrier to improve San Joaquin River salmonid migration in the south Delta. The temporary rock barriers are installed and removed at Middle River near Victoria Canal, Old River near Tracy, Grant Line Canal near Tracy Boulevard Bridge, and the head of Old River. The TBP is operated based on San Joaquin River flow conditions. The agricultural barriers at Middle River and Old River near Tracy can begin operating as early as April 15 but the tide gates are tied open from May 16 to May 31. After May 31, the barriers in Middle River, Old River near Tracy, and Grant Line Canal are permitted to be operational until they are completely removed by November 30. The Head of Old River Barrier is only installed from September 16 to November 30 to improve flow and dissolved oxygenconditions in the San Joaquin River for the immigration of adult Fall-Run Chinook Salmon.

The proportion of juvenile Central Valley Steelhead exposed to the TBP depends on their annual timing of installation and removal. Due to their location, primarily juvenile Central Valley Steelhead migrants originating from the San Joaquin River would be exposed to the TBP. The peak relative abundance of juvenile Central Valley Steelhead in the San Joaquin River in the vicinity of the TBP (Mossdale) occurs in April and May (Reclamation 2019). If the agricultural barriers are operating as early as April 15, there is potential exposure to a large proportion of the juvenile Central Valley Steelhead migrating down the San Joaquin River.

When the Head of Old River barrier is not in place, acoustically tagged juvenile Central Valley Steelhead have demonstrated a high probability of selecting the Old River route (Buchanan 2018[PC1]), which would expose them to the agricultural barriers. When the agricultural barriers are operating with tidal flap gates down, a significant decline in passage and reach survival of acoustically tagged juvenile Central Valley Steelhead migrating past the barrier has been observed compared to when the barrier is not present (DWR 2018). When flap gates are tied up, Central Valley Steelhead passage past the agricultural barrier was improved (DWR 2018). Therefore, although Alternative 1 does not include HORB, which could result in negative impacts to Central Valley Steelhead juvenile migration, the improvements to the agricultural barriers (including flap gates tied up from May 16 to May 31) would help to reduce the negative effect of the barriers on migrating juvenile Central Valley Steelhead during this period relative to No Action Alternative. However, juvenile Central Valley Steelhead migrating before or after this period could be exposed to the agricultural barriers with flaps down, which apparently decreases passage success and survival (DWR 2018). Therefore, the potential negative effects of the agricultural barriers under Alternative 1 on juvenile Central Valley Steelhead depends on when they are installed and whether or not the flap gates are down.

Potential changes to aquatic resources due to Contra Costa Water District operations

As discussed in Chapter 3, CCWD's operations in Alternative 1 are consistent with the operational criteria specified in separate biological opinions and permits that govern operations at CCWD's intakes and Los Vaqueros Reservoir (NMFS 1993, 2007, 2010, 2017; USFWS 1993a, 1993b, 2000, 2007, 2010, 2017; CDFG 1994, 2009a). Therefore, CCWD's operations, including operation of the Rock Slough Intake, under Alternative 1 would remain unchanged from the current operations and the No Action Alternative.

Fish monitoring prior to the construction of the Rock Slough Fish Screen (RSFS) indicates the timing and magnitude of Central Valley Steelhead presence near the Rock Slough Intake. From 1999 to 2011, the 11 years prior to construction of the RSFS, CCWD's Fish Monitoring Program collected 15 juveniles at the Rock Slough Headworks and Pumping Plant #1. Since construction of the Rock Slough Fish Screen, no Central Valley Steelhead have been collected behind the fish screen. CCWD's Fish Monitoring Program also samples at CCWD's other south Delta intakes. Since the intakes have been in operation, CCWD's Fish Monitoring Program has never collected Central Valley Steelhead at CCWD's Old River Intake or Middle River Intake (CCWD 2019).

CCWD's operations, including operation of the Rock Slough, Old River, and Middle River intakes and Los Vaqueros Reservoir, are simulated in the CalSim model. Thus, CalSim results discussed throughout this appendix include the effects of CCWD's operations in combination with all other water diversions and reservoir operations. A further analysis was undertaken to isolate the maximum possible effects of CCWD's operations on Delta hydrodynamics by determining the effect that CCWD pumping at maximum capacity would have on Delta channel water velocity. Results of this analysis are shown below; in all cases the maximum possible effect of CCWD's operations is de minimis.

Due to the location of the Rock Slough Intake near the end of a dead-end slough, far from the main migratory routes, juvenile Central Valley Steelhead are not likely to be in the vicinity of the Rock Slough Intake. However, according to NMFS (2017), juvenile salmonids can be "drawn" into the south Delta under reverse flows and high CVP and SWP pumping rates. One indicator of reverse flows is the net flow in OMR. Rock Slough Intake is located on Rock Slough, approximately 3.5 miles west of the junction of Rock Slough and Old River, which is over 12 river miles north of the gates to the SWP Clifton Court Forebay. Given its location, the Rock Slough Intake does not affect OMR, and any effect that diversions at Rock Slough Intake under Alternative 1 would have in the OMR corridor would be to increase the northerly (positive) flow away from the Banks and Jones Pumping Plants. For juveniles that migrate down the Old and Middle River corridor that are not salvaged at TFCF or Skinner Fish Facility, any effect of Rock Slough Intake diversions would be a positive effect on OMR.

For juveniles that migrate down the mainstems of the Sacramento or San Joaquin Rivers and for juveniles that were salvaged, trucked, and released in the western Delta, the potential effect of Rock Slough diversions on the net reverse flow in San Joaquin River may be relevant. The effect of water diversions at Rock Slough Intake on the velocity in the San Joaquin River at Jersey Point is presented in the effects analysis for juvenile Winter-Run. As detailed in that section, the maximum potential effect of water diversions at Rock Slough Intake (assuming diversions at the maximum permitted capacity of 350 cfs and all water diverted by the Rock Slough Intake comes from the San Joaquin River at Jersey Point) is 0.00625 ft/sec in the San Joaquin River at Jersey Point. For comparison, the velocity threshold for design of fish screens to prevent impingement of salmonids is 0.33 ft/sec, which is 50 times the maximum possible contribution from the Rock Slough diversions.

Recognizing that CCWD owns and operates two additional intakes in the south Delta, the combined effect of all three intakes was examined. CCWD's Old River Intake and Middle River Intake have a physical capacity of 250 cfs at each intake. If CCWD were to divert at all three intakes at the maximum capacity at the same time, total CCWD diversions would be 850 cfs. The corresponding effect on velocity in the San Joaquin River at Jersey Point would be 0.015 ft/sec. The velocity threshold used to protect salmonids from diversions in the vicinity of fish screens (0.33 ft/sec) is over 21 times greater than the maximum possible contribution from CCWD's combined physical capacity. The water diversions at the Rock Slough Intake when combined with diversions at CCWD's Old River Intake and Middle River Intake have a negligible effect on velocity along the migratory path for juvenile Central Valley Steelhead.

Nonetheless, even extremely small changes in velocity can affect the movement of neutrally buoyant particles such as phytoplankton. As shown in the Winter-Run Chinook Salmon section, the diversions at the Rock Slough Intake could move a neutrally buoyant particle in the San Joaquin River at Jersey Point approximately 540 ft over the course of the day. For comparison, the tidal excursion on the San Joaquin River at Jersey Point during a flood tide (i.e., the distance a particle will travel tidally upstream during a flood tide) is about 34,000 ft on average (or 6.4 miles), which is about 63 times the distance that diversions at Rock Slough could move a particle at the same location over the course of a full day. Therefore, the maximum possible contribution of diversions at Rock Slough on movement of neutrally buoyant particles such as phytoplankton is insignificant in comparison to the tidal excursion and mixing at this location. Although the diversions at Rock Slough Intake are not likely to impact juvenile Central Valley Steelhead, the aggregate effect of all water diversions in the Delta, including exports at Jones and Banks Pumping Plants can affect channel velocity.

In summary, CCWD's operations under Alternative 1 would remain consistent with the operational criteria specified in separate biological opinions and permits that govern operations at CCWD's intakes and Los Vaqueros Reservoir, and as shown above, the effect of CCWD's operations on Delta hydrodynamics is negligible.

Potential changes to aquatic resources due to North Bay Aqueduct operations

Under Alternative 1, there would be no changes to operational criteria at the NBA's BSPP relative to current op. Juvenile Central Valley Steelhead could occur in the vicinity of the BSPP; however, the fish screens used at the facility are designed to protect juvenile salmonids per NMFS criteria and should prevent entrainment and greatly minimize impingement of fish against the screen itself (NMFS 2009). In addition, the location of the facility is well off the typical migration corridor of juvenile Central Valley Steelhead (NMFS 2009: 417). No juvenile Central Valley Steelhead have been captured during CDFW monitoring surveys from 1996 to 2004 (http://www.delta.dfg.ca.goc/data/nba).

Alternative 1 also includes sediment removal with a suction dredge that could entrain steelhead individuals occurring near the suction dredging. In addition, aquatic weed removal with a grappling system could disturb steelhead occurring near the removal. The low occurrence of steelhead in monitoring efforts suggest that any potential imacts from sediment and aquatic weed removal would be limited.

Potential changes to aquatic resources due to water transfers

Central Valley Steelhead juveniles could be exposed to increased entrainment, predation, and decreased through-Delta survival as a result of the expanded transfer window under Alternative 1, but as the peak of the juvenile out-migration is in the spring, effects are anticipated to be minimal. No other lifestages of Central Valley Steelhead would co-occur in time and space with water transfers from the Delta.

Potential changes to aquatic resources from Clifton Court aquatic weed removal

Under Alternative 1, the application of aquatic herbicide to the waters of CCF will occur between 28 June and 31 August. Treatment could occur prior to 28 June at tempertures $\geq 25^{\circ}$C; however, steelhead would not be expected to occur at these temperatures. Treatment could also occur after 31 August if protective measures have not been triggered but few if any steelhead would be expected in the Delta during that time period. Juvenile Central Valley Steelhead abundance in the Delta peaks between March and May (Reclamation 2019). Based on typical water temperatures in the vicinity of the salvage facilities during this period, the water temperatures would be incompatible with salmonid life history preferences, generally exceeding 70°F by mid-June. As such, it is unlikely that juvenile Central Valley Steelhead would be rearing near this location after mid-June and the potential application of aquatic herbicide would only occur well after the peak out-migration period (Reclamation 2019) and therefore Central Valley Steelhead are not expected to be exposed to herbicide application activities.

As discussed in Appendix D, treatment of harmful algal blooms with peroxide-based algaecide is proposed to occur as needed, year-round, but there are no anticipated impacts to fish because the oxidation reaction occurs immediately upon contact with the water, destroying algal cell membranes and chlorophyll, with hydrogen peroxide and oxygen as byproducts.

Potential changes to aquatic resources due to changes from Tracy and Skinner fish facility improvements

Small proportions of Sacramento River-origin Central Valley Steelhead and moderate proportions of Mokelumne River and San Joaquin River-origin Central Valley Steelhead are expected to be exposed to the Tracy Fish Facility. However, for fish that arrive at the facility, the proposed improvements resulting in greater salvage efficiency under Alternative 1 are likely to increase survival of juvenile Central Valley Steelhead.

As previously described, juvenile Central Valley Steelhead are largely absent from the Delta between August and November (Reclamation 2019) and, therefore, none to a few late migrants or early migrants have the potential to be exposed to the effects of construction of the carbon dioxide injection device proposed for the Tracy Fish Facility Improvements. Risks of decreased Central Valley Steelhead juvenile salvage during construction would be minimized through appropriate mitigation measures for aquatic resources (Appendix E, Mitigation Measures). Steelhead may be impacted by operation of CO_2 injection device but this would likely be offset by reduced predation at the facility.

Skinner Fish Facility improvements under Alternative 1 to reduce predation on listed fishes following entrainment into CCF could reduce pre-screen loss of juvenile Central Valley Steelhead entrained into CCF; therefore, providing a benefit for all life stages of Central Valley Steelhead. Steelhead may be impacted by predator control activities but this would likely be offset by reduced predation at the facility.

Potential changes to aquatic resources due to changes from Suisun Marsh facilities

Operation of the SMSCG from October through May under Alternative 1 coincides with downstream migration of juvenile Central Valley Steelhead (Reclamation 2019). Montezuma Slough provides an alternative route to their primary migration corridor through Suisun Bay. No data are available to estimate the abundance of juvenile Central Valley Steelhead thus, the proportion of the total run utilizing this route is unknown. However NMFS (2009) determined that operation of the SWSCG is unlikely to impede migration of juvenile salmonids or produce conditions that support unusually high numbers of predators.

Under Alternative 1, the Roaring River Distribution System water diversion intake is equipped with fish screens (3/32-inch opening, or 2.4 mm) operated to maintain screen approach velocity of 0.2 ft/s (for Delta Smelt protection), excluding juvenile Central Valley Steelhead from entrainment (NMFS 2009: 437).

The MIDS diverts water from Goodyear Slough through three 48-inch diameter culverts during high tide. Although the MIDS intakes do not currently have fish screens, it is unlikely juvenile Central Valley Steelhead will be entrained into the water distribution system because Central Valley Steelhead have not been caught in past surveys. Also, the large size and better swimming ability of juvenile listed salmonids in the Delta allow these fish to avoid entrainment at MIDS. In addition, the location of the MIDS intake on Goodyear Slough further reduces the risk of entrainment. Goodyear Slough is not a migratory corridor for Central Valley Steelhead. The operation of the MIDS under Alternative 1 would not impact Central Valley Steelhead.

Goodyear Slough Outfall improves water circulation in the Suisun Marsh. This structure consists of four 48-inch diameter culverts with flap gates designed to drain water from the southern end of Goodyear Slough into Suisun Bay. On flood tides, the gates reduce the amount of tidal inflow into Goodyear Slough. Due to its location and design, Central Valley Steelhead are not likely to encounter this structure or be negatively affected by its operation. Improved water circulation by the operation of the Goodyear Slough Outfall likely benefits Central Valley Steelhead in Suisun Marsh by improving water quality and increasing foraging opportunities.

Potential changes to aquatic resources from actions for Delta Smelt summer-fall habitat Central Valley Steelhead juveniles are in the Delta in the spring. Reclamation proposes to conduct actions for Fall Delta Smelt Habitat in the fall, as adult Central Valley Steelhead are migrating upstream. Fall Delta Smelt Habitat actions are unlikely to affect adult Central Valley Steelhead.

Potential changes to aquatic resources from Clifton Court predator management efforts

Clifton Court predator management under Alternative 1 could reduce pre-screen loss of juvenile Central Valley Steelhead entrained into CCF; therefore, providing a benefit for all life stages of Central Valley Steelhead. Some steelhead may be impacted by predator control activities but this would likely be offset by reduced predation at the facility.

Potential changes to aquatic resources due to the San Joaquin Basin steelhead telemetry study

Potential changes to aquatic resources due to reintroduction changes from Fish Conservation and Culture Laboratory

Potential changes to aquatic resources from monitoring

Population estimates for wild Steelhead remain outstanding in the Central Valley, therefore it is difficult to quantify the effects of the monitoring on Steelhead populations. However, most existing monitoring programs in the Central Valley and Delta/SF Estuary are not designed to capture Steelhead, which are much larger than Chinook Salmon upon river and Delta entry. Existing programs likely have poor capture efficiency for collecting and retaining Steelhead. Therefore, it is unlikely the monitoring programs have any effects to the population.

O.3.3.8.9 North American Green Sturgeon Souther DPS

Potential changes to aquatic resources due to seasonal operations

Hydrodynamic changes associated with river inflows and South Delta exports have been suggested to negatively impact southern DPS Green Sturgeon in two distinct ways: 1) “near-field” mortality associated with entrainment to the export facilities, 2) “far-field” mortality resulting from altered hydrodynamics. The SST completed a thorough review of this subject and defined a driver- linkage-outcome (DLO) framework for specifying how water project operations (the “driver”) can influence juvenile salmonid behavior (the “linkage”) and potentially cause changes in survival or routing (the “outcome”). A similar analysis is not available for southern DPS Green Sturgeon.

Entrainment

As described by NMFS (2009: 386), impacts to the migratory corridor function of juvenile and subadult Green Sturgeon critical habitat from south Delta exports are less clear than for juvenile salmonids because Green Sturgeon spend 1 to 3 years rearing in the Delta environment before transitioning to their marine life history stage. During this Delta rearing phase, Green Sturgeon are free to migrate throughout the Delta. In the conceptual model, it is hypothesized that higher rates of exports may result in higher rates of entrainment. However, estimating entrainment risk from raw salvage data is not possible due to a lack of information on the number of juvenile Green Sturgeon potentially exposed to salvage.

Juvenile southern DPS Green Sturgeon (> 5 mo) are present in the Delta all year and subadults are most abundant from June through November. In the June through September period under Alternative 1 Reclamation proposes an average total export rate slightly higher than No Action Alternative (188 cfs; Figure O1-15 in Appendix O, Attachment 1) and will, therefore, have a similar entrainment risk. Total exports proposed for Alternative 1 in September-November (776 cfs higher than No Action Alternative; Figure O1-16 in Appendix O, Attachment 1) are unlikely to measurably increase entrainment risk relative to No Action Alternative.

Juvenile White and Green Sturgeon are infrequent at the TFCF, but may occur in the facility salvage year-round. Salvage is expected to be similar and slightly higher than No Action Alternative under Alternative 1.

Routing

Juvenile Green Sturgeon (>5 mo) are present in the Delta all year and subadults are most abundant from June to November (Reclamation 2019). Juvenile Green Sturgeon swim and behave quite differently and have distinct body morphologies and habitat associations in the Delta compared to outmigrating salmonids, so it is hypothesized that juvenile Green Sturgeon have different routing-hydrology survival relationships. Per NMFS (2009: 338), Green Sturgeon are likely to be found in the main channels of the Delta and the larger interconnecting sloughs and waterways, with western Delta waterways having a higher likelihood of presence than eastern Delta waterways. It is highly uncertain how Green Sturgeon routing would change with Alternative 1.

Through-Delta Survival

Little is known about the relationship between survival of juvenile Green Sturgeon and Delta hydrology. Green Sturgeon reside in the Delta for 1 to 3 years suggesting they encounter a variety of daily, seasonal, and annual hydrological conditions. The majority of Green Sturgeon in the Delta are likely not surviving through the Delta per se, but using these habitats for rearing and foraging. Per NMFS (2009: 338), Green Sturgeon are likely to be found in the main channels of the Delta and the larger interconnecting sloughs and waterways, with western Delta waterways having a higher likelihood of presence than eastern Delta waterways. For juvenile outmigrating Green Sturgeon present in these regions, increasing negative velocities under Alternative 1 may result in lower survival. However, as described above, there is a lower probability of juvenile Green Sturgeon residing in this area.

Potential changes to aquatic resources due to OMR management

See section above on Seasonal operations, which includes OMR management.

Potential changes to aquatic resources due to Delta Cross Channel operations

Delta Cross Channel operations under Alternative 1 are changed to allow Reclamation to predict water quality exceedances and open the DCC if D-1641 criteria are predicted to be exceeded. This results in greater opening times of the DCC.

Little is known about the migratory behavior of juvenile Green Sturgeon in the Sacramento River basin. It is likely that juvenile Green Sturgeon (larger than the 75 mm) will not enter the Delta prior to their first winter and thus would not be exposed to the open DCC gates. If juvenile Green Sturgeon are exposed to the open DCC gates, they could be entrained into the central / south Delta and exposed to biological and physical conditions in this area, including potentially greater predation. It is likely that these fish will enter the Delta sometime in the winter or spring following their hatching upriver and encounter both types of gate configurations as they enter the Delta.

Potential changes to aquatic resources due to the Temporary Barriers Project

Agricultural Barriers (Temporary Barrier Project, TBP) are included in Alternative 1 and consists of three rock barriers across south Delta channels to improve water levels for agricultural diversions. The temporary rock barriers are installed and removed at Middle River near Victoria Canal, Old River near Tracy, and Grant Line Canal near Tracy Boulevard Bridge. The TBP is operated based on San Joaquin River flow conditions. The agricultural barriers at Middle River and Old River near Tracy can begin operating as early as April 15 but the tide gates are tied open from May 16 to May 31. After May 31, the barriers in Middle River, Old River near Tracy, and Grant Line Canal are permitted to be operational until they are completely removed by November 30.

Juvenile Green Sturgeon are present in the Delta in all months of the year. However, little is known about their spatial distribution. When the south Delta agricultural barriers are operating with tidal flap gates down, a significant decline in passage and reach survival of acoustically tagged juvenile Chinook Salmon migrating past the barrier has been observed compared to when the barrier is not present (DWR 2018). When flap gates are tied up (May 16 to May 31), outmigrating Chinook Salmon passage past the agricultural barrier was improved (DWR 2018). It could be inferred that passage of outmigrating juvenile Green Sturgeon may also be improved when flap gates are tied up. Therefore, the potential negative effects of the agricultural barriers under Alternative 1 depends on when they are installed and whether the flap gates are down or tied up.

Potential changes to aquatic resources due to Contra Costa Water District operations

As discussed in Chapter 3, CCWD’s operations in Alternative 1 are consistent with the operational criteria specified in separate biological opinions and permits that govern operations at CCWD’s intakes and Los Vaqueros Reservoir (NMFS 1993, 2007, 2010, 2017; USFWS 1993a, 1993b, 2000, 2007, 2010, 2017; CDFG 1994, 2009a). Therefore, CCWD operations, includingoperation of the Rock Slough Intake, under Alternative 1 remain unchanged from current conditions and the No Action Alternative.

The Contra Costa Canal Rock Slough Intake is located on a dead-end slough, far from the main migratory routes for southern DPS Green Sturgeon (NMFS 2017c), approximately 18 miles from the Sacramento River and 10 miles from the San Joaquin River via the shortest routes. Water temperatures in Rock Slough range from lows of about 40 degrees F in winter (December and January) to over 70 degrees F beginning in May and continuing through October (NMFS 2017c).

A review of the 24 years of fish monitoring data (1994–2018) near the Rock Slough Intake both pre- and post-construction of the Rock Slough Fish Screen (RSFS) showed that southern DPS Green Sturgeon have never been observed in Rock Slough (CDFG 2002c; Reclamation 2016; NMFS 2017c; Tenera Environmental 2018b, ICF 2018). CCWD's Fish Monitoring Program also samples at CCWD's other south Delta intakes. Since the intakes have been in operation, CCWD's Fish Monitoring Program has never observed southern DPS Green Sturgeon at CCWD's Old River Intake or Middle River Intake (CCWD 2019).

It is unlikely that juvenile, subadult, or adult Green Sturgeon would be present in Rock Slough due to the shallow depth, warm water temperatures, and low dissolved oxygen, which make the area unsuitable habitat during most of the year. Therefore, it is unlikely that Green Sturgeon will be entrained at Rock Slough Intake and unlikely that would be impacted by CCWD operations.

Potential changes to aquatic resources due to North Bay Aqueduct operations

Overall, the modeled exports in Alternative 1 represent a significant increase in export levels and, thus, a greater risk to Green Sturgeon in the waters adjacent to the pumping facility compared to their historical vulnerability (NOAA 2009). However, Green Sturgeon are expected to be fully screened out of the facilities by the positive barrier fish screen in place at the pumping facility.

Alternative 1 also includes sediment removal with a suction dredge that could entrain juvenile Green Stugeon individuals occurring near the suction dredging. In addition, aquatic weed removal with a grappling system could disturb Green Sturgeon occurring near the removal. The low occurrence of Green Sturgeon in monitoring efforts suggest that any potential imacts from sediment and aquatic weed removal would be limited.

Potential changes to aquatic resources due to water transfers

As discussed under the Spring-Run Chinook Salmon water transfer section, under Alternative 1 Reclamation proposes to expand the transfer window to November. This extended transfer window could result in approximately 50 TAF of additional pumping per year in most years, with associated entrainment, routing, and through-Delta survival impacts. Please see the OMR management section for a discussion of the effects of pumping.

Juveniles older than 5 months, subadults, and adult Green Sturgeon could be exposed to the effects of increased pumping due to water transfers. Although southern DPS Green Sturgeon are present in the Delta in all months of the year, Green Sturgeon are likely to be found in the main channels of the Delta and the larger interconnecting sloughs and waterways, with western Delta waterways having a higher likelihood of presence than eastern Delta waterways (NMFS 2009:338). Therefore, there are no negative impacts of increased pumping at Jones and Banks Pumping Plants due to water transfers under Alternative 1.

Juvenile southern DPS Green Sturgeon are present in the Delta in every month of the year (Reclamation 2019). Thus, some portion of the population would be exposed to this action. Increases in Delta inflow during water transfers may have benefits for juvenile Green Sturgeon. However, there is no information on relationships between flow and juvenile Green Sturgeon ecology.

Potential changes to aquatic resources from Clifton Court aquatic weed removal

Few southern DPS juvenile Green Sturgeon Salmon would be expected to be exposed to the Clifton Court Forebay Aquatic Weed Control Program as part of Alternative 1. Although southern DPS juvenile Green

Sturgeon are present in the Delta in all months of the year, Green Sturgeon are likely to be found in the main channels of the Delta and the larger interconnecting sloughs and waterways, with western Delta waterways having a higher likelihood of presence than eastern Delta waterways (NMFS 2009:338). The application of aquatic herbicide to the waters of Clifton Court Forebay will occurbetween 28 June and 31 August. Treatment could occur prior to 28 June at tempertures ≥ 25˚C; however, Green Sturgeon would not be expected to occur at these temperatures. Thus, the likelihood of exposing juvenile Green Sturgeon to the herbicide is very low.

As discussed in Appendix D, treatment of harmful algal blooms with peroxide-based algaecide is proposed to occur as needed, year-round, but there are no anticipated impacts to fish because the oxidation reaction occurs immediately upon contact with the water, destroying algal cell membranes and chlorophyll, with hydrogen peroxide and oxygen as byproducts.

Potential changes to aquatic resources due to changes from Tracy and Skinner fish facility improvements

Upgrades to the TFCF under Alternative 1 will aim to minimize the effects of the salvage process on listed fishes, in particular juvenile salmonids and Green Sturgeon. Salvage improvements will improve survival of salvaged fish, and potentially allow reduction of the expansion factors used to extrapolate take estimates from observed salvage.

Upgrades to the TFCF will aim to minimize the effects of the salvage process on listed fishes, in particular juvenile salmonids and Green Sturgeon. Salvage improvements will improve survival of salvaged fish and potentially allow reduction of the expansion factors used to extrapolate take estimates from observed salvage.

As previously described, juvenile Green Sturgeon can occur in the Delta year-round (Reclamation 2019) and, therefore, have the potential to be exposed to the effects of construction of the CO_2 injection device proposed for the Tracy Fish Facility Improvements. If construction affects the efficiency of Green Sturgeon salvage (which is an element of entrainment risk; Figure 5.12-3), there could be a minor effect to a small number of individuals, although risk would be minimized through appropriate mitigation measures (Appendix E, *Mitigation Measures*).

Skinner Fish Facility improvements under Alternative 1, which involve predator control efforts, can reduce predation on listed fish species, following their entrainment into Clifton Court Forebay. This could also reduce pre-screen loss of juvenile southern DPS Green Sturgeon. It is unknown what proportion of juvenile Green Sturgeon are entrained into CCF but individuals are salvaged infrequently. Thus, Alternative 1 is not likely to negatively impact juvenile Green Sturgeon. There is potential for Green Sturgeon to be impacted by predator control activities. However, Green Sturgeon are rarely encountered at the facilities suggesting few fish would be impacted.

Potential changes to aquatic resources due to changes from Suisun Marsh facilities

Operation of the SMSCG from June through September under Alternative 1 coincides with a portion of the downstream migration of juvenile southern DPS Green Sturgeon, as well as adult southern DPS Green Sturgeon. Montezuma Slough provides an alternative route to their primary migration corridor through Suisun Bay. During full gate operation, the flashboards are installed and the radial gates open and close twice each tidal day. Green Sturgeon are thought to successfully pass through either the boat lock or through the gates during periods when the gates are open. NMFS (2009) determined that operation of the SWSCG is unlikely to produce conditions that support unusually high numbers of predators, change habitat suitability or availability for rearing or migration of juvenile and adult Green Sturgeon. Green

Sturgeon are strong swimmers and therefore the operation of the Suisun Marsh Salinity Control Gate will have no impact on adults or juvenile Green Sturgeon.

The low screen velocity at the intake culverts combined with a small screen mesh size are expected to successfully prevent Green Sturgeon from being entrained into the RRDS under Alternative 1. (NOAA 2009).

The MIDS intakes under Alternative 1 do not currently have fish screens, and juvenile Green Sturgeon are more prone to entrainment than other species such as White Sturgeon (Poletto et al. 2014). However, fisheries monitoring performed in 2004-05 and 2005-06 identified entrainment of 20 fish species, none of which were Green Sturgeon (NOAA 2009). Presence of Green Sturgeon in the area of the MIDS intake is not well studied or documented, but it if Green Sturgeon are present they may potentially avoid entrainment as they do not typically swim along the surface where the diversion is located.

Due to its location and design, Green Sturgeon are not likely to encounter this structure or be negatively affected by its operation. Improved water circulation by the operation of the Goodyear Slough Outfall under Alternative 1 likely benefits juvenile Green Sturgeon in Suisun Marsh by improving water quality and increasing foraging opportunities (NOAA 2009).

Potential changes to aquatic resources from Clifton Court predator management efforts

Predator control efforts under Alternative 1 can reduce predation on listed fish species, following their entrainment into Clifton Court Forebay. This could also reduce pre-screen loss of juvenile southern DPS Green Sturgeon. It is unknown what proportion of juvenile Green Sturgeon are entrained into CCF but individuals are salvaged infrequently.

Potential changes to aquatic resources due to the San Joaquin Basin steelhead telemetry study

Potential changes to aquatic resources due to reintroduction changes from Fish Conservation and Culture Laboratory

Potential changes to aquatic resources from monitoring

Population estimates for Green Sturgeon also remain outstanding in the Central Valley. Similar to Steelhead, the existing monitoring programs very rarely catch Green Sturgeon because most monitoring programs are not designed to capture them. Similar to Steelhead, it is unlikely the monitoring programs have an effect to the population.

O.3.3.9 *Nearshore Pacific Ocean on the California Coast*

O.3.3.9.1 <u>Southern Resident Killer Whale</u>

Potential changes to Southern Killer Whale from Chinook Salmon prey abundance

As previously described in Section O.3.2.9, *Nearshore Pacific Ocean on the California Coast*, and described in more detail in the ROC LTO BA, potential effects to Southern Resident Killer Whale as a result of SWP/CVP operations could occur as a result of effects to Chinook Salmon prey abundance. The ROC LTO BA concluded that there may be positive and negative effects of Alternative 1 (the ROC LTO proposed action), with the former including operation of the south Delta export facilities and the latter including flow and temperature management. Overall, it was concluded that given the medium priority of Central Valley Chinook Salmon stocks and the contribution of hatchery-origin Chinook Salmon released downstream of the potential proposed action influence, the proposed action (Alternative 1) would not be expected to have population-level effects to Southern Resident Killer Whale Chinook Salmon prey. This suggests limited effects of Alternative 1 on Southern Resident Killer Whale.

O.3.4 Alternative 1 – Program-Level Effects

O.3.4.1 *Sacramento River*

Potential changes to aquatic resources from Battle Creek restoration

Under Alternative 1, Reclamation would accelerate implementation of the Battle Creek Salmon and Steelhead Restoration Project, which is intended to reestablish approximately 42 miles of prime salmon and steelhead habitat on Battle Creek and an additional 6 miles on its tributaries. Winter-Run Chinook Salmon are currently limited to a single population that spawns in a 5-mile stretch of the Sacramento River, but they are being reintroduced to Battle Creek (around 200,000 juveniles were released in Battle Creek in 2018). This new population would benefit from the restoration efforts. An additional population of Winter-Run Chinook Salmon on Battle Creek would provide temperature compliance flexibility. This intervention measure would benefit Winter-Run Chinook Salmon and other anadromous salmonids.

Potential adverse construction impacts of this measure are being minimized and mitigated by the Battle Creek Salmon and Steelhead Restoration Program, as described in the program's Final EIR (Reclamation 2005).

Potential changes to aquatic resources from lower intakes near Wilkins Slough

The conservation of Shasta storage to satisfy Winter-Run Chinook Salmon cold water needs would benefit from a reduction in Sacramento River flows at certain times of year. The river near Wilkins Slough used to have a 5,000 cfs minimum navigational flow set by Congress, but this is no longer required. However, as many of the fish screens at diversions in this region were designed to meet the 5,000 cfs minimum, they may not function properly at the lower flows and as a result may not meet state and federal fish screening requirements during the lower flows (NCWA 2014). This could result in take of state-protected and federally protected species that use this section of the river. This action would provide grants to water users within this area to install new diversions and screens that would properly operate at lower flows, thereby allowing Reclamation greater flexibility in managing Sacramento River flows and temperatures for both water users and wildlife, including listed salmonids (NCWA 2014).

Any fish present during the June 1 through October 1 in-water work window could be exposed to temporary disturbances associated with the construction of a cofferdam for this project. Water quality may be temporarily disturbed, in addition to noise associated with construction of the cofferdam. Additionally, fish rescue operations may need be conducted during the period when water within the coffered area needs to be pumped. However, implementation of AMM's identified in Appendix E, *Avoidance and Minimization Measures* would further minimize those effects.

This intervention measure is expected to benefit incubating Winter-Run and Spring-Run Chinook Salmon eggs and alevins by reducing risk of depleting the coldwater pool and to benefit juvenile fish of all species by reducing entrainment.

Potential changes to aquatic resources due to Shasta TCD Improvements

Reclamation would study the feasibility of infrastructure improvements to enhance Shasta TCD performance, including reducing the leakage of warm water into the structure. The leakage increases the temperature of cold water released to maintain suitable temperatures for Winter-Run Chinook Salmon that spawn in the upper Sacramento River from May through August. Fry emergence occurs up to two months after eggs are spawned, so effects of water temperature and flow in the upper Sacramento River on Winter-Run Chinook Salmon fry and alevins potentially occur from May through October, but occur primarily during June through September. The ability to better manage the coldwater pool and cold water releases would result in increased probability of maintaining suitable spawning, incubating, and rearing temperatures throughout the season in all but the driest years.

This intervention measure would potentially benefit Winter-Run and Spring-Run Chinook Salmon and would have no impact on other species.

Potential changes to aquatic resources from operation of the Livingston-Stone National Fish Hatchery (Winter-Run Chinook Salmon)

Expansion of Livingston-Stone National Fish Hatchery would allow increased operation to sustain Winter-Run Chinook Salmon, particularly during drought years. The purpose would be to provide artificial rearing and spawning habitat when in-river environmental conditions (low flow and high temperatures) are not suitable for egg or fry life stages. It will be important to couple other conservation measures together with increased production to ensure that the measure addresses losses of natural production. For example, if in-river conditions are not conducive to migration downriver, fish produced at the hatchery may need to be trucked to a point with higher downstream survival.

Minimizing potential adverse effects of increased hatchery production would depend on complex interactions between hatchery and natural-origin fish and their environment. Livingston-Stone National Fish Hatchery operates an “integrated” hatchery program with the intention of minimizing genetic divergence between hatchery and natural components of the population by exchanging spawners between them (Paquet et al. 2011). A natural consequence of expanding numbers of hatchery fish is an increase of hatchery origin fish on in-river spawning grounds. This coupled with low survival of natural-origin fish may influence the genetic management criteria to include hatchery-origin spawners and variable numbers of males and females under drought conditions.

This intervention measure would potentially benefit the Winter-Run Chinoook Salmon population by reducing the risk of its extinction, but would do so at the risk of reducing its genetic fitness.

Potential changes to aquatic resources from small screen program installation

Installation of fish screens on small irrigation diversions in the Sacramento River has the potential to benefit fish species with life stages that are vulnerable to entrainment by the diversions (e.g., floating eggs, larvae, fry, juveniles, smolts). However, the benefits would be realized only for species with a large proportion of their vulnerable life stages present when the diversions operate. The small diversions in the Sacramento River operate primarily during April to September. The focal fish species with vulnerable life stages present during this period include Central Valley Steelhead, Green Sturgeon, White Sturgeon, Splittail, Pacific and River Lamprey, Hardhead, Striped Bass, American Shad, and Largemouth, Smallmouth, and Spotted Bass. All of these species would potentially benefit from the small screen program. Central Valley Steelhead and Green Sturgeon are federally protected, so their protection is the most critical. Steelhead fry and juveniles and Green Sturgeon larvae and juveniles may be present in the Sacramento River and vulnerable to agricultural diversions throughout the diversion period, so screening the diversions would likely benefit both species. However, benefit of the screens to sturgeon is more uncertain than the benefit to steelhead because the screens would be designed to meet NMFS and CDFW fish screen criteria designed to reduce entrainment of juvenile salmonids, and the effectiveness of such fish screens in reducing larval and juvenile sturgeon entrainment is poorly understood.

Green sturgeon juveniles are believed to be highly susceptible to entrainment in unscreened diversions and impingement on screened diversions (Mussen et al. 2014, NMFS 2018b). Risks of entrainment and impingement in the Sacramento River are increased because the period of juvenile presence in the river (May through December) coincides with peak period of irrigation diversions (April to September). Green sturgeon larvae may be particularly susceptible to entrainment, impingment, and injury at water diversions. The larvae are present in areas where substantial water volumes are diverted, such as the Red Bluff Diversion Dam and Glen-Colusa Irrigation District (GCID) facilities, and these diversion may entrain larval and juvenile sturgeon (Mussen et al. 2014). Due to their small size and relatively poor swimming performance, it is highly likely that entrainment affects larval survival (Heublein et al. 2017a; Verhille et al. 2014). Many small-scale unscreened diversions are present near larval habitat of Green Sturgeon throughout the mainstem Sacramento River.

Focal fish species may be exposed to the effects of construction of screens on water diversion intakes if their vulnerable life stages are present in the river during the typical timing of in-water construction (July 15–October 15). However, the work area for these projects is small, limiting exposure to construction. Potential short-term adverse effects may include temporary degradation of water quality, including increased turbidity and suspended sediments and sediment deposition in the direct vicinity of the work area, and the temporary displacement of individual fish in the work area. If fish are present in the work area, flowing water will be isolated and fish captured and relocated to an appropriate location in an effort to minimize possible mortality. Juveniles would likely experience increased levels of stress and injury during handling, which could be exacerbated by poor water quality (i.e., increased temperatures, low dissolved oxygen saturation), and prolonged periods of holding between capture and release. There may be a minor effect to a small number of individuals, although the risk from these potential effects would be minimized through the implementation of mitigation measures for aquatic resources (Appendix E, Mitigation Measures). In addition, the appropriate conservation measures and handling techniques will be employed to ensure that the stress resulting from handling and transport is short-lived and minor.

This intervention measure is expected to benefit Central Valley Steelhead, Green Sturgeon, White Sturgeon, Splittail, Pacific and River Lamprey, Hardhead, Striped Bass, American Shad, Largemouth Bass, Smallmouth Bass, and Spotted Bass.

Potential changes to aquatic resources from spawning habitat restoration

Reclamation would create additional spawning habitat by injecting approximately 15,000 to 40,000 tons of gravel annually into the Sacramento River to 2030, using the following sites: Keswick Dam Gravel Injection Site, Market Street Injection Site, Redding Riffle, Turtle Bay, Tobiasson Island, Shea Levee sites, and Kapusta. This intervention measure is likely to benefit all Chinook Salmon runs that spawn in the Sacramento River, as well as Central Valley Steelhead and Green Sturgeon.

Adults, eggs, alevins, larvae and juveniles of all the species that occur in the upper Sacramento River would be subject to potential adverse effects from proposed spawning (e.g, gravel augmentation) restoration projects in the upper Sacramento River associated with the proposed measure. Construction activities could result in mortality of eggs and alevins by crushing if heavy equipment enters the stream channel or otherwise disturbs existing redds during in-water activities. Eggs and alevins and other life stages could also be negatively impacted by increases in suspended sediment, turbidity, and contaminant exposure risk, leading to indirect impacts on individuals from reductions in habitat quality (e.g., reduced flow and dissolved oxygen in redds from increases in sediment deposition) or direct impacts from sublethal and lethal exposures to contaminants. Although these potential effects may be unavoidable, exposure of the fish populations to construction effects would be low based on the limited extent of proposed restoration projects relative to the overall distribution of the fish, and the implementation of other mitigation measures for aquatic resources described in Appendix E, *Mitigation Measures*. These measures include MM-AQUA-1, which requires worker awareness training, MM-AQUA-4, erosion and sediment control, and MM-AQUA-5, spill prevention and containment.

Potential changes to aquatic resources from rearing habitat restoration

Reclamation, in coordination with Sacramento River Settlement Contractors, would create 40 to 60 acres of side channel and floodplain habitat at 10 sites in the Sacramento River by 2030. Creation of this additional 40 to 60 acres of rearing habitat would help increase the quantity and quality of Winter-Run, Spring-Run, and Fall-/Late Fall-Run Chinook Salmon and Central Valley Steelhead juvenile rearing habitat in the Upper Sacramento River. Reclamation estimates that this additional 50 acres of rearing habitat could support the progeny of 5,600 returning adult salmonids (see Reclamation 2019).

Adults, eggs, alevins, larvae and juveniles of all the species that occur in the upper Sacramento River would be subject to potential adverse effects from proposed rearing habitat (e.g., side channel) restoration projects in the upper Sacramento River associated with the proposed action. Construction activities could result in mortality of eggs and alevins by crushing if heavy equipment enters the stream channel or otherwise disturbs existing redds during in-water activities. Eggs and alevins and other life stages could also be negatively impacted by increases in suspended sediment, turbidity, and contaminant exposure risk, leading to indirect impacts on individuals from reductions in habitat quality (e.g., reduced flow and dissolved oxygen in redds from increases in sediment deposition) or direct impacts from sublethal and lethal exposures to contaminants. Although these potential effects may be unavoidable, exposure of the fish populations to construction effects would be low based on the limited extent of proposed restoration projects relative to the overall distribution of the fish, and the implementation of other mitigation measures for aquatic resources described in Appendix E, Mitigation Measures. These measures include MM-AQUA-1, which requires worker awareness training, MM-AQUA-4, erosion and sediment control, and MM-AQUA-5, spill prevention and containment.

Potential changes to aquatic resources due to adult rescue activities

O.3.4.1.1 Winter-Run Chinook Salmon

The Fremont Weir fish ladder and Wallace Weir fish rescue facility have improved fish passage in the Yolo Bypass and between the bypass and the river. However, the potential for stranding in isolated pools remains when hydrologic connectivity is not present during droughts or after periods of bypass flooding. Reclamation proposes to trap and haul adult salmonids and sturgeon from Yolo and Sutter bypasses during droughts and after periods of bypass flooding, when flows from the bypasses are most likely to attract upstream migrating adults but prohibit passage to upstream spawning grounds, and move them up the Sacramento River toward spawning grounds. CDFW initiated fish trapping and rescue efforts at the Wallace Weir in 2014 and at Fremont Weir in 2017 to return anadromous fish to the Sacramento River (CDFW 2016, 2017). This measure would continue these actions. This trap and haul program is in addition to weir fish passage projects within the proposed action and would improve survival of adults.

Under Alternative 1, stranded adult Sacramento Winter-Run Chinook Salmon that are blocked from upstream migration would be captured at the Fremont, Wallace, and Tisdale weirs and hauled closer to spawning grounds upstream in the Sacramento River. Adults migrating in-river or that do not become stranded in the Yolo and Sutter bypasses would be unaffected by Alternative 1. The rescue and transport of adult Sacramento Winter-Run Chinook Salmon closer to spawning grounds would result in an increased number of adults returning to spawn in the Sacramento River. Potential adverse effects of adult rescue activities to individual adult Winter-Run Chinook Salmon include increased risk of stress, injury, and/or mortality associated with capture, handling, and transport, which may affect survival of affected individuals after release; however, survival is estimated to be much higher following capture/transport than if left trapped in bypasses. Any adverse effects related to rescue activities would be minimized through the application of AMM8 *Fish Rescue and Salvage Plan* (Reclamation 2019), which establishes detailed procedures for fish rescue and salvage to minimize the number of individuals of listed fish species subject to the adverse effects of rescue activities.

Alternative 1 may adversely affect juvenile Winter-Run Chinook Salmon when Sacramento River flows overtop the Fremont and/or Tisdale Weirs if they become stranded with adults that are targeted by adult rescue activities and are incidentally captured. Potential adverse effects of Alternative 1 on juvenile Winter-Run Chinook Salmon include increased risk of stress, injury, and/or mortality during handling and transport. Risk of these potential effects would be minimized through the application of AMM8 *Fish Rescue and Salvage Plan* (Reclamation 2019), which establishes detailed procedures for fish rescue and salvage to minimize the number of individuals of listed fish species subject to the adverse effects of rescue activities.

Any potential negative population-level effects of Alternative 1 would be expected to be offset by the benefits associated with increased numbers of adult Winter-Run Chinook Salmon returning to spawning grounds. Under the No Action Alternative there is no rescue and transport of stranded adult Winter-Run Chinook Salmon to upstream spawning grounds; therefore, the overall population-level effects of Alternative 1 are expected to be positive relative to the No Action Alternative.

O.3.4.1.2 Spring-Run Chinook Salmon

Under Alternative 1, adult Spring-Run Chinook Salmon that become trapped in the Yolo and Sutter bypasses during droughts and after periods of bypass flooding would be captured and released further upstream in the Sacramento River. CDFW initiated fish trapping and rescue efforts at the Wallace Weir in 2014 and at Fremont Weir in 2017 to return anadromous fish to the Sacramento River (CDFW 2016, 2017). This component would continue these actions. Adults migrating in-river or that do not become stranded in the Yolo and Sutter bypasses would be unaffected by Alternative 1. The rescue and transport of adult Spring-Run Chinook closer to spawning grounds would result in an increased number of adults returning to spawn in the Sacramento River. Potential adverse effects of adult rescue activities to individual adult Spring-Run Chinook Salmon include increased risk of stress, injury, and/or mortality associated with capture, handling, and transport, which may affect survival of individuals after release; however, survival is estimated to be much higher following capture/transport than if left trapped in bypasses. Any adverse effects related to rescue activities would be minimized through the application of AMM8 *Fish Rescue and Salvage Plan* (Reclamation 2019), which establishes detailed procedures for fish rescue and salvage to minimize the number of individuals of listed fish species subject to the adverse effects of rescue activities.

Alternative 1 may adversely affect juvenile Spring-Run Chinook Salmon when Sacramento River flows overtop the Fremont and/or Tisdale Weirs if they become stranded with adults that are targeted by adult rescue activities and are incidentally captured. Potential adverse effects of Alternative 1 on juvenile Spring-Run Chinook include increased risk of stress, injury, and/or mortality during handling and transport. Risk of these potential effects would be minimized through the application of AMM8 *Fish Rescue and Salvage Plan* (Reclamation 2019), which establishes detailed procedures for fish rescue and salvage to minimize the number of individuals of listed fish species subject to the adverse effects of rescue activities.

Any potential negative population-level effects of Alternative 1 would be expected to be offset by the benefits associated with increased numbers of adult Central Valley Spring-Run Chinook Salmon returning to spawning grounds. Under the No Action Alternative there is no rescue and transport of stranded adult Spring-Run Chinook to upstream spawning grounds; therefore, the overall population-level effects of Alternative 1 are expected to be positive relative to the No Action Alternative.

O.3.4.1.3 Fall- /Late Fall-Run Chinook Salmon

Under Alternative 1, adult Fall- /Late Fall-Run Chinook Salmon that become stranded in the Yolo and Sutter bypasses during droughts and after periods of bypass flooding would be captured and released further upstream in the Sacramento River. CDFW initiated fish trapping and rescue efforts at the Wallace Weir in 2014 and at Fremont Weir in 2017 to return anadromous fish to the Sacramento River (CDFW 2016, 2017). This component would continue these actions. Adults migrating in-river or that do not become stranded in the Yolo and Sutter bypasses would be unaffected by Alternative 1. The rescue and transport of adult Fall- /Late Fall-Run Chinook Salmon closer to spawning grounds would result in an increased number of adults returning to spawn in the Sacramento River. Potential adverse effects of adult rescue activities to individual Fall- /Late Fall-Run Chinook Salmon include increased risk of stress, injury, and/or mortality associated with capture, handling, and transport, which may affect survival of individuals after release; however, survival is estimated to be much higher following capture/transport than if left trapped in bypasses. Any adverse effects related to rescue activities would be minimized through the application of AMM8 *Fish Rescue and Salvage Plan* (Reclamation 2019), which establishes detailed procedures for fish rescue and salvage to minimize the number of individuals of listed fish species subject to the adverse effects of rescue activities.

Alternative 1 may adversely affect juvenile Fall- /Late Fall-Run Chinook Salmon when Sacramento River flows overtop the Fremont and/or Tisdale weirs if they become stranded with adults that are targeted by adult rescue activities and are incidentally captured. Potential adverse effects of Alternative 1 on juvenile Fall- /Late Fall-Run Chinook Salmon could therefore include increased risk of stress, injury, and/or mortality during handling and transport. Risk of these potential effects would be minimized through AMM8 *Fish Rescue and Salvage Plan* (Reclamation 2019), which establishes detailed procedures for fish rescue and salvage to minimize the number of individuals of listed fish species subject to the adverse effects of rescue activities

Any potential adverse population-level effects of Alternative 1 would be expected to be offset by the benefits associated with increased numbers of adult Fall- /Late Fall-Run Chinook Salmon returning to spawning grounds. Under the No Action Alternative there is no rescue and transport of stranded adult Fall- /Late Fall-Run Chinook Salmon to upstream spawning grounds; therefore, the overall population-level effects of Alternative 1 are expected to be positive relative to the No Action Alternative.

O.3.4.1.4 Central Valley Steelhead

Under Alternative 1, adult California Central Valley Steelhead trapped in the Yolo and Sutter bypasses would be captured and transported further upstream to release sites in the Sacramento River. CDFW initiated fish trapping and rescue efforts at the Wallace Weir in 2014 and at Fremont Weir in 2017 to return anadromous fish to the Sacramento River (CDFW 2016, 2017). This component would continue these actions. While California Central Valley Steelhead are less likely than Chinook Salmon to utilize floodplain habitat such as the Yolo and Sutter bypasses, there is the potential for adults and juveniles to occur in the bypasses when Sacramento River flows overtop the Fremont and/or Tisdale Weirs. Exposure of adult California Central Valley Steelhead to rescue effects would be restricted to only those adult Steelhead which become stranded in the Yolo and Sutter bypasses and are subsequently rescued and released in the Sacramento River; in-river migrating adults and those that do not become stranded in the bypasses would be unaffected by Alternative 1. The rescue and transport of adult Central Valley Steelhead closer to spawning grounds would result in an increased number of adults returning to spawn in the Sacramento River. Potential adverse effects of adult rescue activities to individual Central Valley Steelhead include increased risk of stress, injury, and/or mortality associated with capture, handling, and transport, which may affect survival of individuals after release; however, survival is estimated to be much higher following capture/transport than if left trapped in bypasses. Any adverse effects related to rescue activities would be minimized through the application of AMM8 *Fish Rescue and Salvage Plan* (Reclamation 2019), which establishes detailed procedures for fish rescue and salvage to minimize the number of individuals of listed fish species subject to the adverse effects of rescue activities.

Juvenile California Central Valley Steelhead could be exposed to the effects of Alternative 1 if they become stranded with adults targeted by adult rescue activities and are incidentally captured. Potential adverse effects of Alternative 1 on juvenile Central Valley Steelhead include increased risk of stress, injury, and/or mortality associated with capture, handling, and transport during adult rescue activities, which could affect survival of individuals after release. However, any adverse effects related to rescue activities would be minimized through the application of AMM8 *Fish Rescue and Salvage Plan* (Reclamation 2019), which establishes detailed procedures for fish rescue and salvage to minimize the number of individuals of listed fish species subject to the adverse effects of rescue activities.

Any potential adverse population-level effects of Alternative 1 would be expected to be offset by the benefits associated with increased numbers of adult California Central Valley Steelhead returning to spawning grounds. Under the No Action Alternative there is no rescue and transport of stranded adult California Central Valley Steelhead to upstream spawning grounds; therefore, the overall population-level effects of Alternative 1 are expected to be positive relative to the No Action Alternative.

O.3.4.1.5 Green Sturgeon

Under Alternative 1, adult Southern DPS North American Green Sturgeon trapped in the Yolo and Sutter bypasses would be captured and transported upstream to release sites in the Sacramento River. Exposure of adult Green Sturgeon to rescue effects would be restricted to only those that become stranded in the Yolo and Sutter bypasses and are subsequently rescued and released to the Sacramento River; in-river migrating adults and those that do not become stranded in the bypasses would be unaffected. CDFW initiated fish trapping and rescue efforts at the Wallace Weir in 2014 and at Fremont Weir in 2017 to return anadromous fish to the Sacramento River (CDFW 2016, 2017). This component would continue these actions. The rescue and transport of adult Green Sturgeon closer to spawning grounds would result in an increased number of adults returning to spawn in the Sacramento River. Potential adverse effects of adult rescue activities to individual Green Sturgeon include increased risk of stress, injury, and/or mortality associated with capture, handling, and transport, which may affect survival of individuals after release; however, survival is estimated to be much higher following capture/transport than if left trapped in bypasses. Any adverse effects related to rescue activities would be minimized through the application of AMM8 *Fish Rescue and Salvage Plan* (Reclamation 2019), which establishes detailed procedures for fish rescue and salvage to minimize the number of individuals of listed fish species subject to the adverse effects of rescue activities.

Juvenile Green Sturgeon could be exposed to the effects of Alternative 1 if they become stranded with adults targeted by adult rescue activities and are incidentally captured. Potential adverse effects of

Alternative 1 include increased risk of stress, injury, and/or mortality associated with capture, handling, and transport during adult rescue activities, which could affect survival of individuals after release; however, survival is estimated to be much higher following capture/transport than if left trapped on bypasses. Any adverse effects related to rescue activities would be minimized through the application of AMM8 Fish Rescue and Salvage Plan (Reclamation 2019), which establishes detailed procedures for fish rescue and salvage to minimize the number of individuals of listed fish species subject to the adverse effects of rescue activities.

Any potential adverse population-level effects of Alternative 1 would be expected to be offset by the benefits associated with increased numbers of adult Green Sturgeon returning to spawning grounds. Under the No Action Alternative, there is no rescue and transport of stranded adult Green Sturgeon to upstream spawning grounds; therefore, the overall population-level effects of Alternative 1 are expected to be positive relative to the No Action Alternative.

Potential changes to aquatic resources due to trap and haul activities

Under Alternative 1, if a Tier 4 year is predicted (i.e., a year with less than 2.5 MAF of storage at the beginning of May), Reclamation would implement a downstream trap and haul strategy for the capture and transport of juvenile Winter-Run Chinook Salmon, Spring-Run Chinook Salmon, Fall- /Late Fall-Run Chinook Salmon, and Central Valley Steelhead in the Sacramento River watershed. In Tier 4 years, low flows and resulting high water temperatures are typically unsuitable for volitional downstream migration and survival. Reclamation would place temporary juvenile collection weirs at key feasible locations downstream of spawning areas in the Sacramento River. Reclamation would transport collected fish to a safe release location or locations in the Delta upstream of Chipps Island. Juvenile trap and haul activities would occur from December 1 through May 31, consistent with the migration period for juvenile Chinook Salmon and Steelhead (NMFS 2014a), depending on hydrologic conditions. In the event of high river flows or potential flooding, the fish weirs would be removed. Under the No Action Alternative, there is no capture and transport of juvenile fish.

O.3.4.1.6 <u>Winter-Run Chinook Salmon</u>

Alternative 1 would increase the number of out-migrating juvenile Winter-Run Chinook Salmon during Tier 4 years relative to the No Action Alternative. Under the No Action Alternative, juveniles could be exposed to low flows and high water temperatures in Tier 4 years, but such exposure would be lessened under Alternative 1 as juveniles are transported around unfavorable conditions to downstream locations where their migrations can continue (Reclamation 2014d: 3–2). Potential adverse effects of Alternative 1 on juvenile Winter-Run Chinook Salmon include increased risk of stress during transport, making juveniles more vulnerable to predation, impaired auditory function, earlier ocean entry, reduced growth rates, and decreased homing ability as adults (Lusardi and Moyle 2017: 479–480). The risk of these negative effects would be reduced through the application of AMM8, *Fish Rescue and Salvage Plan,* which establishes detailed procedures for fish rescue and salvage to minimize the number of individuals of listed fish species subject to the adverse effects of trapping. Although there are negative effects associated with trap and haul, implementation of Alternative 1 could provide benefits to Winter-Run Chinook Salmon relative to the No Action Alternative, where trapping and hauling of juveniles during Tier 4 years would not occur.

O.3.4.1.7 <u>Spring-Run Chinook Salmon</u>

Alternative 1 would increase the number of out-migrating juvenile Spring-Run Chinook Salmon during Tier 4 years relative to the No Action Alternative. Under the No Action Alternative, juveniles could be exposed to low flows and high water temperatures in Tier 4 years, but such exposure would be lessened under Alternative 1 as juveniles are transported around unfavorable conditions to downstream locations where their migrations can continue (Reclamation 2014d: 3–2). Potential adverse effects of Alternative 1 on juvenile Spring-Run Chinook Salmon include increased stress during transport, making juveniles more vulnerable to predation, impaired auditory function, earlier ocean entry, reduced growth rates, and decreased homing ability as adults (Lusardi and Moyle 2017: 479–480). The risk of these potential negative effects would be reduced through the application of AMM8, *Fish Rescue and Salvage Plan,* which establishes detailed procedures for fish rescue and salvage to minimize the number of individuals of listed fish species subject to the adverse effects of trapping. Although there are negative effects associated with trap and haul, implementation of Alternative 1 could provide benefits to Spring-Run Chinook Salmon relative to the No Action Alternative, where trapping and hauling of juveniles during Tier 4 years would not occur.

O.3.4.1.8 Fall- /Late Fall-Run Chinook Salmon

Alternative 1 would increase the number of out-migrating juvenile Fall- /Late Fall-Run Chinook Salmon relative to the No Action Alternative. Under the No Action Alternative, juveniles could be exposed to low flows and high water temperatures in Tier 4 years, but such exposure would be lessened under Alternative 1 as juveniles are transported around unfavorable conditions to downstream locations where their migrations can continue (Reclamation 2014d: 3-2). Potential adverse effects of Alternative 1 on juvenile Fall-Run/Late Fall-Run Chinook Salmon include increased stress during transport, making juveniles more vulnerable to predation, impaired auditory function, earlier ocean entry, reduced growth rates, and decreased homing ability as adults (Lusardi and Moyle 2017: 479–480). The risk of these potential negative effects would be reduced through the application of AMM8, *Fish Rescue and Salvage Plan,* which establishes detailed procedures for fish rescue and salvage to minimize the number of individuals of listed fish species subject to the adverse effects of trapping. Although there are negative effects associated with trap and haul, implementation of Alternative 1 could provide benefits to Fall- /Late Fall-Run Chinook Salmon relative to the No Action Alternative, where trapping and hauling of juveniles during Tier 4 years would not occur.

O.3.4.1.9 Central Valley Steelhead

Alternative 1 would increase the number of out-migrating juvenile California Central Valley Steelhead during Tier 4 years relative to the No Action Alternative. Under the No Action Alternative, juveniles could be exposed to low flows and high water temperatures in Tier 4 years, but such exposure would be lessened under Alternative 1 as juveniles are transported around unfavorable conditions to downstream locations where their migrations can continue (Reclamation 2014d: 3-2). Potential adverse effects of Alternative 1 on juvenile California Central Valley Steelhead include increased stress during transport, making juveniles more vulnerable to predation, impaired auditory function, earlier ocean entry, reduced growth rates, and decreased homing ability as adults (Lusardi and Moyle 2017: 479–480). The risk of these potential negative effects would be reduced through the application of AMM8, *Fish Rescue and Salvage Plan,* which establishes detailed procedures for fish rescue and salvage to minimize the number of individuals of listed fish species subject to the adverse effects of trapping. Although there are negative effects associated with trap and haul, implementation of Alternative 1 could provide benefits to California Central Valley Steelhead relative to the No Action Alternative, where trapping and hauling of juveniles during Tier 4 years would not occur.

O.3.4.1.10 Green Sturgeon

Juvenile trap and haul activities are targeted at salmonids; however, larval and juvenile Green Sturgeon could be affected by the trap and haul program under Alternative 1. Larger Green Sturgeon larvae, as well as juveniles, could be incidentally captured by gear used to trap juvenile salmonids during implementation of Alternative 1. However, because juvenile trap and haul activities would be focused on trapping juvenile salmonids, few Green Sturgeon larvae and juveniles would be expected to be collected; adult Green Sturgeon are not expected to be vulnerable to trapping because of their large size and benthic behavior. Effects on larval and juvenile Green Sturgeon exposed to trapping activities could include increased stress, injury, and/or mortality during capture and handling. Risk of these potential effects would be reduced through application of AMM8, *Fish Rescue and Salvage Plan*, which establishes detailed procedures for fish rescue and salvage to minimize the number of individuals of listed fish species subject to the adverse effects of trapping. Through the implementation of AMM8 and the return of trapped larval and juvenile Green Sturgeon to the Sacramento River, any adverse effects on Green Sturgeon from implementation of Alternative 1 are expected to be minimal.

O.3.4.2 *Stanislaus River*

Potential changes to salmonid habitat in the Stanislaus River related to habitat restoration

Alternatives 1 and 3 include spawning and habitat restoration activities in the Stanislaus River that would result in construction-related temporary disturbance to habitat and may expose nearby fish to stressful conditions. Construction activities may result in a temporary elevation of turbidity, noise and exclusion. However, through coordination with the regulatory agencies and implementation of avoidance and minimization measures, including the implementation of an in-water work window from July 15 through October 15, effects to the particular life stages would be minimized or avoided.

The majority of species and life stages would be unaffected by construction activities due to timing of in-water construction within the in-water work window of July 15 through October. However, some life stages are present during this time, and may be temporarily affected. Implementation of mitigation measures for aquatic resources (Appendix E, Mitigation Measures) would minimize those effects. The species that the avoidance and minimization measures would benefit due to the presence of their life stage during the in-water work window would include holding Spring-Run Chinook Salmon depending on location of in-water work related to the restoration, rearing Central Valley Steelhead that may be present year-round, outmigrating Fall-Run Chinook Salmon.

Although construction may temporarily affect certain fish species and their habitat, restoration of spawning and rearing habitat will result in long-term improvements to the habitat and aquatic inhabitants including increase in riparian vegetation providing Instream object and overhanging object cover, new shaded riverine habitat, and additional areas for food source. Habitat complexity and diversity would also occur resulting in additional cover for predator avoidance and refuge for salmonids or other native fishes.

Restoration activities have the potential to increase growth and survival of juvenile Chinook Salmon, Steelhead, and other native fish by providing increased seasonal access to productive foraging and high quality rearing habitat.

O.3.4.3 *Bay-Delta*

O.3.4.3.1 Delta Smelt

Potential changes to Delta Smelt from food subsidies (Sacramento Deepwater Ship Channel food study; North Delta food subsidies/Colusa Basin drain study; Suisun Marsh Roaring River Distribution System food subsidies study)

As previously noted in the discussion of *Potential changes to Delta Smelt from actions for Delta Smelt summer-fall habitat,* Alternative 1 includes Delta Smelt food subsidy studies in the Sacramento Deepwater Ship Channel, North Delta/Colusa Basin Drain, and Suisun Marsh/RRDS. These studies will allow assessment of the extent to which operating these actions will provide Delta Smelt with additional food relative to the No Action AlternativeNo Action Alternative. This is discussed further in the ROC LTO Ba, where it is also noted that there could be negative effects from sediment mobilization in the Sacramento Deepwater Ship Channel, potentially increasing contaminant exposure. Additional food could allow offsetting of potential negative effects from the previously described differences in seasonal operations (i.e., less spring Delta outflow under Alternative 1 potentially affecting *E. affinis*; less summer/fall outflow affecting *P. forbesi* transport to the low salinity zone).

Potential changes to Delta Smelt from tidal habitat restoration

As described in the ROC LTO BAand as noted for the No Action Alternative, completion of the approximately 6,000 acres of remaining tidal habitat restoration required by the USFWS (2008) BO has the potential to provide positive effects on Delta Smelt as a result of increased food availability, as well as habitat for occupation depending on habitat features. Potential negative effects from contaminants (e.g., methylmercury) would be addressed with minimization measures. As previously discussed, food and habitat effects of tidal habitat restoration have the potential to offset negative effects from seasonal operations (i.e., less spring outflow affecting *E. affinis* abundance; less low salinity zone habitat as a result of less fall Delta outflow), although the offsetting from the same restoration acreage potentially would be less than under the No Action Alternative because the operational effects under Alternative 1 would be greater (see *Potential changes to Delta Smelt due to seasonal operations*).

Potential changes to Delta Smelt from the predator hot spot removal program

The predator hot spot removal program proposed under Alternative 1 has the potential to have limited positive effects on Delta Smelt relative to the No Action Alternative. As explained by Reclamation (2019) in the ROC LTO BA, the potential effects probably would be limited because the hot spot removal program likely would be focused on areas of importance to downstream-migrating juvenile salmonids, which tend to be at the periphery of the Delta Smelt range, and are spatially limited in extent.

Potential changes to Delta Smelt from Delta Cross Channel gate improvements

Programmatic improvements to the DCC under Alternative 1 to allow, for example, diurnal operations for protection of juvenile salmonids, may have limited effects on Delta Smelt (see previous discussion in *Potential changes to Delta Smelt due to changes in Delta Cross Channel operations*; see also ROC LTO BA).

Potential changes to Delta Smelt due to changes from Tracy and Skinner fish facility improvements

The various Tracy and Skinner facility improvements summarized in Section 4.3.6.10, *Intervention Components,* of Appendix D have the potential to provide small positive effects to Delta by improving salvage efficiency relative to the No Action Alternative. However, these improvements would be limited because OMR management would limit the potential for Delta Smelt to be entrained at the south Delta facilities.

Potential changes to Delta Smelt from the small screen program

As described in the ROC LTO BA, the small screen program proposed under Alternative 1 has the potential to have limited positive effects relative to the No Action Alternative on Delta Smelt through reductions in entrainment. The potential is limited to Delta Smelt sufficiently large (>20 mm or so) to be screened, and is limited in effect because entrainment by small diversions is posited to be of minimal importance to Delta Smelt.

Potential changes to Delta Smelt from the Delta fish species conservation hatchery

As described in the ROC LTO BA, the Delta Fish Species Conservation Hatchery has the potential to provide appreciable positive effects to Delta Smelt through breeding and releasing fish to supplement the wild population. The potential positive effect depends on the implementation of various risk reduction strategies to address ecological, demographic, genetic, and uncertainty risks. The conservation hatchery could have negative effects such as discharge of effluent and construction, but these would be limited by application of appropriate measures such as offsite habitat mitigation and treatment of discharged water.

O.3.4.3.2 Longfin Smelt

Potential changes to Longfin Smelt from food subsidies (Sacramento Deepwater Ship Channel food study; North Delta food subsidies/Colusa Basin drain study; Suisun Marsh Roaring River Distribution System food subsidies study)

The timing of food subsidy actions under Alternative 1 is focused on providing Delta Smelt benefits in summer/fall and therefore would be expected to result in limited effects to Longfin Smelt, given their distribution mostly downstream of the potential area of effect.

Potential changes to Longfin Smelt from tidal habitat restoration

As described for the No Action Alternative, there may be some potential positive (greater food availability and habitat for occupancy) and negative (contaminants) effects from completion of 8,000 acres of restoration under Alternative 1, but these effects would be relatively limited because most Longfin Smelt occur downstream of likely restoration areas in the north Delta.

Potential changes to Longfin Smelt from predator hot spot removal program

As described for Delta Smelt, the predator hot spot removal program proposed under Alternative 1 has the potential to have limited positive effects on Longfin Smelt relative to the No Action Alternative, but the potential effects probably would be limited because the hot spot removal program likely would be focused on areas of importance to downstream-migrating juvenile salmonids, which tend to be at the periphery of the Longfin Smelt range (even more so than for Delta Smelt), and are spatially limited in extent.

Potential changes to Longfin Smelt from Delta Cross Channel gate improvements

Programmatic improvements to the DCC under Alternative 1 to allow diurnal operations for protection of juvenile salmonids, for example, may have limited effects on Longfin Smelt (see previous discussion in *Potential changes to Longfin Smelt due to changes in Delta Cross Channel operations*).

Potential changes to Longfin Smelt due to changes from Tracy and Skinner fish facility improvements

Alternative 1 would include a carbon dioxide injection device for predator removal at the Tracy Fish Facility and therefore could have a positive effect on Longfin Smelt salvage efficiency relative to the No Action Alternative in this respect. Given the potential increase in entrainment from seasonal operations, the negative effects from salvage at the Tracy and Skinner fish facilities could outweigh any increases in salvage efficiency at Tracy. However, as previously discussed in *Potential changes to Longfin Smelt due to OMR management*, the population-level effects may be limited given the low entrainment loss observed historically.

Potential changes to Longfin Smelt from the small screen program

As previously described for Delta Smelt, the small screen program proposed under Alternative 1 has the potential to have limited positive effects relative to the No Action Alternative on Longfin Smelt through reductions in entrainment. The potential is limited to Longfin Smelt sufficiently large (>20 mm or so) to be screened, and is limited in effect because entrainment by small diversions may be of minimal importance to Longfin Smelt, by analogy to Delta Smelt, which is more likely to occur in areas with small diversions than Longfin Smelt and for which entrainment by small diversions is posited to be of minimal importance.

Potential changes to Longfin Smelt from the Delta fish species conservation hatchery

Similar to the previously discussed potential effects from reintroduction of Delta Smelt by the Fish Conservation and Culture Laboratory, reintroduction of Delta Smelt from the Delta Fish Species Conservation Hatchery under Alternative 1 could negatively affect Longfin Smelt if, for example, increased hybridization occurred; risk management strategies would be needed to limit such potential negative effects. As previously described for Delta Smelt, the conservation hatchery could have negative effects such as discharge of effluent and construction, but these would be limited by application of appropriate measures such as offsite habitat mitigation and treatment of discharged water.

O.3.4.3.3 Sacramento River Winter-Run Chinook Salmon

Potential changes to aquatic resources from the Sacramento Deepwater Ship Channel food study

This action would hydrologically connect the Sacramento River with the Sacramento Deepwater Ship Channel (SDWSC) via the Stone Lock facility from mid-spring to late fall. Juvenile Winter-Run Chinook Salmon may be exposed to the Sacramento Deepwater Ship Channel (SDWSC) component of Alternative 1. This action would hydrologically connect the Sacramento River with the SDWSC via the Stone Lock facility from mid-spring to late fall (Wood Rodgers 2018) to provide food web benefits to Delta Smelt. Juvenile Winter-Run Chinook Salmon abundance downstream of Stone Lock at Sherwood Harbor is highest in February and March, declines in April, and is moderate in November (Reclamation 2019). Juvenile Winter-Run Chinook Salmon passing the Stone Lock facility when there is a hydrologic connection between the waterways could potentially be routed into the SDWSC. Estimates of salmonid survival in the SDWSC are not available to compare with rates in the Sacramento River route. However, if survival rates are similar, fish entering the SDWSC would not be exposed to entrainment into the interior Delta through the DCC or Georgiana Slough which would provide a benefit associated with Alternative 1. A hydrologically connected SDWSC could potentially attract adult Winter-Run Chinook

Salmon. If the connection is maintained there would likely not be impacts to adults. However, if the connection is not maintained there could be migratory delays and stranding.

Potential changes to aquatic resources from the North Delta food subsidies/Colusa Basin Drain study

Provision of north Delta food subsidies by routing Colusa Basin drain water to the Cache Slough area through the Yolo Bypass would occur in summer/fall and therefore would have limited effects on Winter-Run Chinook Salmon, who are in the Delta between December and May for juveniles, and December to July for adults.

Potential changes to aquatic resources from the Suisun Marsh Roaring River Distribution System food subsidies study

Under Alternative 1, provision of Suisun Marsh food subsidies through coordination of managed wetland flood and drain operations in Suisun Marsh and draining of RRDS to Grizzly Bay/Suisun Bay in conjunction with reoperation of the SMSCG would occur in summer/fall and therefore would have limited effects on Winter-Run Chinook Salmon, who are in the Delta between December and May for juveniles, and December to July for adults.

Potential changes to aquatic resources due to tidal habitat restoration

Although migration through the Delta represents a short period, a large proportion of juvenile Winter-Run Chinook Salmon are expected to be exposed to 8,000 acres of tidal habitat restoration in the Delta. Tidal habitat restoration is expected to benefit juvenile Winter-Run Chinook Salmon in several aspects represented by the Winter-Run Chinook Salmon conceptual model, (Reclamation 2019) including increased food availability and quality and refuge habitat from predators. These benefits can manifest in higher growth rates and increased survival through the Delta. Reclamation and DWR will consult on future tidal habitat restoration with USFWS and NMFS on potential effects to fish from construction-related effects.

Potential changes to aquatic resources from the predator hot spot removal program

Predator hot spot removal is primarily focused on providing positive effects to downstream-migrating juvenile salmonids including Winter-Run Chinook Salmon. Although Alternative 1 would not be limited to existing identified hot spots (e.g., those identified by Grossman et al. 2013), the existing hotspots that may be representative of where removal efforts may be most concentrated are in the primary migratory routes of juvenile Winter-Run Chinook Salmon. All hotspots are limited in scale relative to overall available habitat and previous research has not found a consistent positive effect of predator removal on juvenile Salmon survival (Cavallo et al. 2012; Michel et al. 2017; Sabal et al. 2016). Winter-Run Chinook Salmon juveniles in the Bay-Delta are unlikely to be exposed to the effects of construction at predator hot spot removal locations in the Sacramento River, as the in-water work window is in the summer / fall when Winter-Run Chinook Salmon juveniles are generally in the upper river.

Potential changes to aquatic resources from Delta Cross Channel gate improvements

The DCC is an older structure which requires manual operation and increased use could result in locks braking in either open or closed positions. Migrating Winter-Run Chinook Salmon would benefit from faster operations that prevent straying into the central Delta and catastrophic failure of the facility. Few Winter-Run Chinook Salmon are expected to be exposed to improvements to the Delta Cross Channel. Seasonal closure periods would still be in place to protect migrating salmonids. Potential diurnal operation during closure periods could increase exposure of Winter-Run Chinook Salmon juveniles to entrainment into the interior Delta. Improved biological and physical monitoring associated with improvements would likely minimize potentially increased routing into the interior Delta and subsequent entrainment. Greater operational flexibility and increased gate reliability resulting from improvements would reduce the risk of gate failure that could result in higher rates of entrainment.

Potential changes to aquatic resources due to changes from Tracy and Skinner fish facility improvements

A small proportion of juvenile Winter-Run Chinook Salmon are expected to be exposed to the Tracy Fish Facility (Zeug and Cavallo 2014). However, for fish that arrive at the facility, the proposed improvements are likely to increase survival through the facility. Winter-Run Chinook Salmon adults would not be expected to be exposed to the effects of construction of the carbon dioxide injection device proposed for the Tracy Fish Facility, based on the timing of in-water construction (August to October) and the typical seasonal occurrence of this life stage in the Delta (Reclamation 2019).

Few if any juvenile Winter-Run Chinook Salmon would be expected to be exposed to construction of the carbon dioxide injection device proposed for the Tracy Fish Facility Improvements based on lack of observed salvage during the August to October in-water work window (see Figures F.2.7, F.2.8, and F.2.9 in Appendix Fof the ROC LTO BA). However, a few early migrants could occur during the in-water work window based on occurrence in the north Delta (see Figures WR_Seines and WR_Sherwood in Appendix Fof the ROC LTO BA).

To the extent that the construction affects the ability of juvenile Winter-Run Chinook Salmon to be efficiently salvaged (as part of the entrainment risk habitat attribute in the SAIL conceptual model; Reclamation 2019), there could be a minor effect to a small number of individuals, although risk would be minimized through appropriate mitigation measures, including MM-AQUA-1, MM-AQUA-2, MM-AQUA-7, MM-AQUA-8, MM-AQUA-10 and MM-AQUA-12 (Appendix E, *Mitigation Measures*). There is low potential exposure because of the in-water work window, the application of mitigation measuress, and the small scale of the in-water construction.

Skinner Fish Facility improvements from predator control efforts to reduce predation on listed fishes following entrainment into CCF could reduce pre-screen loss of juvenile Chinook Salmon entrained into CCF. It is important to note that only small proportions of Winter-Run Chinook Salmon are lost at the SWP (Zeug and Cavallo 2014).

Potential changes to aquatic resources from the small screen program

There may be some overlap Winter-Run Chinook Salmon with the main late spring-fall irrigation period for small diversions. Diversion screening could reduce entrainment of late migrating individuals. It is important to note that only a small proportion of the population would be exposed.

Few if any juvenile Winter-Run Chinook Salmon rearing and outmigrating in the Bay-Delta are expected to be exposed to the effects of construction of screens on water diversion intakes. Juvenile Winter-Run Chinook Salmon primarily migrate from November through early May (NMFS 2014c), largely outside of the timing of in-water construction (July 15 to October 15). In addition, the work area for these projects is small, limiting exposure to construction.

Potential changes to aquatic resources from the Delta fish species conservation hatchery

The operation of the Delta Fish Species Conservation Hatchery would not provide benefits to any life stage of Winter-Run Chinook Salmon. Potential negative effects of the Delta Fish Species Conservation Hatchery include inadvertent propagation and spread of invasive or nuisance species, which could affect juvenile Winter-Run Chinook Salmon through changes in food web structure, for example, in the case of invasive quagga and zebra mussels (Fera et al. 2017). Additional impacts could include reduced water quality resulting from hatchery discharge. Potential negative effects from discharged water are expected to be minimal due to the water treatment and the very small size of the discharge compared to flows in the Sacramento River near the hatchery location. Mitigation and minimization measures detailed in the EIR/EIS for the facility (Horizon Water and Environment 2017) indicate that potential impacts are less than significant. Potential exposure of juvenile Winter-Run Chinook Salmon would be restricted to a small spatial area within the primary migration route.

As with the other proposed construction activities in the Bay-Delta, few if any juvenile Winter-Run Chinook Salmon would be expected to be exposed to the effects of construction of the Delta Fishes Conservation Hatchery based on the timing of in-water construction (August to October) and the typical seasonal occurrence of this life stage in the Delta (Reclamation 2019). There may be some exposure of early migrants to in-water and shoreline construction of the hatchery intake and outfall, as illustrated by timing of occurrence in Sacramento seines and trawls (see Figures F.2.4 and F.2.5 in Appendix Fof the ROC LTO BA). The relatively few individuals occurring near the construction site could be subject to effects similar to those previously described for habitat restoration (e.g., temporary loss of habitat leading to predation, degraded water quality, reduced foraging ability caused by reduced visibility, noise-related delay in migration, and direct effects from contact with construction equipment or isolation/stranding within enclosed areas). The risk from these potential effects would be minimized through application of mitigation measures for aquatic resources (Appendix E, *Mitigation Measures*). There is low potential exposure because of the in-water work window, the application of mitigation measures, and the small scale of the in-water construction.

Winter-Run Chinook Salmon adults would not be expected to be exposed to the effects of construction of construction of the Delta Fish Species Conservation Hatchery based on the timing of in-water construction (August to October) and the typical seasonal occurrence of this life stage in the Delta (Reclamation 2019).

O.3.4.3.4 Central Valley Spring-Run Chinook Salmon

Potential changes to aquatic resources from the Sacramento Deepwater Ship Channel food study

This action would hydrologically connect the Sacramento River with the Sacramento Deepwater Ship Channel (SDWSC) via the Stone Lock facility from mid-spring to late fall. Juvenile Spring-Run Chinook Salmon abundance in the Delta is moderate in March and peaks in April (Reclamation 2019). Juvenile Spring-Run Chinook Salmon passing the Stone Lock facility when there is a hydrologic connection between the waterways could potentially be enter into the SDWSC. There are potential benefits to Spring-Run Chinook Salmon from this action. Fish entering the SDWSC would not be exposed to entrainment into the interior Delta through the DCC or Georgiana Slough which would provide a benefit if survival rates are similar. However, estimates of salmonid survival in the SDWSC are not available to compare with rates in the Sacramento River route. Also, there is potential for decreased migration time to the ocean and exposure to larger food sources of Liberty Island, but this is currently uncertain.

Potential changes to aquatic resources from the North Delta food subsidies/Colusa Basin Drain study

Provision of north Delta food subsidies by routing Colusa Basin drain water to the Cache Slough area through the Yolo Bypass would occur in summer/fall and therefore would have limited effects on Spring-Run Chinook Salmon, who are in the Delta between January and February for adults, and November through June for juveniles, with a peak of juvenile migration from March to April.

Potential changes to aquatic resources from the Suisun Marsh Roaring River Distribution System food subsidies study

Under Alternative 1, provision of Suisun Marsh food subsidies through coordination of managed wetland flood and drain operations in Suisun Marsh and draining of RRDS to Grizzly Bay/Suisun Bay in conjunction with reoperation of the SMSCG would occur in summer/fall and therefore would have limited effects on Spring-Run Chinook Salmon, that are in the Delta from January through February for adults, and November through June for juveniles, with a peak of juvenile migration from March to April.

Potential changes to aquatic resources due to tidal habitat restoration

A large proportion of juvenile Spring-Run Chinook Salmon are expected to benefit from continuing to construct the 8,000 acres of tidal habitat restoration in the Delta under Alternative 1. Benefits include increased food availability and quality and refuge habitat from predators. These benefits can manifest in higher growth rates and increased survival through the Delta.

Few if any juvenile Spring-Run Chinook Salmon would be expected to be exposed to the effects of construction of 8,000 acres of tidal habitat restoration, based on the timing of in-water construction (August to October) and the typical seasonal occurrence of this life stage in the Delta (Reclamation 2019). There may be some exposure of yearling migrants that enter the Delta in the fall. Individuals being exposed to construction could experience risk of potential effects similar to those suggested in recent restoration projects such as the Lower Yolo Restoration Project (NMFS 2014c). This includes the following: temporary loss of aquatic and riparian habitat leading to increased predation, increased water temperature, and reduced food availability; degraded water quality from contaminant discharge by heavy equipment and soils, and increased discharges of suspended solids and turbidity, leading to direct toxicological impacts on fish health/performance, indirect impairment of aquatic ecosystem productivity, loss of aquatic vegetation providing physical shelter, and reduced foraging ability caused by decreased visibility; impediments and delay in migration caused by elevated noise levels from machinery; and direct injury or mortality from in-water equipment strikes or isolation/stranding within dewatered cofferdams. Many of these are elements highlighted in the SAIL conceptual model (Reclamation 2019). The risk from these potential effects would be minimized through application of mitigation measures including MM-AQUA-1, MM-AQUA-2, MM-AQUA-4 through MM-AQUA-12, and MM-AQUA-14 (Appendix E, *Mitigation Measures*).

Potential changes to aquatic resources from the predator hot spot removal program

Predator hot spot removal under Alternative 1 is primarily focused on providing positive effects to downstream-migrating juvenile salmonids including Spring-Run Chinook Salmon. Although the action would not be limited to existing identified hot spots (e.g., those identified by Grossman et al. 2013), the existing hotspots that may be representative of where removal efforts may be most concentrated are in the primary migratory routes of juvenile Spring-Run Chinook. All hotspots are limited in scale relative to overall available habitat and previous research has not found a consistent positive effect of predator removal on juvenile Salmon survival (Cavallo et al. 2012; Michel et al. 2017; Sabal et al. 2016).

Potential changes to aquatic resources from Delta Cross Channel gate improvements

Greater operational flexibility and increased gate reliability resulting from improvements to the Delta Cross Channel under Alternative 1 would reduce the risk of gate failure that could result in higher rates of entrainment of Spring-Run Chinook Salmon, if left open. Few Spring-Run Chinook Salmon are expected to be exposed to in-water construction related improvements to the Delta Cross Channel due to observance of species protective work windows. Seasonal closure periods would still be in place to protect Spring-Run Chinook Salmon. The DCC is an older structure which requires manual operation and increased use could result in locks braking in either open or closed positions. Migrating Spring-Run Chinook Salmon would benefit from faster operations that prevent straying into the central Delta and catastrophic failure of the facility. However, improved biological and physical monitoring associated with improvements would likely minimize potentially increased entrainment.

Potential changes to aquatic resources due to changes from Tracy and Skinner fish facility improvements

A number of programmatic actions are proposed to improve salvage efficiency of TFCF, including installing a carbon dioxide injection device to allow remote controlled anesthetization of predators in the secondary channels of the Tracy Fish Facility. These actions could potentially benefit juvenile Spring-Run Chinook Salmon through greater salvage efficiency.

Few if any juvenile Spring-Run Chinook Salmon would be expected to be exposed to construction of the CO_2 injection device proposed for the Tracy Fish Facility Improvements, based on lack of observed salvage during the August to October in-water work window (see figures in Appendix F of the ROC LTO BA*:* WR_salvage_unclipped_date, WR_salvage_clipped_date, and WR_salvage_clipped_CWT_race). Risks to these few individuals would be minimized through appropriate mitigation measures, including MM-AQUA-1, MM-AQUA-2, MM-AQUA-7, MM-AQUA-8, MM-AQUA-10 AND MM-AQUA-12(Appendix E, *Mitigation Measures*), the selected in-water work window, and the small scale of the in-water construction. For juvenile Spring-Run Chinook Salmon that arrive at the facility, the proposed improvements are likely to increase survival through the facility.

Predator control efforts at Skinner Fish Facility under Alternative 1 to reduce predation on listed fishes following entrainment into Clifton Court Forebay could reduce pre-screen loss of juvenile Spring-Run Chinook Salmon entrained into Clifton Court Forebay. Spring-Run Chinook Salmon are unlikely to be in the area during predator control efforts.

Potential changes to aquatic resources from the small screen program

Few if any juvenile Spring-Run Chinook Salmon rearing and outmigrating in the Bay-Delta are expected to be exposed to the effects of construction of screens on water diversion intakes. Juvenile Sacramento River Spring-Run Chinook Salmon primarily from November through early May (NMFS 2014c), largely outside of the timing of in-water construction (July 15 to October 15). In addition, the work area for these projects is small, limiting exposure to construction.

Potential changes to aquatic resources from the Delta fish species conservation hatchery

The operation of the Delta Fish Species Conservation Hatchery would not provide benefits to any life stage of Winter-Run Chinook Salmon. Potential negative effects of the Delta Fish Species Conservation Hatchery include inadvertent propagation and spread of invasive or nuisance species, which could affect juvenile Winter-Run Chinook Salmon through changes in food web structure, for example, in the case of invasive quagga and zebra mussels (Fera et al. 2017). Additional impacts could include reduced water quality resulting from hatchery discharge. Potential negative effects from discharged water are expected to be minimal due to the water treatment and the very small size of the discharge compared to flows in the Sacramento River near the hatchery location. Mitigation and minimization measures detailed in the EIR/EIS for the facility (Horizon Water and Environment 2017) indicate that potential impacts are less than significant. Potential exposure of juvenile Winter-Run Chinook Salmon would be restricted to a small spatial area within the primary migration route.

As with the other proposed construction activities in the Bay-Delta, few if any juvenile Winter-Run Chinook Salmon would be expected to be exposed to the effects of construction of the Delta Fishes Conservation Hatchery based on the timing of in-water construction (August to October) and the typical seasonal occurrence of this life stage in the Delta (Reclamation 2019). There may be some exposure of early migrants to in-water and shoreline construction of the hatchery intake and outfall, as illustrated by timing of occurrence in Sacramento seines and trawls (Reclamation 2019). The relatively few individuals occurring near the construction site could be subject to effects similar to those previously described for habitat restoration (e.g., temporary loss of habitat leading to predation, degraded water quality, reduced foraging ability caused by reduced visibility, noise-related delay in migration, and direct effects from contact with construction equipment or isolation/stranding within enclosed areas). The risk from these potential effects would be minimized through application of mitigation measures MM-AQUA-1, MM-AQUA-2, and MM-AQUA-4 through MM-AQUA-14. (Appendix E, *Mitigation Measures*). There is low potential exposure because of the in-water work window, the application of mitigation measures, and the small scale of the in-water construction.

Winter-Run Chinook Salmon adults would not be expected to be exposed to the effects of construction of construction of the Delta Fish Species Conservation Hatchery based on the timing of in-water construction (August to October) and the typical seasonal occurrence of this life stage in the Delta (Reclamation 2019).

O.3.4.3.5 Central Valley Fall-Run Chinook Salmon

Potential changes to aquatic resources from the Sacramento Deepwater Ship Channel food study

Moderate to high proportions of juvenile Fall-Run Chinook Salmon are expected to be exposed to the Sacramento Deepwater Ship Channel (SDWSC) action. This action would hydrologically connect the Sacramento River with the SDWSC via the Stone Lock facility from mid-spring to late fall (Wood Rodgers 2018). Juvenile Fall-Run Chinook Salmon abundance in the Delta is moderate in peaks in April and May (Table FR_1). Juvenile Fall-Run Chinook Salmon passing the Stone Lock facility when there is a hydrologic connection between the waterways could potentially be entrained into the SDWSC. Estimates of salmonid survival in the SDWSC are not available to compare with rates in the Sacramento River route. However, fish entering the SDWSC would not be exposed to entrainment into the interior Delta through the DCC or Georgiana Slough, which would provide a benefit if survival rates are similar. The effect of this action on juvenile Fall-Run Chinook Salmon is moderate.

No San Joaquin River-origin Fall-Run Chinook Salmon are expected to be exposed to the Sacramento Deepwater Ship Channel.

Potential changes to aquatic resources from the North Delta food subsidies/Colusa Basin Drain study

This action is proposed to occur in July or September which is largely outside of the migration period for juvenile Fall-Run and Late Fall-Run Chinook Salmon in the Delta (Reclamation 2019). For fish that are exposed, increased food production could potentially enhance growth. The effect of this action is expected to be low.

Potential changes to aquatic resources from the Suisun Marsh Roaring River Distribution System food subsidies study

This action is proposed to occur in July or September which is largely outside of the migration period for juvenile Fall-Run and Late Fall-Run Chinook Salmon in the Delta (Reclamation 2019). For fish that are exposed, increased food production could potentially enhance growth. The effect of this action is expected to be low.

Potential changes to aquatic resources due to tidal habitat restoration

A large proportion of juvenile Fall-Run and Late Fall-Run Chinook Salmon are expected to be exposed to 8,000 acres of tidal habitat restoration in the Delta. Tidal habitat restoration is expected to benefit juvenile Chinook Salmon in several aspects represented by the Winter-Run Chinook Salmon conceptual model (Reclamation 2019) including, increased food availability and quality and refuge habitat from predators. These benefits can manifest in higher growth rates and increased survival through the Delta. Migration through the Delta represents a short period in the migration of juvenile Fall-Run and Late Fall-Run Chinook Salmon. Thus the total effect of this action is moderate.

Few juvenile Fall-Run or Late Fall-Run Chinook Salmon would be expected to be exposed to the effects of construction of 8,000 acres of tidal habitat restoration, based on the timing of in-water construction (August to October) and the typical seasonal occurrence of this life stage in the Delta (Reclamation 2019). Individuals being exposed to construction could experience risk of potential effects similar to those suggested in recent restoration projects such as the Lower Yolo Restoration Project (NMFS 2014c). This includes temporary loss of aquatic and riparian habitat leading to increased predation, increased water temperature, and reduced food availability; degraded water quality from contaminant discharge by heavy equipment and soils, and increased discharges of suspended solids and turbidity, leading to direct toxicological impacts on fish health/performance (e.g., gill damage and reduced ability to take in oxygen, increasing metabolic cost), indirect impairment of aquatic ecosystem productivity (e.g., reduction in benthic macroinvertebrate production and availability), loss of aquatic vegetation providing physical shelter, and reduced foraging ability caused by decreased visibility; impediments and delay in migration caused by elevated noise levels from machinery; and direct injury or mortality from in-water equipment strikes or isolation/stranding within dewatered cofferdams. Many of these are elements highlighted in the SAIL conceptual model (Reclamation 2019). The risk from these potential effects would be minimized through application of mitigation measures including MM-AQUA-1, MM-AQUA-2, MM-AQUA-4 through MM-AQUA-12, and MM-AQUA-14 (Appendix E, *Mitigation Measures*).

Potential changes to aquatic resources from the predator hot spot removal program

Predator hot spot removal is primarily focused on providing positive effects to downstream-migrating juvenile salmonids including Fall-Run and Late Fall-Run Chinook Salmon. Although the action would not be limited to existing identified hot spots (e.g., those identified by Grossman et al. 2013), the existing hotspots that may be representative of where removal efforts may be most concentrated are in the primary migratory routes of juvenile Spring-Run Chinook. All hotspots are limited in scale relative to overall available habitat and previous research has not found a consistent positive effect of predator removal on juvenile Salmon survival (Cavallo et al. 2012; Michel et al. 2017; Sabal et al. 2016).

Potential changes to aquatic resources from Delta Cross Channel gate improvements

Greater operational flexibility and increased gate reliability resulting from improvements to the Delta Cross Channel under Alternative 1 would reduce the risk of gate failure that could result in higher rates of entrainment of Fall-Run and Late Fall-Run Chinook Salmon, if left open. Few Fall-Run or Late Fall-Run Chinook Salmon are expected to be exposed to in-water construction related improvements to the Delta Cross Channel due to observance of species protective work windows. Seasonal closure periods would still be in place to protect Chinook Salmon. The DCC is an older structure which requires manual operation and increased use could result in locks braking in either open or closed positions. Migrating

Fall- and Late Fall-Run Chinook Salmon would benefit from faster operations that prevent straying into the central Delta and catastrophic failure of the facility. However, improved biological and physical monitoring associated with improvements would likely minimize potentially increased entrainment.

Potential changes to aquatic resources due to changes from Tracy and Skinner fish facility improvements

A small proportion of juvenile Fall-Run Chinook Salmon are expected to be exposed to the Tracy Fish Facility (Zeug and Cavallo 2014). However, for fish that arrive at the facility, the proposed improvements are likely to increase survival through the facility.

Few juvenile Fall-Run or Late Fall-Run Chinook Salmon would be expected to be exposed to construction of the CO_2 injection device proposed for the Tracy Fish Facility Improvements, based on lack of observed salvage during the August to October in-water work window (see Figures WR_salvage_unclipped_date, WR_salvage_clipped_date, and WR_salvage_clipped_CWT_race in - in Appendix F of the ROC LTO BA). To the extent that the construction affects the ability of juvenile Fall-Run, and Late Fall-Run Chinook Salmon to be efficiently salvaged (as part of the entrainment risk habitat attribute in the SAIL conceptual model; Reclamation 2019), there could be a minor effect to a small number of individuals, although risk would be minimized through appropriate mitigation measures including MM-AQUA-1, MM-AQUA-2, MM-AQUA-7, MM-AQUA-8, MM-AQUA-10 and MM-AQUA-12 (Appendix E, *Mitigation Measures*). Given the low potential exposure because of the in-water work window, the application of mitigation measures, and the small scale of the in-water construction, it is concluded that the negative population-level effects of Tracy Fish Facility Improvements construction would be low on this life stage.

Skinner Fish Facility improvements from predator control efforts to reduce predation on listed fishes following entrainment into Clifton Court Forebay could reduce pre-screen loss of juvenile Chinook Salmon entrined into Clifton Cout Forebay. However, given that only small proportions of Fall-Run Chinook Salmon are lost at the SWP (Zeug and Cavallo 2014), the population-level positive effect of this action would be low. Larger proportions of Late Fall-Run Chinook Salmon are lost at the facilities and this action would have a larger effect for this run.

Potential changes to aquatic resources from the small screen program

Although there may be moderate overlap Fall-Late Fall-Run Chinook Salmon with the main late spring to fall irrigation period for small diversions, and small diversion screening could reduce entrainment of late migraing individuals, the potential population-level positive effect would be low because only a small proportion of the population would be exposed.

Few if any juvenile Fall- /Late-Run Chinook Salmon rearing and outmigrating in the Bay-Delta are expected to be exposed to the effects of construction of screens on water diversion intakes. Juvenile Sacramento River Fall- /Late Fall-Run Chinook Salmon primarily migrate from November through early May (NMFS 2014c), largely outside of the timing of in-water construction (July 15 to October 15). In addition, the work area for these projects is small, limiting exposure to construction.

Potential changes to aquatic resources from the Delta fish species conservation hatchery

Potential effects of the Delta Fishes Conservation Hatchery include inadvertent propagation and release of nuisance species and reduced water quality resulting from hatchery discharge. Mitigation and minimization measures detailed in the EIR/EIS for the facility (Horizon Water and Environment 2017) indicate that potential impacts are less than significant. Potential exposure of juvenile Fall-Run Chinook

Salmon would be restricted to a small spatial area within the primary migration route. The overall impact of the operation of this facility is low.

As with the other proposed construction activities in the Bay-Delta, few juvenile Fall-Run or Late Fall-Run Chinook Salmon would be expected to be exposed to the effects of construction of the Delta Fishes Conservation Hatchery based on the timing of in-water construction (August to October) and the typical seasonal occurrence of this life stage in the Delta (Reclamation 2019). The relatively few individuals occurring near the construction site could be subject to effects similar to those previously described for habitat restoration (e.g., temporary loss of habitat leading to predation, degraded water quality, reduced foraging ability caused by reduced visibility, noise-related delay in migration, and direct effects from contact with construction equipment or isolation/stranding within enclosed areas). The risk from these potential effects would be minimized through application of mitigation measures MM-AQUA-1, MM-AQUA-2, and MM-AQUA-4 through MM-AQUA-14 (Appendix E, *Mitigation Measures*). There is low potential exposure because of the in-water work window, the application of mitigation measures will reduce effects, and the in-water construction is of a small scale.

O.3.4.3.6 Central Valley Steelhead

Potential changes to aquatic resources from the Sacramento Deepwater Ship Channel food study

Moderate to high proportions of Central Valley Steelhead are expected to be exposed to the Sacramento Deepwater Ship Channel (SDWSC) conservation measure under Alternative 1. This conservation measure would hydrologically connect the Sacramento River with the SDWSC via the Stone Lock facility from mid-spring to late fall (Wood Rodgers 2018), allowing food to enter the Delta and an alternate migration pathway. Juvenile Central Valley Steelhead abundance in the Delta peaks in February through May (Reclamation 2019). Juvenile Central Valley Steelhead passing the Stone Lock facility when there is a hydrologic connection between the waterways could potentially be entrained into the SDWSC. Estimates of salmonid survival in the SDWSC are not available to compare with rates in the Sacramento River route. However, fish entering the SDWSC would not be exposed to entrainment into the interior Delta through the DCC or Georgiana Slough which would provide a benefit if survival rates are similar.

No Central Valley Steelhead are expected to be exposed to the Sacramento Deepwater Ship Channel construction, as the in-water work window does not overlap with their occurrence in the Delta.

Potential changes to aquatic resources from the North Delta food subsidies/Colusa Basin Drain study

Provision of north Delta food subsidies by routing Colusa Basin drain water to the Cache Slough area through the Yolo Bypass would occur in summer/fall, and does not overlap in time or space with juvenile Central Valley Steelhead occurrence in the Delta. There would not be any effect to Central Valley Steelhead adults.

Potential changes to aquatic resources from the Suisun Marsh Roaring River Distribution System food subsidies study

Under Alternative 1, provision of Suisun Marsh food subsidies through coordination of managed wetland flood and drain operations in Suisun Marsh and draining of RRDS to Grizzly Bay/Suisun Bay in conjunction with reoperation of the SMSCG would occur in summer/fall and therefore would have limited effects on Central Valley Steelhead juveniles, who are in the Delta between December and July. The action is not expected to have any effect on Central Valley Steelhead adults.

Potential changes to aquatic resources due to tidal habitat restoration

A large proportion of juvenile Central Valley Steelhead are expected to benefit from 8,000 acres of tidal habitat restoration in the Delta under Alternative 1. Tidal habitat restoration is expected to benefit juvenile Central Valley Steelhead in several aspects represented by the Winter-Run Chinook Salmon conceptual model (Reclamation 2019) including, increased food availability and quality and refuge habitat from predators. These benefits can manifest in higher growth rates and increased survival through the Delta; however, the Delta only represents a small fraction of the total migration route.

Few if any juvenile Central Valley Steelhead would be expected to be exposed to the effects of construction of 8,000 acres of tidal habitat restoration, based on the timing of in-water construction (August to October) and the typical seasonal occurrence of this life stage in the Delta (Reclamation 2019). There may be exposure of a few late migrants, as illustrated by timing of occurrence in Chipps mid-water trawls (Reclamation 2019). Individuals being exposed to construction could experience risk of potential effects similar to those suggested in recent restoration projects such as the Lower Yolo Restoration Project (NMFS 2014c). This includes temporary loss of aquatic and riparian habitat leading to increased predation, increased water temperature, and reduced food availability; degraded water quality from contaminant discharge by heavy equipment and soils, and increased discharges of suspended solids and turbidity, leading to direct toxicological impacts on fish health/performance (e.g., gill damage and reduced ability to take in oxygen, increasing metabolic cost), indirect impairment of aquatic ecosystem productivity (e.g., reduction in benthic macroinvertebrate production and availability), loss of aquatic vegetation providing physical shelter, and reduced foraging ability caused by decreased visibility; impediments and delay in migration caused by elevated noise levels from machinery; and direct injury or mortality from in-water equipment strikes or isolation/stranding within dewatered cofferdams. The risk from these potential effects would be minimized through application of mitigation measures MM-AQUA-1, MM-AQUA-2, MM-AQUA-4 through MM-AQUA-12, and MM-AQUA-14.

Potential changes to aquatic resources from the predator hot spot removal program

Predator hot spot removal under Alternative 1 is primarily focused on providing positive effects to downstream-migrating juvenile salmonids, including Central Valley Steelhead. Although the action would not be limited to existing identified hot spots (e.g., those identified by Grossman et al. 2013), the existing hotspots that may be representative of where removal efforts may be most concentrated are in the primary migratory routes of Central Valley Steelhead. All hotspots are limited in scale relative to overall available habitat, and previous research has not found a consistent positive effect of predator removal on juvenile Salmon survival (Cavallo et al. 2012; Michel et al. 2017; Sabal et al. 2016). However, implementation of this action would likely improve conditions for all life stages of Central Valley Steelhead.

Potential changes to aquatic resources from Delta Cross Channel gate improvements

Completion of DCC gate improvements would benefit Central Valley Steelhead of all life stages within the CVP watershed systems. The peak migration of juvenile Central Valley Steelhead in the Sacramento River past Hood, which is near the DCC, occurs from February through mid-June (Reclamation 2019). No San Joaquin River-origin Central Valley Steelhead are expected to be exposed to the DCC. As previously described, juvenile Central Valley Steelhead are largely absent from the Delta between August and November (Reclamation 2019) and, therefore, few late migrants or early migrants have the potential to be exposed to potential construction from improvements to the DCC under Alternative 1.

Potential changes to aquatic resources due to changes from Tracy and Skinner fish facility improvements

Small proportions of Sacramento River-origin Central Valley Steelhead and moderate proportions of Mokelumne River and San Joaquin River-origin Central Valley Steelhead are expected to be exposed to the Tracy Fish Facility. However, for fish that arrive at the facility, the proposed improvements resulting in greater salvage efficiency under Alternative 1 are likely to increase survival of juvenile Central Valley Steelhead.

As previously described, juvenile Central Valley Steelhead are largely absent from the Delta between August and November (Reclamation 2019) and, therefore, none to a few late migrants or early migrants have the potential to be exposed to the effects of construction of the carbon dioxide injection device proposed for the Tracy Fish Facility Improvements. Risks of decrease Central Valley Steelhead juvenile salvage during construction would be minimized through appropriate mitigation measures including MM-AQUA-1, MM-AQUA-2, MM-AQUA-7, MM-AQUA-8, MM-AQUA-10, and MM-AQUA-12..

Skinner Fish Facility improvements under Alternative 1 to reduce predation on listed fishes following entrainment into CCF could reduce pre-screen loss of juvenile Central Valley Steelhead entrained into CCF; therefore, providing a benefit for all life stages of Central Valley Steelhead.

Potential changes to aquatic resources from the small screen program

Fish screens under Alternative 1 would also benefit this lifestage in the same ways described above. Juvenile Central Valley Steelhead outmigrating in the Bay-Delta may be exposed to the effects of construction of screens since they migrate downstream during most months of the year, with a peak emigration period in the spring and a smaller peak in the fall (Hallock et al. 1961). Juvenile Central Valley Steelhead may be found in the work area of these projects; however, MM-AQUA-7 would minimize impacts.

Potential changes to aquatic resources from the Delta fish species conservation hatchery

Potential effects of the Delta Fishes Conservation Hatchery include inadvertent propagation and release of nuisance species and reduced water quality resulting from hatchery discharge. Mitigation and minimization measures detailed in the EIR/EIS for the facility (Horizon Water and Environment 2017) indicate that potential impacts are less than significant. Potential exposure of juvenile Central Valley Steelhead would be restricted to a small spatial area within the primary migration route.

As with the other proposed construction activities in the Delta under Alternative 1, juvenile Central Valley Steelhead are largely absent from the Delta between August and November (Reclamation 2019) which means that none to a few late or early migrants of this life stage could be exposed to Delta Fishes Conservation Hatchery construction. The in-water work constructing the hatchery intake and outfall could result in a small number of individuals experiencing effects such as temporary loss of habitat leading to predation, degraded water quality, noise-related delay in migration, and direct effects from contact with construction equipment or isolation/stranding within enclosed areas. The risk from these potential effects would be minimized through application of mitigation measures including MM-AQUA-1, MM-AQUA-2, MM-AQUA-4 through MM-AQUA-14 (Appendix E, *Mitigation Measures*).

O.3.4.3.7 North American Green Sturgeon Southern DPS

Potential changes to aquatic resources from the Sacramento Deepwater Ship Channel food study

As described above, juvenile Green Sturgeon may potentially be entrained into the SDWSC. Fish entering the SDWSC would not, however, be exposed to entrainment into the interior Delta through the DCC or

Georgiana Slough which would provide a benefit if survival rates are similar between the SDWSC and the Sacramento main stem.

Potential changes to aquatic resources from the North Delta food subsidies/Colusa Basin Drain study

Provision of north Delta or Suisun Marsh food subsidies by routing drain water would occur in summer/fall and therefore could provide food benefits to Green Sturgeon juveniles, who are in the Delta in the fall.

Potential changes to aquatic resources from the Suisun Marsh Roaring River Distribution System food subsidies study

Provision of north Delta or Suisun Marsh food subsidies by routing drain water would occur in summer/fall and therefore could provide food benefits to Green Sturgeon juveniles, who are in the Delta in the fall.

Potential changes to aquatic resources due to tidal habitat restoration

A large proportion of juvenile southern DPS Green Sturgeon are expected to be exposed to continuing to implement the 8,000 acres of tidal habitat restoration in the Delta under Alternative 1. Tidal habitat restoration is expected to benefit juvenile Green Sturgeon in several aspects represented by the Green Sturgeon juvenile conceptual model (Reclamation 2019) including, increased food availability and quality and refuge habitat from predators. These benefits can manifest in higher growth rates and increased survival through the Delta.

Potential changes to aquatic resources from the predator hot spot removal program

Predator hot spot removal under Alternative 1 is primarily focused on providing positive effects to downstream-migrating juvenile salmonids. It is currently unknown if predation on juvenile Green Sturgeon in the Delta is limiting their productivity. Although the action would not be limited to existing identified hot spots (e.g., those identified by Grossman et al. 2013), the existing hotspots that may be representative of where removal efforts may be most concentrated are in the rearing and migratory corridors of juvenile Green Sturgeon.

Potential changes to aquatic resources from Delta Cross Channel gate improvements

Little is known about the migratory behavior of juvenile Green Sturgeon in the Sacramento River basin. It is likely that juvenile Green Sturgeon (larger than the 75 mm) will not enter the Delta prior to their first winter and thus would not be exposed to the open DCC gates. It is likely that these fish will enter the Delta sometime in the winter or spring following their hatching upriver and encounter both types of gate configurations as they enter the Delta. More information is required to accurately assess the migratory movements of juvenile Green Sturgeon in the river system, as well as their movements within the Delta during their rearing phase in estuarine/Delta waters. Greater operational flexibility and increased gate reliability resulting from improvements would reduce the risk of gate failure that could result in higher rates of entrainment.

Potential changes to aquatic resources due to changes from Tracy and Skinner Fish Facility improvements

Upgrades to the TFCF will aim to minimize the effects of the salvage process on listed fishes, in particular juvenile salmonids and Green Sturgeon. Salvage improvements will improve survival of salvaged fish and potentially allow reduction of the expansion factors used to extrapolate take estimates from observed salvage.

As previously described, juvenile Green Sturgeon can occur in the Delta year-round (Reclamation 2019) and, therefore, have the potential to be exposed to the effects of construction of the CO_2 injection device proposed for the Tracy Fish Facility Improvements. If construction affects the efficiency of Green Sturgeon salvage (which is an element of entrainment risk; Reclamation 2019), there could be a minor effect to a small number of individuals, although risk would be minimized through appropriate mitigation measures including MM-AQUA-1, MM-AQUA-2, MM-AQUA-7, MM-AQUA-8, MM-AQUA-10 and MM-AQUA-12 (Appendix E, *Mitigation Measures*).

Skinner Fish Facility improvements under Alternative 1, which involve predator control efforts, can reduce predation on listed fish species, following their entrainment into Clifton Court Forebay. This could also reduce pre-screen loss of juvenile southern DPS Green Sturgeon. It is unknown what proportion of juvenile Green Sturgeon are entrained into CCF but individuals are salvaged infrequently. Thus, Alternative 1 is not likely to negatively impact juvenile Green Sturgeon.

Potential changes to aquatic resources from the small screen program

Southern DPS Green Sturgeon are expected to be present in the Delta during the main irrigation period for small diversions (late spring to fall). Diversion screening under Alternative 1 could reduce entrainment of individual Green Sturgeon. However, there is currently no information on the proportion of juvenile Green Sturgeon that are entrained into small unscreened diversions. North American Green Sturgeon in the juvenile to subadult/adult life stage may be exposed to the effects of construction of screens since they are present in the Sacramento River year-round (Reclamation 2019). Effects are the same as described above for juveniles. MM-AQUA-7 would minimize risk.

Potential changes to aquatic resources from the Delta fish species conservation hatchery

None of the Green Sturgeon life stages would benefit from the Delta Fish Species Conservation Hatchery under Alternative 1. As with the other proposed construction activities in the Delta, the year-round occurrence of juvenile Green Sturgeon in the Delta (Reclamation 2019) means that this life stage, as well as the timing of the adult Green Sturgeon occurring in the Delta during May to October, could be exposed to Delta Fish Species Conservation Hatchery construction under Alternative 1. The in-water work constructing the hatchery intake and outfall could result in a small number of individuals experiencing effects such as temporary loss of habitat leading to predation, degraded water quality, noise-related delay in migration, and direct effects from contact with construction equipment or isolation/stranding within enclosed areas. The risks from these potential effects would be minimized with through the application of mitigation measures including MM-AQUA-1, MM-AQUA-2 and MM-AQUA-4 through MM-AQUA-14 (Appendix E, *Mitigation Measures*).

O.3.4.4 *Nearshore Pacific Ocean on the California Coast*

O.3.4.4.1 <u>Southern Resident Killer Whale</u>

Potential changes to Southern Killer Whale from Chinook Salmon prey abundance

As previously described in Section O.3.3.1.9, *Nearshore Pacific Ocean on the California Coast,* relative to project-level effects, given the medium priority of Central Valley Chinook Salmon stocks and the contribution of hatchery-origin Chinook Salmon released downstream of the potential proposed action influence, the proposed action (Alternative 1) would not be expected to have population-level effects to

Southern Resident Killer Whale Chinook Salmon prey. This suggests limited effects of Alternative 1 programmatic activities on Southern Resident Killer Whale.

O.3.5 Alternative 2 – Project-Level Effects

O.3.5.1 *Trinity River*

O.3.5.1.1 Seasonal Operations

As described in the No Action Alternative and Alternative 1, the Trinity River system would be operated according to the Trinity River ROD with lower Klamath River augmentation flows.

Potential changes to aquatic resources from changes in reservoir storage

Under Alternative 2, storage volume in Trinity Lake would remain the same as under the No Action Alternative in most water year types. On average, storage is expected to increase by 7 TAF under Alternative 2 compared to the No Action Alternative. The effects of changes in reservoir storage conditions as they relate to water temperature can be assessed by looking at temperatures in the Trinity River downstream of Trinity Dam. Under Alternative 2, average monthly water temperatures in the Trinity River downstream of Trinity Dam would remain similar compared to the No Action Alternative (Figure O.3-87). Maximum modeled water temperatures in the Trinity River downstream of Trinity Dam are generally similar under Alternative 2 compared to the No Action Alternative except in August when temperatures are approximately 5°F higher, in September when temperatures are approximately 2°F higher, and in October when temperatures are approximately 4°F lower under Alternative 2 compared to the No Action Alternative.

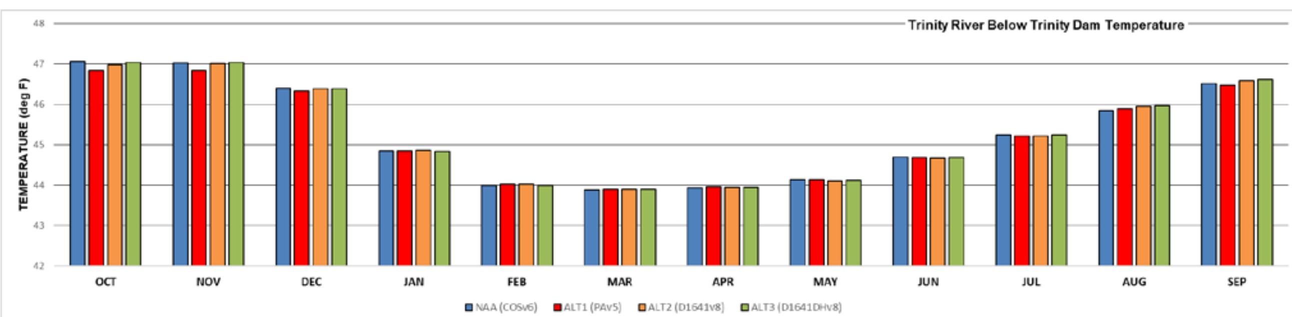


Figure O.3-87. Average Trinity River Water Temperatures below Trinity Dam for the Period October to September, Average of All Water Year Types

No focal fish species occur in Trinity Lake or in the Trinity River downstream of Trinity Dam. Effects of Trinity Reservoir storage on fish in the Trinity River downstream of Lewiston Dam are described below.

Potential changes to aquatic resources from variation in flow

Under Alternative 2 environmental conditions in the Trinity River downstream of Lewiston Dam would be similar to flows under the No Action Alternative in most months and water year types. However, in wet years flows would increase in December under Alternative 2 compared to the No Action Alternative (1,295 cfs versus 1,192 cfs). In above normal years flows under Alternative 2 would decrease in November compared to the No Action Alternative (565 cfs versus 678 cfs) and increase in February compared to the No Action Alternative (801 cfs versus 528 cfs). In critically dry years, flows under Alternative 2 would decrease compared to the No Action Alternative in September and October from 870 cfs to 818 cfs and from 342 cfs to 311 cfs, respectively, and flows would increase in November from 275 cfs to 300 cfs compared to the No Action Alternative.

Coho Salmon

Flows in the Trinity River downstream of Lewiston Dam would generally be similar under Alternative 2 compared to the No Action Alternative. Minor differences (<10%) in November and December of some water year types and a larger difference (17%) in November of above normal water years may affect spawning and juvenile rearing habitat for Coho Salmon. Based on previous flow habitat relationship studies in the Trinity River (USFWS 1999), these differences in flow are not expected to result in a detectable effect on Coho Salmon spawning or juvenile rearing habitat (USFWS 1999). Flows in above normal water years in February would increase by approximately 52% under Alternative 2 (801 cfs) compared to the No Action Alternative (528 cfs). This increase in flow could increase the likelihood of Coho Salmon egg mortality due to redd scour, potentially resulting in reduced incubation success in areas where local conditions contribute to substantial mobilization of gravel in the redds.

Spring-Run Chinook Salmon

Flows in the Trinity River downstream of Lewiston Dam would generally be similar under Alternative 2 compared to the No Action Alternative. Minor differences (<10%) in November and December of some water year types and a larger difference (17%) in November of above normal water years may affect spawning and juvenile rearing habitat for Spring-Run Chinook Salmon. Based on previous flow habitat relationship studies in the Trinity River (USFWS 1999), these differences in flow are not expected to result in a detectable effect on Spring-Run Chinook Salmon spawning or juvenile rearing habitat (USFWS 1999). Flows in above normal water years in February would increase by approximately 52% under Alternative 2 (801 cfs) compared to the No Action Alternative (528 cfs). This increase in flow could increase the likelihood of Spring-Run Chinook Salmon egg mortality due to redd scour, potentially resulting in reduced incubation success in areas where local conditions contribute to substantial mobilization of gravel in the redds.

Fall-Run Chinook Salmon

Flows in the Trinity River downstream of Lewiston Dam would generally be similar under Alternative 2 compared to the No Action Alternative. Minor differences (<10%) in November and December of some water year types and a larger difference (17%) in November of above normal water years may affect spawning habitat for Fall-Run Chinook Salmon. Based on previous flow habitat relationship studies in the Trinity River (USFWS 1999), these differences in flow are not expected to result in a detectable effect on Fall-Run Chinook Salmon spawning or juvenile rearing habitat (USFWS 1999). Flows in above normal water years in February would increase by approximately 52% under Alternative 2 (801 cfs) compared to the No Action Alternative (528 cfs). This increase in flow could increase the likelihood of Fall-Run Chinook Salmon egg mortality due to redd scour, potentially resulting in reduced incubation success in areas where local conditions contribute to substantial mobilization of gravel in the redds.

Steelhead (Winter- and Summer-Run)

Flows in the Trinity River downstream of Lewiston Dam would generally be similar under Alternative 2 compared to the No Action Alternative. Flow under Alternative 2 in February of above normal water years would increase by approximately 52% (801 cfs) compared to the No Action Alternative (528 cfs). This increase in flow may reduce the amount of spawning habitat for Steelhead. Based on previous flow habitat relationship studies in the Trinity River (USFWS 1999: 123), increasing flows from 500 cfs to 800 cfs showed little change in the amount of spawning habitat for Steelhead in the Trinity River from downstream of Lewiston Dam to the confluence with Dutch Creek.

Green Sturgeon

Green Sturgeon occur within the lower 43 miles of the Trinity River, approximately 70 miles downstream of Lewiston Dam. Water temperature and habitat conditions within this section of the Trinity River are heavily influenced by several large tributaries that enter the Trinity River (e.g., the North Fork Trinity River, New River, and the South Fork Trinity River). As a result, minor changes in reservoir operations are likely to be undetectable this far downstream. Therefore, changes in flow under Alternative 2 would not affect Green Sturgeon.

White Sturgeon

White Sturgeon are not likely to be affected by changes in reservoir operations under Alternative 2 compared to the No Action Alternative due to their limited distribution in the lower Klamath River, primarily in the estuary.

Pacific Lamprey

Flows in the Trinity River downstream of Lewiston Dam would generally be similar under Alternative 2 compared to the No Action Alternative. However, minor changes (<10%) to flow would occur under Alternative 2 in November and December of some water year types and a larger change to flow in November (565 cfs compared to 678 cfs under the No Action Alternative) and February (801 cfs compared to 528 cfs under the No Action Alternative) of above normal water years. Increased flows in February overlap with the Pacific Lamprey adult migration period but are not expected to affect migration because Pacific Lamprey migration spans multiple seasons and associated flows. Although previous flow habitat relationship studies in the Trinity River (USFWS 1999) did not focus on Pacific Lamprey, results for salmonids suggest that changes in flow under Alternative 2 would not result in a detectable effect on juvenile rearing or adult holding habitat for Pacific Lamprey compared to the No Action Alternative.

American Shad

American Shad are primarily found in the Lower Klamath River but may occur in the lower sections of the Trinity River up to approximately RM 24 at the town of Willow Creek. Water temperature and habitat conditions within this section of the Trinity River are heavily influenced by several large tributaries that enter the Trinity River (e.g., the North Fork Trinity River, New River, and the South Fork Trinity River). As a result, minor changes in reservoir operations are likely to be undetectable this far downstream. Therefore, changes in flow under Alternative 2 would not affect American Shad.

Potential changes to aquatic resources due to variation in temperature

Modeling results indicate that changes in monthly average water temperature in the Trinity River downstream of Lewiston Dam would be similar between Alternative 2 and the No Action Alternative. Differences in monthly average temperature between Alternative 2 and the No Action Alternative are less than 0.5°F for all months of the year (Figure O.3-88). Modeled maximum temperatures in the Trinity River are lower under Alternative 2 compared to the No Action Alternative in July and October and higher in August, September, and December, with similar maximum temperatures in the remaining months (Figure O.3-89 and Table O.3-24).

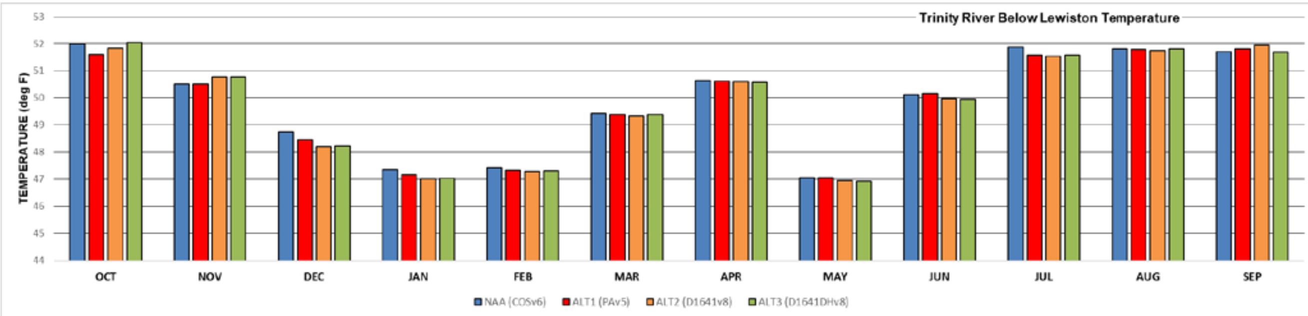


Figure O.3-88. Average Trinity River Water Temperatures below Lewiston Dam for the Period October to September, Average of All Water Year Types

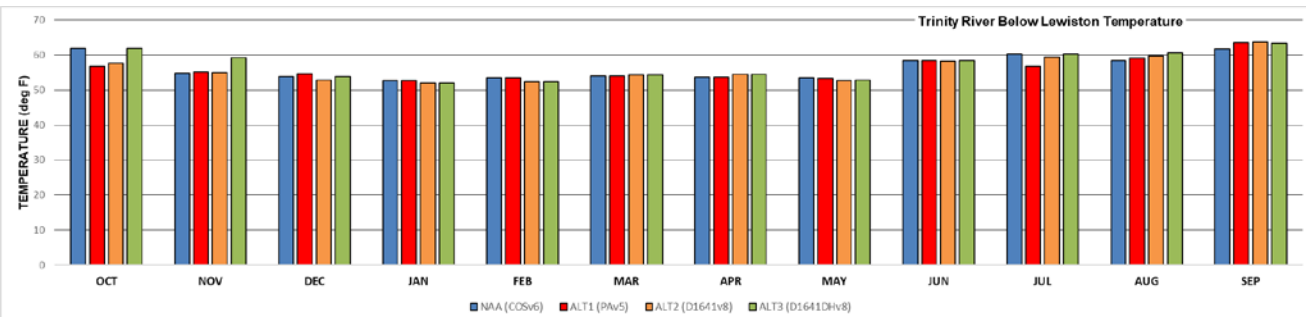


Figure O.3-89. Maximum Trinity River Water Temperatures below Lewiston Dam for the Period October to September, Average of All Water Year Types

Table O.3-24. Maximum Trinity River Water Temperatures below Trinity Dam for the Period October–September, Average of All Water Year Types (Differences >1°F Are Highlighted)

Alt	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
No Action Alternative	61.8	54.8	53.8	52.7	53.4	54.1	53.7	53.5	58.4	60.3	58.4	61.8
ALT 1	56.7	55.2	54.6	52.6	53.5	54.0	53.7	53.4	58.4	56.9	59.1	63.5
ALT 2	57.6	55.1	52.8	52.0	52.4	54.4	54.5	52.7	58.4	59.4	59.7	63.8
ALT 3	61.9	59.3	53.9	52.0	52.4	54.4	54.5	52.9	58.4	60.3	60.6	63.4

In a previous study that looked at flow and water temperatures in the Trinity River (USFWS 1999), results indicated that flows do not have a significant influence on water temperatures from mid-October through early April when cooler air temperatures help maintain cold water temperatures even when flow releases drop below 150 cfs. Once tributary influence begins to decrease and meteorological conditions warm from May to mid-July, flow releases become more influential on downstream temperatures, particularly in hot-dry conditions. Maintaining a flow of 450 cfs in the summer and early fall was found to meet the water temperature objectives for the Trinity River when water released from Lewiston Dam was 53°F or less (USFWS 1999: 203). Water temperatures are most influenced by flow releases from May through mid-October. Flows from May to October would be similar under Alternative 2 compared to the No Action Alternative in most water year types, with the exception of critically dry years. In critically dry years, flows in September and October would decrease by approximately 6% to 9% under Alternative

2 compared to the No Action Alternative from 870 cfs to 818 cfs and from 342 cfs to 311 cfs, respectively. Based on modeling results, changes in flow under Alternative 2 are not likely to have a detectable change in water temperature in the Trinity River downstream of Lewiston Dam in all but critically dry years.

Coho Salmon

Water temperatures in the Trinity River below Lewiston Dam are generally expected to be similar under Alternative 2 compared to the No Action Alternative. Differences in monthly average temperature between Alternative 2 and the No Action Alternative would be less than 0.5°F for all months of the year (Figure O.3-88). Modeled maximum temperatures in the Trinity River in July and October would be approximately 1°F to 4°F lower under Alternative 2 compared to the No Action Alternative and approximately 1°F to 2°F higher in August, September, December, and February with similar maximum temperatures in the remaining months (Figure O.3-89). Maximum temperatures under Alternative 2 increase in August and September and exceed the NCRWQCB (2018) objectives for the Trinity River. Under both the No Action Alternative and Alternative 2, water temperatures exceed the NCRWQCB objectives during this time; however, further increases in temperature that would occur under Alternative 2 may reduce juvenile Coho Salmon rearing success. Conversely, the decreased maximum temperatures under Alternative 2 that occur in July would meet the NCRWQCB (2018) objectives for the Trinity River, and the cooler October water temperatures may improve juvenile rearing conditions compared to conditions under the No Action Alternative.

Spring-Run Chinook Salmon

Water temperatures in the Trinity River below Lewiston Dam are generally expected to be similar under Alternative 2 compared to the No Action Alternative. Differences in monthly average temperature between Alternative 2 and the No Action Alternative would be less than 0.5°F for all months of the year (Figure O.3-88). Modeled maximum temperatures in the Trinity River in July and October would be approximately 1°F to 4°F lower under Alternative 2 compared to the No Action Alternative and approximately 1°F to 2°F higher in August, September, December, and February with similar maximum temperatures in the remaining months (Figure O.3-89). Spring-Run Chinook Salmon spawning usually peaks in October but typically ranges from the third week of September through November. Maximum August and September temperatures under Alternative 2 would exceed the NCRWQCB (2018) objectives for the Trinity River. Under both the No Action Alternative and Alternative 2 water temperatures exceed the NCRWQCB objectives during this time. However, the further increases in temperature predicted under Alternative 2 may limit the success of adult migration, spawning, and juvenile rearing of Spring-Run Chinook Salmon. Conversely, the reduced temperatures under Alternative 2 that occur in July would meet the NCRWQCB (2018) objectives for the Trinity River, and the cooler temperatures in October may improve spawning and juvenile rearing conditions compared to conditions under the No Action Alternative

Fall-Run Chinook Salmon

Water temperatures in the Trinity River below Lewiston Dam are generally expected to be similar under Alternative 2 compared to the No Action Alternative. Differences in monthly average temperature between Alternative 2 and the No Action Alternative would be less than 0.5°F for all months of the year (Figure O.3-88). Modeled maximum temperatures in the Trinity River in July and October would be approximately 1°F to 4°F lower under Alternative 2 compared to the No Action Alternative and approximately 1°F to 2°F higher in August, September, December, and February, with similar maximum temperatures in the remaining months (Figure O.3-89). Fall-Run Chinook Salmon spawning usually occurs between October and December with peak spawning activity occurring in November. Maximum August and September temperatures would exceed the NCRWQCB (2018) objectives for the Trinity River and may affect adult migration for Fall-Run Chinook Salmon compared to the No Action Alternative; however, the reduced temperatures under Alternative 2 in October would improve spawning conditions compared to the No Action Alternative.

Steelhead (Winter- and Summer-Run)

Water temperatures in the Trinity River below Lewiston Dam are generally expected to be similar under Alternative 2 compared to the No Action Alternative. Differences in monthly average temperature between Alternative 2 and the No Action Alternative would be less than 0.5°F for all months of the year (Figure O.3-88). Modeled maximum temperatures in the Trinity River in July and October would be approximately 1°F to 4°F lower under Alternative 2 compared to the No Action Alternative and approximately 1°F to 2°F higher in August, September, December, and February, with similar maximum temperatures in the remaining months (Figure O.3-89). Maximum temperatures under Alt 2 would increase in August and September with temperatures exceeding the NCRWQCB (2018) objectives for the Trinity River. Under both the No Action Alternative and Alt 2 water temperatures would exceed the NCRWQCB objectives during this time. However, larger increases in temperature that would occur under Alternative 2 may further reduce juvenile Steelhead rearing success. Conversely, the reduced maximum temperatures under Alternative 2 that would occur in July meet the NCRWQCB (2018) objectives for the Trinity River, and the cooler temperatures in October would improve juvenile rearing conditions compared to the No Action Alternative.

Green Sturgeon

Green Sturgeon occur within the lower 43 miles of the Trinity River, approximately 70 miles downstream of Lewiston Dam. Water temperature and habitat conditions within this section of the Trinity River are heavily influenced by several large tributaries that enter the Trinity River (e.g., the North Fork Trinity River, New River, and the South Fork Trinity River). As a result, minor changes in reservoir operations are likely to be undetectable this far downstream. Results of previous water temperature modeling for the Trinity River (USFWS 1999) predicted a difference of approximately 1°F in water temperature for flows of 300 cfs and 450 cfs near RM 43 with smaller temperature differences expected downstream of RM 43 to the confluence of the Trinity and Klamath Rivers. Therefore, changes in water temperature under Alternative 2 would not affect Green Sturgeon.

White Sturgeon

White Sturgeon would not be affected by changes in reservoir operations under Alternative 2 compared to the No Action Alternative due to their limited distribution in the lower Klamath River, primarily in the estuary.

Pacific Lamprey

Model results predict that water temperatures in the Trinity River below Lewiston Dam would be similar under Alternative 2 compared to the No Action Alternative. Differences in monthly average temperature between Alternative 2 and the No Action Alternative would be less than 0.5°F for all months of the year (Figure O.3-88). Modeled maximum temperatures in the Trinity River in July and October would be approximately 1°F to 4°F lower under Alternative 2 compared to the No Action Alternative and approximately 1°F to 2°F higher in August, September, December, and February, with similar maximum temperatures in the remaining months (Figure O.3-89). Maximum temperatures under Alternative 2 increase in August and September with temperatures exceeding the NCRWQCB (2018) objectives for the Trinity River. Under both the No Action Alternative and Alternative 2 water temperatures exceed the NCRWQCB objectives during this time. However, larger increases in temperature that would occur under Alternative 2 may further reduce Pacific Lamprey juvenile rearing success. Conversely, the decreased maximum temperatures under Alternative 2 that would occur in July meet the NCRWQCB (2018) objectives for the Trinity River, and the cooler temperatures in October may improve Pacific Lamprey juvenile rearing conditions compared to the No Action Alternative.

American Shad

American Shad are primarily found in the Lower Klamath River but may occur in the lower sections of the Trinity River up to approximately RM 24 at the town of Willow Creek. Water temperature and habitat conditions within this section of the Trinity River are heavily influenced by several large tributaries that enter the Trinity River (e.g., the North Fork Trinity River, New River, and the South Fork Trinity River). As a result, minor changes in reservoir operations are likely to be undetectable this far downstream. Therefore, changes in water temperature under Alternative 2 would not affect American Shad.

O.3.5.1.2 Trinity River Record of Decision

The Trinity River ROD is being implemented under both Alternative 2 and the No Action Alternative. Therefore, implementation of the variable annual flow regime, restoration actions, and monitoring and adaptive management, per the Trinity River ROD under Alternative 2 would have similar effects as the No Action Alternative on Coho Salmon, Chinook Salmon (Spring- and Fall-Run), Steelhead (Winter- and Summer-Run), Green Sturgeon, White Sturgeon, Pacific Lamprey, and American Shad.

O.3.5.2 *Sacramento River*

Potential changes to aquatic resources in the Sacramento River from seasonal operations

Under all the Project alternatives, flows in the upper Sacramento River result from controlled releases from Shasta and Keswick reservoirs, as well as transfers from the Trinity River and natural accretions. Dry hydrologic conditions often lead to inadequate storage in Shasta Reservoir for operators to provide suitable conditions for salmonids and other native species in the upper Sacramento River. In most cases, water temperature rather than flow is the limiting factor creating unsuitable conditions, as discussed below. The primary differences between the No Action Alternative and Alternative 2 for the Sacramento River upstream of the Delta is that the No Action Alternative includes NMFS's 2009 BO RPAs to operate Shasta Reservoir for management of cold water in the reservoir and river to protect anadromous salmonids, and requirements for Fall X2 flow releases, but Alternative 2 does not include either requirement. A minimum flow of 3,250 cfs is required from Keswick Dam to the RBDD during October through March under the No Action Alternative and during October through February under Alternative 2 (NCWA 2014).

CalSim II modeling indicates that average flow released at Keswick Dam under Alternative 2 would generally be higher than or similar to flow under No Action Alternative, except in wet and above normal water years during September and November, when the Alternative 2 flows would be substantially lower than the No Action Alternative flows (Table O.3-25). The higher September and November flows under the No Action Alternative result from Fall X2 releases, which are not included in Alternative 2. Table O.3-25 shows that the highest mean monthly flows for both alternatives occur primarily during winter of wet and above normal water years and during summer of all water year types. Flow releases are high during summer to satisfy downstream demands of water users and Delta water quality and to meet water temperature requirements of incubating Winter-Run Chinook Salmon eggs and alevins downstream of Keswick Dam.

Table O.3-25. CalSim II Monthly Average Flow (cfs) by Water Year Type and Month below Keswick Dam for No Action Alternative, Alternative 2 and Differences between Them

Alternative[1,2,3] Water Year Type[4]	Monthly Flow (cfs)											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
No Action Alternative												
Wet (32%)[5]	7,908	9,796	7,444	17,876	19,288	16,127	8,458	8,662	8,940	13,440	10,474	14,063
Above Normal (16%)	7,054	10,124	6,406	7,629	16,401	8,534	5,221	7,925	10,359	15,316	10,494	9,972
Below Normal (13%)	5,842	4,960	7,558	3,285	7,149	3,925	3,803	7,867	10,930	14,421	10,624	5,493
Dry (24%)	5,660	5,111	8,652	3,697	3,564	3,961	3,719	7,014	10,368	12,658	8,608	4,995
Critically Dry (15%)	4,829	3,755	3,251	3,392	3,580	3,509	4,065	6,895	8,984	10,947	7,793	4,729
Alternative 2												
Wet (32%)	7,820	6,264	9,226	18,273	19,655	16,290	8,670	9,102	9,965	13,319	10,917	8,068
Above Normal (16%)	7,759	6,585	6,681	8,676	17,568	9,023	5,293	8,707	12,953	15,316	11,081	5,931
Below Normal (13%)	6,002	5,023	6,956	4,539	7,365	4,813	4,425	9,445	13,201	14,747	11,942	6,723
Dry (24%)	5,926	5,320	8,291	3,775	3,289	3,793	3,906	8,450	11,537	12,598	8,566	5,523
Critically Dry (15%)	4,877	3,797	3,255	3,272	3,622	4,135	4,348	7,481	10,021	11,248	8,070	5,082
Alternative 2 minus No Action Alternative[6]												
Wet (32%)	-88	-3,532	1,782	398	367	162	212	439	1,025	-121	443	-5,994
Above Normal (16%)	706	-3,539	275	1,047	1,167	489	72	782	2,594	0	587	-4,041
Below Normal (13%)	160	63	-602	1,254	216	888	622	1,578	2,270	326	1,318	1,230
Dry (24%)	266	209	-361	77	-275	-168	187	1,436	1,169	-60	-41	528
Critically Dry (15%)	48	41	4	-119	42	626	283	586	1,037	302	277	353

1 Results based on the 82-year simulation period.
2 Results displayed with calendar year - year type sorting.
3 All scenarios are simulated at ELT (Early Long-Term) Q5 with 2025 climate change and 15 cm sea level rise.
4 Water year types as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999).
5 Percent of years of each type given in parentheses.
6 Bold green font indicates greater than 5% increase in flow; bold red font indicates greater than 5% reduction in flow.

HEC-5Q modeling was used to compare water temperature effects of the No Action Alternative and Alternative 2. Based on recent investigations of Winter-Run Chinook Salmon mortality in the upper Sacramento River (Martin et al. 2017; Anderson 2018), this effects analyses uses an upper water temperature threshold of 53.5°F for suitable salmonid spawning and egg and alevin incubation in the Sacramento River. An important caution regarding the HEC-5Q water temperature modeling results, particularly with regard to meeting water temperature criteria (e.g., 56°F water temperature at Bend

Bridge criterion), relates to the time step used in the modeling. HEC-5Q, like the CalSim II model on which it relies for flow data, has a monthly time step and provides estimates of monthly mean water temperatures. However, most of the regulatory requirements to meet water temperature criteria apply to daily mean (or shorter duration) water temperatures. Daily means are almost always much more variable than monthly means and, therefore, the monthly mean water temperature estimates provided by HEC-5Q are not directly comparable to the regulatory criteria. For example, even with constant flows releases, downstream daily water temperatures would fluctuate around the mean in response to variation in solar radiation and other meteorological conditions within a given month. In view of this limitation, it is helpful to consider the comparisons of temperature effects among the alternatives as indicating the relative likelihoods of exceeding temperature criteria, rather than whether or not the criteria are actually met. These considerations apply to the CalSim II flow data as well, but are less important for flow because there are fewer regulatory criteria for flow and, except during storm events, flow tends to be less variable than water temperature.

During the summer and much of the fall, water released from Keswick Dam warms downstream resulting in warmer water temperatures in more downstream habitats. Therefore, the effects of the alternatives on fish populations depend on the habitat distributions of the populations as well as the results of temperature management operations. Winter-Run Chinook Salmon mostly spawn from Keswick Dam to about 6 miles downstream of the Clear Creek temperature gage, Spring-Run from Keswick Dam to about Balls Ferry, fall-run from Keswick Dam to about RBDD, late fall-run spawning distribution is similar to that of Winter-Run, and Green Sturgeon spawn downstream of the Cow Creek confluence to the GCID oxbow near Hamilton City (NMFS 2018b). Steelhead spawning areas in the upper Sacramento River are poorly known.

Based on the HEC-5Q modeling, the mean monthly water temperatures at Keswick Dam are roughly equal under the No Action Alternative and Alternative 2, except for September of Above Normal water years, which has a 1.3°F higher mean water temperatures under Alternative 2 than under the No Action Alternative (Table O.3-26). Summer mean monthly water temperatures are consistently below the 53.5°F temperature threshold, except in critically dry water years during July through September. The October and November mean water temperatures under Alternative 2 are similar to those under the No Action Alternative and are just above the 53.5°F temperature threshold, except for critically dry water years, when those for both alternatives are well above the threshold (Table O.3-26). For October, the mean water temperature for critically dry water years is 0.7°F higher under Alternative 2 than that under the No Action Alternative. Although this difference is not large, it occurs under highly stressful temperature conditions for salmonids eggs and alevins. The largest predicted increase in mean water temperature under Alternative 2 is 1.3°F for September of Above Normal water years (Table O.3-26). This increase occurs over a range well below the critical temperature threshold and is therefore unlikely to have a large effect on the salmonids. The differences between the No Action Alternative and Alternative 2 in September water temperatures at Keswick Dam are small (Figure O.3-20) relative to those at more downstream locations, as described below.

Table 0.3-26. HEC-5Q Monthly Average Water Temperature (°F) by Water Year Type and Month at Keswick Dam for No Action Alternative, Alternative 2 and Differences between Them

Alternative1,2,3 Water Year Type4	Monthly Temperature (°F)											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
No Action Alternative												
Wet (32%)5	54.3	55.4	52.0	47.3	45.9	46.3	47.8	48.7	49.6	50.4	51.4	51.0
Above Normal (16%)	53.9	54.9	51.4	47.6	46.0	46.5	48.1	48.6	49.3	50.0	51.1	51.0
Below Normal (13%)	54.2	54.3	51.3	48.2	46.9	47.8	49.1	49.4	49.7	50.8	52.0	52.8
Dry (24%)	54.5	54.4	50.8	48.4	47.3	47.8	49.1	49.5	50.1	51.4	53.0	53.2
Critically Dry (15%)	58.9	56.3	51.5	48.2	47.1	48.1	49.5	50.7	52.3	53.9	56.2	58.4
Alternative 2												
Wet (32%)	53.8	54.5	51.5	47.3	45.9	46.4	47.8	48.7	49.5	50.6	51.5	51.7
Above Normal (16%)	53.9	54.4	51.1	47.5	45.9	46.5	48.1	48.5	49.1	50.2	51.2	52.2
Below Normal (13%)	54.6	54.9	51.7	48.1	46.8	47.8	49.1	49.2	49.7	51.0	51.8	52.8
Dry (24%)	54.6	54.8	51.0	48.4	47.3	47.8	49.1	49.1	49.9	51.5	53.0	53.1
Critically Dry (15%)	59.6	56.6	51.6	48.4	47.2	48.0	49.5	50.6	52.3	54.1	56.4	58.8
Alternative 2 minus No Action Alternative6												
Wet (32%)	-0.4	-0.9	-0.5	0.0	0.0	0.0	0.0	0.0	-0.1	0.1	0.0	0.7
Above Normal (16%)	-0.1	-0.5	-0.3	-0.2	0.0	0.0	0.0	-0.1	-0.2	0.2	0.1	1.3
Below Normal (13%)	0.4	0.6	0.4	-0.2	-0.1	0.0	0.0	-0.2	0.0	0.2	-0.2	-0.1
Dry (24%)	0.1	0.4	0.1	0.0	0.0	0.0	0.0	-0.3	-0.2	0.1	0.0	-0.2
Critically Dry (15%)	0.7	0.3	0.1	0.2	0.1	-0.1	0.0	-0.1	0.0	0.2	0.2	0.4

1 Results based on the 82-year simulation period.
2 Results displayed with calendar year - year type sorting.
3 All scenarios are simulated at ELT (Early Long-Term) Q5 with 2025 climate change and 15 cm sea level rise.
4 Water year types as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999).
5 Percent of years of each type given in parentheses.
6 Bold green font indicates greater than 1°F reduction in temperature, bold red font indicates greater than 1°F increase in temperature.

The HEC-5Q results indicate that late spring through early fall water temperatures in the Sacramento River at Clear Creek are slightly warmer than those at Keswick Dam, with larger increases in September water temperature differences between the No Action Alternative and Alternative 2 (Table O.3-27). Summer mean monthly water temperatures are below the 53.5°F temperature threshold, except in drier water years, especially in August and September. All mean temperatures for October and November are above the threshold for both alternatives. At Balls Ferry, the temperatures are warmer still and the September increases are larger (Table O.3-28). The mean September water temperatures for wet and above normal water years at Balls Ferry exceed the critical water temperature threshold under Alternative 2, but not under the No Action Alternative (Table O.3-28). As discussed previously, the monthly mean water temperatures provide a rough estimate of the probability of mean daily water temperatures exceeding a temperature threshold. Because the mean monthly water temperatures are higher under Alternative 2, the probability or frequency of the threshold being exceeded in September of wet and above normal water years is expected to be higher under Alternative 2 than under the No Action Alternative.

Table O.3-27. HEC-5Q Monthly Average Water Temperature (°F) by Water Year Type and Month at Clear Creek Confluence for No Action Alternative, Alternative 2 and Differences between Them

Alternative[1,2,3] Water Year Type[4]	Monthly Temperature (°F)											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
No Action Alternative												
Wet (32%)[5]	54.7	55.3	51.6	47.3	46.2	47.0	49.2	50.3	51.4	51.9	52.9	51.9
Above Normal (16%)	54.4	54.7	51.0	47.7	46.4	47.4	49.9	50.3	51.0	51.3	52.6	52.1
Below Normal (13%)	54.7	54.2	51.0	48.1	47.4	49.0	51.1	51.0	51.3	52.1	53.5	54.5
Dry (24%)	55.2	54.3	50.6	48.3	47.9	49.1	51.0	51.2	51.7	52.8	54.6	55.0
Critically Dry (15%)	59.4	56.1	51.2	48.2	47.8	49.5	51.4	52.4	54.0	55.5	57.8	59.8
Alternative 2												
Wet (32%)	54.4	54.5	51.3	47.3	46.2	47.1	49.3	50.2	51.2	52.1	52.9	53.1
Above Normal (16%)	54.4	54.3	50.9	47.6	46.3	47.5	49.9	50.1	50.6	51.5	52.6	53.9
Below Normal (13%)	55.2	54.8	51.4	48.1	47.3	49.0	51.0	50.6	51.1	52.3	53.1	54.2
Dry (24%)	55.3	54.7	50.8	48.3	48.0	49.2	51.0	50.7	51.4	52.9	54.7	54.7
Critically Dry (15%)	60.1	56.5	51.3	48.4	48.0	49.3	51.4	52.2	53.9	55.6	57.9	60.1
Alternative 2 minus No Action Alternative[6]												
Wet (32%)	-0.3	-0.8	-0.3	0.0	0.0	0.1	0.0	-0.1	-0.2	0.1	0.0	**1.2**
Above Normal (16%)	0.0	-0.4	-0.2	-0.1	0.0	0.1	0.1	-0.2	-0.4	0.2	0.0	**1.8**
Below Normal (13%)	0.4	0.6	0.4	-0.1	-0.1	0.0	-0.1	-0.4	-0.2	0.2	-0.4	-0.3
Dry (24%)	0.1	0.4	0.2	0.1	0.1	0.1	0.0	-0.5	-0.3	0.1	0.0	-0.3
Critically Dry (15%)	0.7	0.3	0.2	0.2	0.1	-0.1	-0.1	-0.2	-0.1	0.2	0.1	0.4

1 Results based on the 82-year simulation period.
2 Results displayed with calendar year - year type sorting.
3 All scenarios are simulated at ELT (Early Long-Term) Q5 with 2025 climate change and 15 cm sea level rise.
4 Water year types as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999).
5 Percent of years of each type given in parentheses.
6 Bold green font indicates greater than 1°F reduction in temperature, bold red font indicates greater than 1°F increase in temperature.

Table O.3-28. HEC-5Q Monthly Average Water Temperature (°F) by Water Year Type and Month at Balls Ferry for No Action Alternative, Alternative 2 and Differences between Them

Alternative[1,2,3] Water Year Type[4]	Monthly Temperature (°F)											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
No Action Alternative												
Wet (32%)[5]	55.1	54.9	50.7	46.9	46.4	47.7	50.8	52.5	53.6	53.3	54.2	52.6
Above Normal (16%)	54.9	54.4	50.2	47.0	46.6	48.2	51.6	52.3	52.7	52.4	53.8	53.0
Below Normal (13%)	55.3	53.8	50.2	47.4	47.6	49.8	52.9	52.6	52.8	53.3	54.6	55.8
Dry (24%)	55.7	53.8	49.8	47.7	47.9	49.8	52.8	53.0	53.2	54.1	55.9	56.4
Critically Dry (15%)	59.7	55.7	50.1	47.9	48.2	50.4	53.0	54.0	55.4	56.7	59.1	60.8
Alternative 2												
Wet (32%)	54.8	54.1	50.5	46.9	46.4	47.8	50.9	52.4	53.3	53.5	54.2	54.3
Above Normal (16%)	54.9	53.8	50.0	47.0	46.6	48.3	51.7	52.0	52.1	52.6	53.8	55.3
Below Normal (13%)	55.7	54.4	50.5	47.4	47.5	49.7	52.7	52.0	52.4	53.4	54.2	55.3
Dry (24%)	55.8	54.1	49.9	47.8	48.0	49.9	52.8	52.4	52.8	54.1	56.0	56.0
Critically Dry (15%)	60.3	56.0	50.2	48.1	48.3	50.2	52.9	53.7	55.2	56.9	59.1	61.1
Alternative 2 minus No Action Alternative[6]												
Wet (32%)	-0.3	-0.8	-0.2	0.0	0.0	0.1	0.0	-0.1	-0.3	0.2	-0.1	**1.7**
Above Normal (16%)	0.0	-0.6	-0.1	0.0	0.0	0.1	0.1	-0.3	-0.6	0.2	0.0	**2.3**
Below Normal (13%)	0.4	0.5	0.3	0.0	-0.1	-0.1	-0.2	-0.6	-0.4	0.2	-0.5	-0.4
Dry (24%)	0.1	0.4	0.1	0.0	0.1	0.1	0.0	-0.7	-0.4	0.1	0.0	-0.3
Critically Dry (15%)	0.6	0.3	0.1	0.2	0.1	-0.2	-0.1	-0.2	-0.2	0.1	0.1	0.3

1 Results based on the 82-year simulation period.
2 Results displayed with calendar year - year type sorting.
3 All scenarios are simulated at ELT (Early Long-Term) Q5 with 2025 climate change and 15 cm sea level rise.
4 Water year types as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999).
5 Percent of years of each type given in parentheses.
6 Bold green font indicates greater than 1°F reduction in temperature, bold red font indicates greater than 1°F increase in temperature.

The downstream trends in water temperature conditions noted for Keswick Dam, Clear Creek and Balls Ferry continue to RBDD, with little difference in water temperatures between the alternatives, except for substantially warmer temperatures in September of wet and above normal water years under Alternative 2 (Table O.3-29). The growing downstream differences in wet and above normal water year temperatures for September can be seen in Figures O.3-20, O.3-31 and O.3-22. These temperature differences are largely limited to the cooler 50% of years. Under both the No Action Alternative and Alternative 2, the mean water temperatures at RBDD for April through October are above the critical water temperature threshold in all water year types. The pattern of increasing water temperatures differences in September of wet and above normal water years between the No Action Alternative and Alternative 2 continues downstream to Hamilton City and Knights Landing, (Table O.3-30 and O.3-31; Figures O.3-23 and O.3-24). However, at these locations there are also water temperature reductions of 1°F to 2°F between the No

Action Alternative and Alternative 2 during May, June, August, and September of above normal, below normal or dry water years, depending on the month (Table O.3-30 and O.3-31; Figures O.3-90 and O.3-91). These reductions result from increases in flow under Alternative 2 relative to the No Action Alternative (Tables O.3-32 through O.3-34).

Table O.3-29. HEC-5Q Monthly Average Water Temperature (°F) by Water Year Type and Month at Red Bluff Diversion Dam for No Action Alternative, Alternative 2 and Differences between Them

Alternative[1,2,3] Water Year Type[4]	Monthly Temperature (°F)											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
No Action Alternative												
Wet (32%)[5]	56.2	54.3	49.3	46.5	47.0	49.3	53.7	56.7	59.1	58.1	58.9	55.4
Above Normal (16%)	56.2	53.7	48.8	46.6	47.1	50.0	54.9	56.9	57.8	56.5	58.3	56.3
Below Normal (13%)	56.6	53.3	48.9	46.7	48.0	51.7	56.4	56.7	57.4	57.4	58.8	60.1
Dry (24%)	57.1	53.0	48.5	46.9	48.3	51.5	56.1	57.5	57.9	58.5	60.6	60.9
Critically Dry (15%)	60.6	54.7	48.6	47.3	49.0	52.4	56.6	58.0	60.0	61.2	63.3	64.3
Alternative 1												
Wet (32%)	55.3	53.6	49.4	46.6	47.0	49.4	53.7	56.5	59.0	58.2	58.7	58.0
Above Normal (16%)	55.3	52.7	48.8	46.8	47.1	50.0	55.0	56.6	57.7	56.6	58.5	59.9
Below Normal (13%)	56.4	53.6	49.2	46.9	48.0	51.5	56.1	56.0	56.9	57.3	58.4	59.5
Dry (24%)	56.3	53.2	48.9	47.0	48.3	51.5	56.2	56.9	57.3	58.4	59.8	60.6
Critically Dry (15%)	60.7	54.9	48.7	47.5	49.2	52.4	56.7	57.7	59.2	61.0	63.0	64.8
Alternative 1 minus No Action Alternative[6]												
Wet (32%)	-0.9	-0.7	0.1	0.1	0.0	0.0	0.0	-0.2	0.0	0.1	-0.2	**2.6**
Above Normal (16%)	-0.9	-1.0	-0.1	0.1	0.0	0.0	0.0	-0.3	-0.1	0.1	0.2	**3.6**
Below Normal (13%)	-0.3	0.3	0.3	0.2	0.0	-0.2	-0.3	-0.7	-0.5	-0.1	-0.4	-0.6
Dry (24%)	-0.9	0.2	0.3	0.1	0.0	0.0	0.0	-0.5	-0.6	-0.1	-0.8	-0.4
Critically Dry (15%)	0.1	0.2	0.1	0.2	0.2	0.0	0.1	-0.3	-0.7	-0.2	-0.3	0.5

1 Results based on the 82-year simulation period.
2 Results displayed with calendar year - year type sorting.
3 All scenarios are simulated at ELT (Early Long-Term) Q5 with 2025 climate change and 15 cm sea level rise.
4 Water year types as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999).
5 Percent of years of each type given in parentheses.
6 Bold green font indicates greater than 1°F reduction in temperature, bold red font indicates greater than 1°F increase in temperature.

Table O.3-30. HEC-5Q Monthly Average Water Temperatures (degree Fahrenheit) by Water Year Type and Month below Hamilton City for No Action Alternative, Alternative 2 and Differences between Them

Alternative[1,2,3] Water Year Type[4]	Monthly Temperature (°F) Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
No Action Alternative												
Wet (32%)[5]	57.8	54.3	48.9	46.5	47.4	50.4	55.4	60.2	64.1	63.0	63.7	58.2
Above Normal (16%)	58.0	53.6	48.6	46.7	47.6	51.1	56.8	61.0	62.8	61.0	62.9	59.6
Below Normal (13%)	58.5	53.5	48.5	46.7	48.6	53.1	58.9	60.7	62.0	61.8	63.2	64.2
Dry (24%)	59.1	53.3	48.3	46.9	49.0	52.8	58.5	61.5	62.7	63.1	65.3	65.1
Critically Dry (15%)	62.2	54.8	48.3	47.4	50.0	54.2	59.6	62.1	64.5	65.9	67.9	67.9
Alternative 2												
Wet (32%)	57.8	53.7	48.9	46.5	47.4	50.4	55.4	59.9	63.4	63.2	63.4	62.1
Above Normal (16%)	58.0	52.9	48.4	46.7	47.6	51.1	56.8	60.4	61.2	61.1	62.6	63.7
Below Normal (13%)	58.7	53.9	48.5	46.8	48.6	52.9	58.5	59.7	60.7	61.8	62.3	63.0
Dry (24%)	59.1	53.5	48.3	47.0	49.0	52.9	58.4	60.4	61.8	63.2	65.5	64.5
Critically Dry (15%)	62.5	55.0	48.3	47.4	50.1	54.0	59.4	61.6	63.9	65.8	67.7	67.8
Alternative 2 minus No Action Alternative[6]												
Wet (32%)	0.0	-0.6	0.0	0.0	0.0	0.0	0.0	-0.3	-0.7	0.2	-0.3	**3.9**
Above Normal (16%)	0.0	-0.6	-0.2	0.0	0.0	0.0	0.0	-0.5	**-1.6**	0.1	-0.3	**4.1**
Below Normal (13%)	0.1	0.4	0.1	0.1	0.0	-0.2	-0.4	**-1.1**	**-1.2**	0.0	-0.9	**-1.2**
Dry (24%)	0.0	0.2	0.1	0.0	0.0	0.1	0.0	**-1.1**	-0.9	0.1	0.1	-0.5
Critically Dry (15%)	0.3	0.2	0.0	0.0	0.1	-0.3	-0.2	-0.5	-0.6	-0.1	-0.2	-0.1

1 Results based on the 82-year simulation period.
2 Results displayed with calendar year - year type sorting.
3 All scenarios are simulated at ELT (Early Long-Term) Q5 with 2025 climate change and 15 cm sea level rise.
4 Water year types as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999).
5 Percent of years of each type given in parentheses.
6 Bold green font indicates greater than 1°F reduction in temperature, bold red font indicates greater than 1°F increase in temperature.

Table O.3-31. HEC-5Q Monthly Average Water Temperature (°F) by Water Year Type and Month at Knights Landing for No Action Alternative, Alternative 2 and Differences between Them

Alternative[1,2,3] Water Year Type[4]	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
No Action Alternative												
Wet (32%)[5]	61.0	55.1	48.8	46.5	48.0	51.9	57.4	65.0	70.9	71.8	72.4	63.9
Above Normal (16%)	61.6	54.3	48.5	47.0	48.3	52.5	59.1	66.6	70.8	69.7	71.6	65.8
Below Normal (13%)	62.7	55.1	48.4	46.9	49.2	55.1	62.0	67.1	69.9	70.5	71.4	70.5
Dry (24%)	63.2	54.9	48.4	46.9	49.7	54.5	61.1	68.0	71.3	71.9	73.6	71.7
Critically Dry (15%)	65.9	56.9	48.5	47.5	51.1	56.5	63.2	68.6	72.4	74.3	75.5	73.3
Alternative 2												
Wet (32%)	61.6	55.1	48.7	46.5	48.0	51.9	57.4	64.7	70.1	71.9	72.0	68.5
Above Normal (16%)	61.8	54.4	48.3	47.0	48.3	52.5	59.1	66.0	68.7	69.7	71.1	69.8
Below Normal (13%)	62.5	55.3	48.5	46.9	49.2	54.8	61.7	66.0	68.2	70.4	70.3	69.2
Dry (24%)	63.1	55.0	48.4	46.9	49.8	54.6	61.1	66.9	70.1	72.0	73.8	71.3
Critically Dry (15%)	66.0	57.0	48.5	47.5	51.1	56.3	63.0	68.1	71.4	74.1	75.2	73.0
Alternative 2 minus No Action Alternative[6]												
Wet (32%)	0.6	0.0	-0.1	0.0	0.0	0.0	0.0	-0.3	-0.8	0.1	-0.3	**4.6**
Above Normal (16%)	0.2	0.1	-0.2	0.0	0.0	0.0	0.0	-0.5	**-2.1**	-0.1	-0.5	**4.0**
Below Normal (13%)	-0.2	0.2	0.1	0.0	0.0	-0.3	-0.4	**-1.1**	**-1.8**	-0.1	**-1.1**	**-1.3**
Dry (24%)	-0.1	0.1	0.0	0.0	0.0	0.1	0.0	**-1.2**	**-1.1**	0.0	0.2	-0.4
Critically Dry (15%)	0.1	0.1	0.0	0.0	0.0	-0.2	-0.2	-0.5	-0.9	-0.3	-0.3	-0.3

1 Results based on the 82-year simulation period.
2 Results displayed with calendar year - year type sorting.
3 All scenarios are simulated at ELT (Early Long-Term) Q5 with 2025 climate change and 15 cm sea level rise.
4 Water year types as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999).
5 Percent of years of each type given in parentheses.
6 Bold green font indicates greater than 1°F reduction in temperature, bold red font indicates greater than 1°F increase in temperature.

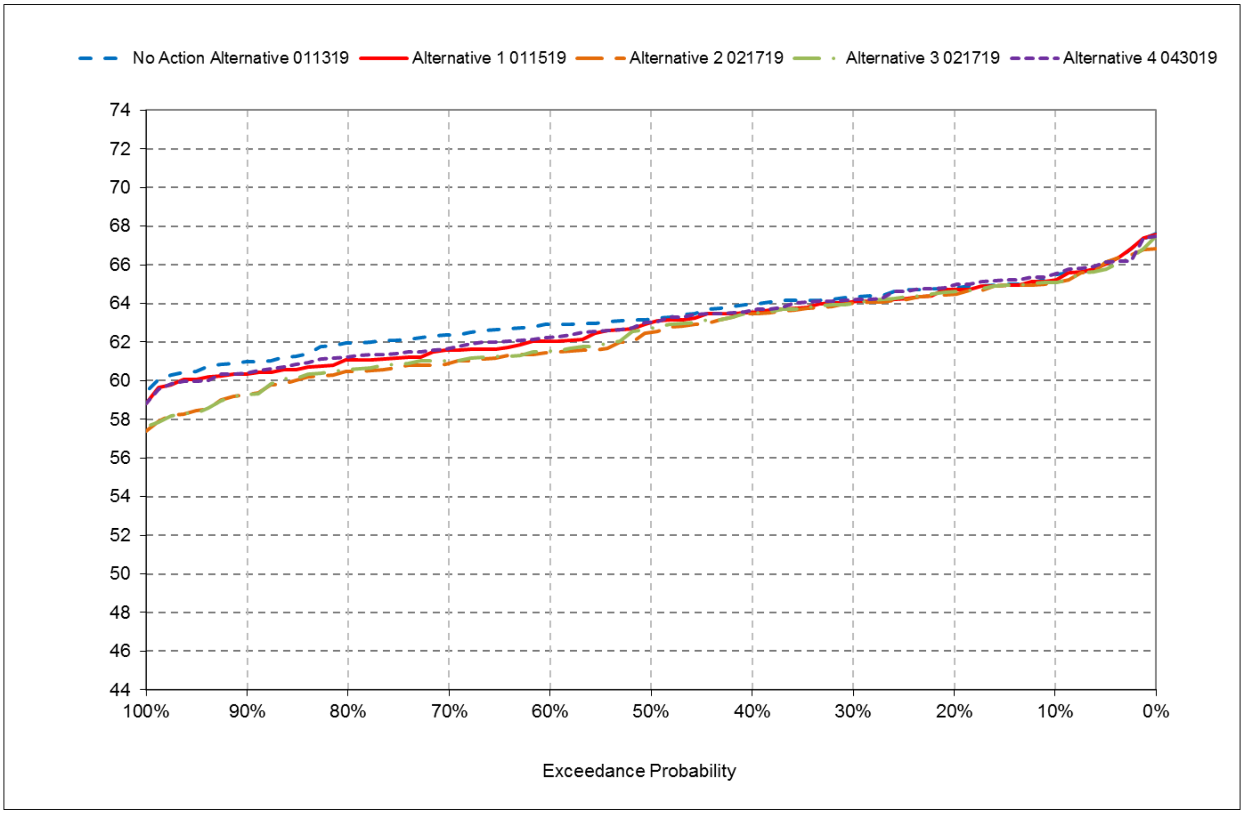


Figure O.3-90. HEC-5Q Sacramento River Water Temperatures at Hamilton CIty under the No Action Alternative and Alternative 1, Alternative 2, Alternative 3, and Alternative 4; June

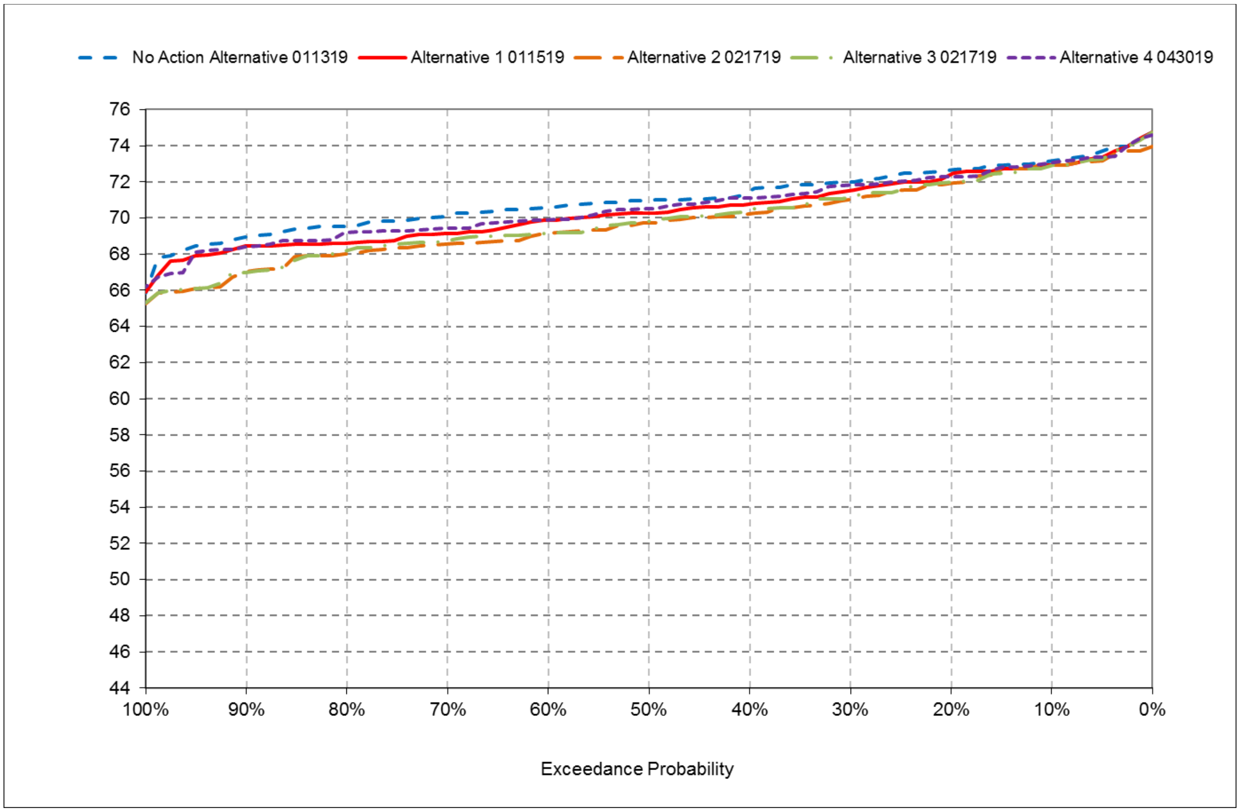


Figure O.3-91. HEC-5Q Sacramento River Water Temperatures at Knights Landing under the No Action Alternative and Alternatives 1, Alternative 2, Alternative 3, and Alternative 4; June

Table O.3-32. CalSim II Monthly Average Flow (cfs) by Water Year Type and Month at Red Dluff Diverson Dam for No Action Alternative, Alternative 2 and Differences between Them

Alternative[1,2,3] Water Year Type[4]	Monthly Flow (cfs)											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
No Action Alternative												
Wet (32%)[5]	8,728	12,255	12,422	29,982	31,345	25,200	14,018	11,059	9,426	12,709	9,781	14,320
Above Normal (16%)	7,927	12,554	11,235	16,772	26,458	16,158	9,459	9,611	10,203	14,275	9,759	10,210
Below Normal (13%)	6,820	6,705	11,915	7,608	12,849	7,303	6,118	8,845	10,980	13,721	10,131	5,837
Dry (24%)	6,538	7,784	15,279	7,303	9,573	9,042	6,326	8,214	10,498	12,221	8,358	5,349
Critically Dry (15%)	5,338	5,218	6,394	6,318	6,527	5,955	5,159	7,866	9,252	10,848	7,654	4,954
Alternative 2												
Wet (32%)	8,524	8,615	14,124	30,274	31,609	25,257	14,102	11,359	10,257	12,501	10,155	8,208
Above Normal (16%)	8,510	8,903	11,437	17,721	27,515	16,537	9,390	10,253	12,554	14,130	10,237	6,037
Below Normal (13%)	6,809	6,674	11,220	8,760	12,958	8,073	6,572	10,078	12,874	13,738	11,206	6,916
Dry (24%)	6,659	7,907	14,831	7,282	9,200	8,779	6,387	9,493	11,448	12,037	8,216	5,746
Critically Dry (15%)	5,326	5,214	6,326	6,123	6,496	6,504	5,348	8,357	10,206	11,085	7,859	5,245
Alternative 2 minus No Action Alternative[6]												
Wet (32%)	-204	**-3,640**	**1,702**	292	264	57	84	301	**831**	-208	374	**-6,112**
Above Normal (16%)	**583**	**-3,651**	203	**949**	1,057	379	-69	**643**	**2,350**	-145	478	**-4,172**
Below Normal (13%)	-11	-31	**-694**	**1,152**	110	**769**	**454**	**1,233**	**1,894**	17	**1,074**	**1,079**
Dry (24%)	121	123	-448	-21	-372	-264	61	**1,280**	**950**	-185	-142	**398**
Critically Dry (15%)	-12	-4	-68	-195	-31	**549**	189	**491**	**954**	237	205	**291**

1 Results based on the 82-year simulation period.
2 Results displayed with calendar year - year type sorting.
3 All scenarios are simulated at ELT (Early Long-Term) Q5 with 2025 climate change and 15 cm sea level rise.
4 Water year types as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999).
5 Percent of years of each type given in parentheses.
6 Bold green font indicates greater than 5% increase in flow; bold red font indicates greater than 5% reduction in flow.

Table O.3-33. CalSim II Monthly Average Flow (cfs) by Water Year Type and Month at Hamilton City for No Action Alternative, Alternative 2 and Differences between Them

Alternative[1,2,3] Water Year Type[4]	Monthly Flow (cfs)											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
No Action Alternative												
Wet (32%)[5]	8,219	12,548	13,755	33,783	35,092	28,342	16,376	11,144	8,207	10,450	7,770	13,867
Above Normal (16%)	7,425	12,867	12,385	19,430	29,641	18,802	11,052	8,831	8,368	11,840	7,780	9,701
Below Normal (13%)	6,440	6,788	13,003	8,908	14,535	8,530	7,083	7,429	8,757	11,240	8,168	5,345
Dry (24%)	5,989	8,176	17,167	8,112	11,042	10,647	7,244	6,779	8,089	9,728	6,468	4,801
Critically Dry (15%)	4,854	5,153	7,089	6,934	7,312	6,875	5,290	6,238	7,000	8,573	5,874	4,436
Alternative 2												
Wet (32%)	8,015	8,908	15,457	34,075	35,356	28,399	16,459	11,439	9,032	10,260	8,138	7,758
Above Normal (16%)	8,008	9,220	12,592	20,379	30,698	19,181	10,983	9,470	10,695	11,722	8,258	5,529
Below Normal (13%)	6,429	6,760	12,309	10,060	14,645	9,299	7,536	8,647	10,637	11,194	9,261	6,426
Dry (24%)	6,109	8,299	16,719	8,092	10,670	10,383	7,305	8,043	9,040	9,539	6,327	5,201
Critically Dry (15%)	4,848	5,149	7,021	6,739	7,281	7,424	5,479	6,714	7,948	8,809	6,111	4,753
Alternative 2 minus No Action Alternative[6]												
Wet (32%)	-204	**-3,640**	**1,703**	292	264	57	84	295	**825**	-190	368	**-6,109**
Above Normal (16%)	**583**	**-3,647**	208	949	1,057	379	-69	**639**	**2,328**	-118	**478**	**-4,172**
Below Normal (13%)	-11	-28	**-694**	**1,152**	110	**769**	**454**	**1,218**	**1,880**	-47	**1,094**	**1,081**
Dry (24%)	121	123	-448	-21	-372	-264	61	**1,263**	**951**	-189	-142	**400**
Critically Dry (15%)	-6	-4	-68	-195	-31	**549**	189	**476**	**949**	237	237	**317**

1 Results based on the 82-year simulation period.
2 Results displayed with calendar year - year type sorting.
3 All scenarios are simulated at ELT (Early Long-Term) Q5 with 2025 climate change and 15 cm sea level rise.
4 Water year types as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999).
5 Percent of years of each type given in parentheses.
6 Bold green font indicates greater than 5% increase in flow; bold red font indicates greater than 5% reduction in flow.

Table O.3-34. CalSim II Monthly Average Flow (cfs) by Water Year Type and Month at Wilkins Slough for No Action Alternative, Alternative 2 and Differences between Them

Alternative[1,2,3] Water Year Type[4]	Monthly Flow (cfs)											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
No Action Alternative												
Wet (32%)[5]	7,511	12,176	11,622	18,870	19,567	17,810	14,598	9,612	6,426	7,574	5,293	13,916
Above Normal (16%)	6,711	11,184	11,185	16,976	18,484	17,432	12,412	7,174	6,171	8,650	5,448	9,654
Below Normal (13%)	6,046	6,466	11,361	10,381	13,627	9,842	7,454	5,489	5,958	7,948	5,637	5,132
Dry (24%)	5,215	8,027	12,724	9,098	12,422	12,174	8,077	4,381	5,159	6,678	4,291	4,665
Critically Dry (15%)	4,072	4,733	7,847	8,021	8,590	8,066	5,306	3,683	4,176	5,648	3,817	4,154
Alternative 2												
Wet (32%)	7,547	8,450	12,284	18,868	19,583	17,786	14,684	9,903	7,239	7,355	5,691	7,796
Above Normal (16%)	7,503	7,157	11,329	17,508	19,060	17,407	12,361	7,824	8,469	8,448	5,983	5,480
Below Normal (13%)	6,019	6,446	10,958	11,107	13,832	10,522	7,898	6,691	7,795	7,851	6,785	6,187
Dry (24%)	5,319	8,224	12,723	9,041	12,253	12,092	8,148	5,639	6,044	6,472	4,191	5,087
Critically Dry (15%)	4,065	4,749	7,796	7,809	8,570	8,616	5,467	4,161	5,110	5,856	4,073	4,478
Alternative 2 minus No Action Alternative[6]												
Wet (32%)	36	**-3,727**	**662**	-2	17	-23	86	290	**813**	-219	**399**	**-6,121**
Above Normal (16%)	**791**	**-4,028**	144	532	576	-25	-51	**650**	**2,298**	-202	**535**	**-4,174**
Below Normal (13%)	-27	-20	-403	**727**	205	**680**	**444**	**1,201**	**1,837**	-97	**1,148**	**1,056**
Dry (24%)	105	197	0	-58	-169	-82	71	**1,258**	**885**	-206	-100	**422**
Critically Dry (15%)	-7	16	-51	-211	-20	**550**	162	**478**	**935**	208	**256**	**323**

1 Results based on the 82-year simulation period.
2 Results displayed with calendar year - year type sorting.
3 All scenarios are simulated at ELT (Early Long-Term) Q5 with 2025 climate change and 15 cm sea level rise.
4 Water year types as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999).
5 Percent of years of each type given in parentheses.
6 Bold green font indicates greater than 5% increase in flow; bold red font indicates greater than 5% reduction in flow.

The reduced downstream warming of the river in September of wet and above normal water years under the No Action Alternative relative to the Alternative 2 is due, at least in part, to the much higher flow releases for Fall X2, as noted above (Table O.3-25). Note that November Fall X2 flow releases under the No Action Alternative do not result in higher water temperatures under Alternative 2 (e.g., Table O.3-31), presumably because November air temperatures would, on average, be similar to or lower than the water temperatures.

It is expected that, in general, water temperatures between the No Action Alternative and Alternative 2 would be largely similar, with the exception of September of wet and above normal water years, when water temperatures are warmer under the Alternative 2 because this alternative would not include the Fall X2 flows that reduce downstream warming under the No Action Alternative, and with the exception of May, June, August and September of various water year types at the most downstream locations, when water temperatures are cooler under Alternative 2 because of higher flows.

O.3.5.2.1 Sacramento River Winter-Run Chinook Salmon

Spawning and Egg/Alevin Incubation

Winter-Run Chinook Salmon adults spawn from May through August with peak spawning during June and July (Section O.2.4.2.1, *Winter-Run Chinook Salmon*). Fry emergence occurs up to 3 months after eggs are spawned, so effects of flow and water temperature on Winter-Run eggs and alevins may occur from May through November, but primarily occur during June through October.

As previously noted, CalSim II modeling indicates that mean monthly flow released at Keswick Dam under Alternative 2 would generally be higher than or similar to flow under No Action Alternative, except in wet and above normal water years during September and November, when the Alternative 2 flows would be substantially lower than the No Action Alternative flows (Table O.3-25). By September in most years, a large proportion of Winter-Run Chinook Salmon redds still contain incubating alevins. Assuming flows are stable enough to avoid dewatering the redds, which is generally true in September, the most important effect of flows on alevins is to transport dissolved oxygen to the developing alevins and to flush potentially toxic metabolites out of the redds. Although the mean September wet and above normal water year flows are substantially lower under Alternative 2 than under the No Action Alternative, the flows under Alternative 2 flows remain moderately high (>6,000 cfs) (Figure O.3-25). Flows at this level are expected to provide sufficient flow velocity to keep the redds clean and well oxygenated. With regard to redd dewatering, there are some reductions in mean monthly flows below Keswick Dam during the fall under Alternative 2, but these are similar to the fall reductions expected under the No Action Alternative (Table O.3-25). Therefore, differences in flow between the No Action Alternative and Alternative 2 are expected to have little effect on Winter-Run Chinook Salmon spawning and incubation habitat.

As noted in the previous section, there are few differences between the No Action Alternative and Alternative 2 in the HEC-5Q water temperature results for the Winter-Run Chinook Salmon spawning period (Table O.3-26). The largest difference for the Keswick Dam location, a 1.3°F increase in September of Above Normal water years under Alternative 2, would occur within a range of temperature well below the 53.5°F water temperature threshold, and therefore would not affect Winter-Run Chinook Salmon eggs or alevins. The mean October water temperatures at Keswick are predicted to be above the water temperature threshold in about 85% of years under both the No Action Alternative and Alternative 2 (Figure O.3-18). September mean monthly water temperatures exceed the threshold in critically dry water years under both alternatives (Table O.3-26). At the more downstream Winter-Run Chinook Salmon spawning locations, the September water temperatures exceed the threshold for more of the water year types (Tables O.3-27 and O.3-28). At these location, water temperature increases between the No Action Alternative and Alternative 2 for September of wet and above normal water years result in water temperatures approaching or exceeding the 53.5°F temperature threshold under Alternative 2, but not under the No Action Alternative, which would result in adverse effects on Winter-Run Chinook Salmon eggs and alevins under Alternative 2.

Recent investigations of Winter-Run Chinook Salmon mortality in the upper Sacramento River (Martin et al. 2017; Anderson 2018) yielded models for estimating mortality of Winter-Run Chinook Salmon eggs and alevins under different water temperature conditions. These models, referred to hereinafter as the

Martin and Anderson models, were used to compare water-temperature-related mortality of Winter-Run Chinook Salmon eggs and alevins under Alternative 2 and the No Action Alternative. The modeling was based on the HEC-5Q water temperature estimates for the years used in the HEC-5Q modeling (1922 to 2002). The results for all water year types combined indicate that egg/alevin mortality under Alternative 2 would be similar to that under the No Action Alternative (Figure O.3-92). Figure O.3-92 combines results for all water year types, including wet years, when there is little temperature-related mortality. This obscures the modeling results for drier years, when egg/alevin mortalities are especially high. For critically dry water years, the mortality modeling also shows little difference in mortality between Alternative 2 and the No Action Alternative (Figure O.3-93).

The flow effects resulting from Alternative 2 would have a less-than-significant effect relative to the No Action Alternative on Winter-Run Chinook Salmon spawning and the egg and alevin life stages, but the water temperature effects would have a significant adverse impact relative to the No Action Alternative because of the temperature increases in September of wet and above normal water years.

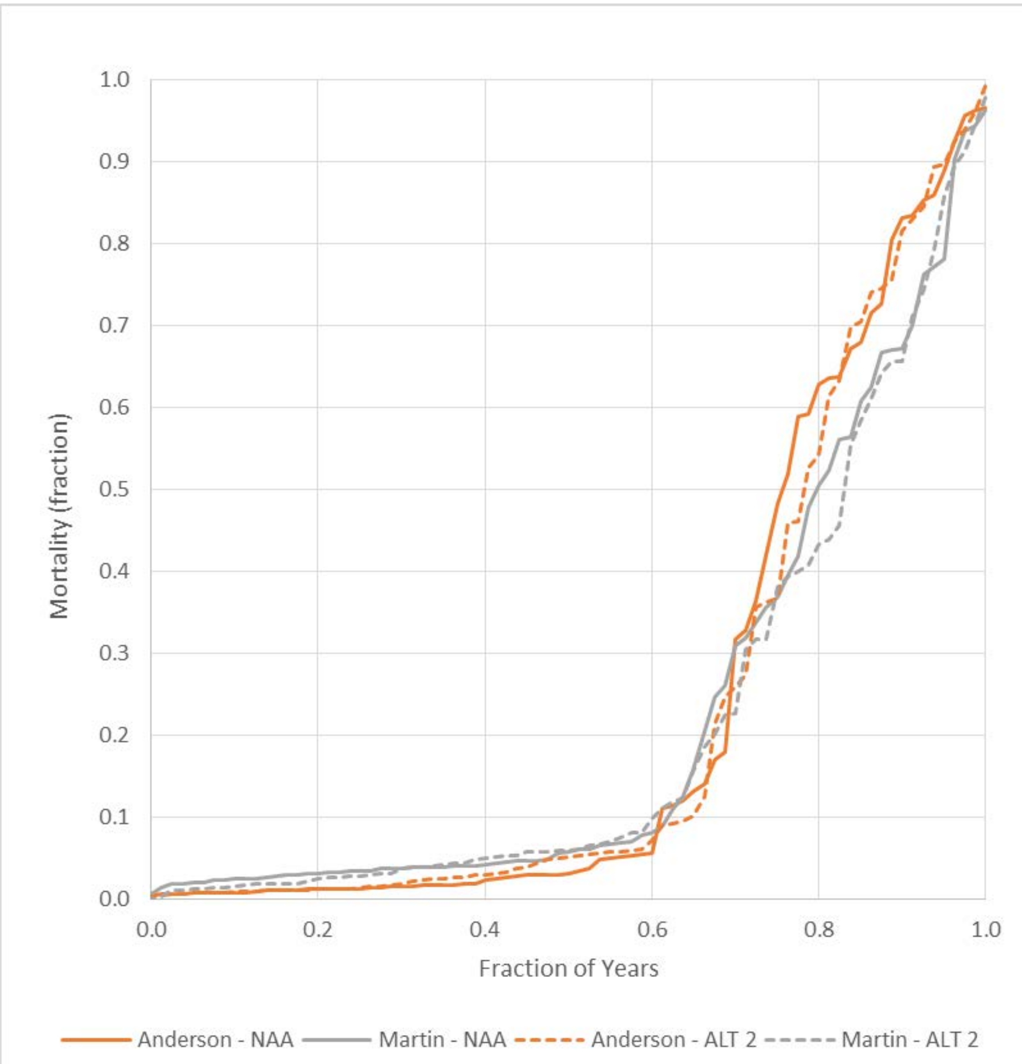


Figure O.3-92. Exceedances of Winter-Run Chinook Salmon Temperature-Dependent Egg Mortality, Alternative 2 vs. No Action Alternative; All Water Year Types.

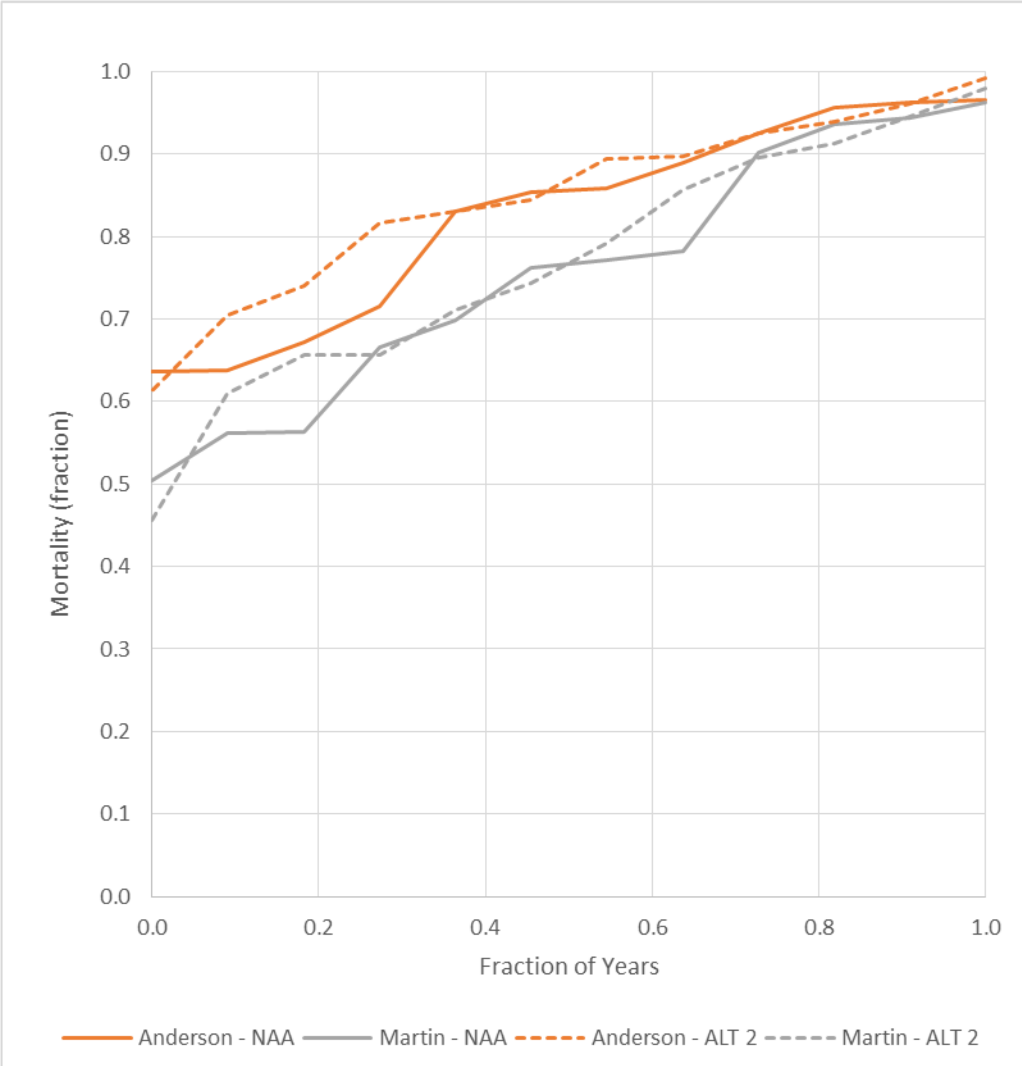


Figure O.3-93. Exceedances of Winter-Run Chinook Salmon Temperature-Dependent Egg Mortality, Alternative 2 vs. No Action Alternative; Critically Dry Water Years

Juvenile Rearing and Emigration

Winter-Run Chinook Salmon juveniles rear in the Sacramento River primarily from late summer to late winter, and emigrate from the river to the Delta beginning in November (see Section O.2.4.2.1, *Winter-Run Chinook Salmon*). The proportion of juveniles surviving to emigrate to the Delta depends largely on habitat conditions, including flow and water temperature. Inundated floodplain habitat has been shown to benefit growth and survival of juvenile salmon (Sommer et al. 2001, 2005; Katz et al. 2017), but natural flood flows largely determine the availability of this habitat, rather than operations of the CVP and SWP dams.

Sacramento River flow during the Winter-Run Chinook Salmon juvenile rearing and emigration period differs substantially between the No Action Alternative and Alternative 1, especially during September and November of wet and above normal water years (Tables O.3-25, O.3-32 through O.3-34). The juveniles rear primarily in the upper and middle Sacramento River until about October, when they begin to appear in the lower river (e.g., Knights Landing) (del Rosario et al. 2013). As noted previously, because the No Action Alternative includes Fall X2 releases but Alternative 2 does not, the mean monthly flows during September and November are much lower under Alternative 2 than under the No Action Alternative, which would potentially reduce suitable rearing habitat for juveniles (Tables O.3-25 and O.3-32 through O.3-34; Figures O.3-25, O.3-28 and O.3-29).

Emigration of juvenile Winter-Run Chinook Salmon from the Sacramento River is triggered by pulse flows of about 14,000 cfs and above (at Wilkins Slough) (del Rosario et al. 2013). CalSim II September flows at Wilkins Slough exceed this threshold in about 18% of years under the No Action Alternative and never exceed it under Alternative 2, but September is too early for juvenile Winter-Run Chinook Salmon to emigrate to the Delta (del Rosario et al. 2013). For November, when Winter-Run juveniles are ready to emigrate, monthly mean flow at Wilkins Slough is much higher under the No Action Alternative than under Alternative 2, but remains below the 14,000 cfs threshold for both alternatives, except for the highest 9% of flows (Figure O.3-29). There are no differences between the alternatives for these highest flows. An important limitation with this analysis is that the CalSim II flow estimates are monthly averages and Winter-Run Chinook Salmon emigration can be triggered by flow pulses that exceed 14,000 cfs for only a few days (del Rosario et al. 2013), so the flow differences in Figure O.3-29 incompletely represent the likelihood of triggering pulse flows occurring under the two alternatives.

Results from a more recent analysis suggest that the reduction in November flows from the No Action Alternative to Alternative 2 during wet and above normal water years could adversely affect Winter-Run Chinook Salmon juveniles emigrating at that time. The NMFS Southwest Fisheries Science Center ran statistical models using 2012-2017 tagging data from Spring-Run Chinook Salmon and Fall-Run Chinook Salmon and found a significant increase in smolt survival when Sacramento River flow at Wilkins Slough was above 9,100 cfs during the smolts out-migration period (Cordoleani et al. 2019). The CalSim II results for November at Wilkins Slough indicate that, under the No Action Alternative, 50% of years would have mean monthly flows that exceed the 9,100 cfs threshold, but that under Alternative 2 only 20% of years would exceed the threshold (Figure O.3-29). If these results apply to Winter-Run Chinook Salmon juveniles emigrating in November, they indicate a potential adverse effect of Alternative 2 on emigrating Winter-Run juveniles. The applicability of the results to Winter-Run Chinook Salmon are currently unknown, so the effect on Winter-Run Chinook Salmon is uncertain.

The USEPA (2003) gives 61°F as the critical 7 day average daily maximum (7DADM) water temperature for Winter-Run Chinook Salmon juveniles rearing in the upper Sacramento River and 64°F (7DADM) for those rearing in the middle Sacramento River (Knights Landing). Under the No Action Alternative, NMFS's RPA 1.2.4 requires Reclamation to maintain water temperature from May 15 through October 31 in the Sacramento River at no more than 56°F at compliance locations between Ball's Ferry and Red Bluff Diversion Dam. Under Alternative 2, SWRCB's WRO 90-5 has similar but more flexible water temperature requirements for Reclamation (NMFS 2011, RPA 1.2.4; SWRCB 1990, WRO-90-5). Therefore, under both alternatives, juveniles rearing in the upper Sacramento River are likely to be well protected from water temperature extremes through the end of October in all but the driest years.

Under the No Action Alternative and Alternative 2, mean monthly water temperatures at Keswick exceed the 61°F threshold in only about 5% of years in September and October, with no appreciable water temperatures differences between the alternatives for water temperatures greater than the 61 degree Fahrenheit threshold (Figures O.3-18 and O.3-19; Table O.3-26). The monthly average temperatures for these months should reasonably estimate daily mean temperatures because operations at Shasta and Keswick dams create relatively stable summer and fall flow and water temperature conditions in the upper Sacramento River. From November through March, by which months most juvenile Winter-Run Chinook Salmon have emigrated to the Delta, there are only minor differencs in mean water temperatures at all locations from Keswick Dam to Knights Landing (Tables O.3-26 through O.3-31).

The water temperature effects on juvenile Winter-Run Chinook Salmon rearing in or emigrating from the Sacramento River resulting from Alternative 2 would be less-than-significant relative to the No Action Alternative, but the flow effects are potentially significant because the reductions in September flows in wet and above normal water years could reduce rearing habitat and the reductions November flows in wet and above normal water years could reduce smolt survival.

Adult Upstream Migration and Holding

Winter-Run Chinook Salmon adults enter the Sacramento River from the Delta and make their way to the upper Sacramento River, beginning as early as December. They hold in the upper River within 10 to 15 miles of Keswick Dam until they are ready to spawn, which may extend through August (Windell et al. 2017).

There are no flow or temperature requirements for the middle Sacramento River designed to protect fish. However, releases from Shasta Reservoir during November through early May may be reduced to conserve water for the May through October Winter-Run and Spring-Run Chinook Salmon spawning and incubation periods, resulting in reduced flow in the middle river (NMFS 2011: RPA I.2.2; SWRCB 1990: WRO 90-5). Lower flow in the Sacramento River relative to flow from the lower Yolo and Sutter bypasses and agricultural drains may affect navigation cues and straying of Winter-Run Chinook Salmon adults into canals and behind weirs, increasing their stranding risk. Once the adults reach holding habitat in the upper Sacramento River, they are more directly affected by Shasta and Keswick reservoir operations designed to preserve cold water for the Winter-Run and Spring-Run Chinook Salmon spawning and incubation periods. During the December through August period of adult Winter-Run Chinook Salmon immigration and holding, the mean monthly flows under Alternative 2 at Keswick Dam, RBDD, Hamilton City and Wilkins Slough would generally be similar to or greater than flows under the No Action Alternative, except during December of below normal water years at Keswick, RBDD and Hamilton City (Tables O.3-25, O.3-32 through O.3-34). However, the mean monthly CalSim II flows in December of below normal water years are greater than 6,500 cfs at all four sites for both alternatives, which is much higher than needed enough to allow upstream passage.

The USEPA (2003) gives 68°F as the critical 7DADM water temperature for Winter-Run Chinook Salmon adults migrating upstream in the Sacramento River and 61°F for adult Winter-Run holding in the upper river. There are no major differences in HEC-5Q water temperature estimates between the No Action Alternative and Alternative 2 during any of the months that adult Winter-Run Chinook Salmon migrate upstream in the Sacramento River or hold in the upper river (Tables O.3-26 through O.3-31). However, the monthly mean water temperatures are moderately cooler under Alternative 2 at Hamilton City and Knights Landing sites during May, June and August in some of the water year types (Tables O.3-30 and O.3-31). Under both alternatives, the mean monthly water temperatures in the middle Sacramento River (Knights Landing) would be below the 68°F threshold for immigrating adults from December through April, but would exceed the threshold in May of critically dry water years and June through August of all water year types (Table O.3-31). Most Winter-Run Chinook Salmon adults have migrated upstream of RBDD by late May (see Section O.2.4.2.1, *Winter-Run Chinook Salmon*) and would therefore not be adversely affected by the elevated summer downstream water temperatures. In the upper Sacramento River from Keswick to Balls Ferry, the mean water temperatures would be well below the 61°F threshold for holding adults from December through August under both alternatives (Table O.3-26, O.3-27, and O.3-28).

Alternative 2 is expected to have a less-than-signficant effect on Winter-Run Chinook Salmon adult upstream migration and holding relative to the No Action Alternative.

O.3.5.2.2 Central Valley Spring-Run Chinook Salmon

O.3.5.2.3 Spawning and Egg/Alevin Incubation

Spring-Run Chinook Salmon adults spawn from August through October with peak spawning in September (see Section O.2.4.2.2, *Spring-Run Chinook Salmon*). Monitoring Spring-Run Chinook Salmon spawning in the mainstem Sacramento River is complicated due to lack of spatial/geographic segregation and temporal isolation from Fall-Run Chinook Salmon. Most spring-sun spawning occurs between the Keswick Dam and Ball Ferry Bridge (NMFS 2017b). Fry emergence occurs up to 3 months after eggs are spawned (Moyle 2002), so effects of flow in the upper Sacramento River on incubating Spring-Run Chinook Salmon eggs and alevins potentially occur from August through January, peaking in December.

As previously noted, CalSim II modeling indicates that mean monthly flow released at Keswick Dam under Alternative 2 would generally be higher than or similar to flow under No Action Alternative, except in wet and above normal water years during September and November, when the Alternative 2 flows would be substantially lower (up to 43% lower) than the No Action Alternative flows (Table O.3-25). Spawning and incubating eggs and alevins could be negatively or positively affected by the flow reductions. Assuming flows are stable enough to avoid dewatering the redds, which as noted previously is an important criterion for operators of Shasta and Keswick dams, the most important effect of flows on eggs and alevins is to transport dissolved oxygen to the developing eggs and alevins and to flush potentially toxic metabolites out of the redds. Although the mean September and November wet and above normal water year flows are substantially lower under Alternative 2 than under the No Action Alternative, the flows under Alternative 2 flows remain sufficiently high (>5,900 and >7,700 cfs for September and November, respectively) to provide the flow velocity needed to keep most redds clean and well oxygenated (Figure O.3-25). Therefore, differences in flow between the No Action Alternative and Alternative 2 are expected to have little effect on Spring-Run Chinook Salmon spawning and incubation habitat.

Differences in water temperature during the Spring-Run Chinook Salmon spawning period may be important. As described previously, HEC-5Q mean October water temperatures at Keswick Dam under Alternative 2 are predicted to be similar to the No Action Alternative and above the 53.5°F water temperature threshold in in most years (Figure O.3-18; Tables O.3-26). Summer mean monthly water temperatures are consistently below the 53.5°F temperature threshold, except in critically dry water years during August through October. For October, the mean water temperature for critically dry water years is 0.7°F higher than those under the No Action Alternative. Although this difference in mean October critically dry water year water temperatures between the No Action Alternative and Alternative 2 is not large, it occurs under highly stressful temperature conditions for salmonid eggs and alevins. The largest predicted increase in mean water temperature under Alternative 2 is 1.3°F for September of Above Normal water years (Table O.3-26). This increase occurs over a range well below the critical temperature threshold and is therefore unlikely to have a large effect on the salmonids. The differences between the No Action Alternative and Alternative 2 in September water temperatures at Keswick Dam are generally small (Figure O.3-20).

Between the Clear Creek confluence and Balls Ferry, where more of the Spring-Run Chinook Salmon spawning occurs, more of the October mean monthly water temperatures under Alternative 2 exceed the threshold in all years, but most of them continue to be above or equal to the No Action Alternative means (Tables O.3-27 and O.3-28). September water temperatures in wet and above normal water years are expected to be higher under Alternative 2 than under the No Action Alternative, especially downstream of Keswick Dam (Tables O.3-27 through O.3-31), and the increases would result in more years with mean water temperatures exceeding the 53.5°F water temperature threshold (Figures O.3-30 and O.3-31). At Balls Ferry, the temperatures are even higher than at Clear Creek and the September increases are larger (Table O.3-28). September water temperatures for wet and above normal water years at Balls Ferry exceed the critical water temperature threshold under Alternative 2, but not under the No Action Alternative (Table O.3-28). Because the mean monthly water temperatures are higher than the threshold under Alternative 2, the probability or frequency of the threshold being exceeded by daily mean temperatures in September of wet and above normal water years is expected to be higher under Alternative 2 than under the No Action Alternative. The critical temperature threshold for spawning adult Chinook Salmon in the Sacramento River is the same as that for eggs and alevins, 53.5°F (Martin et al. 2017) or 55.4°F (USEPA 2003).

The HEC-5Q modeling results, which show an increased exceedance of the 53.5°F water temperature threshold during September under Alternative 2 relative to the No Action Alternative, suggest that Alternative 2 would have a significant adverse impact on Spring-Run Chinook Salmon spawning and egg and alevin incubation. It is concluded that Alternative 2 would have a significant impact on Spring-Run Chinook Salmon spawning and egg and alevin incubation with respect to water temperature.

O.3.5.2.4 Juvenile Rearing and Emigration

Spring-Run Chinook Salmon juveniles rear in the Sacramento River primarily from November through early May and most emigrate to the Delta during December and again in March and April (see Section O.2.4.2.2, *Spring-Run Chinook Salmon*). Migratory cues, such as increased flow and/or turbidity from runoff, may spur emigration of juveniles from the upper Sacramento River basin when they have reached the appropriate stage of maturation (NMFS 2009). Inundated floodplain habitats have been shown to benefit growth and survival of juvenile salmon (Sommer et al. 2001, 2005; Katz et al. 2017), but natural flood flows largely determine the availability of this habitat, rather than operations of the CVP and SWP dams.

Based on the CalSim II modeling results, during most of the Spring-Run Chinook Salmon juvenile rearing and emigration period, Sacramento River flow would be higher under Alternative 2 than under the No Action Alternative and many of the increases would be greater than 5% (Table O.3-25). However, the mean monthly flows for November of wet and above normal water years would be much lower under Alternative 2, because of the Fall X2 flows that are included in the No Action Alternative but not Alternative 2. Despite the reductions, the November flows under Alternative 2 remain relatively high (Tables O.3-25 and O.3-32 through O.3-34; Figures O.3-28 and O.3-29), so they are not expected to substantially affect rearing juveniles. Furthermore, as noted above, emigration occurs primarily in December and in the spring. Mean monthly flows would also be lower under Alternative 2 in January of critically dry water years, December, February and March of dry water years and December of below normal water years, (Tables O.3-25 and O.3-32 through O.3-33). Of these, only reductions in December of below normal years and February of dry years are greater than 5%. Results from a recent study suggest that for Spring-Run Chinook Salmon that do emigrate as early as November, the Alternative 2 flow reductions in November of wet and above normal water years would have a potentially adverse effect. The NMFS Southwest Fisheries Science Center ran statistical models using 2012-2017 tagging data from Spring-Run Chinook Salmon and Fall-Run Chinook Salmon and found a significant increase in smolt survival when Sacramento River flow at Wilkins Slough was above 9,100 cfs during the smolts emigration period (Cordoleani et al. 2019). The CalSim II results for November at Wilkins Slough indicate that 50% of years would have mean monthly flows that exceed the 9,100 cfs threshold under the No Action Alternative, and 20% of years would have flows that exceed the threshold under Alternative 2 (Figure (O.3-29). As shown by recent sampling at RBDD (Figure O.3-31-A), almost all Spring-Run Chinook Salmon juveniles emigrate from the upper Sacramento River after November, so the percentage of Spring-Run juveniles that would be affected by the expected reductions in November flows at Wilkins Slough would be small. Therefore changes in flow resulting from Alternative 2 are not expected to substantially affect rearing and emigrating juvenile Spring-Run Chinook Salmon.

The USEPA (2003) gives 61°F as the critical 7 day average daily maximum (7DADM) water temperature for Spring-Run Chinook Salmon juveniles rearing in the upper Sacramento River and 64°F (7DADM) for those rearing in the middle Sacramento River (Knights Landing). Under the No Action Alternative and Alternative 2, HEC-5Q estimates of mean monthly water temperatures from Keswick to RBDD do not exceed the 61°F threshold during any month and water year type during the November through May rearing period (Tables O.3-26 through O.3-29). The mean monthly water temperatures for Hamilton City do not exceed the 64°F threshold for the middle Sacramento River during any of the months, but the mean monthly water temperatures for May exceed the middle river threshold at Knights Landing in all water year types under both alternatives. However, the May temperatures are consistently lower under Alternative 2 than the No Action Alternative, especially in below normal and dry water years (Table O.3-31). These results indicate that water temperature conditions would be too warm for juvenile Spring-Run Chinook Salmon rearing and emigrating in the middle Sacramento River during May, but would be improved under Alternative 2 relative to the No Action Alternative. It should be noted that May is the last month during spring or summer that Spring-Run Chinook Salmon juveniles are found in the middle river, and it is likely that when water temperatures are too high they emigrate to the ocean before May. However, early emigration could have other adverse effects.

The flow and water temperature effects resulting from Alternative 2 would have a less-than-significant effect relative to the No Action Alternative on juvenile Spring-Run Chinook Salmon in the Sacramento River.

O.3.5.2.5 Adult Upstream Migration and Holding

Spring-Run Chinook Salmon adults enter the Sacramento River from the Delta as early as January and make their way to the upper Sacramento River beginning in February, where they hold until ready to spawn in late summer and early fall (Windell et al. 2017). Adults may continue migrating upstream until August, and holding continues until October when spawning is complete. There are no flow or temperature requirements for the middle Sacramento River designed to protect fish. Once the adults reach holding habitat in the upper Sacramento River, they are more directly affected by Shasta and Keswick reservoir operations designed to preserve cold water for the Winter-Run and Spring-Run Chinook Salmon spawning and incubation periods.

During the January through August period of adult Spring-Run Chinook Salmon immigration, the mean monthly CalSim II flows under Alternative 2 at Keswick, RBDD, Hamilton City, and Wilkins Slough would generally be similar to or greater than those under the No Action Alternative (Tables O.3-25 and O.3-32 through O.3-34). During the holding period, September flow in wet and above normal years would be much lower under Alternative 2 than under the No Action Alternative (Tables O.3-25 and O.3-32 through O.3-34; Figure O.3-25), but the mean September Alternative 2 flows at Keswick Dam would not fall below 6,000 cfs over the range of flows for which the alternatives have major flow differences (i.e., upper 50% in Figure O.3-25). A flow of 6,000 cfs would presumably be sufficient to maintain good water quality conditions in the Spring-Run Chinook Salmon holding habitats. Note that monthly mean flows for these months should reasonably estimate daily mean flows because operations at Shasta and Keswick dams create relatively stable summer and fall flow and water temperature conditions in the upper Sacramento River.

The USEPA (2003) gives 68°F as the critical 7DADM water temperature for Spring-Run Chinook Salmon adults migrating upstream in the Sacramento River and 61°F for adult Spring-Run holding in the upper river. Throughout the January through August period of Spring-Run Chinook Salmon upstream migration, HEC-5Q water temperatures for Alternative 2 are similar to or slightly lower than those for the No Action Alternative, including greater than 1°F reductions in mean monthly water temperature for May, June, and August in various water year types at Hamilton City and Knights Landing (Tables O.3-26 through O.3-31). Under both alternatives, the mean monthly water temperatures in the middle Sacramento River (Knights Landing) would be below the 68°F threshold for immigrating adults from December through April, but would exceed the threshold in May of critically dry water years and in June through August of all water year types (Table O.3-31). The high May through August water temperatures would be likely to adversely affect any Spring-Run Chinook Salmon adults that were migrating upstream in those months. High water temperatures were found to cause adult Spring-Run Chinook Salmon in Butte Creek to terminate their upstream migrations, which made them more susceptible to mortality from rising water temperatures (Mosser et al. 2012). The June temperature reductions under Alternative 2 occur in a range slightly above the 68°F threshold and, therefore, would likely have a beneficial effect on upstream migrating adults. In the upper Sacramento River at Keswick Dam to Balls Ferry, the mean water temperatures under both alternatives would be well below the 61°F threshold for holding adults from February through October (Tables O.3-26 through O.3-28). As previously noted, flow below Keswick Dam is relatively stable during the summer and fall months, so monthly mean flows and temperatures are likely to be fairly representative of daily means in those months.

May through August water temperature reductions under Alternative 2, especially in the middle Sacramento River are expected to have a beneficial effect on adult Spring-Run Chinook Salmon migrating upstream to spawn. Temperatures in the upper River under Alternative 2 and changes in flow in the upper and middle River are expected to have a less-than-significant impact on migrating and holding adults. Therefore, Alternative 2 is expected to have a less-than-significant effect relative to the No Action Alternative on Spring-Run Chinook Salmon with respect to flow, and a minor beneficial effect with respect to water temperature.

O.3.5.2.6 Central Valley Steelhead

Spawning and Egg Incubation

CV steelhead adults spawn from November through April with peak spawning from January through March. Based on the general timing of hatching and fry emergence, eggs and alevins may occur from November through May. Little is known about steelhead spawning locations in the Sacramento River, but it is generally assumed that spawning occurs primarily between Keswick Dam and RBDD.

During the steelhead spawning and incubation period, CalSim II modeling indicates that Alternative 2 flows would be substantially lower than No Action Alternative flows in November of wet and above normal water years (Table O.3-25). Reductions in mean monthly flow of approximately 3,500 cfs under Alternative 2 would increase the amount of available spawning habitat (as measured by WUA) by approximately 18% relative to the No Action Alternative (Figure WUA-SH-S). However, in subsequent months, Alternative 2 flows would generally be higher than those under the No Action Alternative, reducing the amount of available spawning habitat. For example, higher flows under Alternative 2 in December of wet years (averaging approximately 1,800 cfs higher) would reduce WUA by approximately 6%, and higher flows in January of above normal and below normal water years (averaging approximately 1,000 and 1,300 cfs higher, respectively) would reduce WUA by approximately 3%. Therefore, changes in flows under Alternative 2 would have both positive and negative effects on the availability of steelhead spawning habitat relative to the No Action Alternative.

HEC-5Q modeling for Alternative 2 indicates that the water temperatures in the upper Sacramento River during the steelhead spawning and incubation period (November through May) would be similar to those under the No Action Alternative (Tables O.3-26 through O.3-29). Based on the steelhead spawning and incubation threshold of 53°F (see O.3.3 Alternative 1, Central Valley Steelhead Spawning and Egg Incubation), both alternatives would maintain suitable water temperatures for spawning and incubation through April or May in the reach between Keswick Dam and Clear Creek (Tables O.3-6 through O.3-8). Therefore, changes in water temperatures under Alternative 2 would not likely have significant effects on spawning adults, eggs, and alevins relative to the No Action Alternative.

Juvenile Rearing and Emigration

CV steelhead rear year-round in the Sacramento River, and use the river downstream from spawning areas as both a rearing and migration corridor. The timing of downstream migration is variable but generally peaks in the upper river at RBDD in spring and summer (March through June) and in the lower river at Knights Landing in winter and spring (January through May) (NMFS 2009). The peak migration of yearling and older juveniles through the Delta occurs in March and April (NMFS 2009).

CalSim II modeling indicates that the largest differences in Sacramento River flows between Alternative 2 and the No Action Alternative would occur in the late summer and fall (September and November) of above normal and wet years, and in late spring (most notably May and June) of most water year types, potentially affecting fry and juvenile rearing habitat (Table O.3-25). Based on the flow-habitat relationships for Late Fall-Run Chinook Salmon fry and juvenile life stages (see O.3.3 Alternative 1, Central Valley Steelhead Juvenile Rearing and Emigration), lower flows under Alternative 2 in the fall of wet and above normal water years would increase the amount of juvenile rearing habitat (as measured by WUA), while higher flows in spring would have variable effects on fry and juvenile rearing habitat (Figures O.3-39 and O.3-40). For example, in wet years, reductions in average flows of approximately 6,000 cfs in September and 3,500 cfs in November under Alternative 2 would increase juvenile WUA by 30% and 40% relative to the No Action Alternative. In below normal years, increases in average flows of 1,600 cfs in May and 2,300 cfs in June would reduce juvenile WUA by approximately 10% relative to the No Action Alternative. These same flow increases would reduce fry WUA by 4% in May and increase fry WUA by 6% in June. Therefore, changes in flows under Alternative 2 would have both positive and negative effects on the availability of steelhead rearing habitat relative to the No Action Alternative.

In the upper Sacramento River, HEC-5Q modeling for Alternative 2 and the No Action Alternative indicates that average water temperatures between Keswick Dam and RBDD would be maintained at or below the “core rearing area threshold” of 61°F (see O.3.3 Alternative 1, Central Valley Steelhead Juvenile Rearing and Emigration) throughout the year except in the summer (July through September) of critically dry water years (Tables O.3-26 through O.3-29). During the summer, water temperatures under Alternative 2 would be similar or cooler than those under the No Action Alternative, except in September of wet and above normal years when average water temperatures would be 0.7 to 3.4°F higher (Tables O.3-26 to O.3-29); however, there would be no major differences in the frequency and magnitude of temperatures above 61°F (Figure O.3-22). Similarly, water temperatures during the steelhead emigration season (January through June) are expected to similar or cooler than those under the No Action Alternative (Table O.3-29 to O.3-31). For example, although water temperatures at Knights Landing would frequently exceed the 64°F “non-core rearing area” threshold in May under both alternatives (e.g., Figure O.3-41), water temperatures would average over 1°F cooler in below normal and dry water years (Table O.3-31). Therefore, changes in water temperature under Alternative 2 would not likely have significant effects on rearing and emigrating steelhead relative to the No Action Alternative.

Adult Upstream Migration and Holding

Adult steelhead immigration into Central Valley streams potentially occurs during all months of the year but typically begins in August and continues through March or April (McEwan 2001; NMFS 2014a). In the Sacramento River, adults migrate upstream past RBDD during all months of the year, but primarily during September and October (NMFS 2009). Adults may hold until the spawning season which generally extends from November through April.

During the steelhead immigration and holding period, lower flows in September and November of wet and above normal water years under Alternative 2 could affect immigrating and holding adults. However, mean monthly flows would be maintained at a minimum of 3,250 under both alternatives, and would not differ substantially in frequency and magnitude between the alternatives until flows exceed approximately 5,000 cfs (Figures O.3-25, O.3-27 and O.3-29). Within this flow range (>5,000 cfs), no adverse effects on migrating and holding adults would be expected; flows of this magnitude would presumably be sufficient to maintain suitable passage and holding conditions under both alternatives.

Under both Alternative 2 and the No Action Alternative, HEC-5Q modeling indicates that suitable water temperatures for steelhead immigration in the Sacramento River (based on the immigration threshold of 68°F; see O.3.3 Alternative 1, Central Valley Steelhead Adult Upstream Migration and Holding) would generally not occur until September or October (Table O.3-31). However, under Alternative 2, substantially lower flows in September would increase the frequency of water temperatures exceeding this threshold, resulting in potential delays in migration or adverse physiological effects on migrating adults relative to the No Action Alternative. For example, at Knights Landing, mean monthly water temperatures in September exceeded 68°F approximately 80% of the time compared to 52% of the time under the No Action Alternative (Figure O.3-24). Therefore, changes in water temperatures under Alternative 2 in September would have a potentially adverse effect on immigrating adult steelhead in the Sacramento River relative to the No Action Alternative. Lower flows in September would also result in higher water temperatures in the upper Sacramento River, potentially affecting holding adults. However, no major differences would be expected to occur in the frequency and magnitude of water temperatures exceeding the threshold for holding adults (61°F; see O.3.3 Alternative 1, Central Valley Steelhead Adult Upstream Migration and Holding) (Figure O.3-22).

O.3.5.2.7 Southern DPS Green Sturgeon

Spawning and Egg Incubation

Green Sturgeon spawn in deep pools (averaging about 28 feet deep) (NMFS 2018b). Eggs from spawning Southern DPS Green Sturgeon have been found in the middle and upper Sacramento River from the GCID oxbow (RM 207) to Inks Creek (RM 265) and spawning is believed to extend upstream to the confluence with Cow Creek (RM 277) (Heublein et al. 2017b). Spawning occurs primarily from April through July, although it periodically occurs in late summer and fall (as late as October) (Heublein et al. 2009, 2017b, NMFS 2018b). Eggs hatch about a week after fertilization (at 60ºF) (Heublein et al. 2017b). Because the incubation time for Green Sturgeon is so short, the effects analysis period for incubating eggs is considered to be the same as the spawning period. Based on laboratory studies for Northern DPS Green Sturgeon, Heublein et al. 2017b) concluded that the optimal range for normal embryo development of Southern DPS Green Sturgeon is 53 to 64°F, and impaired fitness occurs below 52°F and above 71°F.

During the April through July Green Sturgeon spawning period, CalSim II estimates of mean monthly flows at RBDD (RM 244) under the No Action Alternative and Alternative 2 range from about 5,000 cfs for April of critically dry water years to about 14,300 cfs in July of Above Normal water years (Table

O.3-32). Mean flows during most of this period are moderate (~8,000 cfs to ~12,000 cfs). These flow levels are likely to be suitable for Green Sturgeon spawning and egg incubation, and no adverse effects are expected to result. Differences in flows between Alternative 2 and the No Action Alternative are small in most months, but flows are moderately higher for Alternative 2 in May and June of all water years (Table O.3-32). During the August through October period, when Green Sturgeon spawning occurs in occasional years, the flows under both alternatives tend to be lower than those in April through July, but the mean flows would be close to or above 5,000 cfs for all water year types in all three months. Large reductions in mean flows from the No Action Alternative to Alternative 2 are predicted for September of wet and above normal water years and, although the resulting Alternative 2 mean flows are greater than 5,000 cfs, the flow reductions are so large (about 44%) that conditions for Green Sturgeon spawning and egg incubation are likely to be adversely affected (Table O.3-32). However, September spawning occurs only sporadically, so any effect on the Green Sturgeon population would be minor (NMFS 2018b). Therefore, the September flow reductions are expected to have a minor adverse impact on Green Sturgeon.

Based on the HEC-5Q modeling, mean water temperatures during the April through July primary spawning period of Green Sturgeon are below the 53 and 52°F lower temperature thresholds for Green Sturgeon egg development (see Section O.3.3, *Alternative 1*) at Clear Creek and Balls Ferry during many of the months and water year types (Tables O.3-27 and O.3-28). As discussed previously, daily water temperatures are likely to be more variable than monthly mean temperatures, so the reductions of the mean temperatures below the 52 and 53°F thresholds probably underestimate the largest daily reductions below the thresholds.

The HEC-5Q modeling results show little difference in Clear Creek confluence mean water temperatures between Alternative 2 and the No Action Alternative during the April through July primary Green Sturgeon spawning and incubation period (Table O.3-27). Therefore, Alternative 2 is unlikely to cause a reduction in water temperatures relative to the No Action Alternative and thereby would not adversely affect Green Sturgeon spawning and egg incubation.

Larval and Juvenile Rearing and Emigration

As discussed under Alternative 1 (Section O.3.3, *Alternative 1*), the larval period for Green Sturgeon is considered to be April through September. The downstream distribution of Green Sturgeon larvae in the Sacramento River is uncertain, but is estimated to extend to the Colusa area, at RM 157 (Heublein et al. 2017b). The upstream limit is the Cow Creek confluence. Green Sturgeon juveniles rear in the Sacramento River from about May through December (NMFS 2017b). During most of this period, the juveniles are likely to be found anywhere from the upstream spawning habitat near the Cow Creek confluence to the Delta.

CalSim modeling for the Sacramento River at RBDD indicates that mean monthly flows during the April through September period of larval rearing are generally similar between the No Action Alternative and Alternative 2 in April, July and August but would be greater in May (all water years except wet), June (all water years) and September (below normal to critically dry years) (Table O.3-32). The September reductions in flow from the No Action Alternative to Alternative 2 during wet and above normal years would potentially affect Green Sturgeon larvae adversely because, as discussed for Alternative 1 (Section O.3.3, *Alternative 1*), there appears to be a positive relationship between annual outflow and abundance of White Sturgeon larvae and juveniles. However, but the applicability of the relationship to Green Sturgeon is uncertain.

CalSim modeling for the Sacramento River at Hamilton City indicates that mean monthly flows during the period of juvenile rearing and emigration, May through December, are generally similar between the No Action Alternative and Alternative 2 except for higher flows under Alternative 2 during May (all years except wet), June (all years), and September (below normal to critically dry) (Table O.3-32). Reductions in flows occur in September and November (wet and above normal years) and below normal years in December. These reductions in flow could adversely affect Green Sturgeon juveniles under Alternative 2 because, as noted above, there may be a positive relationship between annual outflow and abundance of Green Sturgeon.

There are few notable differences in the HEC-5Q mean monthly water temperature estimates at RBDD or Hamilton City between the No Action Alternative and Alternative 2 during the Green Sturgeon larval and juvenile rearing and emigration period in any month, except for September (Tables O.3-29 and O.3-30). During over half of the years in September, the Alternative 2 water temperature at RBDD is greater than the No Action Alternative temperature, with a maximum difference of about 3°F (Figure O.3-22). Over the range of years for which there are temperature differences, the water temperatures of both the No Action Alternative and Alternative 2 are under the 63°F lower limit of the optimal range for larvae. However, the Alternative 2 water temperatures are closer to the optimal range and therefore would potentially provide more favorable conditions for larval growth and survival. For the juveniles at RBDD, the September water temperatures under the No Action Alternative are below the 59°F lower limit of the optimal temperature range in about half of the years, and under Alternative 2 they are below the optimal range in about a third of the years (Figure O.3-22). The September HEC-5Q temperature estimates for Hamilton City also fall within or are closer to the optimal ranges of Green Sturgeon larvae and juveniles in more years under the Alternative 2 than the No Action Alternative, however overall temperatures are slightly lower in the other months (Table O.3-30; Figure O.3-23).

The CalSim II flow results indicate that Alternative 2 would have a less-than-significant adverse impact on rearing larval and juvenile southern DPS Green Sturgeon relative to the No Action Alternative, and the HEC-5Q water temperature modeling results indicate that Alternative 2 would provide a minor adverse impact to rearing larval and juvenile Green Sturgeon relative to the No Action Alternative.

Adult Upstream Migration and Holding

Green Sturgeon adults enter the Sacramento River from the Delta as early as February and ultimately make their way upstream to spawn in deep pools from the GCID oxbow (near Hamilton City) to the Cow Creek confluence (Heublein et al. 2017b). After spawning, the adults hold in the river for varying amounts of time, but typically emigrate back to the San Francisco Estuary and the ocean from about October through December (Heublein et al. 2017b).

Flows during the February through December period of Green Sturgeon immigration, spawning and holding would generally be similar between Alternative 2 and the No Action Alternative at RBDD, Hamilton City, and Wilkins Slough (Tables O.3-32 through O.3-34). Exceptions include moderately higher mean monthly flows under Alternative 2 at all locations during May and June, and in September during below normal to critically dry years. Substantially lower flows under Alternative 2 occur during September and November during wet and above normal years. All of the more notable flow differences occur within a range of river flows (~5,000 cfs to 14,000 cfs) that are not expected to substantially affect upstream passage of migrating Green Sturgeon, but the September and November flow reductions under Alternative 2 at Hamilton City and RBDD could result in reduced habitat quality in holding pool habitats, adversely affecting holding adults.

There are few major differences in mean monthly water temperatures between the No Action Alternative and Alternative 2 in the Sacramento River at Knights Landing during the February through April period when most adult Green Sturgeon migrate upstream or during the later months (through December) when the sturgeon migrate downstream after spawning (Table O.3-31). Temperatures are lower during May and June, which would benefit migrating adults by bringing temperatures closer to the 66 degree threshold. However, increases of more than 4°F are expected in September of wet and above normal water years. The means exceed the 66°F threshold for migrating Green Sturgeon adults in both water year types under Alternative 2 and in neither water year type under the No Action Alternative. The mean monthly water temperatures at Knights Landing also exceed the 66°F threshold under both alternatives during June through August of all water year types and May of all but wet years (Table O.3-31). Adults migrating downstream from May through September would potentially be adversely affected by the high water temperatures. However, adults migrating upstream would be less affected because most upstream immigration occurs before late spring (Heublein et al. 2009), when water temperatures are below the 66°F threshold.

During the May through December spawning and post-spawn holding period for Green Sturgeon, the HEC-5Q mean monthly water temperatures at Hamilton City, which is located in the most downstream, warmest section of the Green Sturgeon spawning reach, are generally similar between the No Action Alternative and Alternative 2, except for higher temperatures under Alternative 2 in September (Table O.3-30). The mean monthly water temperatures during the hottest months of this period, July through September, range from 58 to 68°F (both in September). The temperatures frequently exceed the 63°F threshold for spawning adults and the 61°F threshold for holding adults during these months. During September, the mean water temperatures exceed the 63 and 61°F thresholds in wet and above normal years under Alternative 2 but not under the No Action Alternative and the mean water temperatures in the remaining water years are slightly lower under Alternative 2 than under the No Action Alternative. September water temperatures are cooler at RBDD and there is no difference at this location between Alternative 2 and the No Action Alternative in the frequency of the threshold exceedances (Figure O.3-22). During October through December, the mean monthly water temperatures stay below both thresholds in every water year type.

The CalSim II modeling results indicate that for adult southern DPS Green Sturgeon holding in September or November, reduced flows under Alternative 2 would have a potentially significant adverse impact on holding habitat relative to the No Action Alternative. The HEC-5Q modeling results indicate that the water temperatures for September of wet and above normal water years would be substantially higher under Alternative 2 than under the No Action Alternative and would exceed the 61°F thresholds for migrating, spawning and holding adult Green Sturgeon only under Alternative 2. In conclusion, the HEC-5Q results for Alternative 2 are expected to result in substantially less favorable water temperatures for Green Sturgeon in September of wet and above normal water years and moderately more favorable water temperatures in a number of other water year types and months. In combination, the reduced flows in September and November of wet and above normal water years and increased water temperatures in September of wet and above normal water years are expected to have a significant adverse impact on southern DPS Green Sturgeon adults.

O.3.5.2.8 Fall-Run Chinook Salmon

Spawning and Egg/Alevin Incubation

Fall-Run Chinook Salmon migrate upstream past RBDD on the Sacramento River between July and December, typically spawning in upstream reaches from October through January, with a peak in October and November. Eggs and alevins are present from October through April. The primary spawning area used by Fall-Run Chinook Salmon in the Sacramento River is the area from Keswick Dam downstream to RBDD. Spawning densities for all Chinook Salmon runs are highest in this reach, but the distribution of spawning fall-run generally extends downstream to spawning areas below RBDD (Gard 2013).

During the Fall-Run Chinook Salmon spawning and incubation period, relatively large reductions in flows in November of wet and above normal water years under Alternative 2 (averaging 3,500 cfs lower than No Action Alternative flows) would increase the amount of available spawning habitat, while moderate increases in flow in subsequent months (averaging 1,000 to 2,000 cfs higher than No Action Alternative flows) would decrease available spawning habitat (Figure O.3-35). For example, in wet years, a reduction in average flow of 3,500 cfs in November would increase the amount of available spawning habitat (as measured by WUA) by 72%, while an increase in average flow of 1,800 cfs in December would decrease available spawning habitat by 24%. In above normal years, a reduction in average flow of 3,500 cfs in November would increase the amount of available spawning habitat by 74%, while an increase in average flow of 1,000 cfs in January would decrease available spawning habitat by 15%. Therefore, changes in flows under Alternative 2 would have both positive and negative effects on the availability of spawning habitat relative to the No Action Alternative.

HEC-5Q modeling indicates that Alternative 2 would not substantially affect the frequency of water temperatures exceeding the 53.5°F threshold (see O.3.3.1.2, Sacramento River, *Potential changes to aquatic resources in the Sacramento River from seasonal operations*) during the Fall-Run Chinook Salmon spawning and incubation period (Table O.3-26). For example, during October, a peak spawning month, mean monthly water temperatures at Keswick Dam under the Alternative 2 and the No Action Alternative exceeded 53.5°F approximately 80% of the time (Figure O.3-18). Therefore, changes in flows and water temperatures under Alternative 2 are not likely to have significant effects on steelhead spawning and incubation relative to the No Action Alternative.

Juvenile Rearing and Emigration

Fall-Run Chinook Salmon juveniles rear in the Sacramento River primarily from December through May. Following emergence, juveniles rear for variable lengths of time in the Sacramento River before entering the Delta and estuary, and may emigrate as fry, parr, or smolts. The timing of emigration is variable but generally peaks in the upper river from January through April and in the lower river from January through May (NMFS 2009).

Relative to the No Action Alternative, higher winter and spring flows in the Sacramento River under Alternative 2 could affect rearing and emigrating Fall-Run Chinook Salmon. The largest differences in flows between Alternative 2 and the No Action Alternative would occur in December of wet years (averaging 1,800 cfs) and in January and May of below normal years (averaging 1,300 and 1,600 cfs, respectively), potentially affecting the availability of fry and juvenile rearing habitat (Table O.3-26). Based on the flow-habitat relationships for Fall-Run Chinook Salmon fry and juvenile life stages (see O.3.3 Alternative 1, Central Valley Fall-Run Chinook Salmon, Juvenile Rearing and Emigration), higher flows under Alternative 2 in December of wet years and January of below normal years would reduce the amount of fry rearing habitat (as measured by WUA) by 7% and 9%, respectively (Figures O.3-36 and O.3-37). In May of below normal years, fry WUA would be reduced by 3% while juvenile WUA would be reduced by 9%. While these results indicate that Alternative 2 would potentially reduce the availability of suitable rearing habitat for Fall-Run Chinook Salmon relative to the No Action Alternative, uncertainty exists in the importance of this reduction relative to other factors that affect the quantity and quality of rearing habitat for juvenile Chinook Salmon in the Sacramento River.

In the upper Sacramento River, HEC-5Q modeling for Alternative 2 and the No Action Alternative indicates that both alternatives would maintain suitable water temperatures (≤ 61°F; see O.3.3 Alternative 1, Central Valley Steelhead Juvenile Rearing and Emigration) between Keswick Dam and RBDD during the Fall-Run Chinook Salmon fry and juvenile rearing period (December through May) (Tables O.3-26 through O.3-29). Farther downstream, mean monthly water temperatures in the lower river at Knights Landing would be similar or slightly cooler under Alternative 2 (Table O.3-7-7), but there would be no differences in the frequency of temperatures exceeding the 64°F "non-core rearing area threshold" (Figure O.3-41). Therefore, changes in Sacramento River water temperatures under Alternative 2 would not likely have significant effects on rearing and emigrating juvenile Fall-Run Chinook Salmon relative to the No Action Alternative.

Adult Upstream Migration and Holding

Fall-Run Chinook Salmon migrate upstream past RBDD on the Sacramento River between July and December. Adults may hold until the spawning season, which occurs primarily from October through January.

CALSIM II modeling indicates that mean monthly flows in the Sacramento River under Alternative 2 would be substantially lower in September and November of wet and above normal water years relative to the No Action Alternative (Tables O.3-25, O.3-32, and O.3-33). However, flows under both alternatives would be maintained at or above 3,250 cfs throughout the immigration and holding period. Although flows would differ substantially in September and November, the differences would be limited to flows exceeding approximately 5,000 cfs (Figures O.3-25, O.3-27, and O.3-29). Within this range (>5,000 cfs), no adverse effects on migrating and holding adults would be expected; flows of this magnitude would presumably be sufficient to maintain suitable passage and holding conditions under both alternatives.

Under both Alternative 2 and the No Action Alternative, HEC-5Q modeling indicates that suitable water temperatures for Fall-Run Chinook Salmon immigration in the Sacramento River (based on the immigration threshold of 68°F; see O.3.3 Alternative 1, Central Valley Fall-Run Adult Upstream Migration and Holding) would generally not occur until September or October (Table O.3-31). However, under Alternative 2, substantially lower flows in September would increase the frequency of water temperatures exceeding this threshold, resulting in potential delays in migration or adverse physiological effects on migrating adults relative to the No Action Alternative. For example, at Knights Landing, mean monthly water temperatures in September exceeded 68°F approximately 80% of the time compared to 52% of the time under the No Action Alternative (Figure O.3-24). Therefore, changes in water temperatures under Alternative 2 in September would have a potentially adverse effect on immigrating adult Fall-Run Chinook Salmon in the Sacramento River relative to the No Action Alternative. Lower flows in September would also result in higher water temperatures in the upper Sacramento River, potentially affecting holding adults. However, no major differences would be expected to occur in the frequency and magnitude of water temperatures exceeding the threshold for holding adults (61°F; see O.3.3 Alternative 1, Central Valley Fall-Run Adult Upstream Migration and Holding) (Figure O.3-22).

O.3.5.2.9 Late Fall-Run Chinook Salmon

Spawning and Egg/Alevin Incubation

Late Fall-Run Chinook Salmon spawn primarily from December through April, and eggs and alevins are present in the gravel from December through June. In the Sacramento River, most adults spawn upstream of Red Bluff Diversion Dam, with the majority spawning between Keswick Dam and the ACID Dam.

During the late Fall-Run Chinook Salmon spawning and incubation period, CalSim II modeling indicates that mean monthly flows at Keswick Dam under Alternative 2 would generally be higher than or similar to the flows under the No Action Alternative (Table O.3-5). The largest increases in flow are expected to occur in the winters of wet, above normal, and below normal years, averaging approximately 1,000 cfs to 2,000 cfs higher than flows under the No Action Alternative. Based on PHABSIM results (flow-habitat relationships) developed by the USFWS for the Sacramento River between Keswick Dam and Battle Creek (USFWS 2003a), higher flows under Alternative 2 would reduce the amount of available spawning habitat for Late Fall-Run Chinook Salmon (as measured by WUA) (Figure O.3-38). For example, spawning habitat WUA would be reduced by approximately 16% in December of wet years and 10% in January and February of above normal years. While these results indicate that Alternative 2 would potentially reduce the availability of suitable spawning habitat for late Fall-Run Chinook Salmon relative to the No Action Alternative, uncertainty exists regarding the importance of these reductions on spawning success or fry production in the Sacramento River.

HEC-5Q modeling for Alternative 2 indicates that the water temperatures in the upper Sacramento River during the Late Fall-Run Chinook Salmon spawning and incubation period (November through June) would be similar to those under the No Action Alternative (Tables O.3-26 through O.3-29). Based on the spawning and incubation threshold of 53.5°F (see O.3.3.1.2, Sacramento River, *Potential changes to aquatic resources in the Sacramento River from seasonal operations*), both alternatives would maintain suitable water temperatures from spawning and incubation through May or June in the reach between Keswick Dam and Balls Ferry (Table O.3-26 to O.3-28). Therefore, changes in water temperatures under Alternative 2 are unlikely to have significant effects on spawning adults, eggs, and alevins relative to the No Action Alternative.

Juvenile Rearing and Emigration

Late fall–run Chinook Salmon fry generally emerge from March through June, and juveniles rear in the Sacramento River through the summer before emigrating at a relatively large size (150- to 170-mm fork length) primarily from November through May.

Similar to Alternative 1, CalSim II modeling indicates that Sacramento River flows under Alternative 2 would generally be higher than or similar to the flows under the No Action Alternative during early rearing period (March through August) and substantially lower in September and November of wet and above normal water years (Table O.3-25). Based on PHABSIM results (flow-habitat relationships) for Late Fall-Run Chinook Salmon fry (<60 mm) and juveniles (≥60 mm) developed by the USFWS for the Sacramento River between Keswick Dam and Battle Creek (USFWS 2005), generally higher flows during spring and summer would reduce the amount of available fry and juvenile rearing habitat (Figures O.3-39 and O.3-40). For example, in below normal water years, higher flows from March to May under Alternative 2 (averaging 600 cfs to 1,600 cfs higher than No Action Alternative flows) would result in 3% to 10% reductions in fry WUA relative to the No Action Alternative. In May and June, higher flows under Alternative 2 (averaging 1,600 cfs higher in May and 2,300 cfs higher in June) would correspond to 12% and 9% reductions in juvenile WUA relative to the No Action Alternative. However, substantially lower flows under Alternative 2 in late summer and fall of wet and above normal water years (averaging 4,000 to 6,000 cfs lower in September and 3,500 cfs lower in November) correspond to 39% and 33% increases in juvenile WUA relative to the No Action Alternative. Therefore, changes in flows under Alternative 2 would have both positive and negative effects on the availability of juvenile rearing habitat relative to the No Action Alternative.

In the upper Sacramento River, HEC-5Q modeling for Alternative 2 and the No Action Alternative indicates that average water temperatures between Keswick Dam and RBDD would be maintained at or below the “core rearing area threshold” of 61°F (see O.3.3 Alternative 1, Central Valley Steelhead Juvenile Rearing and Emigration) throughout the year except in the summer (July through September) of critically dry water years (Tables O.3-26 through O.3-29). During the summer, water temperatures under Alternative 2 would be similar or cooler than those under the No Action Alternative except in September of wet and above normal years when average water temperatures would be 0.7 to 3.4°F higher (Tables O.3-26 to O.3-29); however, there would be no major differences in the frequency and magnitude of temperatures above 61°F (Figure O.3-22). Similarly, water temperatures during the Late Fall-Run Chinook Salmon emigration season (November through May) are expected to similar or cooler than those under the No Action Alternative (Table O.3-29 to O.3-31). Although the frequency of water temperatures exceeding the 64°F “non-core rearing area” threshold would be similar under the two alternatives (e.g., Figure O.3-41), water temperatures in May at Hamilton City and Knights Landing would average up to 1.1°F to 1.2°F cooler in May (Tables O.3-30 and O.3-31). Therefore, changes in water temperature under Alternative 2 would not likely have significant effects on rearing and emigrating Late Fall-Run Chinook Salmon relative to the No Action Alternative.

Adult Upstream Migration and Holding

In the Sacramento River, adult Late Fall-Run Chinook Salmon migrate from October through April, with a peak during January through March (NMFS 2009). Adults hold for 1 to 3 months prior to spawning, which occurs primarily from December through April.

Under Alternative 2, CALSIM II modeling indicates that mean monthly flows in the Sacramento River during the Late Fall-Run Chinook Salmon immigration period would be similar or higher than those under the No Action Alternative except in November of wet and above normal water years when flows would be substantially reduced relative to the No Action Alternative (Tables O.3-25, O.3-32, and O.3-33). However, flows under both alternatives would be maintained at or above 3,250 cfs throughout the immigration period. Although flows would differ substantially in November, the differences would be limited to flows exceeding approximately 5,000 cfs (Figures O.3-25, O.3-27, and O.3-29). Within this range (>5,000 cfs), no adverse effects on migrating and holding adults would be expected; flows of this magnitude would presumably be sufficient to maintain suitable passage and holding conditions under both alternatives.

Based on the water temperature thresholds for immigration (68°F) and holding (61°F) (see O.3.3 Alternative 1, Central Valley Fall-Run Adult Upstream Migration and Holding), Alternative 2 and the No Action Alternative would maintain suitable water temperatures for Late Fall-Run Chinook Salmon throughout the immigration and holding period (October through April) (Tables O.3-29 and-O.3-31). Therefore, changes in water temperatures under Alternative 2 would not likely have significant effects on immigrating and holding Late Fall-Run Chinook Salmon in the Sacramento River relative to the No Action Alternative.

O.3.5.2.10 White Sturgeon

Spawning and Egg Incubation

White sturgeon spawn in deep water in the middle and lower Sacramento River from Verona (RM 80) to just upstream of Colusa (~RM 156) from late February to early June, but primarily during March and April, (Moyle et al. 2015; Heublein et al. 2017). The adults typically return promptly to the Delta/Estuary after spawning.

During the March and April spawning and egg incubation period of White Sturgeon, CalSim II estimates of mean monthly flows at Wilkins Slough (RM 117) under the No Action Alternative and Alternative 2 range from about 5,300 cfs for April of critically dry water years to about 17,800 cfs for March of wet water years (Table O.3-34). These flow levels are likely to be adequate for White Sturgeon spawning and egg incubation, so no adverse effects are expected to result. Differences in flows between Alternative 2 and the No Action Alternative are small in both months, but flows are moderately higher for Alternative 2 in March of below normal and critically dry water years and April of below normal years (Table O.3-34). Therefore, it is concluded that Alternative 2 would have no flow effects on White Sturgeon eggs and embryos relative to the No Action Alternative.

The HEC-5Q water temperature modeling results for March and April indicate that mean monthly water temperatures at Knights Landing were well below the 63°F threshold for optimal temperatures (see Section O.3.3.1.2, *Sacramento River*), except in April of critically dry water years (Table O.3-31). As noted earlier, the mean monthly water temperatures for water year types combine water temperatures for many years and therefore mask individual year variations. The monthly means for individual years show that April water temperatures exceed the 63°F threshold in 15% of years, but lie below the 68°F lethal temperature in all years (Figure O.3-43). There are no appreciable differences in water temperatures between Alternative 2 and No Action Alternative in March or April (Table O.3-31; Figure O.3-43). During June, the warmest month of the full spawning and egg incubation period, the mean monthly water temperatures are predicted to exceed the 68°F lethal temperature in all water year types, but the water temperatures are lower for Alternative 2 than for the No Action Alternative (Table O.3-31). Therefore, it is concluded that Alternative 2 would have no water temperature effects on White Sturgeon eggs and embryos relative to the No Action Alternative.

O.3.5.2.11 Larval and Juvenile Rearing and Emigration

During the March through June larval period, water temperature modeling indicates that water temperatures frequently exceed water temperature thresholds (61 and 68°F, see Section O.3.3.1.2, *Sacramento River*) at Knights Landing under the No Action Alternative and Alternative 2 (Table O.3-31), especially in June. Such high levels of temperature threshold exceedances suggest that typical water temperature conditions in the lower Sacramento River may be highly stressful for White Sturgeon larvae. In any case, the water temperatures, especially in June, are lower under Alternative 2 than under the No Action Alternative (Table O.3-31). It is concluded that Alternative 2 compared to the No Action Alternative will not have an adverse effect on larval and juvenile rearing.

During the of White Sturgeon juvenile emigration period, approximately April to July, CalSim II results indicate that flows at Wilkins Slough during May and June would increase with Alternative 2 compared to No Action Alternative (Table O.3-14). Alternative 2 may have a beneficial effect on juvenile White Sturgeon.

Adult Upstream Migration and Holding

As previously noted, White Sturgeon adults to initiate their upstream spawning migrations during late winter and early spring, presumably in response to elevated flows (Heublein et al. 2017). CalSim II flows at Wilkins Slough for December through February are not much different between Alternative 2 and No Action Alternative for all water year types. There are a few months and water year types when flows are higher under Alternative 2, such as December during wet years and January during below normal years. These increased flows would be beneficial for White Sturgeon migration, but all flows are between 7,700 and 18,800 cfs which are adequate for migration. There are no temperature differences from December through February for Knights Landing. Alternative 2 would have no flow or water temperature effects on White Sturgeon adults.

The CalSim II flow results for Wilkins Slough and the HEC-5Q water temperature results for Knight Landing indicate that Alternative 2 would not have an adverse effect on White Sturgeon relative to the No Action Alternative.

O.3.5.2.12 Sacramento Splittail

Sacramento splittail occur in the Sacramento River upstream of the Delta from about December through May. The adults spawn in river-margin and inundated floodplain habitats in February through April (Feyrer et al. 2005, 2006; Sommer et al. 2007; Moyle et al. 2015). The larvae hatch several days after spawning then rear for about a month in habitat similar to the spawning habitat (Moyle et al. 2004). The juveniles rear upstream and then begin their downstream migration during April and May, as the river level recedes back to the channel (Moyle et al. 2004; Feyrer et al. 2005). Floodplain spawning in wet years overwhelmingly dominates production, but spawning in side channels and channel margins is important during low-flow years when floodplains are not inundated. In the Sacramento River drainage, splittail spawn from Colusa to Knights Landing, but the the most important spawning areas are the inundated floodplains of the Yolo and Sutter bypasses (Feyrer et al. 2005).

High flows benefit adults migrating upstream (Feyrer et al. 2006), and greatly enhance spawning and rearing habitat for larvae and early juveniles (Crain et al. 2004). Mean monthly flows at Wilkins Slough during January through March of wet and above normal water years consistently equal or exceed 17,000 cfs under both alternatives (Table O.3-33). Figure O.3-44 shows the expected mean February flows for each year of the CalSim II record. About 15% of the years have mean February flows greater than 22,500 cfs, which is the approximate flow at which the Tisdale Weir begins to spill into the Sutter Bypass (DWR 2010b). In any case, differences between Alternative 2 and the No Action Alternative in flows at Wilkins Slough during December through May are relatively minor, and generally result from higher flow under the Alternative 2 (Table O.3-34; Figure O.3-44). It is concluded that Alternative 2 would have no flow effects on Sacramento Splittail relative to the No Action Alternative.

Preferred water temperature for Sacramento splittail ranges from about 66°F for adults to about 75°F for juveniles, and the “upper limit of safe temperatures” ranges from about 75°F for adults and 81°F for juveniles (Young and Cech 1996). Mean monthly water temperatures during December through May at Knights Landing, which is at the approximate downstream limit of splittail spawning in the Sacramento River, range up to 68°F under both alternatives in May of critically dry water years (Table O.3-31). There are no meaningful water temperature differences between the alternatives at Knights Landing during the December through May period when Sacramento Splittail occupy the river upstream of the Delta, except in May of below normal and dry water years when water temperatures are just over 1°F lower under Alternative 2 than the No Action Alternative (Table O.3-31). There is evidence that some juvenile splittail remain in the Sacramento River well upstream of the Delta through the entire year (Feyrer et al. 2005), but summer water temperatures in the more upstream locations where they have been found are considerably cooler than those at Knights Landing (compare Tables O.3-30 and O.3-31). Therefore, Alternative 2 is considered to have no adverse water temperature effects on splittail relative to the No Action Alternative.

The CalSim II flow results for Wilkins Slough and the HEC-5Q water temperature results for Knight Landing indicate that Alternative 2 would not have an adverse impact on Sacramento Splittail relative to the No Action Alternative.

O.3.5.2.13 Pacific Lamprey

Sacramento River Pacific Lamprey adults enter the Sacramento River from the Delta primarily during about March through June and hold in the river for about a year prior to spawning (Moyle et al. 2015). Spawning occurs in gravel redds in the upper river from March through July. The eggs and pro-larvae incubate for about 1 to 1.5 months. After the larvae (ammocoetes) emerge, they drift downstream and burrow into fine sediments primarily in off-channels habitats, where they rear (Schultz et al. 2014; Moyle et al. 2015). After 5 or more years, the ammocoetes metamorphose to the macropthalmia (juvenile) stage and migrate downstream to the Delta and ocean, typically migrating from March through June during pulse flow events (Moyle et al. 2015).

River flow potentially affects survival of Pacific Lamprey eggs and larvae, and migratory habitat of the juveniles and adults. Pacific lamprey build their spawning redds in shallow water (about 0.5 to 3.5 feet) (Gunckel et al. 2009; Schultz et al. 2014; Moyle et al. 2015), so reductions in water level can dewater the redds. The larvae select habitats, often off-channel, with fine sediments, low flow velocity, and shallow depths (~1 ft), so they are vulnerable to stranding by reductions in water level. Migrations of the juveniles and adults may be triggered by surges in flow (Moyle et al. 2015).

The types of variations in flow that potentially affect Pacific Lamprey, as described above, often occur on a time scale of hours or days, and therefore may not be detectable using the CalSim II monthly time-step modeling results. However, the CalSim II results mostly show no large differences in Sacramento River flow between the No Action Alternative and Alternative 2, so there is no reason to expect much difference in short period flow fluctuations between the alternatives. The biggest differences in monthly mean flows occur in September and November of wet and above normal water years, when flows are much lower under Alternative 2 than the No Action Alternative because Alternative 2 operations do not include releases for Fall X2 flows (Table O.3-32; Figures O.3-25 and O.3-28). Pacific lamprey are generally done spawning by late July and the prelarvae have finished emerging from their redds by early September. In contrast, the larvae are present in the river yearround and so could be vulnerable to flow reductions during September and November. However, water levels during these months are generally relatively stable because they are largely determined by Shasta and Keswick dam releases rather than runoff. The adults and juveniles carry out their migrations primarily during March through June. CalSim II modeling flow results for these months are generally higher under Alternative 2 than under the No Action Alternative (Table O.3-33 and O.3-34). Therefore, Alternative 2 and the No Action Alternative are expected to similarly affect Pacific Lamprey with respect to flow in the Sacramento River.

As described for Alternative 1, laboratory studies conducted on Columbia River Pacific Lamprey indicated that survival of incubating eggs and pre-larvae and of young larvae was greatest at a water temperature of 64°F and lowest at the highest water temperature included in the study, 72°F (Meeuwig et al. 2005). HEC-5Q modeling results indicate that mean monthly water temperatures in the Sacramento River between Keswick and RDBB during the March through August spawning and egg/prelarvae incubation period would be consistently below 64°F, with minor differences between the alternatives (Tables O.3-26 through O.3-29). During September, when Pacific Lamprey larvae would be present in the river, mean water temperatures would exceed the 64°F optimal temperature at RBDD in critically dry water years. September has the highest water temperatures of the year upstream of RBDD. Mean September water temperatures at RBDD for individual years exceed 64°F in about 7% of years for both alternatives, but are below 72°F for all years (Figure O.3-22). The downstream distribution of Pacific Lamprey larvae is uncertain, but if the larvae drift well downstream of RBDD or enter the Sacramento River from downstream tributaries, they would be subject to higher water temperatures, especially during July and August. However, there are few differences between July and August water temperatures at the lower temperature modeling sites, except in below normal water years when water temperatures are about

1°F cooler under Alternative 2, which would likely benefit the larvae (Table O.3-30 and O.3-31; Figure O.3-45). There are no biologically meaningful differences in water temperature conditions for Pacific Lamprey between the No Action Alternative and Alternative 2.

The CalSim II flow results and the HEC-5Q water temperature results indicate that Alternative 2 would have a less-than-significant impact on Pacific Lamprey relative to the No Action Alternative.

O.3.5.2.14 River Lamprey

River Lamprey adults migrate from the ocean to spawning areas during the fall and late winter (Beamish 1980). Spawning is believed to occur from February through May in small tributary streams (Moyle 2002). The redds are built at the upstream end of small riffles (Moyle 2002). After the larvae (ammocoetes) emerge, they drift downstream and burrow into sediments in pools or side channels where they rear. After several years, the larvae metamorphose in late July and the juvenile (macrothalmia) migrate downstream in the following year from May to July (Moyle 2002).

River flow potentially affects survival of River Lamprey eggs and larvae, and migratory habitat of the juveniles and adults. River lamprey build their spawning redds in shallow water (Moyle et al. 2015), so reductions in water level can dewater the redds. Assuming River Lamprey larvae habitat requirements are similar to those of Pacific Lamprey, the larvae select habitats, often off-channel, with low flow velocity and shallow depths, so they are vulnerable to stranding by reductions in water level.

The types of variations in flow likely to cause redd dewatering and stranding of larvae often occur on a time scale of hours or days and, therefore, may not be detectable using the CalSim II monthly time-step modeling results. However, the CalSim II results mostly show little difference in Sacramento River flow between the No Action Alternative and Alternative 2, so there is no reason to expect much difference in short period flow fluctuations between the alternatives. The biggest differences in monthly mean flows occur in September and November of wet and above normal water years, when flows are lower under Alternative 2 than the No Action Alternative because Alternative 2 operations do not include releases for Fall X2 flows (Table O.3-32; Figures O.3-25 and O.3-28). River lamprey are generally done spawning by May and, assuming their incubation times are similar to those of Pacific Lamprey, the prelarvae complete their emergence from redds by June or July. In contrast, the larvae are present in the river yearround and so could be vulnerable to flow reductions during September and November. However, water levels during these months are generally relatively stable because they are largely determined by Shasta and Keswick dam releases rather than runoff.

The juveniles carry out their migrations during May through July. CalSim II modeling flow results for May and June at Hamilton City and Wilkins Slough are consistently higher under Alternative 2 than under the No Action Alternative, but flows for July are generally slightly lower (Table O.3-33 and O.3-34). The adults migrate upstream primarily in the fall and winter and could be adversely affected by the September and November reductions in flow under Alternative 2 relative to the No Action Alternative (Table O.3-52), but little is know about flow needs of migrating adult River Lamprey. Overall, Alternative 2 and the No Action Alternative are expected to similarly affect River Lamprey with respect to flow in the Sacramento River.

The water temperature requirements of River Lamprey have not been studied, but they are assumed to be similar to those of Columbia River Pacific Lamprey with 64°F for maximum survival of eggs and prelavae and 72°F and above for minimum survival (Meeuwig et al. 2005). HEC-5Q modeling results indicate that mean monthly water temperatures in the Sacramento River between Keswick and RDBB during the February through May spawning and egg/prelarvae incubation period would be consistently below 64°F, with minor differences between the alternatives (Tables O.3-26 through O.3-29). It should be noted that River Lamprey are believed to spawn in tributary streams rather than the mainstem, but this is uncertain (Moyle et al. 2015). During September, when River Lamprey larvae would be present in the river, mean water temperatures would exceed the 64°F optimal temperature at RBDD in critically dry water years. September has the highest water temperatures of the year upstream of RBDD. Mean September water temperatures at RBDD for individual years exceed 64°F in about 7% of years for both alternatives, but are below 72°F for all years (Figure O.3-22). The downstream distribution of River Lamprey larvae is uncertain, but if the larvae drift well downstream of RBDD or enter the Sacramento River from downstream tributaries, they would subject to higher water temperatures, especially during July and August. However, there are few differences between July and August water temperatures at the downstream temperature modeling sites, except in below normal water years when water temperatures are about 1 dgree Fahrenheit cooler under Alternative 2, which would likely benefit the larvae (Table O.3-30 and O.3-31; Figure O.3-45). There are no biologically meaningful differences in water temperature conditions for River Lamprey between the No Action Alternative and Alternative 2.

The CalSim II flow results and the HEC-5Q water temperature results indicate that Alternative 2 would have a less-than-signficant impact on River Lamprey relative to the No Action Alternative.

O.3.5.2.15 Hardhead

Hardhead are believed to spawn in riffles, runs, and heads of pools, primarily during April and May (Moyle et al. 2015). Most spawning probably occurs in tributaries rather than in the Sacramento River mainstem (Moyle et al. 2015). Larvae and juveniles likely inhabit stream margins with abundant cover, and move into deeper habitats as they grow larger. Adults occupy the deepest part of pools. Juvenile and adult Hardhead are present in the Sacramento River year-round. They tend to prefer water temperatures near 67°F (Thompson et al. 2012), but have been captured at RBDD, where water temperatures are generally much cooler (USFWS 2002) (Table O.3-9).

Spawning success of Hardhead in the lower Tuolumne River is highest when there are higher flows during in April and May (Brown and Ford 2002), which is likely true for the Sacramento River Hardhead as well. The CalSim II results for Keswick, Red Bluff, Hamilton, and Wilkins Slough indicate that monthly mean flow would be moderately higher under Alternative 2 than under the No Action Alternative during the April and May peak spawning months (Tables O.3-25, O.3-32 through O.3-34). During most of the other months, when Hardhead may forage in the river, flows would generally be similar between Alternative 2 and the No Action Alternative, but, from Keswick Dam to Wilkins Slough, they would be 10 to 27% higher under Alternative 2 in June of all water year types and would be 29 to 44% lower in September and November of wet and above normal water years. The large flow reductions in September and November would likely have little effect on Hardhead because they are predicted for wet and above normal years, when flows are generally high, and because by September and November, Hardhead hatched in the spring would be well developed and have gravitated to deeper water. Similarly, the large flow increases in June would likely have little effect because June flows are adequate under both alternatives. The flow effects of Alternative 2 are not expected to substantially affect hardhead.

Hardhead juveniles and adults performed well in laboratory tests at water temperatures from about 61 to 70°F (Thompson et al. 2012). They consistently preferred a mean water temperature of 67°F and avoided temperatures above about 79°F. HEC-5Q modeling results indicate that mean monthly water temperatures in the Sacramento River would be below 79°F at all locations under both alternatives (Tables O.3-26 through O.3-31). There would be only minor differences in mean water temperatures between the alternatives, except for moderate increases under Alternative 2 during September of wet and above normal water years. However, these mean water temperatures would be only slightly warmer than the

Hardhead preferred temperature, and only at Knights Landing (Table O.3-31). There are no biologically meaningful differences in water temperature conditions for Hardhead between the No Action Alternative and Alternative 2.

The CalSim II flow results and the HEC-5Q water temperature results indicate that Alternative 2 would not have no impact on Hardhead relative to the No Action Alternative.

O.3.5.2.16 Central California Roach

As discussed under Alternative 1, California Roach primarily inhabit small tributary streams (Baumsteiger and Moyle 2019) and have a broad range of habitat types and temperature tolerances (Moyle 2002). Given that most Central California Roach inhabit tributary streams rather than the mainstem Sacramento River and have a broad range of habitat types and temperature tolerances, it is unlikely that flow or water temperature conditions under Alternative 2 would adversely affect California Roach. Therefore, Alternative 2 is expected to have no impact on Central California Roach relative to the No Action Alternative.

O.3.5.2.17 Striped Bass

Striped Bass spawn in the Sacramento River primarily between about Verona (RM 78) and Wilkins Slough (RM 121) during April through June (Moyle 2002). No spawning occurs until water temperature reaches 57°F (Moyle 2002). The eggs are free-floating and negatively buoyant and hatch in about two days after spawning (at 66°F) as they drift downstream. Low flows can result in eggs settling on the bottom, which they cannot survive for long. The larvae may inhabit shallow, open water of the lower river from April to mid-June and then are carried by flows to the Delta and Suisun Bay (Stevens 1966; Moyle 2002). Adult striped bass are found in the upper Sacramento River at RBDD and upstream, primarily from late spring through early fall, where they forage heavily on juvenile salmon and other fish (Tucker et al. 1998).

High flows in April through June benefit striped bass eggs because they help prevent them from settling to the river bottom. High flows likely also accelerate transport of Striped Bass larvae to their nursery habitats in the Delta and Suisun Bay (Moyle 2002). CalSim II flow results for Wilkins Slough indicate that mean monthly flow during April through June under Alternative 2 would be similar to or higher than flow under the No Action Alternative, with higher flow especially in May and June, which would potentially benefit conditions for eggs and larvae drifting downstream (Table O.3-34). The greatest reductions in flow resulting from Alternative 2 would occur in September and November of wet and above normal water years. Adult Striped Bass may reside throughout the Sacramento River in September (Tucker et al. 1998). However, although the Alternative 2 mean monthly flows are reduced from the No Action Alternative flows in wet and above normal years, they remain close to or well above 5,000 cfs (Tables O.3-32 through O.3-34), which is likely adequate for foraging Striped Bass.

Optimal spawning temperature range for Striped Bass is 59 to 68°F and spawning ceases at about 70°F (Moyle 2002). The eggs can withstand temperatures of about 54 to 75°F, with the optimum being about 64°F (Emmett et al. 1991). Larvae tolerate temperatures of 50 to 77°F, but optimal temperatures for survival are 59 to 72°F (Emmett et al. 1991). Striped Bass adults and juveniles are tolerant of a wide range and rapid swings of water temperatures. The adults appear to prefer water temperatures ranging from about 68 to 75°F (Emmett et al., 1991) and juveniles prefer rearing temperatures of 61 to 66°F (Hasler 1988). Adults are under stress at temperatures over 77°F, and temperatures over 86°F are lethal (Moyle 2002).

HEC-5Q modeling results indicate that mean monthly water temperatures in the Sacramento River at Knights Landing during the April through June spawning period would be within the optimal range for spawning in April of all but wet years and in May of all but critically dry years, but would be above the optimal range in June during all water year types (Table O.3-31). The mean monthly temperatures would be below the optimal range for adults during April and May of all water year types, except critically dry years in May, but would be within this range in all water year types in June. The temperatures would be acceptable for eggs and optimal for larvae throughout the spawning period (Table O.3-31). Juvenile striped bass generally do not occur in the Sacramento River upstream of the Delta. The adults, as noted earlier, may forage in the river upstream to and above RBDD from about May through early October. Mean monthly water temperatures at RBDD throughout this period would be well below the optimal range for adults (Table O.3-29).

The largest difference in water temperatures between the No Action Alternative and Alternative 2 at Knights Landing during the Striped Bass spawning season are moderate reductions in May of below normal and dry years and June of above normal, below normal and dry water years (Table O.3-31). With these reductions, water temperatures under Alternative 2 would be closer to the optimal range for spawning than those under the No Action Alternative, providing a minor benefit. The largest temperature differences at any time of year are substantial increases under Alternative 2 for September of wet and above normal water years. These increases would be potentially beneficial for foraging Striped Bass adults because the No Action Alternative water temperatures for these months and water year types would be well below the optimal range for adults throughout the river (Tables O.3-29 through O.3-31).

The CalSim II flow results and the HEC-5Q water temperature results indicate that Alternative 2, with regard to flow and water temperature, would have a less-than-significant impact on Striped Bass relative to the No Action Alternative.

O.3.5.2.18 American Shad

American shad migrate upstream in the Sacramento River starting in March, and typically spawn from April to June. Water temperature influences the timing of runs, with peak runs and spawning usually occurring at water temperatures of 62°F to 75°F (Moyle 2002). Shad eggs drift downstream from spawning areas and hatch in 3 to 12 days, depending on water temperature (MacKenzie et al. 1985). However, more rapid development at higher temperatures appears to be associated with lower survival rates of embryos (Moyle 2002). Larval shad are planktonic for about 4 weeks, after which they metamorphose to actively swimming juveniles. Juveniles spend the next several months in freshwater, and seem to prefer temperatures of 63°F to 77°F. In the Sacramento River, summer rearing habitat occurs in the main river from Colusa to the north Delta (Stevens et al. 1987). As the season progresses, juvenile shad move downstream and enter salt water primarily during September through November (Moyle 2002). In general, variations in river discharge and temperature during early larval development are considered important regulators of year-class strength and recruitment of American shad (Hinrichsen et al. 2013). Although the importance of various potential mechanisms is unknown, the abundance of juvenile American shad in the Sacramento-San Joaquin Delta has been shown to be positively correlated with freshwater inflow during the April through June spawning and nursery periods (Stevens et al. 1987, Kimmerer 2002, Kimmerer et al. 2009).

During the spawning and larval rearing period (April through June), CalSim II modeling results at Wilkins Slough indicates that average monthly flows in May and June under Alternative 2 would be higher than those under the No Action Alternative, which may have positive effects on spawning and early rearing success of American shad (Table O.3-25). In addition, with higher flows under Alternative 2, HEC-5Q modeling results indicate that mean monthly temperatures in the lower Sacramento River

(Knights Landing) during May and June would be lower on average, which may improve water temperatures for developing embryos and larvae (Table O.3-31; Figures O.3-41 and O.3-91). The largest differences in flows and water temperatures in the Sacramento River under Alternative 2 and the No Action Alternative would occur in September and November of wet and above normal water years (Table O.3-31 and O.3-34). However, the importance of river inflows and river temperatures for juvenile shad in September and November is unknown. Correlations between Delta inflows and abundance of juvenile shad have been demonstrated for the months of April through August, with the highest correlations in April through June, suggesting that the principal factors influencing abundance occur during periods of larval dispersal and transport. Sacramento River flows and temperatures under Alternative 2 may have minor benefits to American Shad relative to the No Action Alternative, but because the potential effects are highly uncertain, Alternative 2 is considered to have a less-than-significant effect on American Shad.

O.3.5.2.19 Largemouth Bass

The Sacramento River above the Delta generally provides poor habitat conditions for Largemouth Bass because of large seasonal flow fluctuations, relatively cold water, and lack of suitable nesting and rearing habitat. Consequently, Largemouth Bass populations in the Sacramento River above the Delta are largely dependent on upstream sources, including reservoirs, floodplain ponds and sloughs, and irrigation canals that provide suitable conditions for spawning and rearing during the late spring and summer months.

Largemouth bass spawning activity typically starts in April when water temperatures reach 59 to 61°F, and continues through June (Moyle 2002). Nests are typically constructed at a depth of about 3 feet (Brown et al. 2009a). Optimal temperatures for successful spawning and incubation are 68 to 70°F, although spawning is generally observed over a range of 55 to 79°F (Stuber et al. 1982). Eggs hatch in 2 to 7 days after spawning and the sac fry usually spend 5 to 8 days in the nest until they begin actively feeding (Moyle 2002). Optimal temperatures for growth of juvenile and adult bass range from 77 to 86°F, although growth will occur over a much wider range (50 to 95°F) (Moyle 2002).

The CALSIM II and HEC-5Q modeling results for Alternative 2 indicate that Sacramento River flows would be higher and water temperatures would be lower in May and June relative to the No Action Alternative, potentially affecting largemouth bass spawning and incubation (Tables O.3-31 and O.3-34). However, based on modeled mean monthly water temperatures in the lower Sacramento River at Knights Landing, no substantial changes would be expected to occur in the frequency of suitable water temperatures for spawning and incubation (Figures O.3-41 and O.3-91). The relatively large changes in flows and water temperatures in September and November of wet and above normal years under Alternative 2 (Tables O.3-31 and O.3-34) could also affect habitat conditions for juvenile and adult bass, but water temperatures would remain below optimum levels for growth under both alternatives. Consequently, the generally poor habitat conditions for largemouth bass in the Sacramento River under the No Action Alternative would persist under Alternative 1. Therefore, changes in Sacramento River flows and water temperatures associated with Alternative 1 would have a less-than-significant effect on largemouth bass in the Sacramento River relative to the No Action Alternative.

O.3.5.2.20 Smallmouth Bass

The temperature optimal range for Smallmouth Bass spawning is 55 to 70°F (Brown et al. 2009b) and the optimal for adult growth is approximately 77 to 80°F, but rapid growth of has been seen in the wild at temperatures as high as 84°F, providing prey is abundant (Moyle 2002). Young-of-year Smallmouth Bass will select temperatures as high as 84 to 87°F. Populations are rarely established in water temperatures that do not exceed 66°F in summer for extended periods, and most smallmouth populations in California are present where summer temperatures are typically 69 to 71°F. In northern California reservoirs most spawning takes place in May and June, but spawning in streams may occur into July, depending on flows and temperatures. Males start making nest depressions when water temperatures reach 55°F to 61°F. The nests are typically built at depths of about 3 to 8 feet (Brown et al. 2009). In streams, nesting and reproduction can be disrupted by flow reductions that lead to nest dewatering, or elevated flows that wash embryos and fry out of nests or lower water temperatures excessively (Graham and Orth 1986; Lukas and Orth 1995).

CalSim II results for Wilkins Slough flow for Alternative 1 compared to No Action Alternative during the May through July spawning season indicate increased flow during May and June of all of the water year types and slightly reduced flow in July, except in critically dry water years (Table O.3-52). Higher flows could adversely affect embryos and fry by dewatering nests or washing them out of the nests, but it is unknown what magnitude of flows would have these effects.

HEC-5Q monthly mean water temperatures at Hamilton City consistently fall within the 55 to 70°F optimal spawning range during the spawning season of May through July under both Alternative 2 and the No Action Alternative (Table O.3-30). At Knights Landing, however, the temperatures fall within the optimal range during May of all water year types, but lie above the range during June and July of most water year types (Table O.3-31). The water temperatures under Alternative 2 are generally similar or moderately lower than those under the No Action Alternative. The monthly mean summer water temperatures at Hamilton City consistently fall below the 66°F threshold that has been found to be a minimum for Smallmouth Bass to establish populations in California (Moyle 2002), except for critically dry water years in August and September (Table O.3-30). At Knights Landing, however, the 66°F threshold is exceeded in all summer months and water year types except September of wet and above normal years under the No Action Alternative (Table O.3-31). Note that the large wet-and-above-normal-year September water temperature increases under Alternative 2 result in water temperatures exceeding the threshold, which may benefit Smallmouth Bass. The mean water temperatures are consistently well below the optimal range for adult growth, 77 to 80°F, at both locations.

The CalSim II flow and HEC-5Q water temperature results indicate that Alternative 2 would have a less-than-significant impact on Smallmouth Bass relative to the No Action Alternative with regard to flow and water temperature.

O.3.5.2.21 <u>Spotted Bass</u>

Spotted Bass inhabit streams and reservoirs and prefer moderate-size, clear, low-gradient sections of rivers and reservoirs (McKechnie 1966). They prefer pool habitat and slower, more turbid water than Smallmouth Bass but faster water than Largemouth Bass (Moyle 2002). Their summer water temperature preference is 75 to 87°F (Moyle 2002). In streams, nests are constructed in low-current areas on bottoms ranging from debris to gravel (Moyle 2002). Spawning depths are deeper than those of largemouth bass (Aasen and Henry 1981). They spawn in the spring when water temperatures rise to 59 to 64°F (Aasen and Henry 1981; Howland 1931). Spawning continues through late May and early June, until temperatures reach 71 to 73°F.

During the spring (April through June) spawning season, CalSim II results for Wilkins Slough monthly mean flows under Alternative 2 are mostly higher than the No Action Alternative flows (Table O.3-34). Higher flows could adversely affect embryos and fry by dewatering nests or washing them out of the nests, but it is unknown what magnitude of flows would have these effects.

HEC-5Q monthly mean water temperatures at Knights Landing during the spawning season of April through June would largely be within the 59 - 64°F spawning range in April under Alternative 2 and the

No Action Alternative, but would exceed the range in May and June under both alternatives. The preferred summer water temperatures range of 75 to 87°F would be available only in critically dry years, especially in August, under both Alternative 2 and the No Action Alternative (Table O.3-31).

The CalSim II flow results and the HEC-5Q water temperature results indicate that Alternative 2, with regard to flow and water temperature, would have a less-than-significant impact on Spotted Bass relative to the No Action Alternative.

Potential changes to aquatic resources in the Sacramento River from Shasta cold water pool management

Shasta Cold Water Pool Management will not occur under either Alternative 2 or the No Action Alternative. Therefore, Alternative 2 and the No Action Alternative are likely to have similar effects on aquatic resources with respect to some potential effects of this action. However, the No Action Alternative includes NMFS's 2009 BO RPAs to operate Shasta Reservoir for management of cold water in the reservoir and river for protection of anadromous salmonids, and includes requirements for Fall X2 flow releases, but Alternative 2 includes neither requirement. The effects of these differences in operations on water temperatures and flows in the Sacramento River and potential effects on water temperature and flow differences on the focal fish species in the river are discussed above in the assessments for the individual fish species in the section *Potential changes to aquatic resources in the Sacramento River from seasonal operations* under Alternative 2.

Potential changes to aquatic resources in the Sacramento River from spring pulse flows

Spring Pulse Flows for fish will not occur under either Alternative 2 or the No Action Alternative. Therefore, Alternative 2 and the No Action Alternative are likely to have similar effects on aquatic resources with respect to potential effects of this action.

Potential changes to aquatic resources in the Sacramento River from fall and winter refill and redd maintenance

Fall and winter refill and redd maintenance will not occur under either Alternative 2 or the No Action Alternative. Therefore, Alternative 2 and the No Action Alternative are likely to have similar effects on aquatic resources with respect to potential effects of this action.

Potential changes to aquatic resources in the Sacramento River from rice decomposition smoothing

Rice decomposition smoothing will not occur under either Alternative 2 or the No Action Alternative. Therefore, Alternative 2 and the No Action Alternative are likely to have similar effects on aquatic resources with respect to potential effects of this action.

O.3.5.3 *Clear Creek*

O.3.5.3.1 <u>Whiskeytown Reservoir Operations</u>

Under Alternative 2 Reclamation would operate the CVP to meet the legal requirements for flow associated with their water rights but would not release additional flows for downstream fish and wildlife purposes. Similar to the No Action Alternative, flows from Whiskeytown Dam to Clear Creek would be managed for base flow of 50 cfs to 100 cfs based on downstream water rights and the 1963 Reclamation proposal to USFWS and NPS. Unlike the No Action Alternative, there would be no planned channel maintenance flows or pulse flows released from Whiskeytown Dam.

Under current operations and the No Action Alternative, Whiskeytown Lake is annually drawn down 13 feet (approximately 35 TAF) between November and April for flood control purposes, although it can be lowered as much as 30 feet as needed for maintenance. Model output for Whiskeytown Lake predicts that compared to the No Action Alternative, minimum reservoir volumes would be lower under Alternative 2 during the months of May (1.3 TAF lower) and July (37.4 TAF lower) (Figure O.3-94, Table O.3-35). During those two months, water surface elevations would also be lower than under the No Action Alternative. In March, April, and June, water surface elevations would be higher than under the No Action Alternative, an increase of 6.6 TAF, 1.6 TAF, and 2.2 TAF, respectively. In all other months, Whiskeytown Lake storage volume under Alternative 2 would be 0.1 TAF to 0.2 TAF higher than under the No Action Alternative.

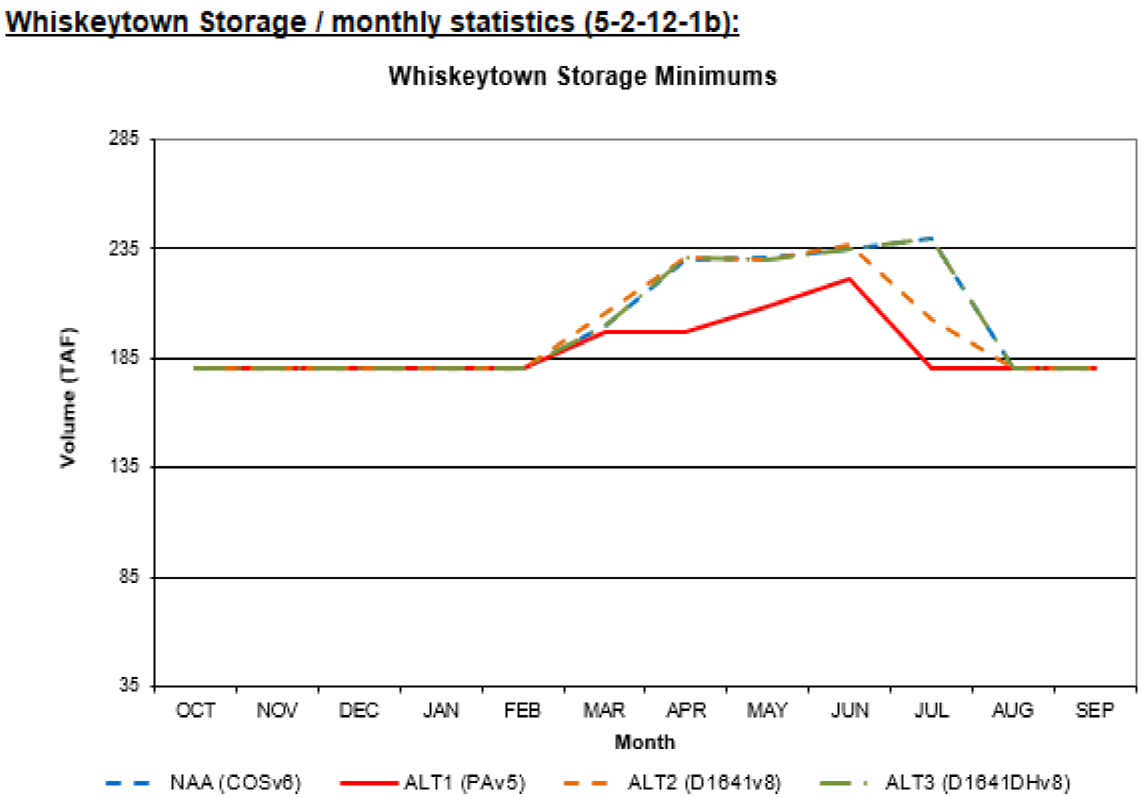


Figure O.3-94. Modeled Whiskeytown Lake Minimum Storage Volume under the No Action Alternative, Alternative 1, Alternative 2, and Alternative 3 during All Water Year Types

Table O.3-35. Modeled Differences in Whiskeytown Lake Minimum Storage Volumes from March to July under Alternative 2 Relative to the No Action Alternative

Month	Change in Volume from No Action Alternative (TAF)
March	6.6
April	1.6
May	-1.3
June	2.2
July	-37.4

The additional seasonal draw-downs in May and July under Alternative 2 could cause an increase in bank and bed erosion in newly exposed areas of tributary stream mouths where they are devoid of stabilizing riparian vegetation. This scour could cause channel incision (i.e., down-cutting) and result in increased lake water turbidity. Channel incision can create erosional nick points that propagate upstream until they encounter scour-resistant grade-controlling materials such as bedrock, at which point a cascade can form. However, annual minimum storage volume is not expected to change under this alternative. The additional draw-downs therefore represent a change in timing and duration of lower water surface elevation, not a new type or mechanism of disturbance, and channel incision may have already occurred and stabilized as a result of past operations.

Potential changes to aquatic resources from seasonal variation in water surface elevation

Hardhead

Hardhead migrate from the reservoir into tributaries in April and May to spawn upstream of Whiskeytown Lake. The timing of proposed increased draw-downs from March through July under Alternative 2 could affect Hardhead if the lower water surface elevations in May expose any previously submerged cascades at tributary mouths or create new ones. No such cascades have been documented, but if they are present or created by tributary incision at low water, they could present barriers to migration that would prevent reservoir-dwelling adult Hardhead from spawning in tributary streams. Alternately, higher water surface elevation in April may benefit migrating Hardhead at the start of their upstream migration season.

Hardhead are not a cold-water species, so drawing additional cold water from the bottom layers of the reservoir would not be expected to affect them directly. Hardhead have shown sensitivity to high sediment loads (Gard 2002), so increased reservoir turbidity due to varial zone erosion during draw-down periods could reduce suitability of reservoir and downstream waters for Hardhead persistence.

The increased annual variations in reservoir water surface elevations under Alternative 2 could cause Hardhead to be affected by reducing habitat connectivity and increasing water turbidity. However, under Alternative 2 the largest change to storage volume and water surface elevation in Whiskeytown Lake would occur in July, after Hardhead upstream migration and spawning are likely to be complete. Higher water surface elevation in April could affect migrating Hardhead at the start of their upstream migration season.

Other Fish Species

Central California Roach are not likely to be affected by changes in reservoir operations because, although they are found in upstream tributaries, they do not reside in Whiskeytown Lake, having likely been extirpated from the reach after the reservoir was originally filled in 1963. Future operations of Whiskeytown Dam under Alternative 2 are therefore unlikely to affect either individuals or populations.

Increased annual variations in reservoir water surface elevation under Alternative 2 compared to the No Action Alternative could cause varying effects to stocked and introduced nonnative game species in Whiskeytown Lake. Stocked species would not be expected to be affected by changes in reservoir operations. Rainbow Trout, Brown Trout, Kokanee Salmon, and Brook Trout typically spawn in tributary streams, but they are capable of spawning in lakes if they are unable to access moving water. Whiskeytown Lake Kokanee spawn in the fall, a period when no differences in water levels are expected under Alternative 2 compared to the No Action Alternative. Pond species such as Largemouth Bass, Smallmouth Bass, Spotted Bass, Bluegill, Black Crappie, Channel Catfish, and Brown Bullhead are able to tolerate a wide range of conditions, but the basses and panfish spawn in relatively shallow lake areas when water warms to at least 50°F in late spring or summer. Reducing reservoir volume in July could put some of their nests at risk of being dewatered. However, these species have rapid reproductive rates which can enable them to recover from episodic recruitment failures.

O.3.5.3.2 Clear Creek Flows

Under Alternative 2 Reclamation proposes minimum base flows in Clear Creek of 50 cfs to 100 cfs in normal water years and 30 cfs to 70 cfs in critically dry water years, based on downstream water rights and the 1963 Reclamation proposal to USFWS and NPS, as described in the No Action Alternative (Table O.3-36). Under Alternative 2 there are no channel maintenance flows or pulse flows, whereas under the No Action Alternative channel maintenance flows would occur in congruence with flood operations and two pulse flows would be released in May and June of at least 600 cfs for at least 3 days per pulse per year.

Table O.3-36. Minimum Flows at Whiskeytown Dam

Period	Alternative 2 Normal Year (cfs)	Alternative 2 Critically Dry Year (cfs)	No Action Alternative Normal Year (cfs)	No Action Alternative Critically Dry Year (cfs)
Jan 1 to Oct 31	50	30	50	30
Nov 1 to Dec 31	100	70	100	70

Modeling results indicate that average Clear Creek flow below Whiskeytown Dam under Alternative 2 would generally exceed Alternative 2 minimum instream flows in all water year types but remain lower than average flow under the No Action Alternative in all months and water year types (Figure O.3-95). Relative to the No Action Alternative, the minimum decrease in flow would be 69 cfs in dry years, and the maximum decrease would be 100 cfs in wet years (Figure O.3-96).

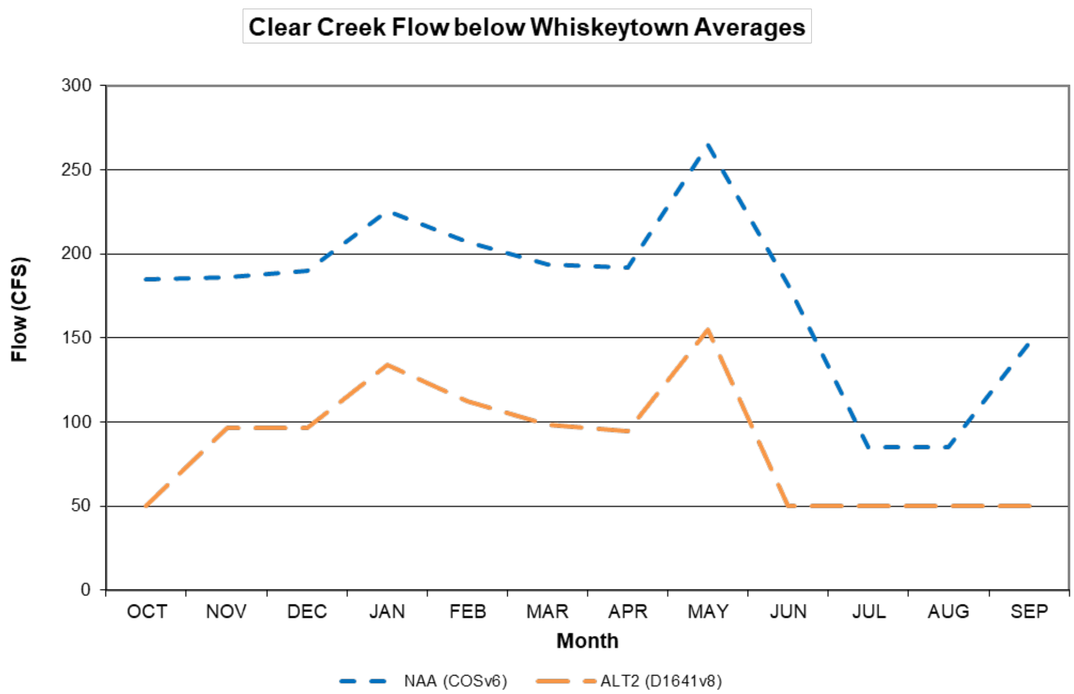
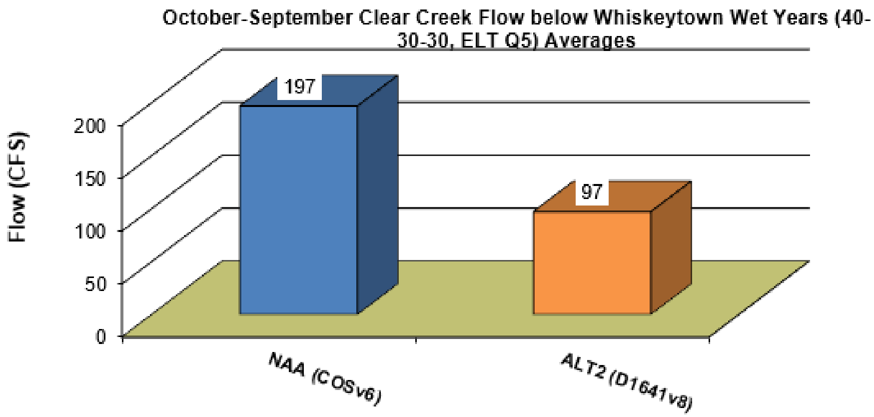


Figure O.3-95. Average Monthly Flow in Clear Creek below Whiskeytown Dam for the No Action Alternative and Alternative 2 during All Water Years (40-30-30 Index)



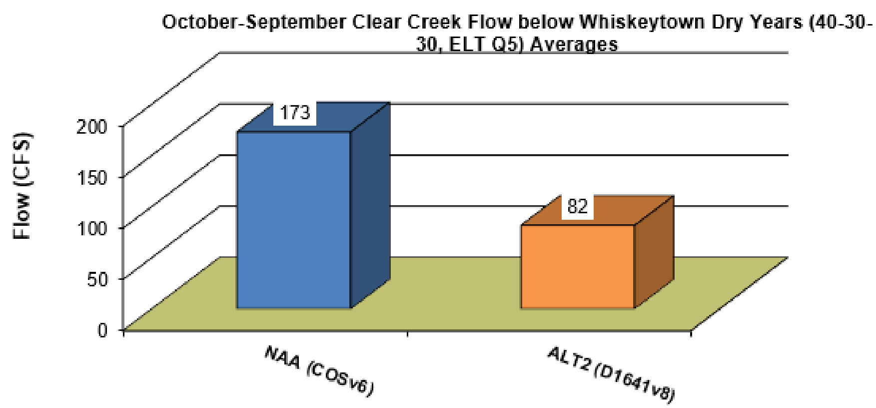


Figure O.3-96. Average Annual Flow in Clear Creek below Whiskeytown Dam for the No Action Alternative and Alternative 2 during Wet and Dry Water Years (40-30-30 Index).

Potential changes to aquatic resources in Clear Creek from variation in flow

Spring-Run Chinook Salmon

Under Alternative 2 Clear Creek flow downstream of Whiskeytown Dam would average approximately 58% of Clear Creek flow under the No Action Alternative in all water years. These differences in flow would coincide with the seasonal occurrence of all life stages of Spring-Run Chinook Salmon in Clear Creek, including migrating and holding adults, spawning adults, rearing and outmigrating juveniles, and eggs and fry. Because flow under Alternative 2 would be substantially less than flow under the No Action Alternative, this difference in base flow under Alternative 2 may adversely affect Spring-Run Chinook eggs and fry by increasing temperature and reducing DO, juveniles by decreasing available habitat and reducing migration cues for juveniles, and adults by decreasing pool connectivity and available holding and spawning habitat.

The lack of channel maintenance flows and pulse flows under Alternative 2 would result in a reduction of gravel mobilization and attraction flows in Clear Creek, which would adversely affect all life stages of Spring-Run Chinook Salmon. Reduced gravel mobilization would lead to a decrease in suitable spawning habitat, while the lack of pulse flows would lead to a reduction in cues triggering upstream and downstream migration. Implementation of Mitigation Measure AQUA-3 would mitigate any adverse effects of flow in Clear Creek downstream of Whiskeytown Dam under Alternative 2; therefore, Alternative 2 is not expected to adversely affect Spring-Run Chinook Salmon compared to the No Action Alternative.

Fall-Run Chinook Salmon

Under Alternative 2 Clear Creek flow downstream of Whiskeytown Dam would average approximately 58% of Clear Creek flow under the No Action Alternative in all water years. These differences in flow would coincide with the seasonal occurrence of all life stages of Fall-Run Chinook Salmon in Clear Creek, including migrating and spawning adults, rearing and outmigrating juveniles, and eggs and fry. Because flow under Alternative 2 would be substantially less than flow under the No Action Alternative, this difference in base flow under Alternative 2 may adversely affect Fall-Run Chinook eggs and fry by increasing temperature and reducing DO, juveniles by decreasing available habitat and reducing migration cues for juveniles, and adults by decreasing pool connectivity and available holding and spawning habitat.

The lack of channel maintenance flows and pulse flows under Alternative 2 would result in the reduction of gravel mobilization and attraction flows in Clear Creek, which would negatively affect all life stages of Fall-Run Chinook Salmon. Reduced gravel mobilization would lead to a decrease in suitable spawning habitat, while the lack of pulse flows would lead to a reduction in cues triggering upstream and downstream migration. Implementation of Mitigation Measure AQUA-3 would mitigate any adverse effects of flow in Clear Creek downstream of Whiskeytown Dam under Alternative 2; therefore, Alternative 2 is not expected to adversely affect Fall-Run Chinook Salmon compared to the No Action Alternative.

Central Valley Steelhead

Under Alternative 2 Clear Creek flow downstream of Whiskeytown Dam would average approximately 58% of Clear Creek flow under the No Action Alternative in all water years. These differences in flow would coincide with the seasonal occurrence of all California Central Valley DPS Steelhead life stages in Clear Creek, including migrating and spawning adults, rearing and outmigrating juveniles, and eggs and fry. Because flow under Alternative 2 would be substantially less than flow under the No Action Alternative, this difference in base flow under Alternative 2 may adversely affect Central Valley Steelhead eggs and fry by increasing temperature and reducing DO, juveniles by decreasing available habitat and reducing migration cues for juveniles, and adults by decreasing pool connectivity and available holding and spawning habitat.

The lack of channel maintenance flows and pulse flows under Alternative 2 would result in the reduction of gravel mobilization and attraction flows in Clear Creek, which would negatively affect all life stages of California Central Valley DPS Steelhead. Reduced gravel mobilization would lead to a decrease in suitable spawning habitat, while the lack of pulse flows would lead to a reduction in cues triggering upstream and downstream migration. Implementation of Mitigation Measure AQUA-1 would mitigate any adverse effects of flow in Clear Creek downstream of Whiskeytown Dam under Alternative 2; therefore, Alternative 2 is not expected to adversely affect Steelhead compared to the No Action Alternative.

Pacific Lamprey

Under Alternative 2 Clear Creek flow downstream of Whiskeytown Dam would average approximately 58% of Clear Creek flow under the No Action Alternative in all water years. These differences in flow would coincide with the seasonal occurrence of various life stages of Pacific Lamprey in Clear Creek, including spawning and outmigrating adults and ammocoetes. Because the modeled flow under Alternative 2 is significantly lower than flow under the No Action Alternative, changes to base flows under Alternative 2 could potentially adversely affect Pacific Lamprey by increasing temperature, reducing DO, and reducing available habitat.

The lack of channel maintenance flows and pulse flows under Alternative 2 would result in the reduction of gravel mobilization and attraction flows in Clear Creek, which would negatively affect all life stages of Pacific Lamprey. Implementation of Mitigation Measure AQUA-3 would mitigate any adverse effects of flow in Clear Creek downstream of Whiskeytown Dam under Alternative 2; therefore, Alternative 2 is not expected to adversely affect Pacific Lamprey compared to the No Action Alternative.

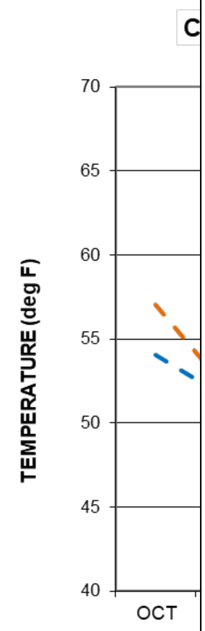
Potential changes to aquatic resources in Clear Creek from variation in water temperature

Under Alternative 2, Reclamation would manage Whiskeytown releases without any water temperature thresholds, whereas under the No Action Alternative, daily water temperature objectives would be 60°F at the Igo gage from June 1 through September 15 and 56°F at the Igo gage from September 15 through October 31.

Modeling results show that changes in water temperatures in Clear Creek downstream of Whiskeytown Dam would be similar under Alternative 2 and No Action Alternative between November and January of all water year types (Figure O.3-97). Water temperatures under Alternative 2 would exceed those under the No Action Alternative in all other months with temperature differences reaching a maximum of approximately 5°F throughout the summer. Clear Creek water temperatures would exceed 65°F in July under Alternative 2 as opposed to 60°F under the No Action Alternative.

Figure O.3-97. Average Monthly Water Temperatures in Clear Creek above Sacramento River for the No Action Alternative and Alternative 2 during All Water Year Types (40-30-30 Index).

Table O.3-37. Water Temperatures Suitable for Spring-Run and Fall-Run Chinook Salmon, and Central Valley Steelhead by Life Stage

Life Stage	**Peak Occurrence**	**Optimal**	**Suboptimal**	**Stre**  **ss-inducing**
Spring-Run Chinook Salmon				
Eggs to fry	September to October	< 54°F	54°F to 58°F	> 58°F
Rearing to out-migrating	November to May	< 60°F	60°F to 65°F	> 65°F
Migrating adults	March to June	< 56°F	56°F to 65°F	> 65°F
Adult holding	May to August	< 60.8°F	60.8°F to 66.2°F	> 66.2°F
Fall-Run Chinook Salmon				
Eggs to fry	October to April	48.2°F to 55.4°F	55.4°F to 62.6°F	> 62.6°F
Rearing to out-migrating	April to June	55.4°F to 68°F	68°F to 75.2°F	> 75.2°F
Migrating adults	June to April	50°F to 68°F	68°F to 69.8°F	> 69.8°F
Central Valley Steelhead				
Eggs to fry	January	46°F to 52°F	52°F to 55°F	> 55°F
Rearing to out-migrating	January to May	< 65°F	65°F to 68°F	> 68°F
Migrating adults	September to October	< 52°F	52°F to 70°F	> 70°F
Adult holding	December to March	< 60.8°F	60.8°F to 66.2°F	> 66.2°F

Sources: NMFS 2016a; Stillwater Sciences 2006; CDFG 2012a, 2012b.

Spring-Run Chinook Salmon

Under Alternative 2, Spring-Run Chinook Salmon eggs and emerging fry would experience stress-inducing temperatures during September of all water year types (Table O.3-37, Figure O.3-97). In October, temperatures would fall within the stress-inducing range for eggs and emerging fry during critically dry year types and within the suboptimal range for during all other year types. November temperatures would be optimal during all water year types (Figure O.3-97). Rearing to outmigrating juveniles would experience optimal temperature ranges under Alternative 2 during their period of peak occurrence in all water year types (Figure O.3-97). Migrating adults would experience sub-optimal temperatures in June of critically dry years and optimal temperatures during all other months of peak occurrence during all other water year types (Figure O.3-97). Relative to the No Action Alternative, Spring-Run Chinook Salmon would experience more frequent stress-inducing temperatures during the incubation and emerging fry life stages. Implementation of Mitigation Measure AQUA-3 would mitigate any adverse effects of flow and water temperature in Clear Creek downstream of Whiskeytown Dam under Alternative 2; therefore, Alternative 2 is not expected to adversely affect Spring-Run Chinook Salmon compared to the No Action Alternative.

Fall-Run Chinook Salmon

Under Alternative 2, Fall-Run Chinook eggs and emerging fry would experience suboptimal temperatures in Clear Creek during October of all water year types (56.1°F to 58.9°F), whereas under the No Action Alternative suboptimal October temperatures would only be encountered in critically dry year types. For the remainder of their period of peak occurrence during all year types, eggs and emerging fry would experience optimal temperature conditions (Table O.3-37, Figure O.3-97). Rearing and outmigrating juveniles would experience optimal temperature conditions during their period of peak occurrence for all water year types, as would migrating adults (Figure O.3-97). Alternative 2 could result in increased occurrences of suboptimal temperatures for incubation and emerging fry. However, HEC-5Q/RecTemp provides water temperature results as average monthly values, which do not have sufficient temporal resolution to facilitate direct comparison with average daily temperature objectives. Implementation of Mitigation Measure AQUA-1 would mitigate any adverse effects of flow in Clear Creek downstream of Whiskeytown Dam under Alternative 2; therefore, Alternative 2 is not expected to adversely affect Fall-Run Chinook Salmon compared to the No Action Alternative.

Central Valley Steelhead

Under Alternative 2, California Central Valley Steelhead migrating adults would experience suboptimal temperatures in Clear Creek in all water years (Table O.3-37, Figure O.3-97). All other life stages of California Central Valley Steelhead would encounter optimal temperatures during their periods of peak occurrence during all water year types. Under the No Action Alternative, California Central Valley Steelhead would experience temperatures within the same optimal and suboptimal temperature ranges as under Alternative 2. Therefore, relative to the No Action Alternative, Alternative 2 is expected to have a negligible effect.

Pacific Lamprey

Under Alternative 2, spawning Pacific Lamprey would experience temperatures ranges suitable for spawning in April and May of all water year types. During the remainder of the peak spawning period, Pacific Lamprey will experience temperatures below the general spawning range; however, under Alternative 2, temperatures are slightly higher than under the No Action Alternative (Table O.3-38, Figure O.3-97). Modeled Alternative 2 and No Action Alternative temperatures do not exceed suitable ranges during the period of peak occurrence of ammocoetes and outmigrating adults in any water year types (Figure O.3-97). Overall, Alternative 2 and the No Action Alternative should not negatively affect Pacific Lamprey in Clear Creek, as suitable temperatures overlap or coincide with the period of peak occurrence for all life stages.

Table O.3-38. Summary Table of Water Temperatures Suitable for Pacific Lamprey by Life Stage

Life Stage	**Peak Occurrence**	**Temperature Range**
Ammocoetes	Year-round	< 82°F [1]
Adult spawning	January to May	50°F to 64°F, peak 57°F to 59°F
Adult out-migration	Early winter to spring	<68°F

Source: Stillwater Sciences 2014.
[1] Temperature of 82°F is lethal to ammocoetes of four North American species of lamprey, however it is uncertain if Pacific Lampreys have similar tolerances.

O.3.5.3.3 Spring Creek Debris Dam

Existing operations of the SCDD will continue under both Alternative 2 and the No Action Alternative. Therefore, Alternative 2 and the No Action Alternative are likely to have similar effects on aquatic resources.

O.3.5.3.4 Clear Creek Restoration Program

The goals of the Clear Creek Restoration Program are to (1) provide flows to allow sufficient spawning, incubation, rearing, and out-migration for Central Valley Chinook Salmon and Steelhead; (2) restore the stream channel and associated instream habitat; (3) operate the segregation weir to create reproductive isolation between Fall-Run (Fall-Run and Late Fall-Run) Chinook and Spring-Run Chinook Salmon; and (4) determine impacts of restoration actions on anadromous fish and geomorphology.

The program manages flows and temperatures through releases from Whiskeytown Dam on a year-round basis to improve survival and condition of Salmon and Steelhead in Clear Creek. The magnitude and timing of flows and water temperature are controlled to meet this goal. The 2009 NMFS BO RPA Action I.1.3 (Clear Creek Spawning Gravel Augmentation), implemented under the No Action Alternative, requires restoration on a two-mile section of Clear Creek floodplain and stream channel by annual gravel augmentation to recharge and maintain gravel supply (approximately 8,000 to 10,000 tons of gravel per year). The aim of the 2009 NMFS BO RPA Action I.1.3 is to create and maintain 347,288 square feet of usable spawning habitat in Clear Creek. However, under Alternative 2 the gravel augmentation in Clear Creek set forth by the 2009 NMFS BO RPA Action I.1.3 would not be implemented. Additionally, the picket weir (segregation weir) would not be operated under Alternative 2. Therefore, this section analyzes effects on focal species resulting from differences between Alternative 2 and the No Action Alternative.

Potential changes in aquatic resources due to gravel augmentation and segregation weir operation

Fall-Run and Spring-Run Chinook Salmon

Gravel augmentation would not occur under Alternative 2. As a result, spawning gravel availability in Clear Creek would likely decrease over time through downstream transport of existing coarse sediment during periods of high flow, leading to decreased quantity and quality of Central Valley Fall-Run and Spring-Run Chinook spawning and incubation habitat. A decrease in available spawning and incubation habitat could increase the probability of redd superimposition and limit the number of successful spawners and juvenile recruits, leading to potential adverse effects on Fall-Run and Spring-Run Chinook

Salmon. Operation of the segregation weir would not occur under Alternative 2. Therefore, hybridization of Fall-Run and Spring-Run Chinook Salmon would likely increase over time, leading to additional, potential adverse effects on Spring-Run Chinook Salmon population genetic integrity. However, these potential adverse effects would be reduced to a negligible level by implementation of Mitigation Measure AQUA-3.

Central Valley Steelhead

Gravel augmentation would not occur under Alternative 2. As a result, spawning gravel availability in Clear Creek would likely decrease over time through downstream transport of existing coarse sediment during periods of high flow, leading to decreased quantity and quality of Central Valley Steelhead spawning and incubation habitat. A decrease in available spawning and incubation habitat could increase the probability of redd superimposition and limit the number of successful spawners and juvenile recruits, leading to adverse effects on Central Valley Steelhead. These potential adverse effects would be reduced to a negligible level by implementation of Mitigation Measure AQUA-3.

Pacific Lamprey

Gravel augmentation would not occur under Alternative 2. As a result, spawning gravel availability in Clear Creek would likely decrease over time through downstream transport of existing coarse sediment during periods of high flow, leading to decreased quantity and quality of Pacific Lamprey spawning and incubation habitat. A decrease in available spawning and incubation habitat could limit the number of successful spawners, leading to adverse effects on Pacific Lamprey.

O.3.5.4 *Feather River*

O.3.5.4.1 FERC Project #2100-134

DWR, under Alternative 2, would operate Oroville Dam consistent with the NMFS, USFWS, and CDFW environmental requirements applicable for the current FERC License for the Oroville Complex (FERC Project #2100-134). Reclamation would operate Oroville Dam with minimum flows of 700 cfs to 800 cfs below the Thermalito Diversion Dam in the low flow channel (2006 Settlement Agreement), 750 cfs to 1,700 cfs below the Thermalito Afterbay outlet in the high flow channel (HFC; 1983 DWR-CDFG Agreement), and the DFG/DWR operation objective of 2,800 cfs at the mouth of the Feather River from April through September, with options to vary flow depending on year types. Under the No Action Alternative, DWR would operate Oroville Dam in accordance with ongoing management policies, criteria, and regulations, including water right permits and licenses issued by the SWRCB and operational requirements of the 2008 USFWS BO and the 2009 NMFS BO. Under the No Action Alternative, DWR typically releases water from Lake Oroville to meet the requirements of instream flows and D-1641.

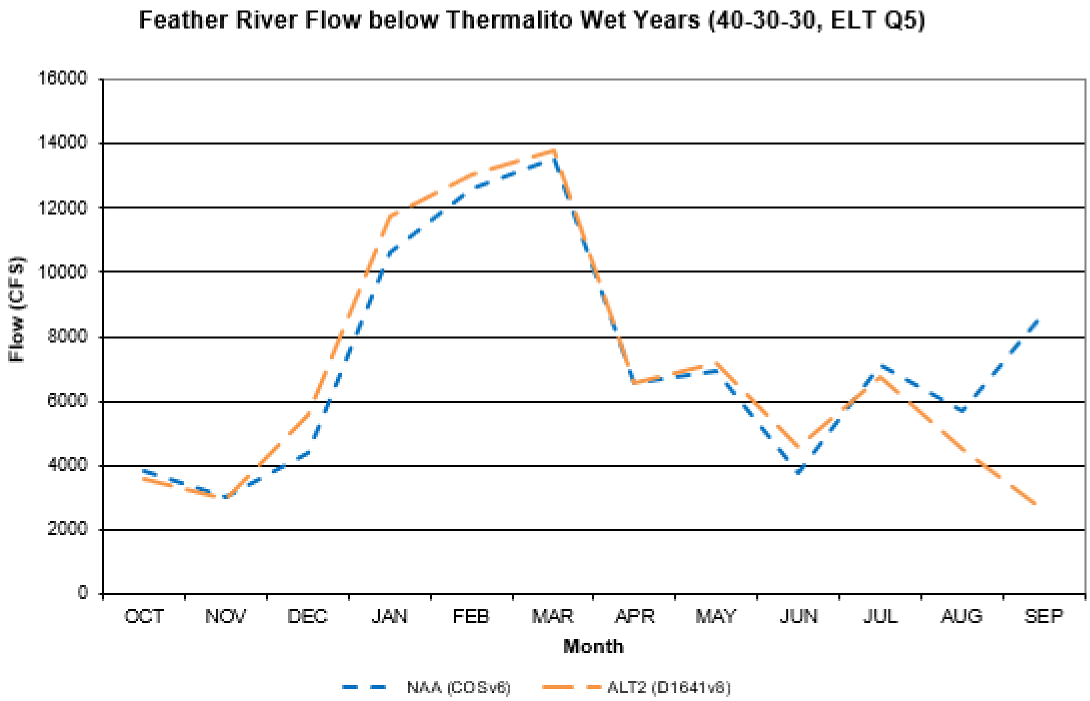
Potential changes to aquatic resources in the Feather River due to seasonal variation in flow

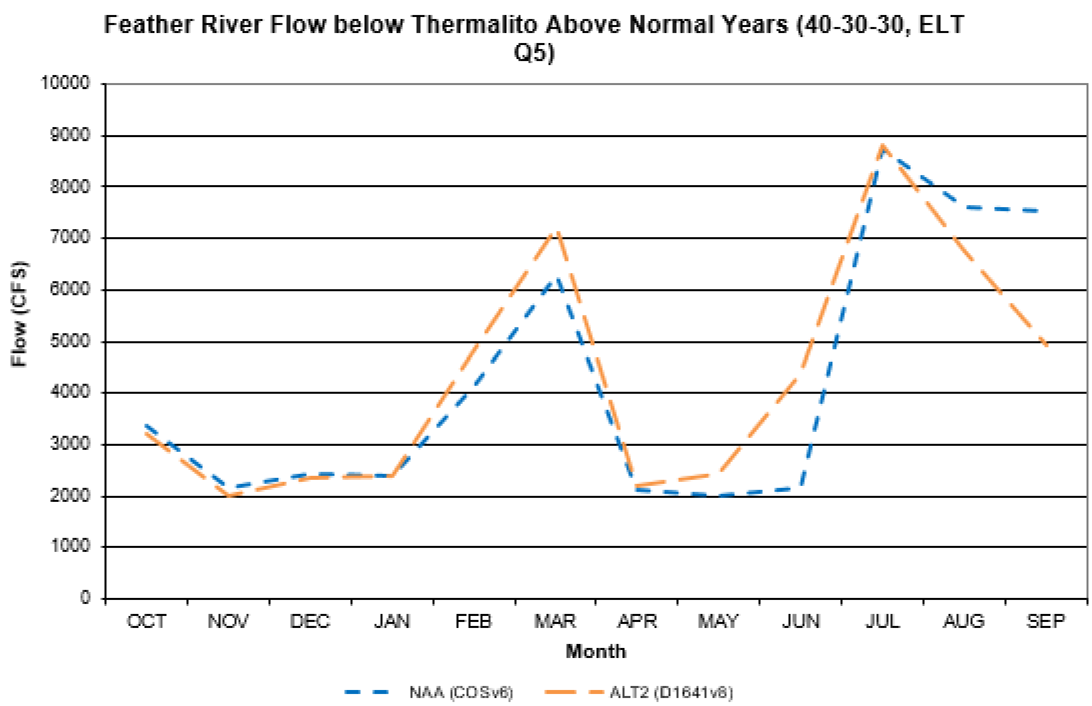
CalSim II model output shows that Feather River flows under Alternative 2 and the No Action Alternative would comply with Feather River HFC minimum instream flow requirements during all months in wet, above normal, and below normal water years. In dry years where the preceding April to July unimpaired runoff is less than 55% of normal, Alternative 2 and the No Action Alternative would comply with minimum instream flow requirements in the HFC; however, where the preceding April to July unimpaired runoff is greater than 55% of normal, Alternative 2 would not comply with minimum instream flow requirements from October through March (Table O.3-39 and Figure O.3-98). In critically dry years where the preceding April to July runoff is 55% or greater of normal, Alternative 2 and the No Action Alternative would not comply with minimum instream flows from October to March; however, where the preceding April to July runoff is less than 55% of normal, Alternative 2 and the No Action Alternative would not comply with minimum instream flow requirements in the HFC only in November (Table O.3-39 and Figure O.3-98).

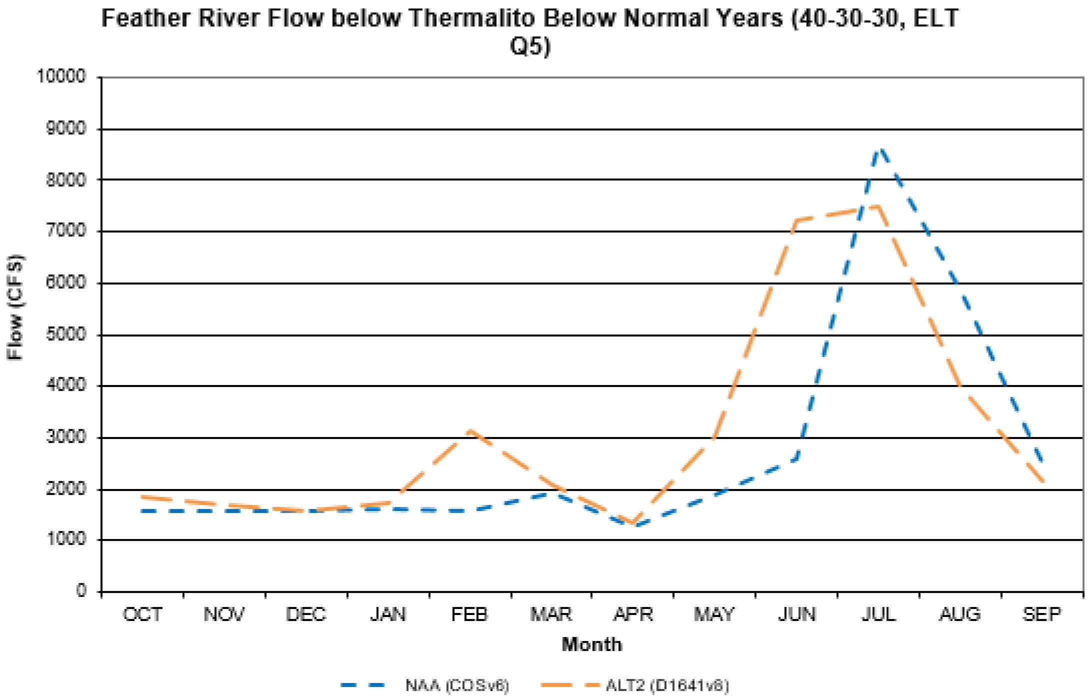
Table O.3-39. Feather River HFC Minimum Instream Flow Requirements

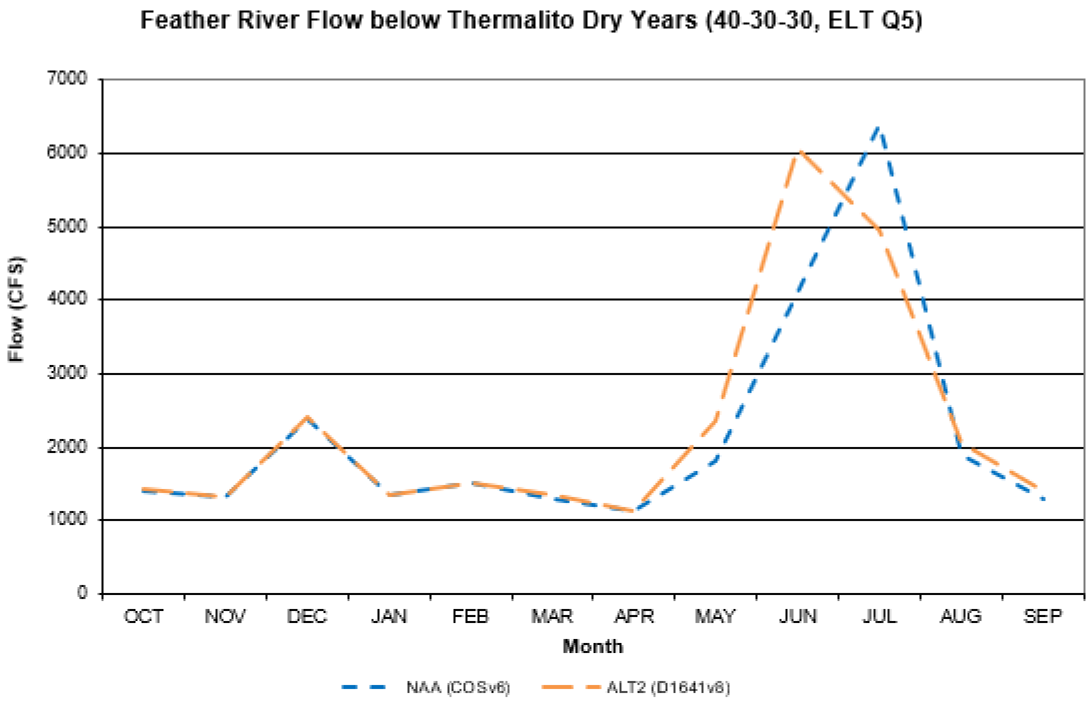
Preceding April to July Unimpaired Runoff (Percent of Normal)	Oct to Feb Minimum Instream Flow (cfs)	March Minimum Instream Flow (cfs)	April to Sept Minimum Instream Flow (cfs)
55% or greater	1,700	1,700	1,000
Less than 55%	1,200	1,000	1,000

Overall, flows under Alternative 2 and the No Action Alternative are similar, but flows under the No Action Alternative are greater than flows under Alternative 2 from July through September of wet, above normal, and below normal years, and flows under Alternative 2 are greater than under the No Action Alternative from April through June of above normal, below normal, and dry water years (Figure O.3-98). Flows under Alternative 2 are also much greater than under the No Action Alternative in February of below normal years.


Feather River Flow below Thermalito Wet Years (40-30-30, ELT Q5)
16000
14000
12000
10000
8000
6000
4000
2000
0
Flow (CFS)
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
Month
NAA (COSv6)
ALT2 (D1641v8)


Feather River Flow below Thermalito Above Normal Years (40-30-30, ELT Q5)
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
Flow (CFS)
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
Month
NAA (COSv6)
ALT2 (D1641v8)


Feather River Flow below Thermalito Below Normal Years (40-30-30, ELT Q5)
Flow (CFS)
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
Month
NAA (COSv6)
ALT2 (D1641v8)


Feather River Flow below Thermalito Dry Years (40-30-30, ELT Q5)
Flow (CFS)
7000
6000
5000
4000
3000
2000
1000
0
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
Month
NAA (COSv6)
ALT2 (D1641v8)

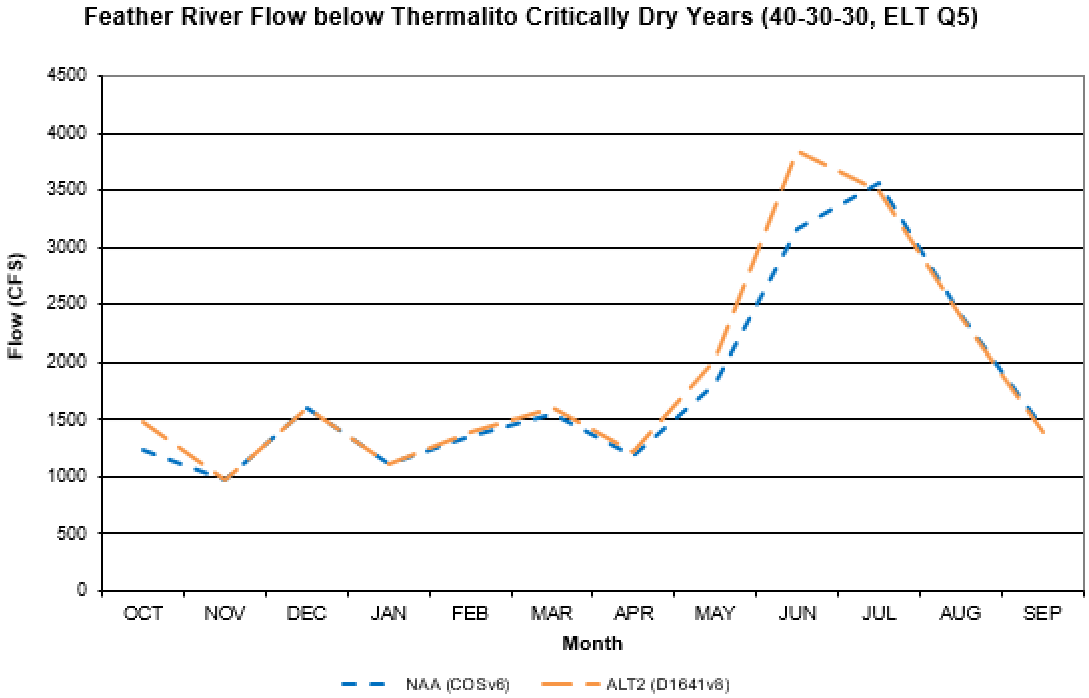


Figure O.3-98. CalSim II estimates of Feather River Long-Term Average Flow below Thermalito, All Scenarios in Wet, Above Normal, Below Normal, Dry, and Critically Dry Water Years

Winter-Run Chinook Salmon

Winter-Run Chinook Salmon are not likely to be affected by changes in flow under Alternative 2 compared to the No Action Alternative due to their limited distribution in the Feather River.

Spring-Run Chinook Salmon

Spring-Run Chinook Salmon would be exposed to the effects of Alternative 2 based on their seasonal occurrence in the Feather River, minimum instream flow requirements in the HFC, and compliance with D-1641. Eggs and emerging fry of Spring-Run Chinook Salmon occur in the Feather River from September through February (NMFS 2016a); juvenile Spring-Run Chinook Salmon occur in the Feather River year-round, with peak abundance from November through May; and adult Spring-Run Chinook Salmon peak in abundance in the Feather River from March through June. All life stages would thus be exposed to the effects of Alternative 2.

Spring-Run Chinook Salmon eggs and emerging fry would benefit from increased Alternative 2 flows, leading to increased dissolved oxygenin February of below normal years when Alternative 2 flows are higher than No Action Alternative flows (Figure O.3-98). Juvenile Spring-Run Chinook Salmon would benefit from increased Alternative 2 flows relative to No Action Alternative flows from November through March of wet years, January through April of above normal years, and February of below normal years when the increased flows result in increased rearing and foraging habitat and higher dissolved oxygencontent (Figure O.3-98). Adult Spring-Run Chinook Salmon would benefit from increased Alternative 2 flows relative to No Action Alternative flows from April through June of below normal, dry, and critically dry years due to the resulting increased attraction flows and holding habitat (Figure O.3-98). Because Spring-Run Chinook Salmon benefit from increased Alternative 2 flows relative to No Action Alternative flows during key months of all life stages, and because Alternative 2 flows do not comply with minimum instream flow requirements only in dry and critically dry years, flow-related actions under Alternative 2 may have beneficial effects on Spring-Run Chinook Salmon.

Fall-Run Chinook Salmon

Fall-Run Chinook Salmon would be exposed to the effects of Alternative 2 based on their seasonal occurrence in the Feather River, minimum instream flow requirements in the HFC, and compliance with D-1641. Fall-Run Chinook Salmon occur in the Feather River year-round, with eggs and emerging fry occurring between January and April, juveniles out-migrating year-round with peaks from January to April and August to November, and holding and migrating adults occurring between April and July (NMFS 2016a). All life stages would thus be exposed to the effects of Alternative 2.

Fall-Run Chinook Salmon eggs and emerging fry may benefit from the increased dissolved oxygendue to higher Alternative 2 flows from January to April of wet and above normal years and in February of below normal years (Figure O.3-98). Juvenile Fall-Run Chinook Salmon would benefit from increased Alternative 2 flows relative to No Action Alternative flows from January to April of wet and above normal years and in February of below normal years when increased flows result in increased rearing and foraging habitat and higher dissolved oxygencontent (Figure O.3-98). Migrating adult Fall-Run Chinook Salmon would benefit from increased Alternative 2 flows relative to No Action Alternative flows from April to July of below normal, dry, and critically dry years due to increased attraction flows and holding habitat (Figure O.3-98). Because Fall-Run Chinook Salmon benefit from increased Alternative 2 flows relative to No Action Alternative flows during key months of all life stages and because Alternative 2 flows do not comply with minimum instream flow requirements only in dry and critically dry years, flow-related actions under Alternative 2 may have beneficial effects on Fall-Run Chinook Salmon.

Central Valley Steelhead

Central Valley Steelhead would be exposed to the effects of Alternative 2 based on their seasonal occurrence in the Feather River, minimum instream flow requirements in the HFC, and compliance with D-1641. Central Valley Steelhead eggs and fry occur in the Feather River from December to May; juveniles typically migrate to the ocean from January to May after spending 1 to 3 years in freshwater (CDFG 1996); peak adult migration occurs in September and October; and adult holding occurs December to March (NMFS 2016a).

Alternative 2 flows can affect Central Valley Steelhead by influencing water temperature, DO, sedimentation, substrate composition, habitat, food availability, predation, entrainment and stranding risk, habitat availability, and migration cues. Differences in flow under Alternative 2 and the No Action Alternative are minimal during the January to May period in which Central Valley Steelhead juveniles are out-migrating in all but below normal water years when Alternative 2 flows are considerably higher than No Action Alternative flows from mid-January through mid-March and can benefit juveniles via increased rearing and foraging habitat and higher dissolved oxygencontent (Figure O.3-98). The same is true for the December to May period in which Central Valley Steelhead eggs and fry may be present in the Feather River. During the September and October adult peak migration period, No Action Alternative flows are considerably higher than Alternative 2 flows in September in wet and above normal water years, causing higher levels of flow attraction (Figure O.3-98); there are minimal differences in all other water years. During adult holding from December to March, differences between Alternative 2 and No Action Alternative flows are minimal except for in February of below normal water years when increased flows could increase available habitat. Because Central Valley Steelhead benefit from increased Alternative 2 flows relative to No Action Alternative flows during key months of all life stages and because Alternative 2 flows do not comply with minimum instream flow requirements only in dry and critically dry years, flow-related actions under Alternative 2 may have beneficial effects on Central Valley Steelhead.

North American Green Sturgeon

North American Green Sturgeon would be exposed to the effects of Alternative 2 based on their seasonal occurrence in the Feather River, minimum instream flow requirements in the HFC, and compliance with D-1641. Green Sturgeon eggs and larvae occur in the Feather River from March to July; larvae and juveniles occur from April to August; subadults occur year-round; and adults occur from March to August (NMFS 2016a).

Differences in flow under Alternative 2 and the No Action Alternative are minimal during all water years in the March to August period in which Green Sturgeon eggs, larvae, juveniles, and adults occur in the Feather River; subadults occur year-round. Thus, only Green Sturgeon subadults would be exposed to the larger differences between Alternative 2 and the No Action Alternative in February of below normal water years when Alternative 2 flows are greater than they are under the No Action Alternative and in September of above normal and wet water years when No Action Alternative flows are greater than flows under Alternative 2. Because flow differences between Alternative 2 and the No Action Alternative during key periods of Green Sturgeon presence in the Feather River are minimal and flows below the minimum instream flow requirements occur only in dry and critically dry water years, flow-related actions under Alternative 2 are not anticipated to substantially affect North American Green Sturgeon.

Potential changes to aquatic resources in the Feather River due to changes in water temperature from differences in flow

Water flow, combined with other environmental drivers, has the potential to affect aspects of water quality such as temperature. Water temperature has the potential to influence the condition and survival of fish species during all stages of their life cycle. Optimal water temperatures can facilitate physiological responses that range from faster growth rates to a heightened immune system, leading to a higher likelihood of survival. In contrast, effects of elevated water temperatures include an inability to satisfy metabolic demand and acute to chronic physiological stress, possibly leading to mortality (Stillwater Sciences 2006; Martin et al. 2017).

Water temperatures in the Feather River HFC at Gridley Bridge follow a seasonal pattern where they increase to a high point around 72°F in July or August and decrease to a low point around 47°F in January (Figure O.3-99). Flow releases from Oroville facilities influence Feather River water temperature primarily in summer and fall when these releases can help to lessen water temperatures when air temperatures and solar radiation levels are at their highest. Minimum water temperatures in the Feather River do not change substantially between water year type, but water temperatures can reach a maximum up to 4°F warmer (approximately 75°F) in critically dry years than in wet years (approximately 71°F; Figure O.3-89).

Effects of water temperature on fish in the Feather River vary among species and life stages. Temperatures surpass suboptimal levels for all species and life stages at 68°F and stress-inducing levels at 75.2°F (Table O.3-40). There is, therefore, potential for adverse temperature-related effects on Feather River fish species.

Alternative 2 was designed to follow flow regulation procedures similar to procedures under the No Action Alternative as a way to minimize potential adverse temperature-related effects on various fish species in the Feather River. Certain water temperature objectives were developed to aid the development of Alternative 2 operations (Table O.3-41).

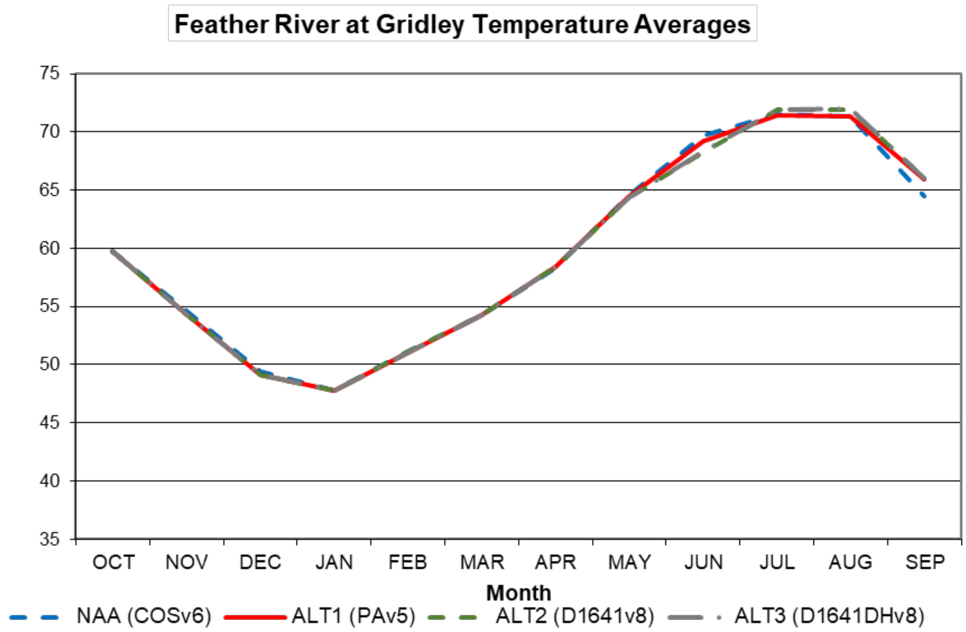


Figure O.3-99. RecTemp average Feather River water temperatures at Gridley Bridge under the No Action Alternative, Alternative 1, Alternative 2, and Alternative 3 scenarios.

Figure O.3-100. RecTemp Average Estimated Feather River Water Temperatures at Gridley Bridge in Wet, Above Normal, Below Normal, Dry, and Critically Dry Water Year Types under the No Action Alternative, Alternative 1, Alternative 2, and Alternative 3 Scenarios

Table O.3-40. Water Temperatures Suitable for Spring- and Fall-Run Chinook, Central Valley Steelhead, and Green Sturgeon by Life Stage

Life Stage	**Peak Occurrence**	**Optimal**	**Suboptimal**	**Stress-inducing**
Spring-Run Chinook				
Eggs to fry	September to October	< 54°F	54°F to 58°F	> 58°F
Rearing to out-migrating	November to May	< 60°F	60°F to 65°F	> 65°F
Migrating adults	March to June	< 56°F	56°F to 65°F	> 65°F
Adult holding	May to August	< 60.8°F	60.8°F to 66.2°F	> 66.2°F
Fall-Run Chinook				
Eggs to fry	October to April	48.2°F to 55.4°F	55.4°F to 62.6°F	> 62.6°F
Rearing to out-migrating	April to June	55.4°F to 68°F	68°F to 75.2°F	> 75.2°F
Migrating adults	June to April	50°F to 68°F	68°F to 69.8°F	> 69.8°F
Central Valley Steelhead				
Eggs to fry	January	46°F to 52°F	52°F to 55°F	> 55°F
Rearing to out-migrating	January to May	< 65°F	65°F to 68°F	> 68°F
Migrating adults	September to October	< 52°F	52°F to 70°F	> 70°F
Adult holding	December to March	< 60.8°F	60.8°F to 66.2°F	> 66.2°F
Green Sturgeon				
Eggs to fry	May to July	53°F to 65°F	65°F to 66°F	> 66°F
Rearing to out-migrating	May to October	58°F to 66°F	66°F to 69°F	> 69°F
Migrating adults	March to May	53°F to 64°F	64°F to 66°F	> 66°F
Post-spawn adults	March to August	46°F to 68°F	68°F to 70°F	>70°F

Source: NMFS 2016a; Stillwater Sciences 2006; CDFG 2012a, 2012b.

Table O.3-41. Maximum Daily Mean Water Temperature Objectives for the HFC

Period	**Temperature (°F)**
January 1 to March 31	56
April 1 to 30	61
May 1 to 15	64
May 16 to 31	64
June 1 to August 31	64
September 1 to 8	61
September 9 to 30	61
October 1 to 31	60
November 1 to December 31	56

Source: NMFS 2016a.

Modeling results indicate that water temperatures under Alternative 2 operations would be similar to temperatures under the No Action Alternative for much of the year (Figures O.3-99 and O.3-100). However, in August and September, water temperatures at Gridley Bridge would reach averages up to 1°F warmer than under the No Action Alternative (Figure O.3-99). The most pronounced difference in August and September water temperatures between Alternative 2 and No Action Alternative scenarios would occur in wet years when this temperature difference could reach as much as 3°F and 1°F warmer in below normal years, whereas no difference is projected in dry or critically dry water years (Figure O.3-100). In below normal to dry water years, a notable difference in water temperature between Alternative 2 and No Action Alternative scenarios would occur instead in June, when Alternative 2 water temperatures would be lower than No Action Alternative temperatures by approximately 4°F (Figure O.3-100). In below normal to dry water years, a small difference in water temperature between Alternative 2 and No Action Alternative scenarios would also occur in July, when Alternative 2 water temperatures would surpass No Action Alternative temperatures by approximately 1°F (Figure O.3-100). These differences in water temperature between Alternative 2 and the No Action Alternative would therefore predominantly occur in summer months when water temperatures are higher (> 60°F) and more likely to lead to physiological stress and mortality.

Winter-Run Chinook Salmon

Winter-Run Chinook Salmon are not likely to be affected by changes in flow under Alternative 2 compared to the No Action Alternative due to their limited distribution in the Feather River.

Spring-Run Chinook Salmon

Effects of water temperature on Spring-Run Chinook Salmon have been heavily studied in the Feather River, resulting in an understanding of the optimal (beneficial), suboptimal, and stress-inducing (adverse) temperature ranges for each life stage (Table O.3-40).

In the Feather River, Spring-Run Chinook eggs and emerging fry occur from September to February, peaking in abundance from September to October (NMFS 2016a). The only difference in water temperature between Alternative 2 and No Action Alternative scenarios during this period would occur in September of wet to dry water years when temperatures under Alternative 2 flows could be up to 3°F higher than temperatures under No Action Alternative flows (Figure O.3-100). This would result in potentially adverse effects from the slightly higher water temperatures under Alternative 2 than under the No Action Alternative, yet water temperatures under both scenarios would fall in the stress-inducing range for this life stage (Table O.3-40). The slightly higher water temperatures in September under Alternative 2 in wet and above normal water years, therefore, would result in a slightly adverse effect on Spring-Run Chinook Salmon eggs and emerging fry relative to the effect of the No Action Alternative.

The occurrence of rearing juvenile Spring-Run Chinook Salmon in the Feather River is possible year-round, but peak abundance is usually between November and May. During this period of peak abundance, there is little to no projected difference between water temperatures under Alternative 2 and the No Action Alternative (Figure O.3-99); therefore, the effect of water temperatures on juvenile Spring-Run Chinook Salmon would be negligible under Alternative 2 operations relative to operations under No Action Alternative.

Migrating adult (ocean to river) Spring-Run Chinook Salmon reach the Feather River between March and June at generally consistent levels across all four months. During the first three months of this time span, water temperatures would be nearly identical under Alternative 1 and the No Action Alternative (Figure O.3-99). In June of above normal and dry water years, however, water temperatures under Alternative 2 could be up to 4°F lower than under the No Action Alternative (Figure O.3-100), yet modeled water temperatures are above the threshold for stress-inducing temperatures for migrating adults under both Alternative 2 and the No Action Alternative (Table O.3-40). Effects of water temperature on this life stage, therefore, are anticipated to be slightly less severe under Alternative 2 than under the No Action Alternative.

Holding adult Spring-Run Chinook Salmon have the potential to occur in the Feather River from March to September with peak abundance between May and August. As indicated by the RecTemp model, Feather River water temperatures would be similar under Alternative 2 and the No Action Alternative during peak abundance and the majority of the possible time range (Figures O.3-99 and O.3-100) but would differ in June and September of wet to normal water years when temperatures under Alternative 2 flows could be up to 3°F higher than temperatures under No Action Alternative flows (Figure O.3-100). Additionally, water temperatures in normal to dry water years would also differ when temperatures under Alternative 2 flows would be up to 4°F lower than temperatures under No Action Alternative flows (Figure O.3-100). Water temperatures in most water type years would remain at stress-inducing levels for holding adults for an additional month under Alternative 2 than under the No Action Alternative, before decreasing into the suboptimal range in September and June (Table O.3-40). Alternative 2 operations would therefore result in slightly adverse temperature-related effects on holding adult Spring-Run Chinook Salmon relative to the effects under the No Action Alternative in September and slightly lower adverse effects in June.

Alternative 2 has the potential for slightly adverse water temperature-related effects on eggs and fry, but very slightly beneficial effects on migrating adults and holding adults, so its overall effect on Spring-Run Chinook Salmon relative to the No Action Alternative is slightly adverse.

Fall-Run Chinook Salmon

Effects of water temperature on Fall-Run Chinook Salmon have been heavily studied in the Feather River, resulting in an understanding of the optimal (beneficial), suboptimal, and stress-inducing (adverse) temperature ranges for each life stage (Table O.3-40).

In the Feather River, Fall-Run Chinook Salmon eggs and emerging fry occur from October to April (CDFG 2012c). During this period there is no projected difference between water temperatures under Alternative 2 and the No Action Alternative (Figures O.3-99 and O.3-100); therefore, the effect of water temperatures on Fall-Run Chinook eggs and fry would be negligible under Alternative 2 operations relative to under No Action Alternative operations.

Juvenile Fall-Run Chinook Salmon typically occur in the Feather River from April to June. During the first two months of this time span, water temperatures would be essentially identical under Alternative 2 and the No Action Alternative (Figures O.3-99 and O.3-100). In June of below normal and dry water years, however, water temperatures under Alternative 2 could be up to 4°F lower than under the No Action Alternative (Figure O.3-100). The effect of this temperature difference would be slightly beneficial as temperature in these years would likely rise to suboptimal levels for juvenile Fall-Run Chinook Salmon under both Alternative 2 and No Action Alternative scenarios.

Migrating adult (ocean to river) Fall-Run Chinook Salmon reach the Feather River between June and April. This time span includes the slightly higher August and September water temperatures under Alternative 2 in wet and above normal years as well as the slightly lower June water temperatures in normal to dry years (Figure O.3-100). For migrating adult Fall-Run Chinook Salmon, water temperatures under Alternative 2 would then reach suboptimal and stress-inducing levels a couple of weeks more in summer of wet and above normal water than under the No Action Alternative but would drop to suboptimal and optimal levels approximately a couple of weeks more than under the No Action Alternative scenario in early summer of years below normal and dry water years (Figure O.3-100 and Table O.3-40). The net effect of Alternative 2 water temperatures on migrating adult Fall-Run Chinook Salmon relative to the No Action Alternative would be expected to be slightly adverse overall but would ultimately depend on rainfall levels experienced in the watershed.

Alternative 2 has the potential for slightly beneficial water temperature-related effects on juveniles and slightly adverse on migrating adults. Overall effect on Fall-Run Chinook Salmon relative to the No Action Alternative is slightly beneficial.

Central Valley Steelhead

Effects of water temperature on Central Valley Steelhead have been heavily studied, resulting in an understanding of the optimal (beneficial), suboptimal, and stress-inducing (adverse) temperature ranges for each life stage (Table O.3-40).

Central Valley Steelhead eggs and emerging fry occur in the Feather River from December to May, peaking in abundance in January (NMFS 2016a). Under Alternative 2 and the No Action Alternative, water temperature estimates for all water year types are essentially identical throughout this time period (Figure O.3-100), so no effect of Alternative 2 relative to the No Action Alternative is expected for Central Valley Steelhead eggs and fry.

Rearing juveniles typically migrate to the ocean from January to May after spending 1 to 3 years in freshwater (CDFG 1996). Under Alternative 2 and the No Action Alternative, water temperature estimates for all water year types are nearly identical throughout this time period (Figure O.3-100). Therefore, no effect of Alternative 2 relative to the No Action Alternative is expected for juvenile Central Valley Steelhead.

Migrating adult (ocean to river) Central Valley Steelhead reach the Feather River between September and October. Modeled water temperatures for Alternative 2 and the No Action Alternative differ in September of wet and above normal water years when temperatures under Alternative 2 could be up to 3°F higher than temperatures under No Action Alternative flows (Figure O.3-100), yet water temperatures would remain in the suboptimal range for migrating adults under Alternative 2 and the No Action Alternative (Table O.3-40). Adverse effects of water temperature on this life stage are therefore anticipated to be slightly more severe under Alternative 2 than under the No Action Alternative.

Holding adult Central Valley Steelhead have the potential to occur in the Feather River from December to March. Under Alternative 2 and the No Action Alternative, water temperature estimates for all water year types are essentially identical throughout this time period (Figure O.3-100), and no effect of Alternative 2 relative to the No Action Alternative is expected for Central Valley Steelhead eggs and fry.

Alternative 2 has the potential for slightly adverse water temperature-related effects on migrating adults. Overall effects on Central Valley Steelhead under Alternative 2 relative to the No Action Alternative is slightly adverse.

North American Green Sturgeon

Effects of water temperature on North American Green Sturgeon have been heavily studied in the Feather River, resulting in an understanding of the optimal (beneficial), suboptimal, and stress-inducing (adverse) temperature ranges for each life stage (Table O.3-40).

Green Sturgeon eggs and emerging fry occur in the Feather River from May to July (NMFS 2016a). During May, water temperatures would be essentially identical under Alternative 2 and the No Action Alternative (Figures O.3-99 and O.3-100). In June of below normal and dry water years, however, water temperatures under Alternative 2 could be up to 4°F lower than under the No Action Alternative (Figure O.3-100), yet modeled water temperatures are above the threshold for stress-inducing temperatures for eggs and fry under both Alternative 2 and the No Action Alternative (Table O.3-40). However, in July of below normal and dry water years, water temperatures would be up to 1°F higher under Alternative 2 than under the No Action Alternative (Figure O.3-100), and similarly to June would have stress-inducing temperatures for eggs and fry under both Alternative 2 and the No Action Alternative (Table O.3-40). Effects of water temperature on this life stage of Green Sturgeon are therefore anticipated to be slightly less severe under Alternative 2 than under the No Action Alternative.

Rearing juvenile Green Sturgeon are present in the Feather River from May to October, with abundance peaking in September. During May and October, water temperatures would be essentially identical under Alternative 2 and the No Action Alternative (Figures O.3-99 and O.3-100). In June of below normal and dry water years, however, water temperatures under Alternative 2 could be up to 4°F lower than under the No Action Alternative (Figure O.3-100). This would result in water temperatures reaching suboptimal stress-inducing levels for juveniles later in June under Alternative 2 than under the No Action Alternative (Table O.3-40). However, in July of below normal and dry water years, water temperatures would be up to 1°F higher under Alternative 2 than under the No Action Alternative (Figure O.3-100), which would likely have stress-inducing temperatures for juveniles under both Alternative 2 and the No Action Alternative (Table O.3-40). Water temperatures would differ in August and September of wet and above normal water years when temperatures under Alternative 2 flows could be up to 3°F higher than temperatures under No Action Alternative flows (Figure O.3-100). Water temperatures in wet and above normal years would drop from stress-inducing levels for juveniles to suboptimal levels and again to optimal levels later in the month under Alternative 2 than under the No Action Alternative (Figure O.3-100, Table O.3-40). The effects of water temperature on juvenile Green Sturgeon under Alternative 2 would then be dependent on water year types with slightly beneficial effects in below normal and dry water years and slightly adverse effects in wet and above normal water years; therefore, the net effect would be slightly adverse under Alternative 2 than under the No Action Alternative.

Migrating adult (ocean to river) Green Sturgeon reach the Feather River between March and May and, upon spawning, can remain in the vicinity until August. From March to May, water temperatures would be essentially identical under Alternative 2 and the No Action Alternative (Figures O.3-99 and O.3-100). In June of below normal and dry water years, however, water temperatures under Alternative 2 could be up to 4°F lower than under the No Action Alternative (Figure O.3-100). Modeled June water temperatures are above the threshold for stress-inducing temperatures for migrating adults under both Alternative 2 and the No Action Alternative (Table O.3-40). However, water temperatures would reach the suboptimal threshold for post-spawn adults later in below normal and dry years under the No Action Alternative and optimal levels under Alternative 2. Water temperatures would differ in August of wet and above normal water years when temperatures under Alternative 2 flows could be up to 1°F higher than temperatures under No Action Alternative flows (Figure O.3-100), which would likely result in stress-inducing levels in migrating adults under both Alternative 2 and the No Action Alternative; yet these temperatures could reach stress inducing temperatures for post-spawn adults a couple of weeks more under Alternative 2 than under the No Action Alternative. Effects of water temperature on this life stage, therefore, are anticipated to be slightly less severe under Alternative 2 than under the No Action Alternative.

Alternative 2 has the potential for slightly adverse water temperature-related effects on juveniles in wet and above normal years but slightly beneficial effects on eggs, fry, and post-spawn adults in below normal and dry years. Overall, effect on North American Green Sturgeon under Alternative 2 relative to the No Action Alternative is minor and dependent on annual rainfall totals.

O.3.5.5 *American River*

Potential changes to aquatic resources in the American River from flood control

Flood Control for the American River at Folsom Dam would be the same under the Alternative 2, compared to the No Action Alternative, since flood control follows the USACE Water Control Manual and flow management for Alternative 2 is according to the American River 2006 Flow Management Standard (Water Forum 2006), the same as the No Action Alternative. The Water Control Manual has been updated over time, and a new Water Control Manual was developed that utilizes forecasted inflow as the criteria for determining flood control releases. The new manual looks ahead five days and considers the forecasted inflow volume for the total of those five days. If that volume exceeds a threshold, a flood control release is specified. The concept is to pre-emptively draw the reservoir down in anticipation of high inflows, thus providing space to store the rain event when it arrives. This will allow Reclamation to pass higher precipitation events with lower peak releases which relieves stress on the downstream levees and provides a higher level of flood protection to downstream areas.

Potential changes to aquatic resources from Folsom Reservoir operations in the American River to meet Delta salinity requirements

Folsom Reservoir operations to address Delta water quality requirements under D-1641 would not change under Alternative 2, compared to the No Action Alternative. Folsom Reservoir flow requirements includes releases to meet Delta standards under D-1641, as needed. Since Folsom Reservoir is the closest reservoir to the Delta, releases from Folsom can more quickly address Delta water quality requirements. Releases to address Delta water quality objectives would be conducted, as needed, in coordination with the American River stakeholders. Releases to address Delta water quality objectives would improve water quality conditions, and thus habitat conditions for fish and other aquatic species in the Delta when hydrologic conditions are negatively affecting salinity levels.

Potential changes to aquatic resources from flows in the American River

Flows in the American River would be the same under Alternative 2, compared to the No Action Alternative, since flow management for Alternative 2 is according to the American River 2006 Flow Management Standard (Water Forum 2006), the same as the No Action Alternative. Under the Alternative 2, flow releases are managed according to the American River 2006 Water Forum Lower American Flow Management Standard, with the objective of providing suitable conditions for Fall-Run Chinook Salmon and Steelhead. Under the Flow Management Standard, flows are managed according to the Minimum Flow Requirements (MFR), which establishes minimum flows, as measured by the total release at Nimbus Dam, which vary throughout the year in response to the hydrology of the Sacramento and American River basins. The October 1 through December 31 MFR range between 800 and 2,000 cfs. The January 1 through Labor Day MFR range between 800 and 1,750 cfs. The post Labor Day through September MFR range between 800 and 1,500 cfs. As a general rule, the MFR must equal or exceed 800 cfs year round. Narrowly defined exceptions to this rule allow Nimbus releases to drop below 800 cfs to avoid depletion of water storage in Folsom Reservoir when dry or critically dry hydrologic conditions are forecasted to occur. These narrowly defined exceptions to the MFR are an important component of the Flow Management Standard. Since the No Action Alternative follows the existing condition implementation of the Alternative 2 would result in no change to flows in the lower American River.

Potential changes to aquatic resources in the American River due to changes in water temperature

Alternative 2 does not include water temperature objectives. However, water temperature modeling indicates that differences in water temperatures are more a function of hydrologic conditions than operations to meet objectives, water temperatures in the American River would be similar for Alternative 2, compared to the No Action Alternative (Figure 8). Since flow objectives are the same for Alternative 2 as for the No Action Alternative and follow the American River 2006 Flow Management Standard (Water

Forum 2006), the flow conditions in the American River remain the same, and thus water temperatures no change in water temperatures are expected under Alternative 2. Temperature modeling indicates that there would be no change average water temperatures in the American River (Figure 8), or in wet years (Figure 9) and dry years (Figure 10).

Potential changes to aquatic resources in the American River from habitat restoration

No additional habitat restoration is proposed under the No Action Alternative, therefore, there would be no changes to habitat in the lower American River.

O.3.5.6 *Stanislaus River*

Potential changes to aquatic resources in the Stanislaus River due to changes in flow

O.3.5.6.1 Below Goodwin Dam

Below Goodwin Dam, the largest difference in flow under Alternative 2 (compared to the No Action Alternative, Figures 11 and 12) would occur between the months of February through September. As mentioned previously, flows are currently managed to benefit various Central Valley lifestages for salmonids occur in the river during this period. Decreases in flow could affect juvenile salmonid out-migration, reduce suitable habitat for to varying degree by salmonid life stages, or have other undesirable results. Specifically, the flow differences under Alternatives 2 may result in higher water temperature, therefore, if Steelhead are present within the river, survival would be impeded with the decrease. Specifically, Steelhead eggs and emerging fry may be present in the river, as the species egg/fry emergence period is from December through June. Additionally, Steelhead that rear year-round within the river may also be exposed to the decreased flow and associated effects such as increased water temperature, decreased dissolved oxygen, and loss of suitable off-channel rearing and refuge habitat.

O.3.5.6.2 Mouth of Stanislaus River

The largest difference in flow under Alternative 2 at the mouth of the Stanislaus River would occur between the months of March through May (Figures 13 and 14). Similar to the discussions above, decreased flows compared to the No Action Alternative has effects to salmonid habitat, and in turn, the individuals. The larger flow decreases would likely increase water temperatures; therefore, salmonids, if present within the river, would likely not survive the summer and subsequent life stages would be determinately affected.

During the March through May period, Central Valley Steelhead are emerging (through June), and would be exposed to higher water temperatures and associated decreased dissolved oxygen. Rearing Steelhead and Chinook Salmon, if present, would be exposed to the same conditions.

Spring-Run Chinook Salmon emigrate from the Stanislaus River from mid-January through June; therefore, under Alternative 2, the Salmon would be exposed to lower flows and increased water temperatures as well. Similar to decreases in flow below Goodwin Dam, reduction of flow may decrease the quality and quantity of off-channel habitat for rearing and refuge. As the majority of adult Chinook Salmon hold from March to mid-September in the Stanislaus River, the Salmon would be exposed to the lower flow for a few months. Based on the typical seasonal occurrence of this life stage in the Stanislaus River (mid-January to late June), no adult migrating Spring-Run Chinook Salmon would be expected to be exposed to the effects of the alteration of dissolved oxygen requirements at Ripon.

Spring-Run Chinook Salmon that do hold in the river, and survive to spawn in early fall would likely not successfully reproduce due to higher water temperature. The Steelhead egg/fry that may be present through June, would be exposed to higher water temperatures, likely decreasing survival. Additionally, reduced flow would decrease the quality and quantity of habitat conditions. Off-channel habitat for rearing and refuge would potentially decrease.

Alternative 2 does result in higher flows at the mouth of the Stanislaus River when compared to the No Action Alternative during the January through February period. This increase is beneficial of spawning and emerging fry for salmonids, Steelhead. The increase in flow would directly result in increasing migratory cues for both emigrating and immigrating Steelhead.

Potential changes to aquatic resources in the Stanislaus River due to changes in water temperature

Alternatives 2 and 3 result in the highest increase in TAF compared to the No Action Alternative (Figures O.3-101 and O.3-102). The overall average increase in TAF benefits salmonids in the Stanislaus River by potentially increasing coldwater pool available for downstream salmonids. Recognizing that there is no ability for Reclamation to release water from different depths at New Melones, increased water depth above the static intake structure would function like a thermal cap, keeping the water below cooler. More cold water in New Melones Reservoir may lower water temperatures downstream of Goodwin Dam, which would benefit salmonids in all life stages in the lower Stanislaus River.

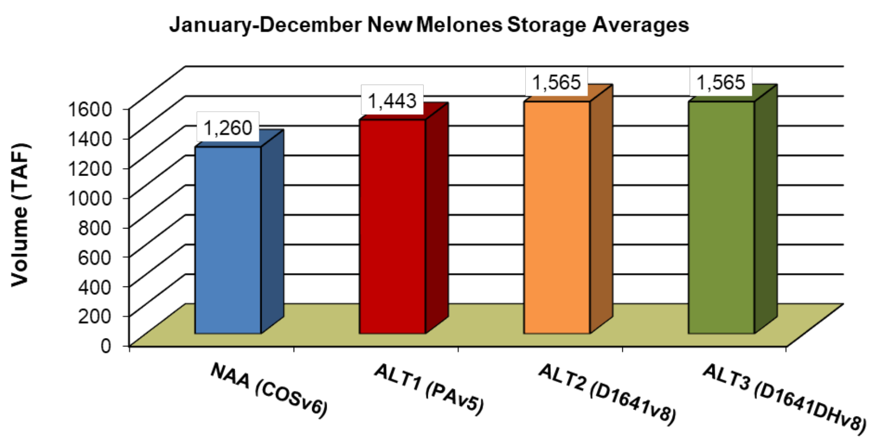


Figure O.3-101. Average Annual Storage at New Melones Reservoir by Project Alternative

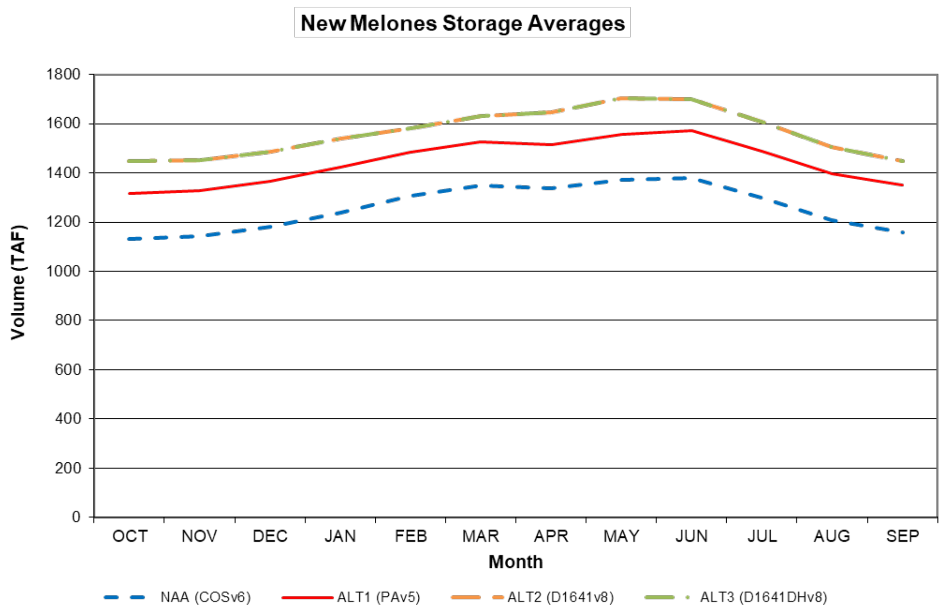


Figure O.3-102. Average Monthly Storage at New Melones Reservoir by Project Alternative

Temperature modeling for the Stanislaus River at Ripon shows that there is a small increase in overall annual temperature for Alternatives 1 through 3 with the No Action Alternative reflecting the coolest conditions (Figures O.3-103 and O.3-104). Monthly average temperature shows that Alternatives 2 and 3 are warmer from March through May, but cooler from July through September. Juvenile salmonids rear and out-migrate during the March through May period, which may be exposed to warmer conditions and represent a more sensitive lifestage. During July through September, Steelhead and possibly Spring-Run Chinook Salmon may hold and warmer conditions may incrementally reduce the amount of suitable holding habitat available.

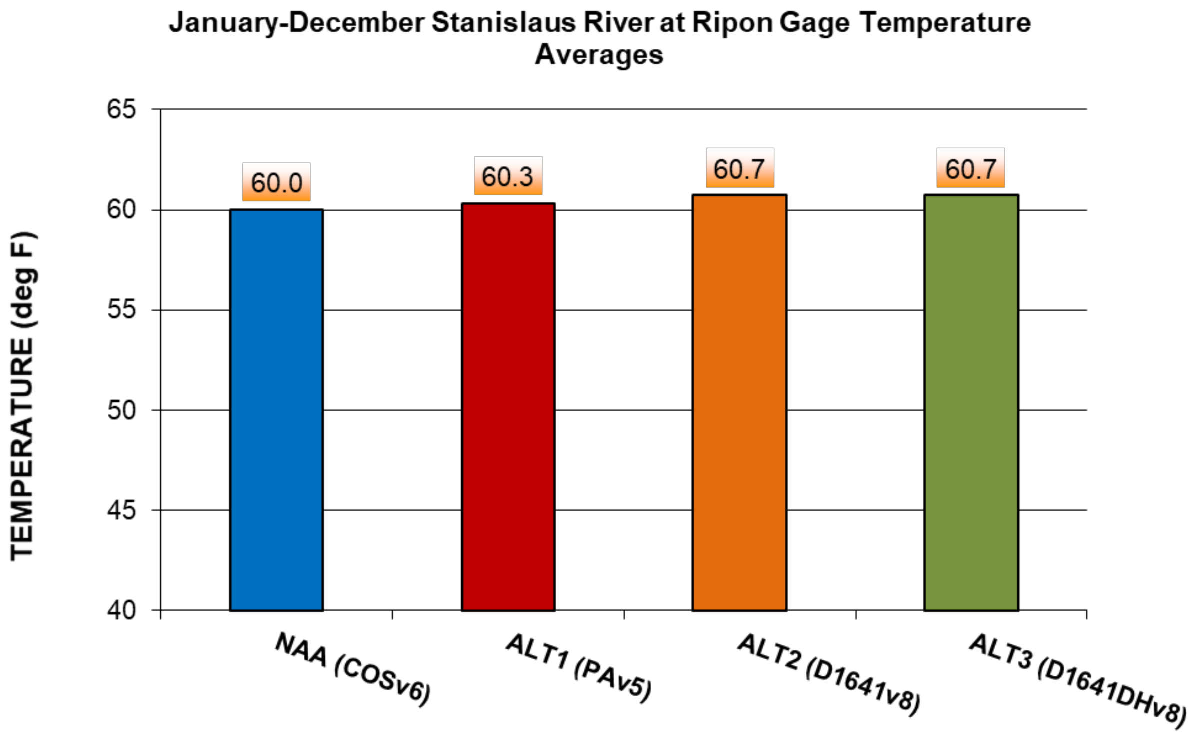


Figure O.3-103. Annual Average Water Temperature at Ripon on the Stanislaus River

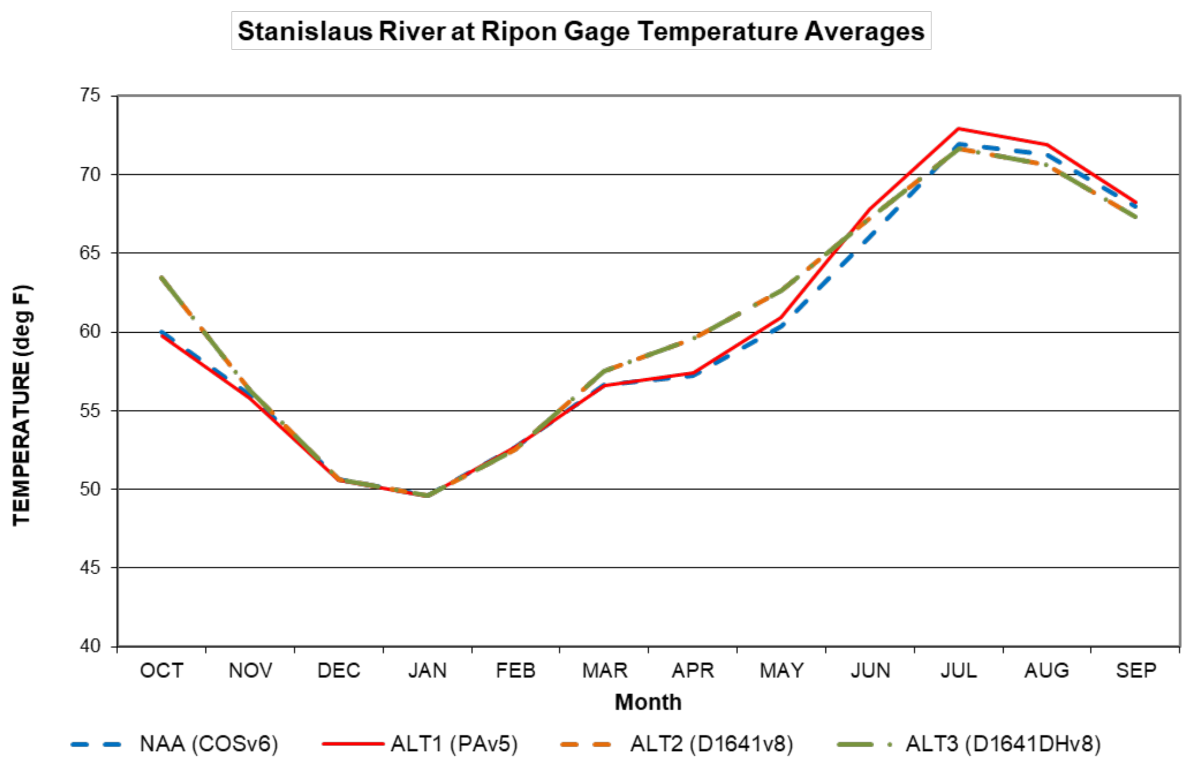


Figure O.3-104. Average Monthly Temperature at Ripon on the Stanislaus River

Restoration activities have the potential to increase growth and survival of juvenile Chinook Salmon, Steelhead, and other naïve fish by providing increased seasonal access to productive foraging and high quality rearing habitat.

O.3.5.7 *San Joaquin River*

The following effects would be expected to be similar under Alternative 2 to the potential effects as previously described for the No Action Alternative:

Potential changes to aquatic resources in the San Joaquin River due to changes in flow

Potential changes to aquatic resources in the San Joaquin River due to changes in water temperature

O.3.5.8 *Bay-Delta*

O.3.5.8.1 Delta Smelt

Potential changes to Delta Smelt due to seasonal operations

Relative to the No Action Alternative, potential negative effects on Delta Smelt from seasonal operations would tend to be greater under Alternative 2. Absence of the entrainment risk management included in the USFWS (2008) BO such as OMR restrictions would lead to appreciably lower OMR flows in December to June (Appendix F, Attachment 3-2, Figures 40-9 through 40-15), which based on historical data could lead to relatively high proportional entrainment loss of Delta Smelt (Kimmerer 2008; Miller 2011; Kimmerer 2011).

With respect to other habitat attributes discussed previously under analysis of *Potential changes to Delta Smelt due to seasonal operations* for Alternative 1, delivery of sediment to the Delta and resulting turbidity-related predation risk would be expected to be similar to the No Action Alternative, as indicated by similarity of CalSim-modeled flows in the Sacramento River at Rio Vista (e.g., Appendix E, Attachment 3-2, Figures 32-9 through 32-14). Related to predation risk from Silversides, March to May south Delta exports would be greater under Alternative 2 than the No Action Alternative (which could give less predation risk under Alternative 2, based on the correlative analysis described in the ROC LTO BA), whereas June to September Delta inflow would be similar or potentially greater under the No Action Alternative as a result of inclusion of the USFWS (2008) BO RPA for fall X2 under the No Action Alternative, resulting in potentially greater Silverside abundance and therefore predation risk under Alternative 2. As discussed for Alternative 1, the extent to which the opposing effects of differences in exports and inflow could affect Silverside abundance under Alternative 1 is uncertain, particularly given that the relationships are correlations and do not necessarily imply causality and require further investigation (Reclamation 2019). Similar to Alternative 1, the inclusion of the USFWS (2008) fall X2 criteria under the No Action Alternative but not in Alternative 2 has the potential to affect Delta Smelt predation risk by resulting in less overlap of the low salinity zone with turbid habitat.

As described for Alternative 1, various aspects of seasonal operations under Alternative 2 have the potential to affect Delta Smelt food availability relative to the No Action Alternative. There would be little difference in Yolo Bypass flooding and therefore little difference between Alternative 2 and the No Action Alternative in potential food effects for adult Delta Smelt in winter/spring (Appendix E, Attachment 3-2, Figures 25-6 through 25-18). In spring, the general similarity in X2 between Alternative 1 and Alternative 2 has the potential to produce similar negative effects on Delta Smelt prey (*E. affinis*) as described for Alternative 1; Alternative 2 also includes completion of the 8,000 acres of tidal restoration to offset such effects, although given less Delta outflow than the No Action Alternative and absence of any of the food subsidy actions proposed for Alternative 1, 8,000 acres of restoration may not be sufficient to offset negative effects of Alternative 2. Summer/fall subsidy of *P. forbesi* to the low salinity zone, as described for Alternative 1, may be negatively affected relative to the No Action Alternative to a similar extent as under Alternative 1, given the general similarity in the frequency of negative San Joaquin River at Jersey Point flows under Alternative 2 and Alternative 1 (Figures O.3-70 through).3-72).

Relative to the No Action Alternative and similar to Alternative 1, under Alternative 2 the size of the low salinity zone in wet and above normal years would be expected to be considerably reduced (Figures O.3-73 through O.3-75), and the percentage of time that the low salinity zone is outside of Suisun Bay would also be expected to considerably less under Alternative 2 than Alternative 1 (Figure O.3-76), thereby potentially negatively affecting Delta Smelt under Alternative 2 relative to the No Action Alternative.

Based on the overall similarity between Alternative 1 and Alternative 2 in operations during the summer/fall period of potential harmful algal bloom occurrence, there would be expected to be little difference in modeled velocity (a potential indicator of harmful algal bloom disruption) between Alternative 2 and the No Action Alternative, given the similarity in velocity between the No Action Alternative and Alternative 1 (Reclamation 2019). This suggests that there would be little difference in harmful algal bloom potential between Alternative 2 and the No Action Alternative.

Potential changes to Delta Smelt due to changes in Delta Cross Channel operations

The potential effects of DCC operations on Delta Smelt under Alternative 2 may be generally similar to those occurring under Alternative 1 but somewhat different given that the DCC would be open more often under Alternative 2. However, the nature of the difference is uncertain given the uncertainty in the effects that the DCC has on Delta Smelt, as described for Alternative 1.

Potential changes in Delta Smelt survival related to the Temporary Barriers Project

Under Alternative 2, potential effects of the three south Delta agricultural barriers on Delta Smelt generally would be expected to be similar to the effects under Alternative 1 (i.e., near-field predation and potential effects on transport of *P. forbesi* to the low salinity zone; see also ROC LTO BA), although the effects may be greater because of less OMR restrictions and therefore greater risk of Delta Smelt being present in the south Delta under Alternative 2. As with Alternative 1, there may be less potential effect because of no HOR barrier, although Delta Smelt would rarely be found near the HOR barrier based on historical observations.

Potential changes to Delta Smelt due to changes from Tracy and Skinner fish facilities improvements

The potential effects to Delta Smelt from the Tracy and Skinner fish facilities under Alternative 2 (i.e., mortality from pre-screen loss, collection, handling, transport, and release, with only a very small fraction potentially surviving the salvage process) would be somewhat greater than the effects described under the No Action Alternative and Alternative 1 because of the probable greater proportion of Delta Smelt entering the south Delta in the absence of OMR management that would continue under the No Action Alternative and is proposed under Alternative 1.

The following project-level effects would be expected to be similar under Alternative 2 to the potential effects as previously described for the No Action Alternative and Alternative 1 because of limited potential for effect or because the operations are similar:

Potential changes to Delta Smelt from Contra Costa Water District operations

Potential changes to Delta Smelt from North Bay Aqueduct operations

Potential changes to Delta Smelt from water transfers

Potential changes to Delta Smelt from Clifton Court aquatic weed and algal bloom management

Potential changes to Delta Smelt due to changes from Suisun Marsh facilities

O.3.5.8.2 Longfin Smelt

Potential changes to Longfin Smelt due to seasonal operations

As described for Alternative 1, the principal potential effect of seasonal operations on Longfin Smelt would be changes in population abundance as a result of changes in Delta outflow. During the December–May period identified as important for Delta outflow by Nobriga and Rosenfield (2016), CalSim modeling suggests that under Alternative 2 Delta outflow generally would be less than No Action Alternative in December (Appendix F, Attachment 3-2, Figures 41-9 through 41-14), thereby potentially negatively affecting Longfin Smelt through reductions in population abundance. However, as described for Alternative 1, the magnitude of the difference may be limited because of density-dependent effects (Nobriga and Rosenfield 2016), there is appreciable (several orders of magnitude) variability in the estimates generated by the Nobriga and Rosenfield (2016) model, and other analyses have found stronger correlations with general hydrological conditions rather than Delta outflow specifically (Maunder et al. 2015). As described for Alternative 1, completion of the 8,000 acres of tidal habitat restoration would have the potential to provide positive effects to Longfin Smelt larvae in the north Delta and therefore provide some offsetting of potential negative effects from seasonal operations, although this offsetting may be limited because Longfin Smelt would tend to be downstream of restored areas.

Relative to the No Action Alternative, there is the potential for Longfin Smelt entrainment risk to be greater under Alternative 2, as reflected by generally lower OMR flow in December to May (Appendix F, Attachment 3-2, Figures 40-9 through 40-15) and generally lower San Joaquin River flow at Jersey Point in January to March (Figures O.3-77 through O.3-79). However, as noted previously for Alternative 1, it should be borne in mind that the modeling for Alternative 2 does not reflect continued adherence to the criteria of the CDFG (2009) SWP ITP, nor to any subsequent ITP that may govern Longfin Smelt south Delta entrainment protection. In addition and as previously discussed for Alternative 1, while entrainment risk may be relatively greater under Alternative 2 compared to the No Action Alternative, estimates of Longfin Smelt population-level entrainment loss during the D-1641-based regulatory period (i.e., prior to 2007, and what is included under Alternatives 2 and 3) suggest that low percentages (0–3.6%) of Longfin Smelt were lost to entrainment (ICF International 2016, Table 4.2-10 [p. 4-286] and Table 4.2-11 [p. 4-288]). This suggests that Longfin Smelt proportional entrainment loss under Alternative 2 would also be limited.

Potential changes to Longfin Smelt due to changes in Delta Cross Channel operations

As discussed for Alternative 1, the potential effects of DCC operations on Longfin Smelt under Alternative 2 would be expected to be limited given that Longfin Smelt occur downstream of the DCC and there has been limited south Delta entrainment under the D-1641 management framework.

Potential changes in Longfin Smelt survival related to the Temporary Barriers Project

Under Alternative 2, potential effects of the three south Delta agricultural barriers on Longfin Smelt (e.g., near-field predation) could be greater than the No Action Alternative, but as with Alternative 1, effects would be expected to be limited given the low frequency of occurrence of Longfin Smelt occurring in the south Delta (Merz et al. 2013).

Potential changes to Longfin Smelt due to changes from Tracy and Skinner fish facilities

The potential effects to Longfin Smelt from the Tracy and Skinner fish facilities under Alternative 2 (e.g., prescreen predation loss) would be somewhat greater than the effects described under the No Action Alternative and Alternative 1 because of the probable greater proportion of Longfin Smelt entering the south Delta in the absence of OMR management that would continue under the No Action Alternative and is proposed under Alternative 1. However, the effects would be limited because of historically low entrainment loss of Longfin Smelt.

The following project-level effects would be expected to be similar under Alternative 2 to the potential effects as previously described for the No Action Alternative and Alternative 1 because of limited potential for effect or because the operations are similar:

Potential changes to Longfin Smelt from Contra Costa Water District operations

Potential changes to Longfin Smelt from North Bay Aqueduct operations

Potential changes to Longfin Smelt from water transfers

Potential changes to Longfin Smelt from Clifton Court aquatic weed and algal bloom management

Potential changes to Longfin Smelt due to changes from Suisun Marsh facilities

O.3.5.8.3 Sacramento Winter-Run Chinook Salmon

Potential changes to aquatic resources due to seasonal operations

Rearing Winter-Run Chinook Salmon are present in the Delta between October and May. Key habitat attributes relevant to seasonal operations in the Delta include out-migration cues and entrainment risk.

Hydrodynamic changes associated with river inflows and South Delta exports have been suggested to adversely affect juvenile Chinook Salmon in two distinct ways: 1) “near-field” mortality associated with entrainment to the export facilities, and 2) “far-field” mortality resulting from altered hydrodynamics. Near-field or entrainment effects of proposed seasonal operations can be assessed by examining patterns of proportional population entrainment available from decades of coded wire tag studies (e.g., Zeug and Cavallo 2014). A foundation for assessing far-field effects has been provided by work of the Collaborative Adaptive Management Team’s (CAMT) Salmonid Scoping Team (SST). The SST completed a thorough review of this subject and defined a driver-linkage-outcome (DLO) framework for specifying how water project operations (the “driver”) can influence juvenile salmonid behavior (the “linkage”) and potentially cause changes in survival or routing (the “outcome”). The SST concluded altered “Channel Velocity” and altered “Flow Direction” were the only two hydrodynamic mechanisms by which exports and river inflows could affect juvenile salmonids in the Delta. Figure O.3-105 provides a simplified conceptual model of the DLO defined by the CAMT SST.

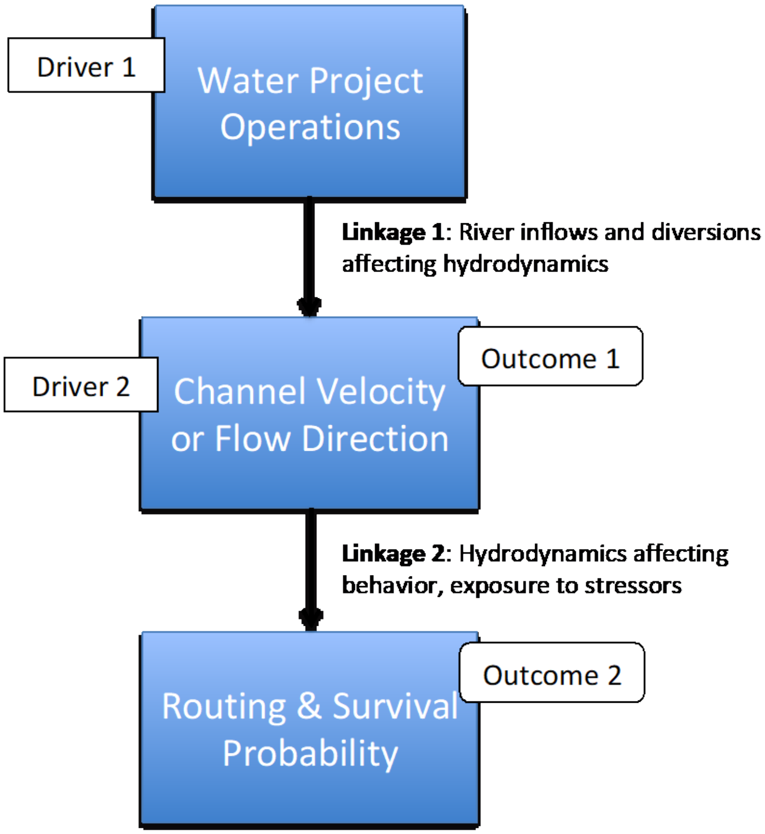


Figure O.3-105. Conceptual Model for Far-Field Effects of Water Project Operations on Juvenile Salmonids in the Delta. This CM is a Simplified Version of the Information Provided by the CAMT SST

To assess the potential for water project operations to influence survival and routing, Reclamation and DWR analyzed Delta hydrodynamic conditions by creating maps from DSM2 Hydro modeling. The maps are based on a comparative metric, proportion overlap (more below), to capture channel-level hydrodynamic details as a single number for color-scale mapping of Delta channels.

The objective of the comparative metric is to summarize the water velocity time series for each channel and scenario such the channel-level comparison is captured in a single number. For the proportion overlap metric, kernel density estimates are calculated on each time series. The kernel density estimates represent a non-parametric smoothing of the empirical distribution of time series values. The proportion overlap of two kernel density estimates is calculated with the following steps: 1) calculate the total area under the curve (AUC_t) as the sum of the AUC for each density estimate, 2) calculate the AUC of the overlapping portions (AUC_o) of the two density distributions being compared, and 3) calculate the overlapping proportion of the density distributions as AUC_o/AUC_t. Proportion overlap is naturally bound by zero and one; a value of zero indicates no overlap and a value of one indicates complete overlap. Lower values of proportion overlap identify channels demonstrating larger differences in a scenario comparison.

The proportion overlap metric is best applied over relatively short time periods because seasonal and annual variation in water velocity can overwhelm differences between scenarios. Thus, Reclamation calculated proportion overlap for every DSM2 channel for two seasons (December to Feburary and March to May) in each water year (1922–2003). DSM2 output was excluded from water year 1921 to allow for an extensive burn-in period. The proportion overlap was calculated based on hourly DSM2 output.

Because each season was roughly 90 days, each comparison involved roughly 4,300 DSM2 values (2 scenarios * 24 hours * 90 days) for each channel.

Because the proportion overlap was calculated for each channel in each water year, the proportion overlap values were summarized prior to mapping (i.e., not feasible to map proportion overlap for every comparison in every water year). To summarize, the minimum proportion overlap for each channel for each water year type for each comparison were found. The minimum values represent the maximum expected effect. Note that the year with the minimum proportion overlap for one channel might not be the same year as for another channel.

Entrainment

In the December through June period, the average total export rate, under Alternative 2, is higher than the export rate under No Action Alternative. Therefore, higher entrainment is expected compared to the No Action Alternative.

Zeug and Cavallo (2014) analyzed more than 1,000 release groups representing more than 28 million coded wire tagged juvenile fish including winter, late fall and Fall-Run Chinook Salmon. This data represents large release groups of tagged smolts where the number of fish representing each release group lost to entrainment at the export facilities has been estimated. Cavallo (2016) provided a supplemental assessment of Winter-Run Chinook Salmon entrainment risk (building upon Zeug and Cavallo 2014) that showed total CVP and SWP exports described entrainment risk better than OMR or other flow metrics. Entrainment loss results as reported below represents the proportion of coded wire tagged Winter-Run Chinook Salmon released upstream of the Delta which were entrained at South Delta export facilities. This proportion accounts for and includes expansion for sampling effort at the salvage facilities and also prescreen mortality. For December through February, Alternative 2 has an average total export rate greater than No Action Alternative (10,142 and 7,617 cfs respectively; Figure O1-1 in Appendix O, Attachment 1), and will therefore have greater entrainment risk. However, entrainment losses should average 0.8% and not exceed 2.2%. In the March through June period, total exports for Alternative 2 increase entrainment risk relative to No Action Alternative (6,851 vs. 4,164 cfs, respectively; Figure O1-2 in Appendix O, Attachment 1), but entrainment losses should average 0.4% and not exceed 1.6%.

Routing

Routing of juvenile Chinook Salmon into alternative migration routes is closely related to hydrodynamics (Perry et al. 2015; Cavallo et al. 2015; Steel et al. 2012). Changes to hydrodynamics in Delta channels resulting from Alternative 2 were evaluated using DSM2. Juvenile Winter-Run Chinook Salmon are present in the Sacramento River at Sherwood Harbor upstream of the first distributary junctions between November and March with peak abundance in February and March (Reclamation 2019).

In the December to February period, velocity overlap between Alternative 2 and No Action Alternative in the Sacramento River mainstem between the Sutter-Steamboat and DCC/Georgiana Slough Junctions, was more than 89%, 83%, 68%, 71%, and 57% in critically dry, dry, below normal, above normal, and wet years, respectively (Figure O1-21 in Appendix O, Attachment 1). During the December through February period, velocities were higher under Alternative 2 in below normal, above normal, and wet years and slightly lower in critically dry and dry years indicating routing into the interior Delta would be lower relative to No Action Alternative in normal and wet years and slightly higher relative to No Action Alternative in dry years (Perry et al. 2015; Figures O1-25 in Appendix O, Attachment 1). During the March to May period, velocity overlap between No Action Alternative and Alternative 2 was more than

90%, 82%, 75%, 62%, and 86% in critically dry, dry, below normal, above normal, and wet years, respectively (Figure O1-22 in Appendix O, Attachment 1).

Abundance of juvenile Winter-Run Chinook Salmon at Chipps Island peaks in March and April but fish are collected between December and May (Reclamation 2019). During this time period, Winter-Run Chinook Salmon originating from the Sacramento River that enter the interior Delta via Georgiana Slough and the Delta Cross Channel can potentially be exposed to hydrodynamic effects associated with the CVP and SWP that could affect routing. Once these fish arrive at the junction of the Mokelumne River and the San Joaquin River, they can move south toward the export facilities or west toward the ocean. In the December through February period analysis of DSM2 data indicates that there is little change to velocities in the region of the junction of the Mokelumne and San Joaquin Rivers between Alternative 2 and the No Action Alternative (Figure in Appendix O, Attachment 1O1-23). Similar results were obtained when comparing Alternative 2 to the No Action Alternative in the March to May period (Reclamation 2019).

Through-Delta Survival

Perry et al. (2018) found that the effect of flow on survival is not uniform throughout the Delta. Relationships between flow and survival were significant only in reaches where flow changes from bi-directional to unidirectional when discharge increases.

To examine potential effects of Alternative 2, changes in velocity distributions were examined for the Sacramento River at Walnut Grove and Steamboat Slough which are both in this “transitional” region. During the December to February period at Walnut Grove, there are higher velocities under Alternative 2 than the No Action Alternative in wet, above normal, and below normal years. Velocities were lower in critically dry and dry years but overlap was high (>88%; Figure O1-25 in Appendix O, Attachment 1). At Steamboat Slough in the December through February period, there are higher velocities under Alternative 2 than the No Action Alternative in wet, above normal, and below normal years. Velocities were lower in critically dry and dry years but overlap was high (>90%; Figure O1-26). In the March through May period at Walnut Grove, when Alternative 2 was compared to the No Action Alternative, velocity overlap ranged from 80.2-92.8% with generally higher velocities under Alternative 2 (Figure O1-27 in Appendix O, Attachment 1). Velocity overlap at Steamboat Slough in the March through May period ranged from 84.2% to 94.6% with generally higher velocities under Alternative 2 (Figure O1-28 in Appendix O, Attachment 1).

Overall, Alternative 2 results in higher velocities in the Delta in the spring than under No Action Alternative, during the outmigrating juvenile time period. Survival probabilities are non-linear; however, the higher discharge at Freeport in the spring under Alternative 2 results in higher survival in the transition reaches. Higher flows also lead to lower probability of routing into the interior Delta, which has the lowest survival probability regardless of flow.

Potential changes to aquatic resources due to Delta Cross Channel operations

Under Alternative 2, the DCC may be closed for up to 45 days from November through January for fishery protection purposes. From February 1 through May 20, the gates are closed for fishery protection purposes. The gates may also be closed for 14 days from May 21 through June 15 for fishery protection purposes. The peak migration of juvenile Winter-Run Chinook Salmon in the Sacramento River at Sherwood Harbor, which is near the DCC, occurs from February through March (Reclamation 2019). Therefore, the DCC is closed for the majority of the juvenile Winter-Run Chinook Salmon migration period in the Sacramento River and as such the proportion of juvenile Winter-Run Chinook Salmon exposed to an open DCC would be negligible. Juvenile Chinook Salmon entrained into an open DCC and transported to the interior Delta have reduced survival (Perry et al. 2010; Perry et al. 2018).

Potential changes to aquatic resources due to the Temporary Barriers Project

Juvenile Winter-Run Chinook Salmon are not expected to co-occur in space or time with the agricultural barriers indicating no potential impacts.

Potential changes to aquatic resources due to Contra Costa Water District operations

CCWD's operations in Alternative 2 are consistent with the operational criteria specified in separate biological opinions and permits that govern operations at CCWD's intakes and Los Vaqueros Reservoir (NMFS 1993, 2007, 2010, 2017; USFWS 1993a, 1993b, 2000, 2007, 2010, 2017; CDFG 1994, 2009a).

The Contra Costa Canal Rock Slough Intake is located on a dead-end slough, far from the main migratory route for Winter-Run Chinook Salmon (NMFS 2017c), approximately 18 miles from the Sacramento River via the shortest route. Designated critical habitat for Winter-Run Chinook Salmon does not occur within Rock Slough, but is present further to the north in the Delta (NMFS 2017c, 2014). Salmonids are expected to avoid the area of the Rock Slough Intake during certain times of the year based on historical water temperatures.

Fish monitoring prior to the construction of the Rock Slough Fish Screen (RSFS) indicates the timing and magnitude of Winter-Run Chinook Salmon presence near the Rock Slough Intake. Since 1994, fish monitoring has been conducted by CDFW and CCWD consistent with the separate biological opinions and permits that govern CCWD's operations. From 1994 through 1999, CDFW conducted fish monitoring at the Rock Slough Intake and in the Contra Costa Canal up to the first pumping plant. Over this 6-year period, CDFW captured a total of 13 juvenile Winter-Run Chinook Salmon from January through May (CDFG 2002c; NMFS 2017c). From 1999 to 2009, the 11 years prior to construction of the RSFS, CCWD's Fish Monitoring Program collected no juvenile or adult Winter-Run Chinook Salmon at the Rock Slough Headworks (Reclamation 2016; NMFS 2017c) and Contra Costa Canal Pumping Plant #1 (CCWD 2019).

Since construction of the RSFS, operation of the hydraulic rake cleaning system has been shown to trap and kill adult Chinook Salmon and other non-listed fish (Reclamation 2016). From 2011-2018, 47 Salmon were recovered at the RSFS (Reclamation 2016, Appendix A; Tenera Environmental 2018a), but none of the captured fish were identified as Winter-Run Chinook Salmon (NMFS 2017c).

NMFS issued a biological opinion in 2017 (NMFS 2017c) that considered improvements to the RSFS facility including the hydraulic rake cleaning system, operations and maintenance (O&M) of the RSFS and associated appurtenances, and administrative actions such as the transfer of O&M activities from Reclamation to CCWD. NMFS determined that the O&M of RSFS may result in the incidental take of juvenile Winter-Run Chinook Salmon and provided an incidental take limit based upon the number of listed fish collected in the pre and post-construction RSFS monitoring (NMFS 2017c). The incidental take provided in NMFS 2017c is five juvenile Winter-Run Chinook Salmon per year.

CCWD's Fish Monitoring Program also samples behind the fish screens at CCWD's other south Delta intakes. Since the intakes have been in operation, CCWD's Fish Monitoring Program has never collected Winter-Run Chinook Salmon at CCWD's Old River Intake or Middle River Intake (CCWD 2019).

CCWD's operations, including operation of the Rock Slough, Old River, and Middle River intakes and Los Vaqueros Reservoir, are simulated in the CalSim model. Thus, CalSim results discussed throughout this appendix include the effects of CCWD’s operations in combination with all other water diversions and reservoir operations. A further analysis was undertaken to isolate the maximum possible effects of CCWD’s operations on Delta hydrodynamics by determining the effect that CCWD pumping at maximum capacity would have on Delta channel water velocity. Results of this analysis are shown below; in all cases the maximum possible effect of CCWD's operations is de minimis.

Due to the location of the Rock Slough Intake near the end of a dead-end slough, far from the main migratory routes, juvenile Winter-Run Chinook Salmon are not likely to be in the vicinity of the Rock Slough Intake. However, according to NMFS (2017), juvenile Salmon can be “drawn” into the south Delta under reverse flows and high CVP and SWP pumping rates. One indicator of reverse flows is the net flow in Old and Middle Rivers (OMR). Rock Slough Intake is located on Rock Slough, approximately 3.5 miles west of the junction of Rock Slough and Old River, which is over 12 river miles north of the gates to the SWP Clifton Court Forebay. Given its location, the Rock Slough Intake does not affect OMR, and any effect that diversions at Rock Slough Intake would have in the Old and Middle River corridor would be to increase the northerly (positive) flow away from the Banks and Jones Pumping Plants.

However, diversions at the Rock Slough Intake could affect flows in the San Joaquin River at Jersey Point, which is approximately 14 river miles from the Rock Slough Intake (via the shortest route through Franks Tract). Mean velocity in a river channel can be calculated by dividing the flow rate by the cross-sectional area of the channel. The maximum effect of Rock Slough diversions on the channel velocity would be the maximum diversion rate (350 cfs) divided by the minimum cross-sectional area of the channel. This calculation assumes that all water diverted at Rock Slough comes from the San Joaquin River at Jersey Point, which is a conservative assumption (i.e., overestimates the effect on velocity). The cross-sectional area of the San Joaquin River at Jersey Point is approximately 60,500 square feet (sf), but varies depending on the tidal stage from approximately 56,000 sf (at low tide and low San Joaquin River flow) to 68,000 sf (at high tide and high San Joaquin River flow) as shown in Figure O.3-106.

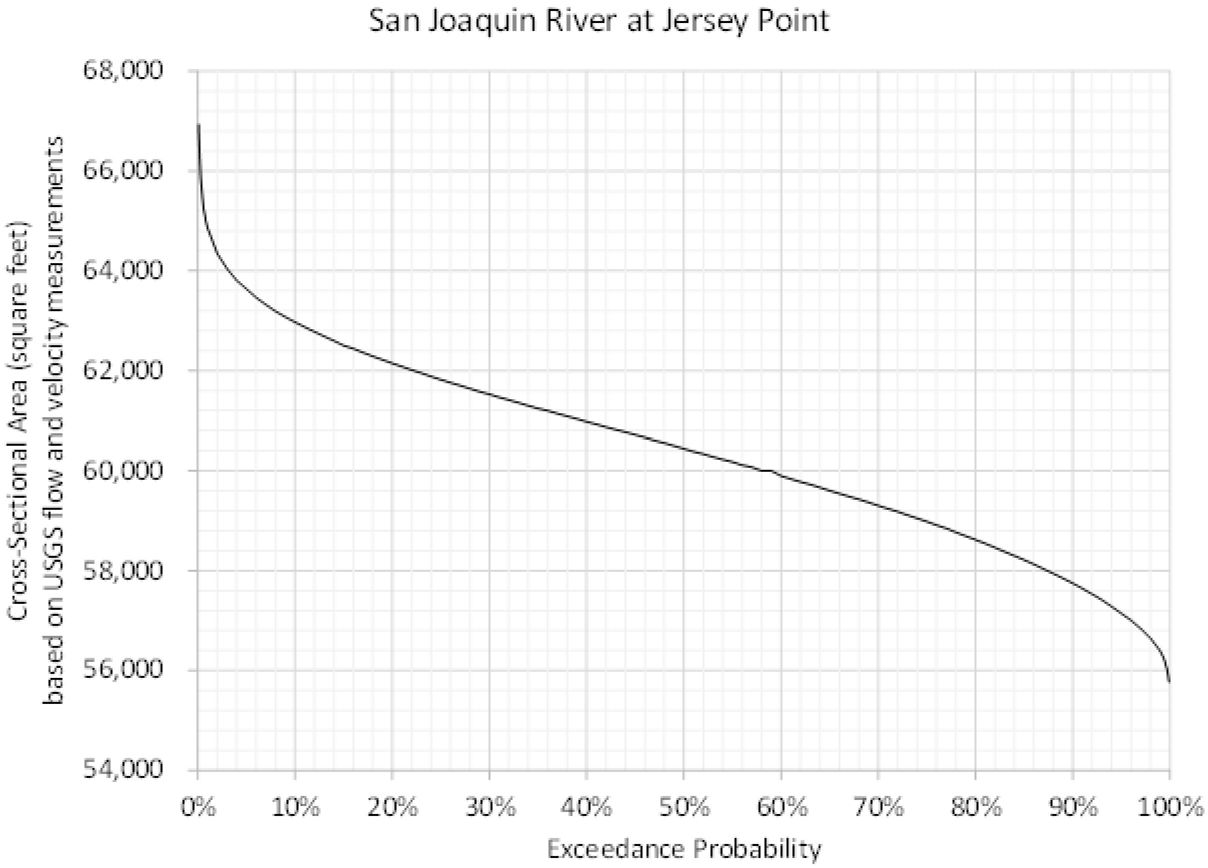


Figure O.3-106. Cross-sectional area of the San Joaquin River at Jersey Point (Station: 11337190) Calculated from USGS Measurements of Flow and Velocity every 15 Minutes for Water Years 2014 through 2018.

The maximum effect of water diversions at Rock Slough Intake on velocity in the San Joaquin River at Jersey Point is calculated as 350 cfs divided by 56,000 square feet; resulting in 0.00625 feet per second (ft/sec). For comparison, the velocity threshold for design of fish screens to prevent impingement of salmonids is 0.33 ft/sec, which is 50 times the maximum possible contribution from Rock Slough diversions. Furthermore, the actual effect is likely to be much lower than 0.00625 ft/sec because the water diverted at the Rock Slough Intake does not all come from the San Joaquin River west of Jersey Point.

Recognizing that CCWD owns and operates two additional intakes in the south Delta, the combined effect of all three intakes is examined. CCWD's Old River Intake and Middle River Intake have a physical capacity of 250 cfs at each intake. If CCWD were to divert at all three intakes at the maximum capacity at the same time, total CCWD diversions would be 850 cfs. The corresponding effect on velocity in the San Joaquin River at Jersey Point would be 0.015 ft/sec. The velocity threshold used to protect salmonids from diversions in the vicinity of fish screens (0.33 ft/sec) is over 21 times greater than the maximum possible contribution from CCWD's combined physical capacity. The water diversions at the Rock Slough Intake when combined with diversions at CCWD's Old River Intake and Middle River Intake have a negligible effect on velocity along the migratory path for juvenile Winter-Run Chinook Salmon and are not likely to affect the movement of juvenile salmonids.

Nonetheless, even extremely small changes in velocity can affect the movement of neutrally buoyant

particles such as phytoplankton. To examine the effect on neutrally buoyant particles, the distance that a particle would travel due to the maximum permitted Rock Slough diversions over the course of a day is calculated. A change in velocity of 0.00625 ft/sec could move a neutrally buoyant particle approximately 540 ft over the course of the day (0.00625 ft/sec * 86,400 sec/day). For comparison, the tidal excursion on the San Joaquin River at Jersey Point during a flood tide (i.e., the distance a particle will travel tidally upstream during a flood tide) is about 34,000 ft on average (or 6.4 miles), which is about 63 times the distance that diversions at Rock Slough could move a particle at the same location over the course of a full day. Therefore, the maximum possible contribution of diversions at Rock Slough on movement of neutrally buoyant particles such as phytoplankton is not significant in comparison to the tidal excursion and mixing at this location.

In summary, CCWD's operations under Alternative 2 would remain consistent with the operational criteria specified in separate biological opinions and permits that govern operations at CCWD's intakes and Los Vaqueros Reservoir, and as shown above, the effect of CCWD's operations on Delta hydrodynamics is negligible.

Potential changes to aquatic resources in North Bay Aqueduct operations

Alternative 2 includes the North Bay Aqueduct (NBA) intake in the North Delta and operation of the Barker Slough Pumping Plant. Listed salmonids may be present in the waterways adjacent to the Barker Slough Pumping Plant (monitoring data is available at https://www.wildlife.ca.gov/Regions/3). There should be no discernable effect to the Winter-Run Chinook Salmon due to the operations of the Barker Slough Pumping Facility. This is due to the infrequent presence of Winter-Run Chinook Salmon in the monitoring surveys indicating a low risk of entrainment. Further, Barker Slough Pumping Facility fish screens are designed to protect juvenile salmonids per NMFS criteria and should prevent entrainment while greatly minimizing any impingement of fish against the screen.

Potential changes to aquatic resources due to water transfers

Under Alternative 2, Reclamation is extending the water transfer window until November, from the current July through September window. This extension could result in increased flows entering the Delta and increased pumping at Jones and Banks Pumping Plants.

Egg, alevin, and fry lifestages of Winter-Run Chinook Salmon do not occur in the Delta, and therefore would not be affected by this action. Winter-Run Chinook Salmon juveniles enter the Delta starting in December, and therefore would be unlikely to be exposed to increased pumping of water transfers through November. Adults returning from the ocean could possibly be in the Delta in July; however, they are strong swimmers, large fish that can avoid predators, and are unlikely to have impacts associated with direct entrainment of the pumping plants.

O.3.5.8.4 Central Valley Spring-Run Chinook Salmon

Potential changes to aquatic resources due to seasonal operations

Reclamation and DWR propose to operate the C.W. Bill Jones Pumping Plant and the Harvey O. Banks Pumping Plant. These pumping plants affect the hydrodynamics of the south and central Delta resulting in effects to Spring-Run Chinook Salmon entrainment, routing and through Delta survival. Hydrodynamic changes associated with river inflows and South Delta exports have been suggested to negatively impact juvenile Chinook Salmon in two distinct ways: 1) "near-field" mortality associated with entrainment to the export facilities, 2) "far-field" mortality resulting from altered hydrodynamics. See Winter-Run Chinook Salmon effects section for more detail concerning "far-field" and "near-field."

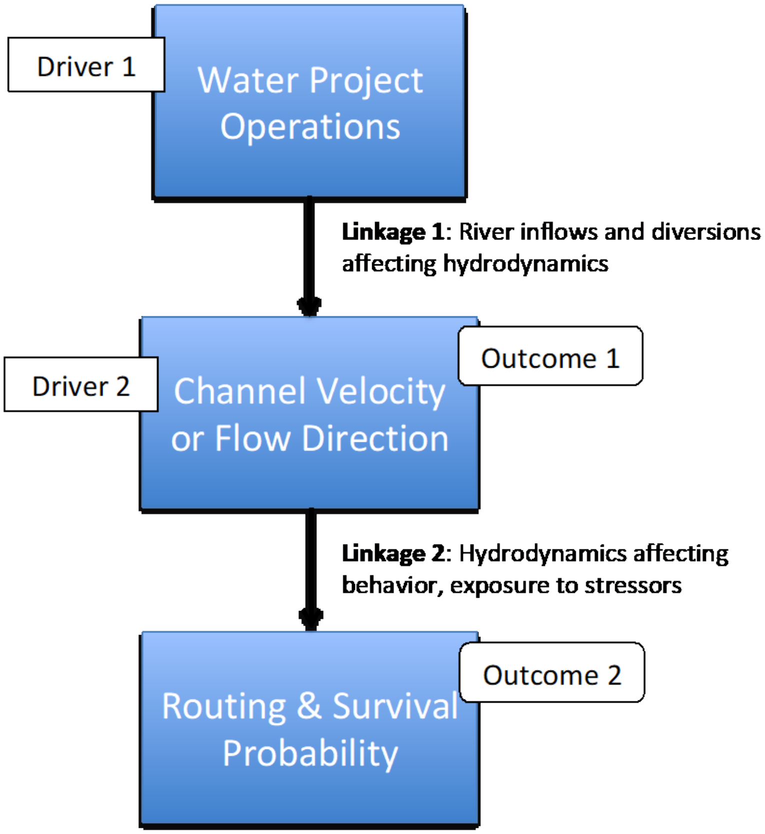


Figure O.3-107. Conceptual model for far-field effects of water project operations on juvenile salmonids in the Delta. This CM is a simplified version of the information provided by the CAMT SST.

Entrainment

Among 6.8 million tagged natural origin and 2.8 million tagged hatchery origin Spring-Run Chinook Salmon juveniles, entrainment loss averaged less than 0.0005% (Zeug and Cavallo 2014). Although data for juvenile Spring-Run Chinook Salmon originating from the San Joaquin River are limited, Zeug and Cavallo (2014) analyzed salvage of San Joaquin River-origin Fall-Run juvenile Chinook Salmon that are found in the Delta at a similar time as Spring-Run Chinook Salmon. Salvage of Fall-Run Chinook Salmon originating from the San Joaquin River averaged 1.4% and increased with export rate at the CVP and SWP (Zeug and Cavallo 2014). However, there were few observations at export rates greater than 3,000 cfs. Average mortality at the facilities represents < 5% total juvenile mortality for San Joaquin River-origin populations but can range as high as 17.5% (Zeug and Cavallo 2014).

In the December through February period, Alternative 2 proposes an average total export rate higher than No Action Alternative (2,525 cfs; Figure O1-1 in Appendix O, Attachment 1) and will, therefore, have a higher entrainment risk. Total exports proposed for Alternative 2 in March-June (2,687 cfs higher than No Action Alternative; Figure O1-2), when juvenile Spring-Run Chinook Salmon are most abundant in the Delta, will increase entrainment risk relative to No Action Alternative. Recent acoustic studies of juvenile Fall-Run Chinook Salmon in the San Joaquin River revealed that when the Head of Old River Barrier is out, >60% of fish detected at Chipps Island came through CVP, indicating that salvage is a higher survival route than volitional migration.

Routing

As stated in the Sacramento Winter-Run Chinook effects section, routing of juvenile Chinook Salmon into alternative migration routes is closely related to hydrodynamics (Perry et al. 2015; Cavallo et al. 2015; Steel et al. 2012). Juvenile Spring-Run Chinook Salmon are present in the Delta between November and early June with a peak in April (Reclamation 2019). In the December to February period, velocity overlap between Alternative 2 and No Action Alternative in the Sacramento River mainstem between the Sutter-Steamboat and DCC/Georgiana Slough Junctions, was more than 89%, 83%, 68%, 71%, and 57% in critically dry, dry, below normal, above normal, and wet years, respectively (Figure O1-21 in Appendix O, Attachment 1). During the December through February period, velocities were higher under Alternative 2 in below normal, above normal, and wet years and slightly lower in critically dry and dry years indicating routing into the interior Delta would be lower relative to No Action Alternative in normal and wet years and slightly higher relative to No Action Alternative in dry years (Perry et al. 2015; Figures O1-25 in Appendix O, Attachment 1). During the March to May period, velocity overlap between No Action Alternative and Alternative 2 was more than 90%, 82%, 75%, 62%, and 86% in critically dry, dry, below normal, above normal, and wet years, respectively (Figure O1-22 in Appendix O, Attachment 1).

Spring-Run Chinook Salmon originating from the Sacramento River that enter the interior Delta via Georgiana Slough and the Delta Cross Channel can be exposed to hydrodynamic project effects that could affect routing. Once these fish arrive at the junction of the Mokelumne River and the San Joaquin River, they can move south toward the export facilities or west toward the ocean. In the December through February period analysis of DSM2 data indicates that there is little change to velocities in the region of the junction of the Mokelumne and San Joaquin Rivers between Alternative 2 and both the No Action Alternative scenarios (Figure O1-23 in Appendix O, Attachment 1). Similar results were obtained when comparing Alternative 2 to No Action Alternative in the March to May period (Figure O1-24 in Appendix O, Attachment 1).

Juvenile Spring-Run Chinook Salmon are present in the Delta between November and early June with a peak in April (Reclamation 2019). Early studies using coded wire tags indicated that survival of San Joaquin River-origin juvenile Chinook Salmon was lower in the Old River Route relative to the San Joaquin main stem (Newman 2008). This finding led to strategies designed to keep larger proportions of fish in the San Joaquin River main stem including the Head of Old River rock barrier and non-physical barriers. Recent studies using acoustic technology have indicated that differences in survival among the two routes are not significant (Buchanan et al. 2013; Buchanan et al. 2018). Thus, fish that enter Old River are unlikely to experience reduced survival.

Spring–run Chinook Salmon originating from the San Joaquin River that remain in the San Joaquin River main stem at the Head of Old River are exposed to additional junctions that lead into the interior Delta including; Turner Cut, Columbia Cut, Middle River, Old River, Fisherman's Cut and False River. In the December through February period analysis of DSM2 data indicates that there is little change to velocities in the region of the junctions with San Joaquin Rivers between Alternative 2 and No Action Alternative scenarios (Figure O1-23 in Appendix O, Attachment 1). Similar results were obtained when comparing Alternative 2 to No Action Alternative in the March to May period (Figure O1-24 in Appendix O, Attachment 1).

In the December through February period, velocity overlap between Alternative 2 and No Action Alternative in the channel upstream of the Head of Old River was 95.1%, 84.0%, 57.3%, 67.7%, and 55.2% in critically dry, dry, below normal, above normal, and wet years, respectively (Figure O1-23 in Appendix O, Attachment 1). In the March to May period, velocity overlap was 84.0%, 62.7%, 61.6%, 65.2%, and 43.4% in critically dry, dry, below normal, above normal, and wet years, respectively (Figure O1-24 in Appendix O, Attachment 1).

Through-Delta Survival

To examine potential effects of Alternative 2, changes in velocity distributions were examined for the Sacramento River at Walnut Grove and Steamboat Slough which are both in this "transitional" region. During the December to February period at Walnut Grove, velocity distributions for Alternative 2 relative to No Action Alternative were most different in wet years (72.9%) with higher velocities in Alternative 2. Velocities were also greater for Alternative 2 relative to No Action Alternative in below normal and above normal years although overlap was greater (>76%; Figure O1-25 in Appendix O, Attachment 1). In critically dry and dry years, velocity distributions were more similar (>88%; Figure O1-25 in Appendix O, Attachment 1). At Steamboat Slough in the December to February period, there was a similar pattern where velocities under Alternative 2 were higher than No Action Alternative in wet, above normal, and below normal years and similar in dry and critically dry years (Figure O1-26 in Appendix O, Attachment 1).

In the March through May period at Walnut Grove, velocity overlap between Alternative 2 and No Action Alternative was >80% across all water year types with generally greater velocities under Alternative 2 (Figure O1-27 in Appendix O, Attachment 1). At Steamboat Slough in the March through May period, overlap between Alternative 2 and No Action Alternative scenarios was high with all values ≥82% and generally greater velocities under Alternative 2 (Figure O1-28 in Appendix O, Attachment 1).

A recent study by Perry et al. (2018) found that the effect of flow on survival is not uniform throughout the Delta. Relationships between flow and survival were significant only in reaches where flow changes from bi-directional to unidirectional when discharge increases. To examine potential effects of Alternative 2, changes in velocity distributions were examined for the San Joaquin River at Highway 4 and the Head of Middle River which are both in the "transitional" region of the San Joaquin River. During the December to February period at the San Joaquin River at Highway 4, velocity distributions for Alternative 2 relative to No Action Alternative exhibited high overlap in all water year types (≥81.9%; Figure O1-29 in Appendix O, Attachment 1). At the Head of Middle River during the December to February period, overlap was high between Alternative 2 and No Action Alternative in critically dry and dry water years (≥79%) and moderate in wet, above normal, and below normal years (66%; Figure O1-30 in Appendix O, Attachment 1).

In the March to May period in the San Joaquin River at Highway 4, velocity overlap was high between Alternative 2 and No Action Alternative (≥80%; Figure O1-31 in Appendix O, Attachment 1). Velocities were similar in all water year types (Figure O1-31). At the Head of Middle River in the March to May period, overlap between Alternative 2 and No Action Alternative was moderate in all water year types (41-65%) and higher in critically dry years >77% (Figure O1-32 in Appendix O, Attachment 1). Velocities were generally lower under Alternative 2 than No Action Alternative (Figure O1-32).

Potential changes to aquatic resources due to Delta Cross Channel operations

The Delta Cross Channel may be closed for up to 45 days from November through January for fishery protection purposes. From February 1 through May 20, the gates are closed for fishery protection purposes. Significant amounts of flow and many juvenile Spring-Run Chinook Salmon enter the DCC (when the gates are open) and Georgiana Slough, especially during increased Delta pumping. Mortality of juvenile Salmon entering the central Delta is higher than for those continuing downstream in the Sacramento River. Juvenile Chinook Salmon that are entrained into an open DCC and transported to the interior Delta have reduced survival (Perry et al. 2010) The gates may also be closed for 14 days from May 21 through June 15 for fishery protection purposes. The peak migration of juvenile Spring-Run Chinook Salmon in the Sacramento River past Knights Landing, which is upstream of the DCC, occurs from March-April (Reclamation 2019). Therefore, the DCC is closed to protect the majority of the juvenile Spring-Run migration period in the Sacramento River and reduce the proportion of fish exposed to an open DCC.

Potential changes to aquatic resources due to the Temporary Barriers Project

The agricultural barriers at Middle River and Old River near Tracy can begin operating as early as April 15 but the tide gates are tied open from May 16 to May 31. After May 31, the barriers in Middle River, Old River near Tracy, and Grant Line Canal are permitted to be operational until they are completely removed by November 30.

The proportion of juvenile Spring-Run Chinook Salmon exposed to the agricultural barriers (Temporary Barrier Program, TBP) depends on their annual timing of installation and removal. Due to their location, primarily migrants originating from the San Joaquin River would be exposed to the TBP. The peak relative abundance of juvenile Spring-Run Chinook Salmon in the Delta is March and April (Reclamation 2019). If the agricultural barriers are operating as early as April 15 then they have the potential to expose a large proportion of the juvenile Spring-Run Chinook Salmon migrating down the San Joaquin River. When the Head of Old River barrier is not in place, acoustically tagged juvenile Chinook Salmon have demonstrated a high probability of selecting the Old River route (Buchanan 2018), which would expose them to the agricultural barriers. When the agricultural barriers are operating with tidal flap gates down, a significant decline in passage and reach survival of acoustically tagged juvenile Chinook Salmon migrating past the barrier has been observed compared to when the barrier is not present (DWR 2018). When flap gates are tied up, Chinook Salmon passage past the agricultural barrier was improved (DWR 2018). Flap gates tied up on agricultural barriers from May 16 to May 31 would help to reduce the negative effect of the barriers during this period. However, juveniles migrating before or after this period could be exposed to the agricultural barriers with flaps down which apparently decreases passage success and survival (DWR 2018).

Potential changes to aquatic resources due to Contra Costa Water District operations

CCWD's operations in Alternative 2 are consistent with the operational criteria specified in separate biological opinions and permits that govern operations at CCWD's intakes and Los Vaqueros Reservoir (NMFS 1993, 2007, 2010, 2017; USFWS 1993a, 1993b, 2000, 2007, 2010, 2017; CDFG 1994, 2009a). Therefore, CCWD's operations, including operation of the Rock Slough Intake, for Alternative 2 remain unchanged from the current operations.

The Contra Costa Canal Rock Slough Intake is located on a dead-end slough, far from the main migratory route for Central Valley Chinook Spring-Run (NMFS 2017c), approximately 18 miles from the Sacramento River and 10 miles from the San Joaquin River via the shortest routes. Designated critical habitat for Spring-Run Chinook Salmon does not occur within Rock Slough, but is present further to the north in the Delta (NMFS 2017c, 2014). Salmonids are expected to avoid the area of the Rock Slough Intake during certain times of the year based on historical water temperatures, which range from lows of about 45°F in winter (December and January) to over 70°F beginning in May and continuing to October (Reclamation 2016).

Fish monitoring prior to the construction of the Rock Slough Fish Screen (RSFS) indicates the timing and magnitude of Central Valley Spring-Run Chinook Salmon presence near the Rock Slough Intake. Since 1994, fish monitoring has been conducted by CDFW and CCWD consistent with the separate biological opinions and permits that govern CCWD's operations. From 1994 through 1999, CDFW conducted fish monitoring at the Rock Slough Intake and in the Contra Costa Canal up to the first pumping plant. Over this 6-year period, CDFW captured a total of 108 juvenile Central Valley Spring-Run Chinook Salmon from March through May (CDFG 2002c; NMFS 2017c). From 1999 to 2009, the 11 years prior to construction of the RSFS, CCWD's Fish Monitoring Program collected a total of 11 juvenile Central Valley Spring-Run Chinook Salmon from March through May at the Rock Slough Headworks (Reclamation 2016; NMFS 2017c) and 4 juvenile Central Valley Spring-Run Chinook Salmon at Pumping Plant #1 (CCWD 2019). No adult Spring-Run were collected in the vicinity of the Rock Slough Intake from 1994 through 2009 (CDFG 2002c; Reclamation 2016; NMFS 2017c). No juvenile or adult Central Valley Spring-Run Chinook Salmon have been collected in CCWD's Fish Monitoring Program at the Rock Slough Intake since 2008.

Since construction of the RSFS, operation of the hydraulic rake cleaning system has been shown to trap and kill adult Chinook Salmon and other non-listed fish (Reclamation 2016). From 2011-2018, 47 Salmon were recovered at the RSFS (Reclamation 2016, Appendix A; Tenera Environmental 2018a), but none of the captured fish were identified as Spring-Run Chinook Salmon (NMFS 2017c).

CCWD's Fish Monitoring Program also samples behind the fish screens at CCWD's other south Delta intakes. Since the intakes have been in operation, CCWD's Fish Monitoring Program has never collected Spring-Run Chinook Salmon at CCWD's Old River Intake or Middle River Intake (CCWD 2019).

CCWD's operations, including operation of the Rock Slough, Old River, and Middle River intakes and Los Vaqueros Reservoir, are simulated in the CalSim model. Thus, CalSim results discussed throughout this appendix include the effects of CCWD's operations in combination with all other water diversions and reservoir operations. A further analysis was undertaken to isolate the maximum possible effects of CCWD's operations on Delta hydrodynamics by determining the effect that CCWD pumping at maximum capacity would have on Delta channel water velocity. Results of this analysis are shown below; in all cases the maximum possible effect of CCWD's operations is de minimis.

Due to the location of the Rock Slough Intake near the end of a dead-end slough, far from the main migratory routes (i.e., 10 miles from the San Joaquin River and 18 miles from the Sacramento River), juvenile Spring-Run Chinook Salmon are not likely to be in the vicinity of the Rock Slough Intake. However, according to NMFS (2017), juvenile Spring-Run can be "drawn" into the south Delta under reverse flows and high CVP and SWP pumping rates.

One indicator of reverse flows is the net flow in OMR. Rock Slough Intake is located on Rock Slough, approximately 3.5 miles west of the junction of Rock Slough and Old River, which is over 12 river miles north of the gates to the SWP Clifton Court Forebay. Given its location, the Rock Slough Intake does not affect net reverse flow in OMR, and any effect that diversions at Rock Slough Intake would have in the OMR corridor would be to increase the northerly (positive) flow away from the Banks and Jones Pumping Plants. For juveniles that migrate down the OMR corridor that are not salvaged at TFCF or Skinner Fish Facility, any effect of Rock Slough Intake diversions would be a positive effect on OMR.

For juveniles that migrate down the mainstem of the Sacramento River or the San Joaquin River and for juveniles that were salvaged, trucked, and released in the western Delta, the potential effect of Rock Slough diversions on the net reverse flow in San Joaquin River may be relevant. The effect of water diversions at Rock Slough Intake on the velocity in the San Joaquin River at Jersey Point is presented in the effects analysis for juvenile Winter-Run Chinook Salmon. As detailed in that section, the maximum potential effect of water diversions at Rock Slough Intake (assuming diversions at the maximum permitted capacity of 350 cfs and all water diverted by the Rock Slough Intake comes from the San Joaquin River at Jersey Point) is 0.00625 ft/sec in the San Joaquin River at Jersey Point. For comparison, the velocity threshold for design of fish screens to prevent impingement of salmonids is 0.33 ft/sec, which is 50 times the maximum possible contribution from the Rock Slough diversions.

Recognizing that CCWD owns and operates two additional intakes in the south Delta, we examine the combined effect of all three intakes. CCWD's Old River Intake and Middle River Intake have a physical capacity of 250 cfs at each intake. If CCWD were to divert at all three intakes at the maximum capacity at the same time, total CCWD diversions would be 850 cfs. The corresponding effect on velocity in the San Joaquin River at Jersey Point would be 0.015 ft/sec. The velocity threshold used to protect salmonids from diversions in the vicinity of fish screens (0.33 ft/sec) is over 21 times greater than the maximum possible contribution from CCWD's combined physical capacity. The water diversions at the Rock Slough Intake when combined with diversions at CCWD's Old River Intake and Middle River Intake have a negligible effect on velocity along the migratory path for juvenile Spring-Run Chinook Salmon and are not likely to affect the movement of juvenile salmonids.

Nonetheless, even extremely small changes in velocity can affect the movement of neutrally buoyant particles such as phytoplankton. As shown in the Winter-Run Chinook Salmon section, the diversions at the Rock Slough Intake could move a neutrally buoyant particle in the San Joaquin River at Jersey Point approximately 540 ft over the course of the day. For comparison, the tidal excursion on the San Joaquin River at Jersey Point during a flood tide (i.e., the distance a particle will travel tidally upstream during a flood tide) is about 34,000 ft on average (or 6.4 miles), which is about 63 times the distance that diversions at Rock Slough could move a particle at the same location over the course of a full day. Therefore, the maximum possible contribution of diversions at Rock Slough on movement of neutrally buoyant particles such as phytoplankton is insignificant in comparison to the tidal excursion and mixing at this location.

In summary, CCWD's operations under Alternative 2 would remain consistent with the operational criteria specified in separate biological opinions and permits that govern operations at CCWD's intakes and Los Vaqueros Reservoir, and as shown above, the effect of CCWD's operations on Delta hydrodynamics is negligible.

Potential changes to aquatic resources in North Bay Aqueduct operations

Alternative 2 includes the North Bay Aqueduct (NBA) intake in the North Delta and operation of the Barker Slough Pumping Plant. Listed salmonids may be present in the waterways adjacent to the Barker Slough Pumping Plant (monitoring data is available at https://www.wildlife.ca.gov/Regions/3)). The NBA is located within designated critical habitat for Spring-Run Chinook Salmon. There should be no discernable effect to the Spring-Run Chinook Salmon due to the operations of the Barker Slough Pumping Facility. This is due to the infrequent presence of Spring-Run Chinook Salmon in the monitoring surveys indicating a low risk of entrainment. Further, Barker Slough Pumping Facility fish screens are designed to protect juvenile salmonids per NMFS criteria and should prevent entrainment while greatly minimizing any impingement of fish against the screen.

Potential changes to aquatic resources due to water transfers

Under Alternative 2, Reclamation is expanding the transfer window to November from the current July to September. Expanding the transfer window could lead to increased pumping at Jones and Banks Pumping Plants, when capacity is available. The Figures below show when capacity is available under Alternative 1 and the No Action Alternative, in terms of exceedances, years in the model period of record, and average by water year types. These values are total available, and are not filtered for the pattern on which water might be acquired for transfer. The pattern of acquisition could decrease these values, as well as reoperation of storage that might be required, or the water cost of meeting D-1641. Prior estimates indicate that approximately 50% of the capacity in the figures below would be useful for water transfers given these timing and upstream considerations. In addition, a 20-30% surcharge on acquisition might be necessary to accommodate the salinity related inefficiencies that arise in operations. Based on the figures below and these additional estimates, expanding the water transfer window could result in an additional approximately 50 TAF of pumping in most yeartypes. As more stored water is available from CVP and SWP reservoirs to pump in wetter yeartypes, most of the available capacity for transfers is in drier yeartypes (Figures O.3-108 through O.3-110).

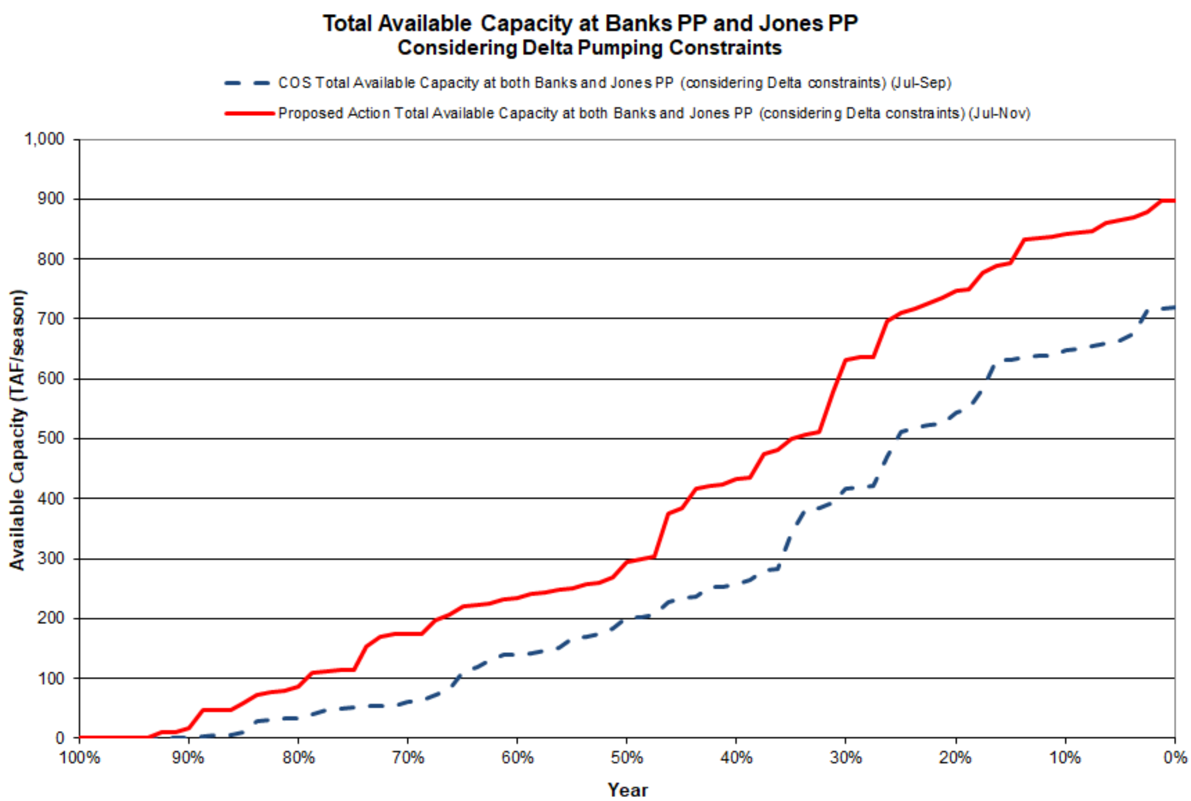


Figure O.3-108. Exceedance of Available Capacity for Transfers at Jones and Banks under the Alternative 1 and No Action Alternative

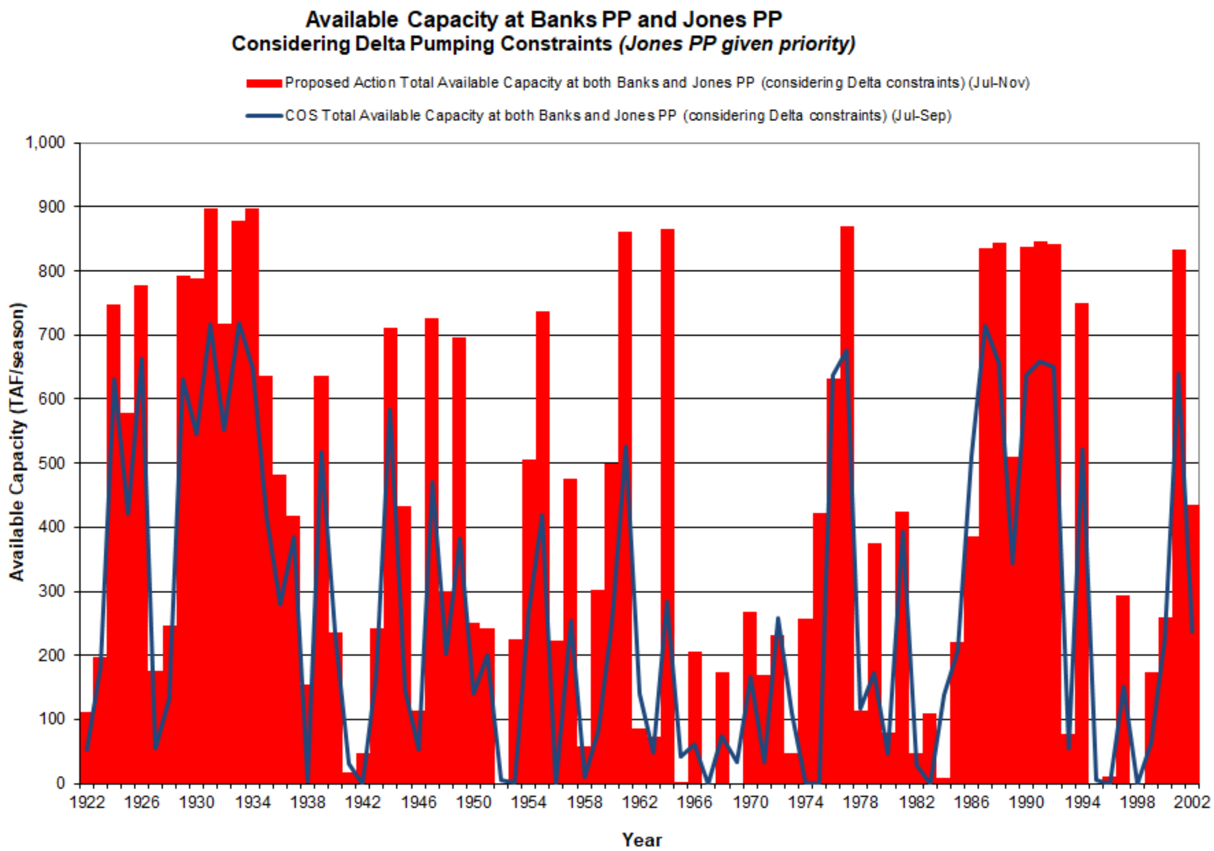


Figure O.3-109. Modeled annual maximum available capacity for transfers under Alternative 1 and No Action Alternative, CalSim period of record (1922–2003)

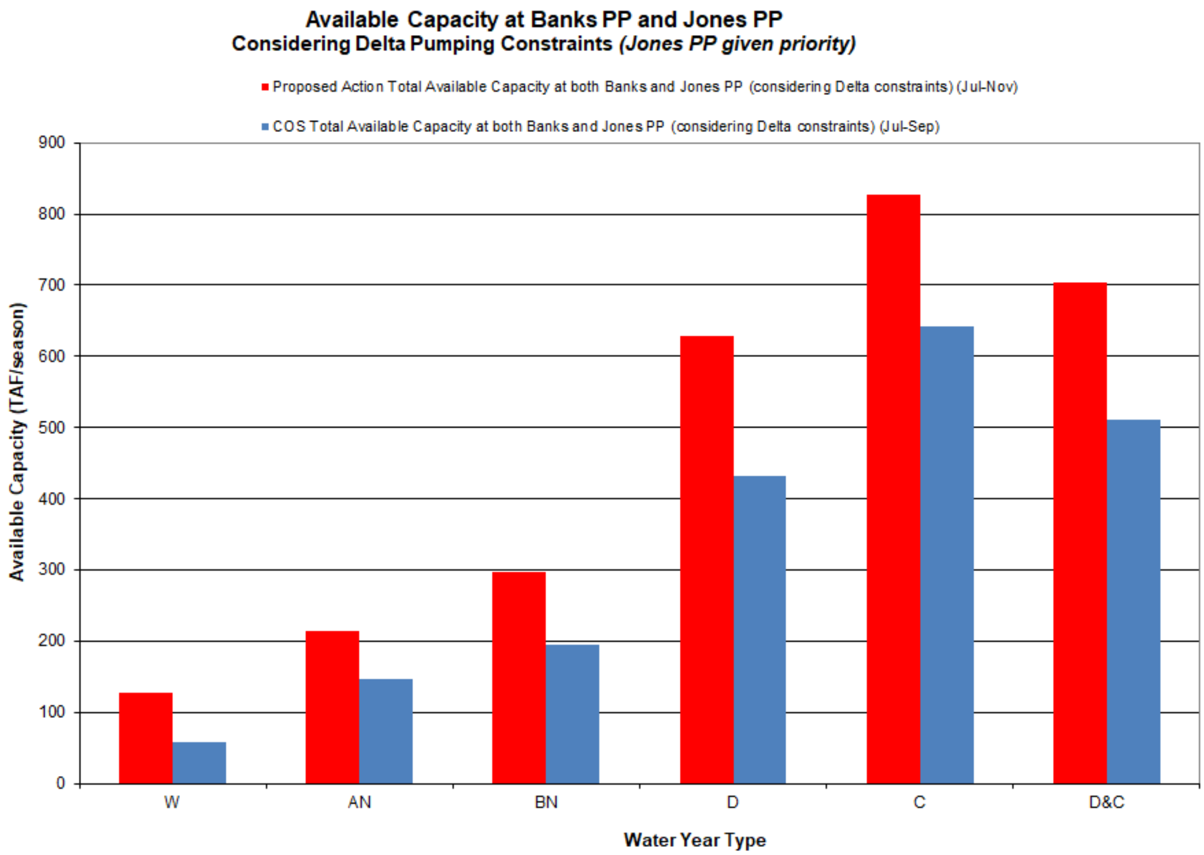


Figure O.3-10. Water Year Type average available capacity at Jones and Banks Pumping Plants

Egg, aelvin, fry, and adult lifestages of Spring-Run Chinook Salmon would not be exposed to the effects of increased water transfers as they do not occur in the Delta during July through November. Juvenile Central Valley Steelhead are detected at Chipps Island between December and July with the highest abundance in March to May (Reclamation 2019). Thus, only the very early or late migrants could potential be exposed to water transfers that occur during this time. These early or late migrant uvenile Spring-Run Chinook Salmon could be exposed to increased effects of entrainment, routing, and decreased Delta survival (see OMR management section) as a result of the expanded water transfer window. Increased flows during conveyance in the Sacramento River could provide small survival benefits to migrating juveniles (Perry et al. 2018).

O.3.5.8.5 Central Valley Fall-Run Chinook Salmon

Potential changes to aquatic resources due to seasonal operations

Hydrodynamic changes associated with river inflows and South Delta exports have been hypothesized to adversely affect juvenile Chinook Salmon in two distinct ways: 1) “near-field” mortality associated with entrainment to the export facilities, 2) “far-field” mortality resulting from altered hydrodynamics. Near-field or entrainment effects of proposed seasonal operations can be most appropriately assessed by examining patterns of proportional population entrainment available from decades of coded wire tag studies (e.g., Zeug and Cavallo 2014). A foundation for assessing far-field effects has been provided by work of the Collaborative Adaptive Management Team's (CAMT) Salmonid Scoping Team (SST). The SST completed a thorough review of this subject and defined a driver- linkage-outcome (DLO) framework for specifying how water project operations (the "driver") can influence juvenile salmonid behavior (the "linkage") and potentially cause changes in survival or routing (the "outcome"). The SST concluded altered "Channel Velocity" and altered "Flow Direction" were the only two hydrodynamic mechanisms by which exports and river inflows could affect juvenile salmonids in the Delta. Figure O.3-111 provides a simplified conceptual model of the DLO defined by the CAMT SST.

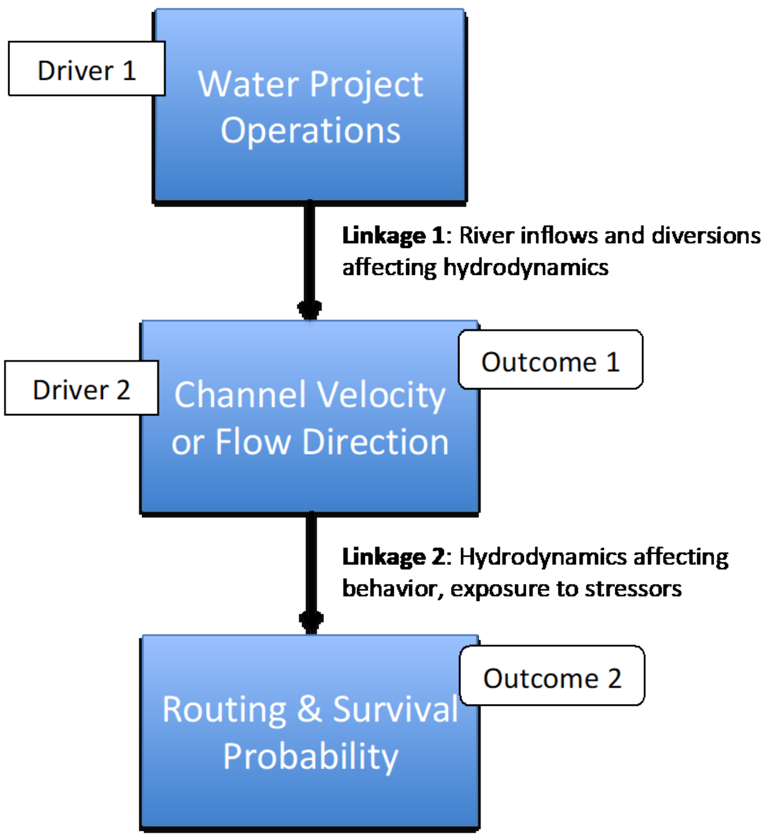


Figure O.3-111. Conceptual model for far-field effects of water project operations on juvenile salmonids in the Delta. This CM is a simplified version of the information provided by the CAMT SST.

Though many juvenile salmonid tagging studies have been conducted in the Delta, the focus has primarily been on estimating reach survival and routing- not assessing export-related hydrodynamic mechanisms defined by the SST's DLO. In fact, most tagging studies have targeted areas of the Delta where "Channel Velocity" and "Flow Direction" may not be appreciably affected by exports (e.g., Newman and Brandes 2010; Perry et al. 2010; Perry et al. 2012; Perry et al. 2015; Michel et al. 2013).

In order to assess the potential for water project operations to influence survival and routing, we analyzed Delta hydrodynamic conditions by utilizing outputs from DSM2 Hydro modeling. Our analysis of DSM2 output is based on our previous work creating map-based visualizations of spatial hydrodynamic patterns at the scale of the Delta. The map-based approach allows us to identify a 'footprint' of the hydrodynamic differences between scenarios. The maps are based on a comparative metric, proportion overlap (more below), to capture channel-level hydrodynamic details as a single number for color-scaled mapping of Delta channels. Our previous work made clear that spatial patterns were more easily discerned by mapping comparative metrics than by mapping descriptive metrics in multiple panels.

The objective of the comparative metric is to summarize the water velocity time series for each channel and scenario such the channel-level comparison is captured in a single number. For the proportion overlap metric, kernel density estimates are calculated on each time series. The kernel density estimates represent a non-parametric smoothing of the empirical distribution of time series values. The proportion overlap of two kernel density estimates is calculated with the following steps: 1) calculate the total area under the curve (AUC_t) as the sum of the AUC for each density estimate, 2) calculate the AUC of the overlapping portions (AUC_o) of the two density distributions being compared, and 3) calculate the overlapping proportion of the density distributions as AUC_o/AUC_t. Proportion overlap is naturally bound by zero and one; a value of zero indicates no overlap and a value of one indicates complete overlap. Lower values of proportion overlap identify channels demonstrating larger differences in a scenario comparison.

The proportion overlap metric is best applied over relatively short time periods because seasonal and annual variation in water velocity can overwhelm differences between scenarios. Thus, we calculated proportion overlap for every DSM2 channel for two seasons (Dec-Feb, May-Mar) in each water year (1922–2003). We excluded DSM2 output from water year 1921 to allow for an extensive burn-in period. We calculated proportion overlap based on hourly DSM2 output. Because each season was roughly 90 days, each comparison involved roughly 4,300 DSM2 values (2 scenarios * 24 hours * 90 days) for each channel.

Because we calculated proportion overlap for each channel in each water year, we summarized the proportion overlap values prior to mapping (i.e., not feasible to map proportion overlap for every comparison in every water year). To summarize, we found the minimum proportion overlap for each channel for each water year type for each comparison. The minimum values represent the maximum expected effect. Note that the year with the minimum proportion overlap for one channel might not be the same year as for another channel.

Entrainment

Zeug and Cavallo (2014) analyzed > 1000 release groups representing, more than 28 million coded wire tagged juvenile fish including winter, late fall and Fall-Run Chinook Salmon. This data is extremely useful because it represents large release groups of tagged smolts where the number of fish representing each release group lost to entrainment at the export facilities has been estimated. Estimating loss from “raw” salvage is problematic because the actual stock or basin of origin is often unknown (e.g., poor performance of length-at-date curves). Furthermore, with “raw” salvage, the number of smolts produced and potentially exposed to entrainment is unknown. The CWT salvage data analyzed by Zeug and Cavallo (2014) overcomes these deficiencies and provides the most appropriate basis for defining stock-specific categories of entrainment risk.

The average proportion Sacramento River-origin Fall-Run Chinook salvaged over a 15-year period was 0.0001 and the proportion of mortality accounted for by entrainment averaged 0.0003 (Zeug and Cavallo 2014). Salvage increased with increasing exports but loss never exceeded 1% regardless of export rate. Late Fall-Run Chinook Salmon juveniles were salvaged at a higher rate than any other race (0.02% of each release group) and entrainment related mortality accounted for almost 1% of total mortality on average (Zeug and Cavallo 2014). Proportional loss of Late-Fall remained low until exports exceeded ~9,000 cfs when proportional loss could approach 8% (Zeug and Cavallo 2014). In the December through February period when Late Fall-Run Chinook Salmon are most abundant, Alternative 2 proposes an average total export rate higher than No Action Alternative (2,525 cfs; Reclamation 2019) and will therefore have a higher entrainment risk. Total exports proposed for Alternative 2 in March-June (2,687 cfs higher than No Action Alternative; Figure O1-2) when juvenile Fall-Run are most abundant in the Delta, will increase entrainment risk relative to No Action Alternative, but entrainment losses for Fall-Run Chinook Salmon will be extremely low. Entrainment risk will also increase for Late Fall-Run Chinook Salmon and losses will likely be higher relative to Fall-Run.

Routing

Routing of juvenile Chinook Salmon into alternative migration routes is closely related to hydrodynamics (Perry et al. 2015; Cavallo et al. 2015; Steel et al. 2012). Changes to hydrodynamics in Delta channels resulting from Alternative 1 were evaluated using DSM2 as described above. Juvenile Fall-Run Chinook Salmon abundance in the Delta is greatest between February and May and Late Fall-Run are present in the Delta between November and July with peaks in January through February and April through May (Reclamation 2019). In the December through February period, velocity overlap between Alternative 1 and No Action Alternative in the Sacramento River main stem between the Sutter-Steamboat and DCC/Georgiana Slough Junctions, was more than 89%, 83%, 68%, 71%, and 57% in critically dry, dry, below normal, above normal, and wet years, respectively (Figure O1-21 in Appendix O, Attachment 1). During the December through February period, velocities were higher under Alternative 2 in below normal, above normal, and wet years and slightly lower in critically dry and dry years indicating routing into the interior Delta would be lower relative to No Action Alternative in normal and wet years and slightly higher relative to No Action Alternative in dry years (Perry et al. 2015; Figure O1-25 in Appendix O, Attachment 1). During the March to May period, velocity overlap between No Action Alternative and Alternative 2 was more than 90%, 82%, 75%, 62%, and 86% in critically dry, dry, below normal, above normal, and wet years, respectively (Figure O1-22 in Appendix O, Attachment 1).

Fall-Run and Late Fall-Run Chinook Salmon juveniles originating from the Sacramento River that enter the interior Delta via Georgiana Slough and the Delta Cross Channel can be exposed to hydrodynamic project effects that could affect routing. Once these fish arrive at the junction of the Mokelumne River and the San Joaquin River, they can move south toward the export facilities or west toward the ocean. In the December through February period analysis of DSM2 data indicates that there is little change to velocities in the region of the junction of the Mokelumne and San Joaquin Rivers between Alternative 2 and the No Action Alternative (Figure O1-23 in Appendix O, Attachment 1). Similar results were obtained when comparing Alternative 2 to the No Action Alternative in the March to May period (Figure O1-24 in Appendix O, Attachment 1).

Through-Delta Survival

A recent study by Perry et al. (2018) found that the effect of flow on survival is not uniform throughout the Delta. Relationships between flow and survival were significant only in reaches where flow changes from bi-directional to unidirectional when discharge increases. To examine potential effects of the proposed project, changes in velocity distributions were examined for the Sacramento River at Walnut Grove and Steamboat Slough which are both in this "transitional" region. During the December to February period at Walnut Grove, velocity distributions for Alternative 2 relative to No Action Alternative were most different in wet years (72.9%) with higher velocities in Alternative 2. Velocities were also greater for Alternative 2 relative to No Action Alternative in below normal and above normal years although overlap was greater (>76%; Figure O1-25 in Appendix O, Attachment 1). In critically dry and dry years, velocity distributions were more similar (>88%; Figure O1-25 in Appendix O, Attachment 1). At Steamboat Slough in the December to February period, there was a similar pattern where velocities under Alternative 2 were higher than No Action Alternative in wet, above normal, and below normal years and similar in dry and critically dry years (Figure O1-26 in Appendix O, Attachment 1).

In the March through May period at Walnut Grove, velocity overlap between Alternative 2 and No Action Alternative was >80% across all water year types with generally greater velocities under Alternative 2 (Figure O1-27 in Appendix O, Attachment 1). At Steamboat Slough in the March through May period, overlap between Alternative 2 and No Action Alternative scenarios was high with all values ≥82% and generally greater velocities under Alternative 2 (Figure O1-28 in Appendix O, Attachment 1).

A recent study by Perry et al. (2018) found that the effect of flow on survival is not uniform throughout the Delta. Relationships between flow and survival were significant only in reaches where flow changes from bi-directional to unidirectional when discharge increases. To examine potential effects of Alternative 2, changes in velocity distributions were examined for the San Joaquin River at Highway 4 and the Head of Middle River which are both in the "transitional" region of the San Joaquin River. During the December to February period at the San Joaquin River at Highway 4, velocity distributions for Alternative 2 relative to No Action Alternative exhibited high overlap in all water year types (≥81.9%; Figure O1-29 in Appendix O, Attachment 1). At the Head of Middle River during the December through February period, overlap was high between Alternative 2 and No Action Alternative in critically dry and dry water years (≥79%) and moderate in wet, above normal, and below normal years (66%; Figure O1-30 in Appendix O, Attachment 1).

In the March to May period in the San Joaquin River at Highway 4, velocity overlap was high between Alternative 2 and No Action Alternative (≥80%; Figure O1-31 in Appendix O, Attachment 1). Velocities were similar in all water year types (Figure O1-31 in Appendix O, Attachment 1). At the Head of Middle River in the March –May period, overlap between Alternative 2 and No Action Alternative was moderate in all water year types (41–65%) and higher in critically dry years >77% (Figure O1-32 in Appendix O, Attachment 1). Velocities were generally lower under Alternative 2 than No Action Alternative (Figure O1-32 in Appendix O, Attachment 1).

Potential changes to aquatic resources due to Delta Cross Channel operations

The Delta Cross Channel may be closed for up to 45 days from November through January for fishery protection purposes. From February 1 through May 20, the gates are closed for fishery protection purposes. The gates may also be closed for 14 days from May 21 through June 15 for fishery protection purposes. The peak migration of juvenile Fall-Run Chinook Salmon in the Sacramento River past West Sacramento, which is near the DCC, occurs from February through May (Reclamation 2019). Therefore, the DCC is closed for the majority of the juvenile Fall-Run Chinook Salmon migration period in the Sacramento River and as such the proportion of fish exposed to an open DCC would be low. Juvenile Fall-Run that are entrained into an open DCC and transported to the interior Delta have reduced survival (Perry et al. 2010).

Potential changes to aquatic resources due to the Temporary Barriers Project

The Temporary Barriers Project (TBP) consists of three rock barriers across south Delta channels to improve water levels for agricultural diversions and one rock barrier to improve San Joaquin River salmonid migration in the south Delta. The temporary rock barriers are installed and removed at Middle River near Victoria Canal, Old River near Tracy, Grant Line Canal near Tracy Boulevard Bridge, and the head of Old River. The TBP is operated based on San Joaquin River flow conditions. The agricultural barriers at Middle River and Old River near Tracy can begin operating as early as April 15 but the tide gates are tied open from May 16 to May 31. After May 31, the barriers in Middle River, Old River near Tracy, and Grant Line Canal are permitted to be operational until they are completely removed by November 30. The head of Old River Barrier is only installed from September 16 to November 30 to improve flow and dissolved oxygenconditions in the San Joaquin River for the immigration of adult Fall-Run Chinook Salmon.

The proportion of juvenile Fall-Run Chinook Salmon exposed to the TBP depends on their annual timing of installation and removal. Due to their location, primarily migrants originating from the San Joaquin River would be exposed to the TBP. The peak relative abundance of juvenile Fall-Run Chinook Salmon in the Delta at Mossdale is February through May (Reclamation 2019). The Head of Old River Barrier would have no effect on juvenile Fall-Run Chinook Salmon if installed from September 16 to November 30 as juvenile Fall-Run Chinook Salmon are largely absent from this section of the San Joaquin River during this time period (Reclamation 2019). If the agricultural barriers are operating as early as April 15 then they have the potential to expose a large proportion of the juvenile Fall-Run migrating down the San Joaquin River. When the Head of Old River barrier is not in place, acoustically tagged juvenile Chinook Salmon have demonstrated a high probability of selecting the Old River route (Buchanan 2018), which would expose them to the agricultural barriers. When the agricultural barriers are operating with tidal flap gates down, a significant decline in passage and reach survival of acoustically tagged juvenile Chinook Salmon migrating past the barrier has been observed compared to when the barrier is not present (DWR 2018). When flap gates are tied up, Chinook Salmon passage past the agricultural barrier was improved (DWR 2018). Flap gates tied up on agricultural barriers from May 16 to May 31 would help to reduce the negative effect of the barriers during this period. However, juveniles migrating before or after this period could be exposed to the agricultural barriers with flaps down which apparently decreases passage success and survival (DWR 2018). Therefore, the potential negative effects of the agricultural barriers depends on when they are installed and whether the flap gates are down or tied up but overall would be medium to high.

Potential changes to aquatic resources due to Contra Costa Water District operations

CCWD’s operations in Alternative 2 are consistent with the operational criteria specified in separate biological opinions and permits that govern operations at CCWD’s intakes and Los Vaqueros Reservoir (NMFS 1993, 2007, 2010, 2017; USFWS 1993a, 1993b, 2000, 2007, 2010, 2017; CDFG 1994, 2009a). Therefore, CCWD’s operations, including operation of the Rock Slough Intake, under Alternative 2 would remain unchanged from the current operations.

Fish monitoring prior to the construction of the Rock Slough Fish Screen (RSFS) indicates the timing and magnitude of Fall-Run/Late Fall-Run Chinook Salmon presence near the Rock Slough Intake. From 1999 to 2011, the 11 years prior to construction of the RSFS, CCWD’s Fish Monitoring Program collected 23 juvenile Fall-Run/Late Fall-Run Chinook Salmon at the Rock Slough Headworks and Contra Costa Pumping Plant #1. Since construction of the Rock Slough Fish Screen in 2012, no Fall-Run/Late Fall-Run Chinook Salmon have been collected behind the fish screen. CCWD’s Fish Monitoring Program also samples at CCWD’s other south Delta intakes. Since the intakes have been in operation, CCWD’s Fish Monitoring Program has never collected Fall-Run/Late Fall-Run Chinook Salmon at CCWD’s Old River Intake or Middle River Intake (CCWD 2019).

CCWD’s operations, including operation of the Rock Slough, Old River, and Middle River intakes and Los Vaqueros Reservoir, are simulated in the CalSim model. Thus, CalSim results discussed throughout this appendix include the effects of CCWD’s operations in combination with all other water diversions and reservoir operations. A further analysis was undertaken to isolate the maximum possible effects of CCWD’s operations on Delta hydrodynamics by determining the effect that CCWD pumping at maximum capacity would have on Delta channel water velocity. Results of this analysis are shown below; in all cases the maximum possible effect of CCWD's operations is de minimis.

Due to the location of the Rock Slough Intake near the end of a dead-end slough, far from the main migratory routes, juvenile Central Valley Fall-Run/Late Fall-Run Chinook Salmon are not likely to be in the vicinity of the Rock Slough Intake. However, according to NMFS (2017), juvenile Salmon can be "drawn" into the south Delta under reverse flows and high CVP and SWP pumping rates.

One indicator of reverse flows is the net flow in Old and Middle Rivers (OMR). Rock Slough Intake is located on Rock Slough, approximately 3.5 miles west of the junction of Rock Slough and Old River, which is over 12 river miles north of the gates to the SWP Clifton Court Forebay. Given its location, the Rock Slough Intake does not affect net reverse flow in Old and Middle Rivers (OMR), and any effect that diversions at Rock Slough Intake would have in the Old and Middle River corridor would be to increase the northerly (positive) flow away from the Banks and Jones Pumping Plants. For juveniles that migrate down the Old and Middle River corridor that are not salvaged at TFCF or Skinner Fish Facility, any effect of Rock Slough Intake diversions would be a positive effect on OMR.

For juveniles that migrate down the mainstems of the Sacramento River or the San Joaquin River and for juveniles that were salvaged, trucked, and released in the western Delta, the potential effect of Rock Slough diversions on the net reverse flow in San Joaquin River may be relevant. The effect of water diversions at Rock Slough Intake on the velocity in the San Joaquin River at Jersey Point is presented in the effects analysis for juvenile Winter-Run. As detailed in that section, the maximum potential effect of water diversions at Rock Slough Intake (assuming diversions at the maximum permitted capacity of 350 cfs and all water diverted by the Rock Slough Intake comes from the San Joaquin River at Jersey Point) is 0.00625 ft/sec in the San Joaquin River at Jersey Point. For comparison, the velocity threshold for design of fish screens to prevent impingement of salmonids is 0.33 ft/sec, which is 50 times the maximum possible contribution from the Rock Slough diversions.

Recognizing that CCWD owns and operates two additional intakes in the south Delta, we examine the combined effect of all three intakes. CCWD's Old River Intake and Middle River Intake have a physical capacity of 250 cfs at each intake. If CCWD were to divert at all three intakes at the maximum capacity at the same time, total CCWD diversions would be 850 cfs. The corresponding effect on velocity in the San Joaquin River at Jersey Point would be 0.015 ft/sec. The velocity threshold used to protect salmonids from diversions in the vicinity of fish screens (0.33 ft/sec) is over 21 times greater than the maximum possible contribution from CCWD's combined physical capacity. The water diversions at the Rock Slough Intake when combined with diversions at CCWD's Old River Intake and Middle River Intake have a negligible effect on velocity along the migratory path for juvenile Central Valley Fall-Run/Late Fall-Run Chinook Salmon and are not likely to affect the movement of juvenile salmonids.

Nonetheless, even extremely small changes in velocity can affect the movement of neutrally buoyant particles such as phytoplankton. As shown in the Winter-Run Chinook Salmon section, the diversions at the Rock Slough Intake could move a neutrally buoyant particle in the San Joaquin River at Jersey Point approximately 540 ft over the course of the day. For comparison, the tidal excursion on the San Joaquin River at Jersey Point during a flood tide (i.e., the distance a particle will travel tidally upstream during a flood tide) is about 34,000 ft on average (or 6.4 miles), which is about 63 times the distance that diversions at Rock Slough could move a particle at the same location over the course of a full day. Therefore, the maximum possible contribution of diversions at Rock Slough on movement of neutrally buoyant particles such as phytoplankton is not significant in comparison to the tidal excursion and mixing at this location.

In summary, CCWD's operations under Alternative 2 would remain consistent with the operational criteria specified in separate biological opinions and permits that govern operations at CCWD's intakes and Los Vaqueros Reservoir, and as shown above, the effect of CCWD's operations on Delta hydrodynamics is negligible.

Potential changes to aquatic resources in North Bay Aqueduct operations

Listed salmonids may be present in the waterways adjacent to the Barker Slough Pumping Plant, however several years of monitoring have failed to consistently capture any salmonids during the winter Delta Smelt surveys (1996 to 2004) in Lindsey Slough or Barker Slough. Captures of Chinook Salmon have usually occurred in the months of February and March and typically are only a single fish per net haul (http://www.delta.dfg.ca.goc/data/nba). Most Chinook Salmon captured have come from Miner Slough, which is a direct distributary from the Sacramento River via Steamboat and Sutter Sloughs. Few if any San Joaquin River-origin Fall-Run Chinook Salmon are expected to be exposed to the North Bay aqueduct because it is not on the migration route of this species.

O.3.5.8.6 Central Valley Steelhead

Potential changes to aquatic resources due to seasonal operations

Entrainment

ICF (2018) analyzed salvage of Central Valley Steelhead at the CVP and SWP between 2003 and 2017 and found that salvage increased with export rate and decreased with San Joaquin River flow. Salvage also decreased with OMR flow. However, OMR is a metric comprised of both exports and San Joaquin River flow which complicates attempts to understand individual effects.

In the December through February period, Alternative 2 proposes an average total export rate slightly higher than the No Action Alternative (2,525 cfs; Figure O1-1 in Appendix O, Attachment 1) and will therefore have higher entrainment risk. Total exports proposed for Alternative 2 in March-June (2,687 cfs higher than No Action Alternative; Figure O1-2 in Appendix O, Attachment 1) when juvenile Central Valley Steelhead are most abundant in the Delta at Chipps Island (Reclamation 2019), will increase entrainment risk relative to No Action Alternative.

Routing

Routing of juvenile Central Valley Steelhead into alternative migration routes is closely related to hydrodynamics (Perry et al. 2015; Cavallo et al. 2015; Steel et al. 2012). Changes to hydrodynamics in Delta channels resulting from Alternative 2 were evaluated using DSM2. Juvenile Central Valley Steelhead are present in the Sacramento River at Hood upstream of the first distributary junctions between November and early June with peak abundance from February to early June (Reclamation 2019). In the December to February period, velocity overlap between Alternative 2 and No Action Alternative in the Sacramento River mainstem between the Sutter-Steamboat and DCC/Georgiana Slough Junctions, was more than 89%, 83%, 68%, 71%, and 57% in critically dry, dry, below normal, above normal, and wet years, respectively (Figure O1-21 in Appendix O, Attachment 1). During the December through February period, velocities were higher under Alternative 2 in below normal, above normal, and wet years and slightly lower in critically dry and dry years indicating routing into the interior Delta would be lower relative to No Action Alternative in normal and wet years and slightly higher relative to No Action Alternative in dry years (Perry et al. 2015; Figure O1-25 in Appendix O, Attachment 1). During the March to May period, velocity overlap between No Action Alternative and Alternative 2 was more than 90%, 82%, 75%, 62%, and 86% in critically dry, dry, below normal, above normal, and wet years, respectively (Figure O1-22).

Through-Delta Survival

A recent study by Perry et al. (2018) found that the effect of flow on survival is not uniform throughout the Delta. Relationships between flow and survival were significant only in reaches where flow changes from bi-directional to unidirectional when discharge increases. To examine potential effects of Alternative 2, changes in velocity distributions were examined for the Sacramento River at Walnut Grove and Steamboat Slough which are both in this “transitional” region. During the December to February period at Walnut Grove, velocity distributions for Alternative 2 relative to No Action Alternative were most different in wet years (72.9%) with higher velocities in Alternative 2. Velocities were also greater for Alternative 2 relative to No Action Alternative in below normal and above normal years although overlap was greater (>76%; Figure O1-25 in Appendix O, Attachment 1). In critically dry and dry years, velocity distributions were more similar (>88%; Figure O1-25 in Appendix O, Attachment 1). At Steamboat Slough in the December to February period, there was a similar pattern where velocities under Alternative 2 were higher than No Action Alternative in wet, above normal, and below normal years and similar in dry and critically dry years (Figure O1-26 in Appendix O, Attachment 1).

In the March through May period at Walnut Grove, velocity overlap between Alternative 2 and No Action Alternative was >80% across all water year types with generally greater velocities under Alternative 2 (Figure O1-27 in Appendix O, Attachment 1). At Steamboat Slough in the March through May period, overlap between Alternative 2 and No Action Alternative scenarios was high with all values ≥82% and generally greater velocities under Alternative 2 (Figure O1-28 in Appendix O, Attachment 1).

A recent study by Perry et al. (2018) found that the effect of flow on survival is not uniform throughout the Delta. Relationships between flow and survival were significant only in reaches where flow changes from bi-directional to unidirectional when discharge increases. To examine potential effects of Alternative 1, changes in velocity distributions were examined for the San Joaquin River at Highway 4 and the Head of Middle River which are both in the “transitional” region of the San Joaquin River. During the December to February period at the San Joaquin River at Highway 4, velocity distributions for Alternative 2 relative to No Action Alternative exhibited high overlap in all water year types (≥81.9%; Figure O1-29 in Appendix O, Attachment 1). At the Head of Middle River during the December through February period, overlap was high between Alternative 2 and No Action Alternative in critically dry and dry water years (≥79%) and moderate in wet, above normal, and below normal years (66%; Figure O1-30 in Appendix O, Attachment 1).

In the March to May period in the San Joaquin River at Highway 4, velocity overlap was high between Alternative 2 and No Action Alternative (≥80%; Figure O1-31 in Appendix O, Attachment 1). Velocities were similar in all water year types (Figure O1-31 in Appendix O, Attachment 1). At the Head of Middle River in the March –May period, overlap between Alternative 2 and No Action Alternative was moderate in all water year types (41-65%) and higher in critically dry years >77% (Figure O1-32 in Appendix O, Attachment 1). Velocities were generally lower under Alternative 2 than No Action Alternative (Figure O1-32 in Appendix O, Attachment 1).

Potential changes to aquatic resources due to Delta Cross Channel operations

Significant flow and many juvenile Central Valley Steelhead enter the central Delta when the DCC gates are open. Mortality of juvenile Central Valley Steelhead entering the central Delta is higher than for those continuing downstream in the Sacramento River. The peak migration of juvenile Central Valley Steelhead in the Sacramento River past Knights Landing, which is upstream of the DCC, occurs from January through February (Reclamation 2019). Therefore under Alternative 2, the continued operation of the DCC to protect the majority of the juvenile Central Valley Steelhead during their migration period in the

Sacramento River would reduce the proportion of fish exposed to an open DCC and result in beneficial impacts to this life stage when compared to the No Action Alternative.

Potential changes to aquatic resources due to the Temporary Barriers Project

The Temporary Barriers Project (TBP) consists of three rock barriers across south Delta channels to improve water levels for agricultural diversions and one rock barrier to improve San Joaquin River salmonid migration in the south Delta. The temporary rock barriers are installed and removed at Middle River near Victoria Canal, Old River near Tracy, Grant Line Canal near Tracy Boulevard Bridge, and the head of Old River. The TBP is operated based on San Joaquin River flow conditions. The agricultural barriers at Middle River and Old River near Tracy can begin operating as early as April 15 but the tide gates are tied open from May 16 to May 31. After May 31, the barriers in Middle River, Old River near Tracy, and Grant Line Canal are permitted to be operational until they are completely removed by November 30. The Head of Old River Barrier is only installed from September 16 to November 30 to improve flow and dissolved oxygenconditions in the San Joaquin River for the immigration of adult Fall-Run Chinook Salmon.

The proportion of juvenile Central Valley Steelhead exposed to the TBP depends on their annual timing of installation and removal. Due to their location, primarily juvenile Central Valley Steelhead migrants originating from the San Joaquin River would be exposed to the TBP. The peak relative abundance of juvenile Central Valley Steelhead in the San Joaquin River in the vicinity of the TBP (Mossdale) occurs in April and May (Reclamation 2019). If the agricultural barriers are operating as early as April 15, there is potential exposure to a large proportion of the juvenile Central Valley Steelhead migrating down the San Joaquin River.

When the Head of Old River barrier is not in place, acoustically tagged juvenile Central Valley Steelhead have demonstrated a high probability of selecting the Old River route (Buchanan 2018), which would expose them to the agricultural barriers. When the agricultural barriers are operating with tidal flap gates down, a significant decline in passage and reach survival of acoustically tagged juvenile Central Valley Steelhead migrating past the barrier has been observed compared to when the barrier is not present (DWR 2018). When flap gates are tied up, Central Valley Steelhead passage past the agricultural barrier was improved (DWR 2018). Therefore, although Alternative 2 does not include HORB, which could result in negative impacts to Central Valley Steelhead juvenile migration, the improvements to the agricultural barriers (including flap gates tied up from May 16 to May 31) would help to reduce the negative effect of the barriers on migrating juvenile Central Valley Steelhead during this period relative to No Action Alternative. However, juvenile Central Valley Steelhead migrating before or after this period could be exposed to the agricultural barriers with flaps down, which apparently decreases passage success and survival (DWR 2018). Therefore, the potential negative effects of the agricultural barriers under Alternative 1 on juvenile Central Valley Steelhead depends on when they are installed and whether or not the flap gates are down.

Potential changes to aquatic resources due to Contra Costa Water District operations

CCWD’s operations in Alternative 2 are consistent with the operational criteria specified in separate biological opinions and permits that govern operations at CCWD’s intakes and Los Vaqueros Reservoir (NMFS 1993, 2007, 2010, 2017; USFWS 1993a, 1993b, 2000, 2007, 2010, 2017; CDFG 1994, 2009a). Therefore, CCWD’s operations, including operation of the Rock Slough Intake, under Alternative 2 would remain unchanged from the current operations.

Fish monitoring prior to the construction of the Rock Slough Fish Screen (RSFS) indicates the timing and magnitude of presence near the Rock Slough Intake. From 1999 to 2011, the 11 years prior to construction of the RSFS, CCWD's Fish Monitoring Program collected 15 juvenile Central Valley Steelhead at the Rock Slough Headworks and Pumping Plant #1. Since construction of the Rock Slough Fish Screen, no Central Valley Steelhead have been collected behind the fish screen. CCWD's Fish Monitoring Program also samples at CCWD's other south Delta intakes. Since the intakes have been in operation, CCWD's Fish Monitoring Program has never collected Central Valley Steelhead at CCWD's Old River Intake or Middle River Intake (CCWD 2019).

CCWD's operations, including operation of the Rock Slough, Old River, and Middle River intakes and Los Vaqueros Reservoir, are simulated in the CalSim model. Thus, CalSim results discussed throughout this appendix include the effects of CCWD's operations in combination with all other water diversions and reservoir operations. A further analysis was undertaken to isolate the maximum possible effects of CCWD's operations on Delta hydrodynamics by determining the effect that CCWD pumping at maximum capacity would have on Delta channel water velocity. Results of this analysis are shown below; in all cases the maximum possible effect of CCWD's operations is de minimis.

Due to the location of the Rock Slough Intake near the end of a dead-end slough, far from the main migratory routes, juvenile Central Valley Steelhead are not likely to be in the vicinity of the Rock Slough Intake. However, according to NMFS (2017), juvenile salmonids can be "drawn" into the south Delta under reverse flows and high CVP and SWP pumping rates. One indicator of reverse flows is the net flow in OMR. Rock Slough Intake is located on Rock Slough, approximately 3.5 miles west of the junction of Rock Slough and Old River, which is over 12 river miles north of the gates to the SWP Clifton Court Forebay. Given its location, the Rock Slough Intake does not affect OMR, and any effect that diversions at Rock Slough Intake under Alternative 2 would have in the OMR corridor would be to increase the northerly (positive) flow away from the Banks and Jones Pumping Plants. For juveniles that migrate down the Old and Middle River corridor that are not salvaged at TFCF or Skinner Fish Facility, any effect of Rock Slough Intake diversions would be a positive effect on OMR.

For juveniles that migrate down the mainstems of the Sacramento or San Joaquin Rivers and for juveniles that were salvaged, trucked, and released in the western Delta, the potential effect of Rock Slough diversions on the net reverse flow in San Joaquin River may be relevant. The effect of water diversions at Rock Slough Intake on the velocity in the San Joaquin River at Jersey Point is presented in the effects analysis for juvenile Winter-Run. As detailed in that section, the maximum potential effect of water diversions at Rock Slough Intake (assuming diversions at the maximum permitted capacity of 350 cfs and all water diverted by the Rock Slough Intake comes from the San Joaquin River at Jersey Point) is 0.00625 ft/sec in the San Joaquin River at Jersey Point. For comparison, the velocity threshold for design of fish screens to prevent impingement of salmonids is 0.33 ft/sec, which is 50 times the maximum possible contribution from the Rock Slough diversions.

Recognizing that CCWD owns and operates two additional intakes in the south Delta, the combined effect of all three intakes was examined. CCWD's Old River Intake and Middle River Intake have a physical capacity of 250 cfs at each intake. If CCWD were to divert at all three intakes at the maximum capacity at the same time, total CCWD diversions would be 850 cfs. The corresponding effect on velocity in the San Joaquin River at Jersey Point would be 0.015 ft/sec. The velocity threshold used to protect salmonids from diversions in the vicinity of fish screens (0.33 ft/sec) is over 21 times greater than the maximum possible contribution from CCWD's combined physical capacity. The water diversions at the Rock Slough Intake when combined with diversions at CCWD's Old River Intake and Middle River Intake have a negligible effect on velocity along the migratory path for juvenile Central Valley Steelhead.

Nonetheless, even extremely small changes in velocity can affect the movement of neutrally buoyant particles such as phytoplankton. As shown in the Winter-Run Chinook Salmon section, the diversions at the Rock Slough Intake could move a neutrally buoyant particle in the San Joaquin River at Jersey Point approximately 540 ft over the course of the day. For comparison, the tidal excursion on the San Joaquin River at Jersey Point during a flood tide (i.e., the distance a particle will travel tidally upstream during a flood tide) is about 34,000 ft on average (or 6.4 miles), which is about 63 times the distance that diversions at Rock Slough could move a particle at the same location over the course of a full day. Therefore, the maximum possible contribution of diversions at Rock Slough on movement of neutrally buoyant particles such as phytoplankton is insignificant in comparison to the tidal excursion and mixing at this location. Although the diversions at Rock Slough Intake are not likely to impact juvenile Central Valley Steelhead, the aggregate effect of all water diversions in the Delta, including exports at Jones and Banks Pumping Plants can affect channel velocity.

In summary, CCWD's operations under Alternative 2 would remain consistent with the operational criteria specified in separate biological opinions and permits that govern operations at CCWD's intakes and Los Vaqueros Reservoir, and as shown above, the effect of CCWD's operations on Delta hydrodynamics is neglibible.

Potential changes to aquatic resources in North Bay Aqueduct operations

Under Alternative 2, there would be no changes to operational criteria at the NBA's BSPP relative to current operations. Juvenile Central Valley Steelhead could occur in the vicinity of the BSPP; however, the fish screens used at the facility are designed to protect juvenile salmonids per NMFS criteria and should prevent entrainment and greatly minimize impingement of fish against the screen itself (NMFS 2009). In addition, the location of the facility is well off the typical migration corridor of juvenile Central Valley Steelhead (NMFS 2009: 417). No juvenile Central Valley Steelhead have been captured during CDFW monitoring surveys from 1996 to 2004 (https://www.wildlife.ca.gov/Conservation/Delta/North-Bay-Aqueduct).

Potential changes to aquatic resources due to water transfers

Central Valley Steelhead juveniles could be exposed to increased entrainment, predation, and decreased through-Delta survival as a result of the expanded transfer window under Alternative 2, but as the peak of the juvenile out-migration is in the spring, effects are anticipated to be minimal. No other lifestages of Central Valley Steelhead would co-occur in time and space with water transfers from the Delta.

O.3.5.8.7 North American Green Sturgeon Southern DPS

Potential changes to aquatic resources due to seasonal operations

Hydrodynamic changes associated with river inflows and South Delta exports have been suggested to negatively impact southern DPS Green Sturgeon in two distinct ways: 1) "near-field" mortality associated with entrainment to the export facilities, 2) "far-field" mortality resulting from altered hydrodynamics. The SST completed a thorough review of this subject and defined a driver- linkage-outcome (DLO) framework for specifying how water project operations (the "driver") can influence juvenile salmonid behavior (the "linkage") and potentially cause changes in survival or routing (the "outcome"). A similar analysis is not available for southern DPS Green Sturgeon.

Entrainment

As described by NMFS (2009: 386), impacts to the migratory corridor function of juvenile and subadult Green Sturgeon critical habitat from south Delta exports are less clear than for juvenile salmonids because Green Sturgeon spend 1 to 3 years rearing in the Delta environment before transitioning to their marine life history stage. During this Delta rearing phase, Green Sturgeon are free to migrate throughout the Delta. In the conceptual model, it is hypothesized that higher rates of exports may result in higher rates of entrainment. However, estimating entrainment risk from raw salvage data is not possible due to a lack of information on the number of juvenile Green Sturgeon potentially exposed to salvage.

Juvenile southern DPS Green Sturgeon (> 5 mo) are present in the Delta all year and subadults are most abundant from June through November. In the June through September period under Alternative 2 Reclamation proposes an average total export rate slightly higher than No Action Alternative (546 cfs; Figure O1-15 in Appendix O, Attachment 1) and are unlikely to measurably increase entrainment risk. Total exports proposed for Alternative 2 in September-November (969 cfs higher than No Action Alternative; Figure O1-16 in Appendix O, Attachment 1) are unlikely to measurably increase entrainment risk relative to No Action Alternative.

Juvenile White and Green Sturgeon are infrequent at the TFCF, but may occur in the facility salvage year-round. Salvage is expected to be similar and slightly higher than No Action Alternative under Alternative 2.

Routing

Juvenile Green Sturgeon (>5 mo) are present in the Delta all year and subadults are most abundant from June to November (Reclamation 2019). Juvenile Green Sturgeon swim and behave quite differently and have distinct body morphologies and habitat associations in the Delta compared to outmigrating salmonids, so it is hypothesized that juvenile Green Sturgeon have different routing-hydrology survival relationships. Per NMFS (2009: 338), Green Sturgeon are likely to be found in the main channels of the Delta and the larger interconnecting sloughs and waterways, with western Delta waterways having a higher likelihood of presence than eastern Delta waterways. It is highly uncertain how Green Sturgeon routing would change with Alternative 2.

Through-Delta Survival

Little is known about the relationship between survival of juvenile Green Sturgeon and Delta hydrology. Green Sturgeon reside in the Delta for 1 to 3 years suggesting they encounter a variety of daily, seasonal, and annual hydrological conditions. The majority of Green Sturgeon in the Delta are likely not surviving through the Delta per se, but using these habitats for rearing and foraging. Per NMFS (2009: 338), Green Sturgeon are likely to be found in the main channels of the Delta and the larger interconnecting sloughs and waterways, with western Delta waterways having a higher likelihood of presence than eastern Delta waterways. For juvenile outmigrating Green Sturgeon present in these regions, increasing negative velocities under Alternative 2 may result in lower survival. However, as described above, there is a lower probability of juvenile Green Sturgeon residing in this area.

Potential changes to aquatic resources due to Delta Cross Channel operations

Delta Cross Channel operations under Alternative 2 are changed to allow Reclamation to predict water quality exceedances and open the DCC if D-1641 criteria are predicted to be exceeded. This results in greater opening times of the DCC.

Little is known about the migratory behavior of juvenile Green Sturgeon in the Sacramento River basin. It is likely that juvenile Green Sturgeon (larger than the 75 mm) will not enter the Delta prior to their first winter and thus would not be exposed to the open DCC gates. If juvenile Green Sturgeon are exposed to the open DCC gates, they could be entrained into the central / south Delta and exposed to biological and physical conditions in this area, including potentially greater predation. It is likely that these fish will enter the Delta sometime in the winter or spring following their hatching upriver and encounter both types of gate configurations as they enter the Delta.

Potential changes to aquatic resources due to the Temporary Barriers Project

Agricultural Barriers (Temporary Barrier Project, TBP) are included in Alternative 2 and consists of three rock barriers across south Delta channels to improve water levels for agricultural diversions. The temporary rock barriers are installed and removed at Middle River near Victoria Canal, Old River near Tracy, and Grant Line Canal near Tracy Boulevard Bridge. The TBP is operated based on San Joaquin River flow conditions. The agricultural barriers at Middle River and Old River near Tracy can begin operating as early as April 15 but the tide gates are tied open from May 16 to May 31. After May 31, the barriers in Middle River, Old River near Tracy, and Grant Line Canal are permitted to be operational until they are completely removed by November 30.

Juvenile Green Sturgeon are present in the Delta in all months of the year. However, little is known about their spatial distribution. When the south Delta agricultural barriers are operating with tidal flap gates down, a significant decline in passage and reach survival of acoustically tagged juvenile Chinook Salmon migrating past the barrier has been observed compared to when the barrier is not present (DWR 2018). When flap gates are tied up (May 16 to May 31), outmigrating Chinook Salmon passage past the agricultural barrier was improved (DWR 2018). It could be inferred that passage of outmigrating juvenile Green Sturgeon may also be improved when flap gates are tied up. Therefore, the potential negative effects of the agricultural barriers under Alternative 2 depends on when they are installed and whether the flap gates are down or tied up.

Potential changes to aquatic resources due to Contra Costa Water District operations

CCWD’s operations in Alternative 2 are consistent with the operational criteria specified in separate biological opinions and permits that govern operations at CCWD’s intakes and Los Vaqueros Reservoir (NMFS 1993, 2007, 2010, 2017; USFWS 1993a, 1993b, 2000, 2007, 2010, 2017; CDFG 1994, 2009a). Therefore, CCWD operations, including operation of the Rock Slough Intake, for Alternative 2 remain unchanged from current conditions and the No Action Alternative.

The Contra Costa Canal Rock Slough Intake is located on a dead-end slough, far from the main migratory routes for southern DPS Green Sturgeon (NMFS 2017c), approximately 18 miles from the Sacramento River and 10 miles from the San Joaquin River via the shortest routes. Water temperatures in Rock Slough range from lows of about 40 degrees F in winter (December and January) to over 70 degrees F beginning in May and continuing through October (NMFS 2017c).

A review of the 24 years of fish monitoring data (1994–2018) near the Rock Slough Intake both pre- and post-construction of the Rock Slough Fish Screen (RSFS) showed that southern DPS Green Sturgeon have never been observed in Rock Slough (CDFG 2002c; Reclamation 2016; NMFS 2017c; Tenera Environmental 2018b, ICF 2018). CCWD’s Fish Monitoring Program also samples at CCWD’s other south Delta intakes. Since the intakes have been in operation, CCWD’s Fish Monitoring Program has never observed southern DPS Green Sturgeon at CCWD’s Old River Intake or Middle River Intake (CCWD 2019).

It is unlikely that juvenile, subadult, or adult Green Sturgeon would be present in Rock Slough due to the shallow depth, warm water temperatures, and low dissolved oxygenwhich make the area unsuitable habitat during most of the year. Therefore, it is unlikely that Green Sturgeon will be entrained at Rock Slough Intake and unlikely that Green Sturgeon would be impacted by CCWD operations.

Potential changes to aquatic resources in North Bay Aqueduct operations

Overall, the modeled exports in Alternative 2 represent a significant increase in export levels and, thus, a greater risk to Green Sturgeon in the waters adjacent to the pumping facility compared to their historical vulnerability (NOAA 2009). However, Green Sturgeon are expected to be fully screened out of the facilities by the positive barrier fish screen in place at the pumping facility.

Potential changes to aquatic resources due to water transfers

As discussed under the Spring-Run Chinook Salmon water transfer section, under Alternative 2 Reclamation proposes to expand the transfer window to November. This extended transfer window could result in approximately 50 TAF of additional pumping per year in most years, with associated entrainment, routing, and through-Delta survival impacts. Please see the OMR management section for a discussion of the effects of pumping.

Juveniles older than 5 months, subadults, and adult Green Sturgeon could be exposed to the effects of increased pumping due to water transfers. Although southern DPS Green Sturgeon are present in the Delta in all months of the year, Green Sturgeon are likely to be found in the main channels of the Delta and the larger interconnecting sloughs and waterways, with western Delta waterways having a higher likelihood of presence than eastern Delta waterways (NMFS 2009:338). Therefore, there are no negative impacts of increased pumping at Jones and Banks Pumping Plants due to water transfers under Alternative 2.

Juvenile southern DPS Green Sturgeon are present in the Delta in every month of the year (Reclamation 2019). Thus, some portion of the population would be exposed to this action. Increases in Delta inflow during water transfers may have benefits for juvenile Green Sturgeon. However, there is no information on relationships between flow and juvenile Green Sturgeon ecology.

O.3.5.9 *Nearshore Pacific Ocean on the California Coast*

Southern Resident Killer Whale

Potential changes to Southern Killer Whale from Chinook Salmon prey abundance

Under Alternative 2, water operations would not include many of the criteria currently in place as part of the NMFS (2009) SWP/CVP BO's RPA. Potential effects to Chinook Salmon, which as described in Section O.3.2.9, *Nearshore Pacific Ocean of the California Coast*, are important prey to Southern Resident Killer Whale, are analyzed above in Sections O.3.4.1.1 *Trinity River*, O.3.4.1.2 *Sacramento River*, O.3.4.1.3 *Clear Creek*, O.3.4.1.4 *Feather River*, O.3.4.1.5 *American River*, O.3.4.1.6 *Stanislaus River*, O.3.4.1.7 *San Joaquin River*, and O.3.4.1.8 *Bay Delta*. Given the NMFS (2009) BO's conclusion that the RPA would avoid jeopardy by not being likely to result in local depletion of Southern Resident Killer Whale prey (NMFS 2009, p.718), Alternative 2 may result in potential negative effects to Central Valley Chinook Salmon stocks and therefore Southern Resident Killer Whale, relative to the No Action Alternative. There is some uncertainty in this conclusion given that effects are potentially limited by the medium importance of Central Valley Chinook Salmon stocks to Southern Resident Killer Whale diet and the relatively high representation of hatchery-origin juvenile Chinook Salmon, many of which are released downstream of the Delta (Reclamation 2019).

O.3.6 Alternative 2 – Program-Level Effects

O.3.6.1 *Sacramento River*

Potential changes to aquatic resources from Battle Creek restoration

Acceleration of the Battle Creek restoration program will not occur under either Alternative 2 or the No Action Alternative. Therefore, Alternative 2 and the No Action Alternative are likely to have similar effects on aquatic resources with respect to potential effects of this measure.

Potential changes to aquatic resources from lower intakes near Wilkins Slough

Lowering intakes of diversions near Wilkins Slough will not occur under either Alternative 2 or the No Action Alternative. Therefore, Alternative 2 and the No Action Alternative are likely to have similar effects on aquatic resources with respect to potential effects of this measure.

Potential changes to aquatic resources due to Shasta TCD Improvements

Improvement of the Shasta TCD will not occur under either Alternative 2 or the No Action Alternative. Therefore, Alternative 2 and the No Action Alternative are likely to have similar effects on aquatic resources with respect to potential effects of this measure.

Potential changes to aquatic resources from operation of the Livingston-Stone National Fish hatchery (Winter-Run Chinook Salmon)

Increased production of Winter-Run Chinook Salmon at the Livingston-Stone National Fish Hatchery will not occur under either Alternative 2 or the No Action Alternative. Therefore, Alternative 2 and the No Action Alternative are likely to have similar effects on aquatic resources with respect to potential effects of this measure.

Potential changes to aquatic resources from small screen program installation

Increased installation and improvements to screens on small diversions in the Sacramento River will not occur under either Alternative 2 or the No Action Alternative. Therefore, Alternative 2 and the No Action Alternative are likely to have similar effects on aquatic resources with respect to potential effects of this measure.

Potential changes to aquatic resources from spawning habitat restoration

Increased spawning habitat restoration will not occur under either Alternative 2 or the No Action Alternative. Therefore, Alternative 2 and the No Action Alternative are likely to have similar effects on aquatic resources with respect to potential effects of this measure.

Potential changes to aquatic resources from rearing habitat restoration

Increased rearing habitat restoration will not occur under either Alternative 2 or the No Action Alternative. Therefore, Alternative 2 and the No Action Alternative are likely to have similar effects on aquatic resources with respect to potential effects of this measure.

Potential changes to aquatic resources due to adult rescue activities

Additional adult rescue (beyond what CDFW is currently doing, as noted for Alternative 1) will not occur under either Alternative 2 or the No Action Alternative. Therefore, Alternative 2 and the No Action Alternative are likely to have similar effects on aquatic resources.

Potential changes to aquatic resources due to trap and haul activities

The juvenile trap and haul strategy is not being implemented under either Alternative 2 or the No Action Alternative. Therefore, Alternative 2 is likely to have similar effects on aquatic resources as the No Action Alternative.

O.3.6.2 *Bay-Delta*

O.3.6.2.1 Delta Smelt

Potential changes to Delta Smelt from tidal habitat restoration

The effects of completion of 8,000 acres of tidal habitat restoration under Alternative 2 would be expected to be similar to those described for Alternative 1.

O.3.6.2.2 Longfin Smelt

Potential changes to Delta Longfin Smelt from tidal habitat restoration

The effects of completion of 8,000 acres of tidal habitat restoration under Alternative 2 would be expected to be similar to those described for Alternative 1.

O.3.6.2.3 Sacramento Winter-Run Chinook Salmon

Potential changes to aquatic resources due to changes to the Sacramento Deepwater Ship Channel food study

This action would hydrologically connect the Sacramento River with the Sacramento Deepwater Ship Channel (SDWSC) via the Stone Lock facility from mid-spring to late fall. Juvenile Winter-Run Chinook Salmon may be exposed to the Sacramento Deepwater Ship Channel (SDWSC) component of Alternative 2. This action would hydrologically connect the Sacramento River with the SDWSC via the Stone Lock facility from mid-spring to late fall (Wood Rodgers 2018) to provide food web benefits to Delta Smelt. Juvenile Winter-Run Chinook Salmon abundance downstream of Stone Lock at Sherwood Harbor is highest in February and March, declines in April, and is moderate in November (Reclamation 2019). Juvenile Winter-Run Chinook Salmon passing the Stone Lock facility when there is a hydrologic connection between the waterways could potentially be routed into the SDWSC. Estimates of salmonid survival in the SDWSC are not available to compare with rates in the Sacramento River route. However, if survival rates are similar, fish entering the SDWSC would not be exposed to entrainment into the interior Delta through the DCC or Georgiana Slough which would provide a benefit associated with Alternative 2. A hydrologically connected SDWSC could potentially attract adult Winter-Run Chinook Salmon. If the connection is maintained there would likely not be impacts to adults. However, if the connection is not maintained there could be migratory delays and stranding.

Potential changes to aquatic resources due to changes to the North Delta food subsidies/Colusa Basin Drain study

Provision of north Delta food subsidies by routing Colusa Basin drain water to the Cache Slough area through the Yolo Bypass would occur in summer/fall and therefore would have limited effects on Winter-Run Chinook Salmon, who are in the Delta between December and May for juveniles, and December to July for adults.

Potential changes to aquatic resources due to changes to the Suisun Marsh Roaring River Distribution System food subsidies study

Under Alternative 2, provision of Suisun Marsh food subsidies through coordination of managed wetland flood and drain operations in Suisun Marsh and draining of RRDS to Grizzly Bay/Suisun Bay in conjunction with reoperation of the SMSCG would occur in summer/fall and therefore would have limited effects on Winter-Run Chinook Salmon, who are in the Delta between December and May for juveniles, and December to July for adults.

Potential changes to aquatic resources due to tidal habitat restoration

Although migration through the Delta represents a short period, a large proportion of juvenile Winter-Run Chinook Salmon are expected to be exposed to 8,000 acres of tidal habitat restoration in the Delta. Tidal habitat restoration is expected to benefit juvenile Winter-Run Chinook Salmon in several aspects represented by the Winter-Run Chinook Salmon conceptual model, (Reclamation 2019) including increased food availability and quality and refuge habitat from predators. These benefits can manifest in higher growth rates and increased survival through the Delta. Reclamation and DWR will consult on future tidal habitat restoration with USFWS and NMFS on potential effects to fish from construction-related effects.

Potential changes to aquatic resources due to changes to predator hot spot removal

Predator hot spot removal is primarily focused on providing positive effects to downstream-migrating juvenile salmonids including Winter-Run Chinook Salmon. Although Alternative 2 would not be limited to existing identified hot spots (e.g., those identified by Grossman et al. 2013), the existing hotspots that may be representative of where removal efforts may be most concentrated are in the primary migratory routes of juvenile Winter-Run Chinook Salmon. All hotspots are limited in scale relative to overall available habitat and previous research has not found a consistent positive effect of predator removal on juvenile salmon survival (Cavallo et al. 2012; Michel et al. 2017; Sabal et al. 2016). Winter-Run Chinook Salmon juveniles in the Bay-Delta are unlikely to be exposed to the effects of construction at predator hot spot removal locations in the Sacramento River, as the in-water work window is in the summer and fall when, Winter-Run Chinook Salmon juveniles are generally in the upper river.

Potential changes to aquatic resources due to changes to Delta Cross Channel gate improvements

The DCC is an older structure which requires manual operation and increased use could result in locks braking in either open or closed positions. Migrating Winter-Run Chinook Salmon would benefit from faster operations that prevent straying into the central Delta and catastrophic failure of the facility. Few Winter-Run Chinook Salmon are expected to be exposed to improvements to the Delta Cross Channel. Seasonal closure periods would still be in place to protect migrating salmonids. Potential diurnal operation during closure periods could increase exposure of Winter-Run Chinook Salmon juveniles to entrainment into the interior Delta. Improved biological and physical monitoring associated with improvements would likely minimize potentially increased routing into the interior Delta and subsequent entrainment. Greater operational flexibility and increased gate reliability resulting from improvements would reduce the risk of gate failure that could result in higher rates of entrainment.

Potential changes to aquatic resources due to changes to Tracy and Skinner Fish Facility improvements

A small proportion of juvenile Winter-Run Chinook Salmon are expected to be exposed to the Tracy Fish Facility (Zeug and Cavallo 2014). However, for fish that arrive at the facility, the proposed improvements are likely to increase survival through the facility. Winter-Run Chinook Salmon adults would not be expected to be exposed to the effects of construction of the carbon dioxide injection device proposed for the Tracy Fish Facility, based on the timing of in-water construction (August to October) and the typical seasonal occurrence of this life stage in the Delta (Reclamation 2019).

Few if any juvenile Winter-Run Chinook Salmon would be expected to be exposed to construction of the carbon dioxide injection device proposed for the Tracy Fish Facility Improvements based on lack of observed salvage during the August to October in-water work window (see Figures F.2.7, F.2.8, and F.2.9 in Appendix F of the ROC LTO BA). However, a few early migrants could occur during the in-water work window based on occurrence in the north Delta (see Figures WR_Seines and WR_Sherwood in Appendix Fof the ROC LTO BA).

To the extent that the construction affects the ability of juvenile Winter-Run Chinook Salmon to be efficiently salvaged (as part of the entrainment risk habitat attribute in the SAIL conceptual model; Reclamation 2019), there could be a minor effect to a small number of individuals, although risk would be minimized through appropriate mitigation measures including MM-AQUA-1, MM-AQUA-2, MM-AQUA-7, MM-AQUA-8, MM-AQUA-10 and MM-AQUA-12 (Appendix E, *Mitigation Measures*). There is low potential exposure because of the in-water work window, the application of mitigation measures, and the small scale of the in-water construction.

Skinner Fish Facility improvements from predator control efforts to reduce predation on listed fishes following entrainment into CCF could reduce pre-screen loss of juvenile Chinook Salmon entrained into CCF. It is important to note that only small proportions of Winter-Run Chinook Salmon are lost at the SWP (Zeug and Cavallo 2014).

Potential changes to aquatic resources due to changes to the small screen program

There may be some overlap Winter-Run Chinook Salmon with the main late spring-fall irrigation period for small diversions. Diversion screening could reduce entrainment of late migrating individuals. It is important to note that only a small proportion of the population would be exposed.

Few if any juvenile Winter-Run Chinook Salmon rearing and outmigrating in the Bay-Delta are expected to be exposed to the effects of construction of screens on water diversion intakes. Juvenile Winter-Run Chinook Salmon primarily migrate from November through early May (NMFS 2014c), largely outside of the timing of in-water construction (July 15 to October 15). In addition, the work area for these projects is small, limiting exposure to construction.

Potential changes to aquatic resources due to changes to the Delta fish species conservation hatchery

The operation of the Delta Fish Species Conservation Hatchery would not provide benefits to any life stage of Winter-Run Chinook Salmon. Potential negative effects of the Delta Fish Species Conservation Hatchery include inadvertent propagation and spread of invasive or nuisance species, which could affect juvenile Winter-Run Chinook Salmon through changes in food web structure, for example, in the case of invasive quagga and zebra mussels (Fera et al. 2017). Additional impacts could include reduced water quality resulting from hatchery discharge. Potential negative effects from discharged water are expected to be minimal due to the water treatment and the very small size of the discharge compared to flows in the Sacramento River near the hatchery location. Mitigation and minimization measures detailed in the

EIR/EIS for the facility (Horizon Water and Environment 2017) indicate that potential impacts are less than significant. Potential exposure of juvenile Winter-Run Chinook Salmon would be restricted to a small spatial area within the primary migration route.

As with the other proposed construction activities in the Bay-Delta, few if any juvenile Winter-Run Chinook Salmon would be expected to be exposed to the effects of construction of the Delta Fishes Conservation Hatchery based on the timing of in-water construction (August to October) and the typical seasonal occurrence of this life stage in the Delta (Reclamation 2019). There may be some exposure of early migrants to in-water and shoreline construction of the hatchery intake and outfall, as illustrated by timing of occurrence in Sacramento seines and trawls (see Figures F.2.4 and F.2.5 in Appendix Fof the ROC LTO BAThe relatively few individuals occurring near the construction site could be subject to effects similar to those previously described for habitat restoration (e.g., temporary loss of habitat leading to predation, degraded water quality, reduced foraging ability caused by reduced visibility, noise-related delay in migration, and direct effects from contact with construction equipment or isolation/stranding within enclosed areas). The risk from these potential effects would be minimized through application of mitigation measures (Appendix E, *Mitigation Measures*). There is low potential exposure because of the in-water work window, the application of mitigation measures, and the small scale of the in-water construction.

Winter-Run Chinook Salmon adults would not be expected to be exposed to the effects of construction of construction of the Delta Fish Species Conservation Hatchery based on the timing of in-water construction (August to October) and the typical seasonal occurrence of this life stage in the Delta (Reclamation 2019).

O.3.6.2.4 Central Valley Spring-Run Chinook Salmon

Potential changes to aquatic resources due to changes to the Sacramento Deepwater Ship Channel food study

This action would hydrologically connect the Sacramento River with the Sacramento Deepwater Ship Channel (SDWSC) via the Stone Lock facility from mid-spring to late fall. Juvenile Spring-Run Chinook Salmon abundance in the Delta is moderate in March and peaks in April (Reclamation 2019). Juvenile Spring-Run Chinook Salmon passing the Stone Lock facility when there is a hydrologic connection between the waterways could potentially be enter into the SDWSC. There are potential benefits to Spring-Run Chinook Salmon from this action. Fish entering the SDWSC would not be exposed to entrainment into the interior Delta through the DCC or Georgiana Slough which would provide a benefit if survival rates are similar. However, estimates of salmonid survival in the SDWSC are not available to compare with rates in the Sacramento River route. Also, there is potential for decreased migration time to the ocean and exposure to larger food sources of Liberty Island, but this is currently uncertain.

Potential changes to aquatic resources due to changes to the North Delta food subsidies/Colusa Basin Drain study

Provision of north Delta food subsidies by routing Colusa Basin drain water to the Cache Slough area through the Yolo Bypass would occur in summer/fall and therefore would have limited effects on Spring-Run Chinook Salmon, who are in the Delta between January and February for adults, and November through June for juveniles, with a peak of juvenile migration from March to April.

Potential changes to aquatic resources due to changes to the Suisun Marsh Roaring River Distribution System food subsidies study

Under Alternative 2, provision of Suisun Marsh food subsidies through coordination of managed wetland flood and drain operations in Suisun Marsh and draining of RRDS to Grizzly Bay/Suisun Bay in conjunction with reoperation of the SMSCG would occur in summer/fall and therefore would have limited effects on Spring-Run Chinook Salmon, who are in the Delta between January and February for adults, and November through June for juveniles, with a peak of juvenile migration from March to April.

Potential changes to aquatic resources due to tidal habitat restoration

A large proportion of juvenile Spring-Run Chinook Salmon are expected to benefit from continuing to construct the 8,000 acres of tidal habitat restoration in the Delta under Alternative 2. Benefits include increased food availability and quality and refuge habitat from predators. These benefits can manifest in higher growth rates and increased survival through the Delta.

Few if any juvenile Spring-Run Chinook Salmon would be expected to be exposed to the effects of construction of 8,000 acres of tidal habitat restoration, based on the timing of in-water construction (August to October) and the typical seasonal occurrence of this life stage in the Delta (Reclamation 2019). There may be some exposure of yearling migrants that enter the Delta in the fall. Individuals being exposed to construction could experience risk of potential effects similar to those suggested in recent restoration projects such as the Lower Yolo Restoration Project (NMFS 2014c). This includes the following: temporary loss of aquatic and riparian habitat leading to increased predation, increased water temperature, and reduced food availability; degraded water quality from contaminant discharge by heavy equipment and soils, and increased discharges of suspended solids and turbidity, leading to direct toxicological impacts on fish health/performance, indirect impairment of aquatic ecosystem productivity, loss of aquatic vegetation providing physical shelter, and reduced foraging ability caused by decreased visibility; impediments and delay in migration caused by elevated noise levels from machinery; and direct injury or mortality from in-water equipment strikes or isolation/stranding within dewatered cofferdams. Many of these are elements highlighted in the SAIL conceptual model (Reclamation 2019). The risk from these potential effects would be minimized through application of mitigation measures MM-AQUA-1, MM-AQUA-2, MM-AQUA-4 through MM-AQUA-12, and MM-AQUA-14 (Appendix E, *Mitigation Measures*).

Potential changes to aquatic resources due to changes to predator hot spot removal

Predator hot spot removal under Alternative 2 is primarily focused on providing positive effects to downstream-migrating juvenile salmonids including Spring-Run Chinook Salmon. Although the action would not be limited to existing identified hot spots (e.g., those identified by Grossman et al. 2013), the existing hotspots that may be representative of where removal efforts may be most concentrated are in the primary migratory routes of juvenile Spring-Run Chinook. All hotspots are limited in scale relative to overall available habitat and previous research has not found a consistent positive effect of predator removal on juvenile salmon survival (Cavallo et al. 2012; Michel et al. 2017; Sabal et al. 2016).

Potential changes to aquatic resources due to changes to Delta Cross Channel gate improvements

Greater operational flexibility and increased gate reliability resulting from improvements to the Delta Cross Channel under Alternative 2 would reduce the risk of gate failure that could result in higher rates of entrainment of Spring-Run Chinook Salmon, if left open. Few Spring-Run Chinook Salmon are expected to be exposed to in-water construction related improvements to the Delta Cross Channel due to observance of species protective work windows. Seasonal closure periods would still be in place to protect Spring-Run Chinook Salmon. The DCC is an older structure which requires manual operation and increased use could result in locks braking in either open or closed positions. Migrating Spring-Run

Chinook Salmon would benefit from faster operations that prevent straying into the central Delta and catastrophic failure of the facility. However, improved biological and physical monitoring associated with improvements would likely minimize potentially increased entrainment.

Potential changes to aquatic resources due to changes to Tracy and Skinner Fish Facility improvements

A number of programmatic actions are proposed to improve salvage efficiency of TFCF, including installing a carbon dioxide injection device to allow remote controlled anesthetization of predators in the secondary channels of the Tracy Fish Facility. These actions could potentially benefit juvenile Spring-Run Chinook Salmon through greater salvage efficiency.

Few if any juvenile Spring-Run Chinook Salmon would be expected to be exposed to construction of the CO_2 injection device proposed for the Tracy Fish Facility Improvements, based on lack of observed salvage during the August to October in-water work window (see figures in Appendix Fof the ROC LTO BA*:* WR_salvage_unclipped_date, WR_salvage_clipped_date, and WR_salvage_clipped_CWT_race). Risks to these few individuals would be minimized through appropriate mitigation measures (Appendix E, *Mitigation Measures*), the selected in-water work window, and the small scale of the in-water construction. For juvenile Spring-Run Chinook Salmon that arrive at the facility, the proposed improvements are likely to increase survival through the facility.

Predator control efforts at Skinner Fish Facility under Alternative 2 to reduce predation on listed fishes following entrainment into Clifton Court Forebay could reduce pre-screen loss of juvenile Spring-Run Chinook Salmon entrained into Clifton Court Forebay. Spring-Run Chinook Salmon are unlikely to be in the area during predator control efforts.

Potential changes to aquatic resources due to changes to the small screen program

Few if any juvenile Spring-Run Chinook Salmon rearing and outmigrating in the Bay-Delta are expected to be exposed to the effects of construction of screens on water diversion intakes. Juvenile Sacramento River Spring-Run Chinook Salmon primarily from November through early May (NMFS 2014c), largely outside of the timing of in-water construction (July 15 to October 15). In addition, the work area for these projects is small, limiting exposure to construction.

Potential changes to aquatic resources due to changes to the Delta fish species conservation hatchery

The operation of the Delta Fish Species Conservation Hatchery would not provide benefits to any life stage of Winter-Run Chinook Salmon. Potential negative effects of the Delta Fish Species Conservation Hatchery include inadvertent propagation and spread of invasive or nuisance species, which could affect juvenile Winter-Run Chinook Salmon through changes in food web structure, for example, in the case of invasive quagga and zebra mussels (Fera et al. 2017). Additional impacts could include reduced water quality resulting from hatchery discharge. Potential negative effects from discharged water are expected to be minimal due to the water treatment and the very small size of the discharge compared to flows in the Sacramento River near the hatchery location. Mitigation and minimization measures detailed in the EIR/EIS for the facility (Horizon Water and Environment 2017) indicate that potential impacts are less than significant. Potential exposure of juvenile Winter-Run Chinook Salmon would be restricted to a small spatial area within the primary migration route.

As with the other proposed construction activities in the Bay-Delta, few if any juvenile Winter-Run Chinook Salmon would be expected to be exposed to the effects of construction of the Delta Fishes Conservation Hatchery based on the timing of in-water construction (August to October) and the typical seasonal occurrence of this life stage in the Delta (Reclamation 2019). There may be some exposure of early migrants to in-water and shoreline construction of the hatchery intake and outfall, as illustrated by timing of occurrence in Sacramento seines and trawls (see Figures F.2.4 and F.2.5 in Appendix Fof the ROC LTO BA). The relatively few individuals occurring near the construction site could be subject to effects similar to those previously described for habitat restoration (e.g., temporary loss of habitat leading to predation, degraded water quality, reduced foraging ability caused by reduced visibility, noise-related delay in migration, and direct effects from contact with construction equipment or isolation/stranding within enclosed areas). The risk from these potential effects would be minimized through application of aquatic resourcesmitigation measures (Appendix E, *Mitigation Measures*). There is low potential exposure because of the in-water work window, the application of mitigation measures, and the small scale of the in-water construction.

Winter-Run Chinook Salmon adults would not be expected to be exposed to the effects of construction of construction of the Delta Fish Species Conservation Hatchery based on the timing of in-water construction (August to October) and the typical seasonal occurrence of this life stage in the Delta (Reclamation 2019).

O.3.6.2.5 Central Valley Fall-Run Chinook Salmon

Potential changes to aquatic resources due to changes to the Sacramento Deepwater Ship Channel food study

Moderate to high proportions of juvenile Fall-Run Chinook Salmon are expected to be exposed to the Sacramento Deepwater Ship Channel (SDWSC) action. This action would hydrologically connect the Sacramento River with the SDWSC via the Stone Lock facility from mid-spring to late fall (Wood Rodgers 2018). Juvenile Fall-Run Chinook Salmon abundance in the Delta is moderate in peaks in April and May (Reclamation 2019). Juvenile Fall-Run Chinook Salmon passing the Stone Lock facility when there is a hydrologic connection between the waterways could potentially be entrained into the SDWSC. Estimates of salmonid survival in the SDWSC are not available to compare with rates in the Sacramento River route. However, fish entering the SDWSC would not be exposed to entrainment into the interior Delta through the DCC or Georgiana Slough which would provide a benefit if survival rates are similar. The effect of this action on juvenile Fall-Run Chinook Salmon is moderate.

No San Joaquin River-origin Fall-Run Chinook Salmon are expected to be exposed to the Sacramento Deepwater Ship Channel.

Potential changes to aquatic resources due to changes to the North Delta food subsidies/Colusa Basin Drain study

This action is proposed to occur in July or September which is largely outside of the migration period for juvenile Fall-Run and Late FallRun Chinook Salmon in the Delta (Reclamation 2019). For fish that are exposed, increased food production could potentially enhance growth. The effect of this action is expected to be low.

Potential changes to aquatic resources due to changes to the Suisun Marsh Roaring River Distribution System food subsidies study

This action is proposed to occur in July or September which is largely outside of the migration period for juvenile Fall-Run and Late Fall-Run Chinook Salmon in the Delta (Reclamation 2019). For fish that are exposed, increased food production could potentially enhance growth. The effect of this action is expected to be low.

Potential changes to aquatic resources due to tidal habitat restoration

A large proportion of juvenile Fall-Run and Late Fall-Run Chinook Salmon are expected to be exposed to 8,000 acres of tidal habitat restoration in the Delta. Tidal habitat restoration is expected to benefit juvenile Chinook Salmon in several aspects represented by the Winter-Run Chinook Salmon conceptual model (Reclamation 2019) including, increased food availability and quality and refuge habitat from predators. These benefits can manifest in higher growth rates and increased survival through the Delta. Migration through the Delta represents a short period in the migration of juvenile Fall- and Late Fall-Run Chinook Salmon. Thus the total effect of this action is moderate.

Few juvenile Fall-Run or Late Fall-Run Chinook Salmon would be expected to be exposed to the effects of construction of 8,000 acres of tidal habitat restoration, based on the timing of in-water construction (August to October) and the typical seasonal occurrence of this life stage in the Delta (Reclamation 2019). Individuals being exposed to construction could experience risk of potential effects similar to those suggested in recent restoration projects such as the Lower Yolo Restoration Project (NMFS 2014c). This includes temporary loss of aquatic and riparian habitat leading to increased predation, increased water temperature, and reduced food availability; degraded water quality from contaminant discharge by heavy equipment and soils, and increased discharges of suspended solids and turbidity, leading to direct toxicological impacts on fish health/performance (e.g., gill damage and reduced ability to take in oxygen, increasing metabolic cost), indirect impairment of aquatic ecosystem productivity (e.g., reduction in benthic macroinvertebrate production and availability), loss of aquatic vegetation providing physical shelter, and reduced foraging ability caused by decreased visibility; impediments and delay in migration caused by elevated noise levels from machinery; and direct injury or mortality from in-water equipment strikes or isolation/stranding within dewatered cofferdams. Many of these are elements highlighted in the SAIL conceptual model (Reclamation 2019). The risk from these potential effects would be minimized through application of mitigation measures MM-AQUA-1, MM-AQUA-2, MM-AQUA-4 through MM-AQUA-12, and MM-AQUA-14 (Appendix E, Mitigation Measures).

Potential changes to aquatic resources due to changes to predator hot spot removal

Predator hot spot removal is primarily focused on providing positive effects to downstream-migrating juvenile salmonids including Fall-Run and Late Fall-Run Chinook Salmon. Although the action would not be limited to existing identified hot spots (e.g., those identified by Grossman et al. 2013), the existing hotspots that may be representative of where removal efforts may be most concentrated are in the primary migratory routes of juvenile Spring-Run Chinook. All hotspots are limited in scale relative to overall available habitat and previous research has not found a consistent positive effect of predator removal on juvenile salmon survival (Cavallo et al. 2012; Michel et al. 2017; Sabal et al. 2016).

Potential changes to aquatic resources due to changes to Delta Cross Channel gate improvements

Greater operational flexibility and increased gate reliability resulting from improvements to the Delta Cross Channel under Alternative 2 would reduce the risk of gate failure that could result in higher rates of entrainment of Fall- and Late Fall-Run Chinook Salmon, if left open. Few Fall-Run or Late Fall-Run Chinook Salmon are expected to be exposed to in-water construction related improvements to the Delta Cross Channel due to observance of species protective work windows. Seasonal closure periods would still be in place to protect Chinook Salmon. The DCC is an older structure which requires manual operation and increased use could result in locks braking in either open or closed positions. Migrating Fall- and Late Fall-Run Chinook Salmon would benefit from faster operations that prevent straying into the central Delta and catastrophic failure of the facility. However, improved biological and physical monitoring associated with improvements would likely minimize potentially increased entrainment.

Potential changes to aquatic resources due to changes to Tracy and Skinner Fish Facility improvements

A small proportion of juvenile Fall-Run Chinook Salmon are expected to be exposed to the Tracy Fish Facility (Zeug and Cavallo 2014). However, for fish that arrive at the facility, the proposed improvements are likely to increase survival through the facility.

Few juvenile Fall-Run or Late Fall-Run Chinook Salmon would be expected to be exposed to construction of the CO_2 injection device proposed for the Tracy Fish Facility Improvements, based on lack of observed salvage during the August to October in-water work window (see Figures WR_salvage_unclipped_date, WR_salvage_clipped_date, and WR_salvage_clipped_CWT_race in Appendix F of the ROC LTO BA). To the extent that the construction affects the ability of juvenile Fall-Run, and Late Fall-Run Chinook Salmon to be efficiently salvaged (as part of the entrainment risk habitat attribute in the SAIL conceptual model; see Figure WR_CM4 of the ROC LTO BA), there could be a minor effect to a small number of individuals, although risk would be minimized through appropriate mitigation measures for aquatic resources (Appendix E, Mitigation Measures). Given the low potential exposure because of the in-water work window, the application of mitigation measures, and the small scale of the in-water construction, it is concluded that the negative population-level effects of Tracy Fish Facility Improvements construction would be low on this life stage.

Skinner Fish Facility improvements from predator control efforts to reduce predation on listed fishes following entrainment into Clifton Court Forebay could reduce pre-screen loss of juvenile Chinook Salmon entrined into Clifton Cout Forebay. However, given that only small proportions of Fall-Run Chinook Salmon are lost at the SWP (Zeug and Cavallo 2014), the population-level positive effect of this action would be low. Larger proportions of Late Fall-Run Chinook Salmon are lost at the facilities and this action would have a larger effect for this run.

Potential changes to aquatic resources due to changes to the small screen program

Although there may be moderate overlap Fall-Run Late Fall-Run Chinook Salmon with the main late spring-fall irrigation period for small diversions, and small diversion screening could reduce entrainment of late migraing individuals, the potential population-level positive effect would be low because only a small proportion of the population would be exposed.

Few if any juvenile Fall- /Late Fall-Run Chinook Salmon rearing and outmigrating in the Bay-Delta are expected to be exposed to the effects of construction of screens on water diversion intakes. Juvenile Sacramento River Fall- /Late Fall-Run Chinook Salmon primarily migrate from November through early May (NMFS 2014c), largely outside of the timing of in-water construction (July 15 to October 15). In addition, the work area for these projects is small, limiting exposure to construction.

Potential changes to aquatic resources due to changes to the Delta fish species conservation hatchery

Potential effects of the Delta Fishes Conservation Hatchery include inadvertent propagation and release of nuisance species and reduced water quality resulting from hatchery discharge. Mitigation and minimization measures detailed in the EIR/EIS for the facility (Horizon Water and Environment 2017) indicate that potential impacts are less than significant. Potential exposure of juvenile Fall-Run Chinook Salmon would be restricted to a small spatial area within the primary migration route. The overall impact of the operation of this facility is low.

As with the other proposed construction activities in the Bay-Delta, few juvenile Fall-Run or Late Fall-Run Chinook Salmon would be expected to be exposed to the effects of construction of the Delta Fishes Conservation Hatchery based on the timing of in-water construction (August to October) and the typical seasonal occurrence of this life stage in the Delta (Reclamation 2019). The relatively few individuals occurring near the construction site could be subject to effects similar to those previously described for habitat restoration (e.g., temporary loss of habitat leading to predation, degraded water quality, reduced foraging ability caused by reduced visibility, noise-related delay in migration, and direct effects from contact with construction equipment or isolation/stranding within enclosed areas). The risk from these potential effects would be minimized through application of mitigation measures for aquatic resources (Appendix E, *Mitigation Measures*). There is low potential exposure because of the in-water work window, the application of mitigation measures will reduce effects, and the in-water construction is of a small scale.

O.3.6.2.6 Central Valley Steelhead

Potential changes to aquatic resources due to changes to the Sacramento Deepwater Ship Channel food study

Moderate to high proportions of Central Valley Steelhead are expected to be exposed to the Sacramento Deepwater Ship Channel (SDWSC) conservation measure under Alternative 2. This conservation measure would hydrologically connect the Sacramento River with the SDWSC via the Stone Lock facility from mid-spring to late fall (Wood Rodgers 2018), allowing food to enter the Delta and an alternate migration pathway. Juvenile Central ValleyV Steelhead abundance in the Delta peaks in February through May (Reclamation 2019). Juvenile Central Valley Steelhead passing the Stone Lock facility when there is a hydrologic connection between the waterways could potentially be entrained into the SDWSC. Estimates of salmonid survival in the SDWSC are not available to compare with rates in the Sacramento River route. However, fish entering the SDWSC would not be exposed to entrainment into the interior Delta through the DCC or Georgiana Slough which would provide a benefit if survival rates are similar.

No Central Valley Steelhead are expected to be exposed to the Sacramento Deepwater Ship Channel construction, as the in-water work window does not overlap with their occurrence in the Delta.

Potential changes to aquatic resources due to changes to the North Delta food subsidies/Colusa Basin Drain study

Provision of north Delta food subsidies by routing Colusa Basin drain water to the Cache Slough area through the Yolo Bypass would occur in summer/fall, and does not overlap in time or space with juvenile Central Valley Steelhead occurrence in the Delta. There would not be any effect to Central Valley Steelhead adults.

Potential changes to aquatic resources due to changes to the Suisun Marsh Roaring River Distribution System food subsidies study

Under Alternative 2, provision of Suisun Marsh food subsidies through coordination of managed wetland flood and drain operations in Suisun Marsh and draining of RRDS to Grizzly Bay/Suisun Bay in conjunction with reoperation of the SMSCG would occur in summer/fall and therefore would have limited effects on Central Valley Steelhead juveniles, who are in the Delta between December and July. The action is not expected to have any effect on Central Valley Steelhead adults.

Potential changes to aquatic resources due to tidal habitat restoration

A large proportion of juvenile Central Valley Steelhead are expected to benefit from 8,000 acres of tidal habitat restoration in the Delta under Alternative 2. Tidal habitat restoration is expected to benefit juvenile Central Valley Steelhead in several aspects represented by the Winter-Run Chinook Salmon conceptual model (Figure 5.6-4) including, increased food availability and quality and refuge habitat from predators. These benefits can manifest in higher growth rates and increased survival through the Delta; however, the Delta only represents a small fraction of the total migration route.

Few if any juvenile Central Valley Steelhead would be expected to be exposed to the effects of construction of 8,000 acres of tidal habitat restoration, based on the timing of in-water construction (August to October) and the typical seasonal occurrence of this life stage in the Delta (Reclamation 2019). There may be exposure of a few late migrants, as illustrated by timing of occurrence in Chipps mid-water trawls (Reclamation 2019). Individuals being exposed to construction could experience risk of potential effects similar to those suggested in recent restoration projects such as the Lower Yolo Restoration Project (NMFS 2014c). This includes temporary loss of aquatic and riparian habitat leading to increased predation, increased water temperature, and reduced food availability; degraded water quality from contaminant discharge by heavy equipment and soils, and increased discharges of suspended solids and turbidity, leading to direct toxicological impacts on fish health/performance (e.g., gill damage and reduced ability to take in oxygen, increasing metabolic cost), indirect impairment of aquatic ecosystem productivity (e.g., reduction in benthic macroinvertebrate production and availability), loss of aquatic vegetation providing physical shelter, and reduced foraging ability caused by decreased visibility; impediments and delay in migration caused by elevated noise levels from machinery; and direct injury or mortality from in-water equipment strikes or isolation/stranding within dewatered cofferdams. The risk from these potential effects would be minimized through application of mitigation measures including MM-AQUA-1, MM-AQUA-2, MM-AQUA-4 through MM-AQUA-12 and MM-AQUA-14.

Potential changes to aquatic resources due to changes to predator hot spot removal

Predator hot spot removal under Alternative 2 is primarily focused on providing positive effects to downstream-migrating juvenile salmonids, including Central Valley Steelhead. Although the action would not be limited to existing identified hot spots (e.g., those identified by Grossman et al. 2013), the existing hotspots that may be representative of where removal efforts may be most concentrated are in the primary migratory routes of Central Valley Steelhead. All hotspots are limited in scale relative to overall available habitat, and previous research has not found a consistent positive effect of predator removal on juvenile salmon survival (Cavallo et al. 2012; Michel et al. 2017; Sabal et al. 2016). However, implementation of this action would likely improve conditions for all life stages of Central Valley Steelhead.

Potential changes to aquatic resources due to changes to Delta Cross Channel gate improvements

Completion of DCC gate improvements would benefit Central Valley Steelhead of all life stages within the CVP watershed systems. The peak migration of juvenile Central Valley Steelhead in the Sacramento River past Hood, which is near the DCC, occurs from February through mid-June (Reclamation 2019). No San Joaquin River-origin Central Valley Steelhead are expected to be exposed to the DCC. As previously described, juvenile Central Valley Steelhead are largely absent from the Delta between August and November (Reclamation 2019) and, therefore, few late migrants or early migrants have the potential to be exposed to potential construction from improvements to the DCC under Alternative 2.

Potential changes to aquatic resources due to changes to Tracy and Skinner Fish Facility improvements

Small proportions of Sacramento River-origin Central Valley Steelhead and moderate proportions of Mokelumne River and San Joaquin River-origin Central Valley Steelhead are expected to be exposed to the Tracy Fish Facility. However, for fish that arrive at the facility, the proposed improvements resulting in greater salvage efficiency under Alternative 2 are likely to increase survival of juvenile Central Valley Steelhead.

As previously described, juvenile Central Valley Steelhead are largely absent from the Delta between August and November (Reclamation 2019) and, therefore, none to a few late migrants or early migrants have the potential to be exposed to the effects of construction of the carbon dioxide injection device proposed for the Tracy Fish Facility Improvements. Risks of decrease Central Valley Steelhead juvenile salvage during construction would be minimized through appropriate mitigation measures.

Skinner Fish Facility improvements under Alternative 2 to reduce predation on listed fishes following entrainment into CCF could reduce pre-screen loss of juvenile Central Valley Steelhead entrained into CCF; therefore, providing a benefit for all life stages of Central Valley Steelhead.

Potential changes to aquatic resources due to changes to the small screen program

Fish screens under Alternative 2 would also benefit this lifestage in the same ways described above. Juvenile Central Valley Steelhead outmigrating in the Bay-Delta may be exposed to the effects of construction of screens since they migrate downstream during most months of the year, with a peak emigration period in the spring and a smaller peak in the fall (Hallock et al. 1961). Juvenile Central Valley Steelhead may be found in the work area of these projects; however, mitigation measures would minimize impacts.

Potential changes to aquatic resources due to changes to the Delta fish species conservation hatchery

Potential effects of the Delta Fishes Conservation Hatchery include inadvertent propagation and release of nuisance species and reduced water quality resulting from hatchery discharge. Mitigation and minimization measures detailed in the EIR/EIS for the facility (Horizon Water and Environment 2017) indicate that potential impacts are less than significant. Potential exposure of juvenile Central Valley Steelhead would be restricted to a small spatial area within the primary migration route.

As with the other proposed construction activities in the Delta under Alternative 2, juvenile Central Valley Steelhead are largely absent from the Delta between August and November (Reclamation 2019) which means that none to a few late or early migrants of this life stage could be exposed to Delta Fishes Conservation Hatchery construction. The in-water work constructing the hatchery intake and outfall could result in a small number of individuals experiencing effects such as temporary loss of habitat leading to predation, degraded water quality, noise-related delay in migration, and direct effects from contact with construction equipment or isolation/stranding within enclosed areas. The risk from these potential effects would be minimized through application of mitigation measures (Appendix E, *Mitigation Measures*).

O.3.6.2.7 North American Green Sturgeon Southern DPS

Potential changes to aquatic resources due to changes to the Sacramento Deepwater Ship Channel food study

As described above, juvenile Green Sturgeon may potentially be entrained into the DWSC. Fish entering the SDWSC would not, however, be exposed to entrainment into the interior Delta through the DCC or Georgiana Slough which would provide a benefit if survival rates are similar between the SDWSC and the Sacramento main stem

Potential changes to aquatic resources due to changes to the North Delta food subsidies/Colusa Basin Drain study

Provision of north Delta or Suisun Marsh food subsidies by routing drain water would occur in summer/fall and therefore could provide food benefits to Green Sturgeon juveniles, who are in the Delta in the fall.

Potential changes to aquatic resources due to changes to the Suisun Marsh Roaring River Distribution System food subsidies study

Provision of north Delta or Suisun Marsh food subsidies by routing drain water would occur in summer/fall and therefore could provide food benefits to Green Sturgeon juveniles, who are in the Delta in the fall.

Potential changes to aquatic resources due to tidal habitat restoration

A large proportion of juvenile southern DPS Green Sturgeon are expected to be exposed to continuing to implement the 8,000 acres of tidal habitat restoration in the Delta under Alternative 2. Tidal habitat restoration is expected to benefit juvenile Green Sturgeon in several aspects represented by the Green Sturgeon juvenile conceptual model (Reclamation 2019) including, increased food availability and quality and refuge habitat from predators. These benefits can manifest in higher growth rates and increased survival through the Delta.

Potential changes to aquatic resources due to changes to predator hot spot removal

Predator hot spot removal under Alternative 2 is primarily focused on providing positive effects to downstream-migrating juvenile salmonids. It is currently unknown if predation on juvenile Green Sturgeon in the Delta is limiting their productivity. Although the action would not be limited to existing identified hot spots (e.g., those identified by Grossman et al. 2013), the existing hotspots that may be representative of where removal efforts may be most concentrated are in the rearing and migratory corridors of juvenile Green Sturgeon.

Potential changes to aquatic resources due to changes to Delta Cross Channel gate improvements

Little is known about the migratory behavior of juvenile Green Sturgeon in the Sacramento River basin. It is likely that juvenile Green Sturgeon (larger than the 75 mm) will not enter the Delta prior to their first winter and thus would not be exposed to the open DCC gates. It is likely that these fish will enter the Delta sometime in the winter or spring following their hatching upriver and encounter both types of gate configurations as they enter the Delta. More information is required to accurately assess the migratory movements of juvenile Green Sturgeon in the river system, as well as their movements within the Delta during their rearing phase in estuarine/Delta waters. Greater operational flexibility and increased gate reliability resulting from improvements would reduce the risk of gate failure that could result in higher rates of entrainment.

Potential changes to aquatic resources due to changes to Tracy and Skinner Fish Facility improvements

Upgrades to the TFCF will aim to minimize the effects of the salvage process on listed fishes, in particular juvenile salmonids and Green Sturgeon. Salvage improvements will improve survival of salvaged fish and potentially allow reduction of the expansion factors used to extrapolate take estimates from observed salvage.

As previously described, juvenile Green Sturgeon can occur in the Delta year-round (Reclamation 2019) and, therefore, have the potential to be exposed to the effects of construction of the CO_2 injection device proposed for the Tracy Fish Facility Improvements. If construction affects the efficiency of Green

Sturgeon salvage (which is an element of entrainment risk; Reclamation 2019), there could be a minor effect to a small number of individuals, although risk would be minimized through appropriate mitigation measures (Appendix E, *Mitigation Measures*).

Skinner Fish Facility improvements under Alternative 2, which involve predator control efforts, can reduce predation on listed fish species, following their entrainment into Clifton Court Forebay. This could also reduce pre-screen loss of juvenile southern DPS Green Sturgeon. It is unknown what proportion of juvenile Green Sturgeon are entrained into CCF but individuals are salvaged infrequently. Thus, Alternative 2 is not likely to negatively impact juvenile Green Sturgeon.

Potential changes to aquatic resources due to changes to the small screen program

Southern DPS Green Sturgeon are expected to be present in the Delta during the main irrigation period for small diversions (late spring-fall). Diversion screening under Alternative 2 could reduce entrainment of individual Green Sturgeon. However, there is currently no information on the proportion of juvenile Green Sturgeon that are entrained into small unscreened diversions. North American Green Sturgeon in the juvenile to subadult/adult life stage may be exposed to the effects of construction of screens since they are present in the Sacramento River year-round (Reclamation 2019). Effects are the same as described above for juveniles. Mitigation measures would minimize risk.

Potential changes to aquatic resources due to changes to the Delta fish species conservation hatchery

None of the Green Sturgeon life stages would benefit from the Delta Fish Species Conservation Hatchery under Alternative 2. As with the other proposed construction activities in the Delta, the year-round occurrence of juvenile Green Sturgeon in the Delta (Reclamation 2019) means that this life stage, as well as the timing of the adult Green Sturgeon occurring in the Delta during May to October, could be exposed to Delta Fish Species Conservation Hatchery construction under Alternative 2. The in-water work constructing the hatchery intake and outfall could result in a small number of individuals experiencing effects such as temporary loss of habitat leading to predation, degraded water quality, noise-related delay in migration, and direct effects from contact with construction equipment or isolation/stranding within enclosed areas. The risks from these potential effects would be minimized with through the application of mitigation measures (Appendix E, *Mitigation Measures*).

O.3.6.3 *Nearshore Pacific Ocean on the California Coast*

O.3.6.3.1 Southern Resident Killer Whale

Potential changes to Southern Killer Whale from Chinook Salmon prey abundance

Following the logic provided in Alternative 1, given the medium priority of Central Valley Chinook Salmon stocks and the contribution of hatchery-origin Chinook Salmon released downstream of the potential proposed action influence, plus the fact that Alternative 2 includes almost none of the programmatic activities proposed under Alternative 1, Alternative 2’s programmatic activities would not be expected to have population-level effects to Southern Resident Killer Whale Chinook Salmon prey. This suggests limited effects of Alternative 2 programmatic activities on Southern Resident Killer Whale.

O.3.7 Alternative 3 – Project-Level Effects

O.3.7.1 *Trinity River*

O.3.7.1.1 <u>Seasonal Operations</u>

As described in the No Action Alternative and Alternative 1, the Trinity River system would be operated according to the Trinity River ROD with lower Klamath River augmentation flows.

Potential changes to aquatic resources due to changes in reservoir storage

Model results predict that under Alternative 3, storage volume in Trinity Lake would remain the same in most water year types compared to the No Action Alternative. On average, storage would be increased by 1 TAF under Alternative 3 compared to the No Action Alternative. The effects of changes in reservoir storage conditions as they relate to water temperature can be assessed by looking at temperatures in the Trinity River downstream of Trinity Dam. Average monthly water temperatures in the Trinity River downstream of Trinity Dam would remain similar under Alternative 3 compared to the No Action Alternative (Figure O.3-112). Maximum modeled water temperatures in the Trinity River downstream of Trinity Dam are generally similar under Alternative 3 compared to the No Action Alternative except in August when temperatures would be approximately 6°F higher and September when temperatures would be approximately 2°F higher under Alternative 3. October temperatures would be approximately 4°F lower under Alternative 3 compared to the No Action Alternative.

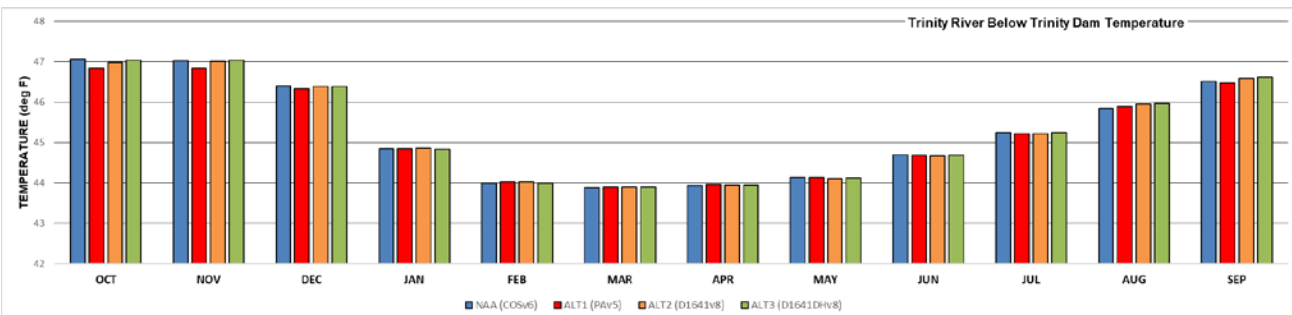


Figure O.3-112. Average Trinity River Water Temperatures below Trinity Dam for the Period October to September, Average of All Water Year Types

No focal fish species occur in Trinity Lake or in the Trinity River downstream of Trinity Dam. Effects of Trinity Reservoir storage on fish in the Trinity River downstream of Lewiston Dam are described below.

Potential changes to aquatic resources from variation in flow

Under Alternative 3 flows in the Trinity River downstream of Lewiston Dam would be similar to flows under the No Action Alternative in most months and water year types. However, in wet years flows would increase in December under Alternative 3 compared to the No Action Alternative (1,297 cfs versus 1,192 cfs). In above normal water years flows under Alternative 3 would decrease in November compared to the No Action Alternative (568 cfs versus 678 cfs) and increase in February compared to the No Action Alternative (801 cfs versus 528 cfs). In critically dry years, flows under Alternative 3 would decrease compared to the No Action Alternative in September and October from 870 cfs to 798 cfs and from 342 cfs to 321 cfs, respectively.

Coho Salmon

Flows in the Trinity River downstream of Lewiston Dam would generally be similar under Alternative 3 compared to the No Action Alternative. Minor differences (<10%) in November and December of some water year types and a larger difference (16%) in November of above normal water years may affect spawning and juvenile rearing habitat for Coho Salmon. Based on previous flow habitat relationship studies in the Trinity River (USFWS 1999), these changes in flow are not expected to result in a detectable effect on Coho Salmon spawning or juvenile rearing habitat (USFWS 1999). Flows in above normal water years in February would increase by approximately 52% under Alternative 3 (801 cfs) compared to the No Action Alternative (528 cfs). This increase in flow could increase the likelihood of Coho Salmon egg mortality due to redd scour, potentially resulting in reduced incubation success in areas where local conditions contribute to substantial mobilization of gravel in the redds.

Spring-Run Chinook Salmon

Flows in the Trinity River downstream of Lewiston Dam would generally be similar under Alternative 3 compared to the No Action Alternative. Minor differences (<10%) in November and December of some water year types and a larger difference (16%) in November of above normal water years may affect spawning and juvenile rearing habitat for Spring-Run Chinook Salmon. Based on previous flow habitat relationship studies in the Trinity River (USFWS 1999), these changes in flow are not expected to result in a detectable effect on Spring-Run Chinook Salmon spawning or juvenile rearing habitat (USFWS 1999). Flows in above normal water years in February would increase by approximately 52% under Alternative 3 (801 cfs) compared to the No Action Alternative (528 cfs). This increase in flow could increase the likelihood of Spring-Run Chinook Salmon egg mortality due to redd scour, potentially resulting in reduced incubation success in areas where local conditions contribute to substantial mobilization of gravel in the redds.

Fall-Run Chinook Salmon

Flows in the Trinity River downstream of Lewiston Dam would generally be similar under Alternative 3 compared to the No Action Alternative. Minor differences (<10%) in November and December of some water year types and a larger difference (16%) in November of above normal water years may affect spawning and juvenile rearing habitat for Fall-Run Chinook Salmon. Based on previous flow habitat relationship studies in the Trinity River (USFWS 1999), these changes in flow are not expected to result in a detectable effect on Fall-Run Chinook Salmon spawning or juvenile rearing habitat (USFWS 1999). Flows in above normal water years in February would increase by approximately 52% under Alternative 3 (801 cfs) compared to the No Action Alternative (528 cfs). This increase in flow could increase the likelihood of Fall-Run Chinook Salmon egg mortality due to redd scour, potentially resulting in reduced incubation success in areas where local conditions contribute to substantial mobilization of gravel in the redds.

Steelhead (Winter- and Summer-Run)

Flows in the Trinity River downstream of Lewiston Dam would generally be similar under Alternative 3 compared to the No Action Alternative. Minor differences (<10%) in November and December of some water year types and a larger difference (16%) in November of above normal water years may affect juvenile rearing habitat for Steelhead. Based on previous flow habitat relationship studies in the Trinity River (USFWS 1999), these changes in flow are not expected to result in a detectable effect on Steelhead juvenile rearing habitat (USFWS 1999). Flows in above normal water years in February would increase by approximately 52% under Alternative 3 (801 cfs) compared to the No Action Alternative (528 cfs).

This increase in flow may reduce the amount of spawning habitat for Steelhead. Based on previous flow habitat relationship studies in the Trinity River (USFWS 1999: 123), increasing flows from 500 cfs to 800 cfs showed little change in the amount of spawning habitat for Steelhead in the Trinity River from downstream of Lewiston Dam to the confluence with Dutch Creek.

Green Sturgeon

Green Sturgeon occur within the lower 43 miles of the Trinity River, approximately 70 miles downstream of Lewiston Dam. Water temperature and habitat conditions within this section of the Trinity River are heavily influenced by several large tributaries that enter the Trinity River (e.g., the North Fork Trinity River, New River, and the South Fork Trinity River). As a result, minor changes in reservoir operations are likely to be undetectable this far downstream. Therefore, changes in flow under Alternative 2 would not affect Green Sturgeon.

White Sturgeon

White Sturgeon are not likely to be affected by changes in reservoir operations under Alternative 2 compared to the No Action Alternative due to their limited distribution in the lower Klamath River, primarily in the estuary.

Pacific Lamprey

Flows in the Trinity River downstream of Lewiston Dam would generally be similar under Alternative 3 compared to the No Action Alternative. However, minor differences (<10%) in November and December of some water year types and a larger difference in November (16%) and February (52%) of above normal water years are expected. Increased flows in February overlap with the Pacific Lamprey adult migration period but are not expected to affect migration because Pacific Lamprey migration spans multiple seasons and associated flows. Although previous flow habitat relationship studies in the Trinity River (USFWS 1999) did not focus on Pacific Lamprey, results for salmonids suggest that changes in flow under Alternative 3 would not result in a detectable effect on juvenile rearing or adult holding habitat for Pacific Lamprey compared to the No Action Alternative.

American Shad

American Shad are primarily found in the lower Klamath River but may occur in the lower sections of the Trinity River up to approximately RM 24 at the town of Willow Creek. Water temperature and habitat conditions within this section of the Trinity River are heavily influenced by several large tributaries that enter the Trinity River (e.g., the North Fork Trinity River, New River, and the South Fork Trinity River). As a result, minor changes in reservoir operations are likely to be undetectable this far downstream. Therefore, changes in flow under Alternative 3 would not affect American Shad.

Potential changes to aquatic resources due to variation in temperature

Modeling results indicate that changes in monthly average water temperature in the Trinity River downstream of Lewiston Dam would be similar between Alternative 3 and the No Action Alternative. Changes in monthly average temperature between Alternative 3 and the No Action Alternative would be less than 0.5°F different for all months of the year (Figure O.3-113). Modeled maximum temperatures in the Trinity River would be higher under Alternative 3 compared to the No Action Alternative in August, September, and November when the maximum temperature would be approximately 2°F to 5°F higher and lower in February when the maximum temperature would be approximately 1°F lower. Maximum temperatures would be similar in the remaining months (Figure O.3-113 and Table O.3-42).

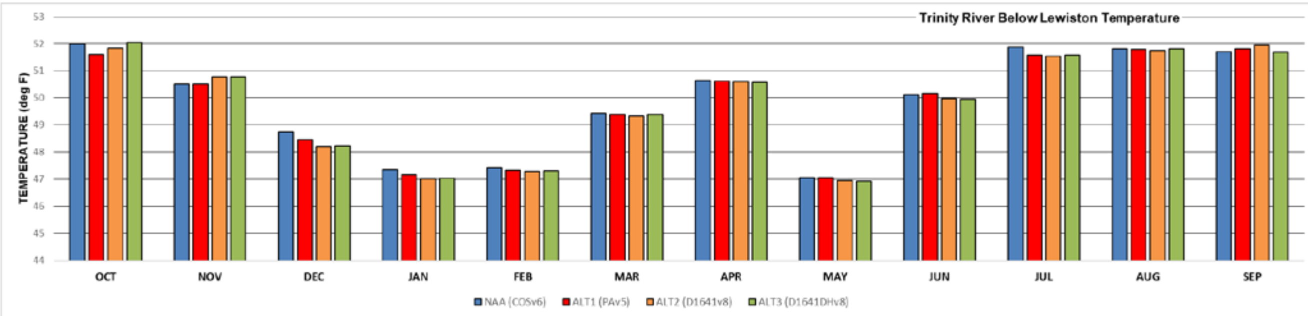


Figure O.3-113. Average Trinity River Water Temperatures below Lewiston Dam for the Period October to September, Average of All Water Year Types

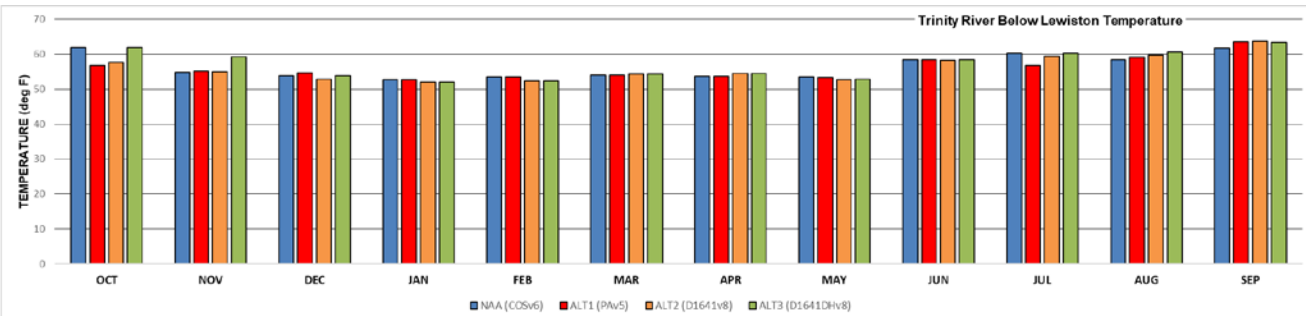


Figure O.3-114. Maximum Trinity River Water Temperatures below Lewiston Dam for the Period October to September, Average of All Water Year Types

Table O.3-42. Maximum Trinity River Water Temperatures below Trinity Dam for the Period October–September, Average of All Water Year Types (Differences >1°F Are Highlighted)

Alt	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
No Action Alternative	61.8	54.8	53.8	52.7	53.4	54.1	53.7	53.5	58.4	60.3	58.4	61.8
ALT 1	56.7	55.2	54.6	52.6	53.5	54.0	53.7	53.4	58.4	56.9	59.1	63.5
ALT 2	57.6	55.1	52.8	52.0	52.4	54.4	54.5	52.7	58.4	59.4	59.7	63.8
ALT 3	61.9	59.3	53.9	52.0	52.4	54.4	54.5	52.9	58.4	60.3	60.6	63.4

In a previous study that looked at flow and water temperatures in the Trinity River (USFWS 1999), results indicated that flows do not have a significant influence on water temperatures from mid-October through early April when cooler air temperatures help maintain cold water temperatures even when flow releases drop below 150 cfs. Once tributary influence begins to decrease and meteorological conditions warm from May to mid-July, flow releases become more influential on downstream temperatures, particularly during hot-dry conditions. Maintaining a flow of 450 cfs during the summer and early fall was found to meet the water temperature objectives for the Trinity River when water released from Lewiston Dam was 53°F or less (USFWS 1999: 203). Water temperatures are most influenced by flow releases from May through mid-October. Flows from May to October would be similar under Alternative 3 compared to the No Action Alternative in most water year types with the exception of critically dry water years. In critically dry years, flows in September would decrease by approximately 6% under Alternative 3 compared to the No Action Alternative, from 870 cfs to 798 cfs. Based on modeling results, changes in flow under Alternative 3 are not likely to have a detectable change in water temperature in the Trinity River downstream of Lewiston Dam.

Coho Salmon

Water temperatures in the Trinity River below Lewiston Dam are generally expected to be similar under Alternative 3 compared to the No Action Alternative. Differences in monthly average temperature between Alternative 3 and the No Action Alternative would be less than 0.5°F for all months of the year (Figure O.3-113). Modeled maximum temperatures in the Trinity River in July, September, and November would be approximately 2°F to 5°F higher under Alternative 3 compared to the No Action Alternative and approximately 1°F lower in February with similar maximum temperatures in the remaining months (Figure O.3-114). Maximum temperatures under Alt 3 from August to October exceed the NCRWQCB (2018) objectives for the Trinity River and may reduce juvenile Coho Salmon rearing success compared to conditions under the No Action Alternative.

Spring-Run Chinook Salmon

Water temperatures in the Trinity River below Lewiston Dam are generally expected to be similar under Alternative 3 compared to the No Action Alternative. Differences in monthly average temperature between Alternative 3 and the No Action Alternative would be less than 0.5°F for all months of the year (Figure O.3-113). Modeled maximum temperatures in the Trinity River in July, September, and November would be approximately 2°F to 5°F higher under Alternative 3 compared to the No Action Alternative and approximately 1°F lower in February, with similar maximum temperatures in the remaining months. Spring-Run Chinook Salmon spawning usually peaks in October but typically ranges from the third week of September through November. Maximum August to October temperatures under Alternative 3 would exceed the NCRWQCB (2018) objectives for the Trinity River and may limit the success of adult migration, spawning, and juvenile rearing of Spring-Run Chinook Salmon compared to conditions under the No Action Alternative.

Fall-Run Chinook Salmon

Water temperatures in the Trinity River below Lewiston Dam are generally expected to be similar under Alternative 3 compared to the No Action Alternative. Differences in monthly average temperature between Alternative 3 and the No Action Alternative would be less than 0.5°F different for all months of the year (Figure O.3-113). Modeled maximum temperatures in the Trinity River in July, September, and November would be approximately 2°F to 5°F higher under Alternative 3 compared to the No Action Alternative and approximately 1°F lower in February with similar maximum temperatures in the remaining months (Figure O.3-114). Fall-Run Chinook Salmon spawning usually occurs between October and December with peak spawning activity occurring in November. Maximum August to October temperatures under Alternative 3 exceed the NCRWQCB (2018) objectives for the Trinity River and may limit the success of adult migration and spawning of Fall-Run Chinook Salmon compared to conditions under the No Action Alternative.

Steelhead (Winter- and Summer-Run)

Water temperatures in the Trinity River below Lewiston Dam are generally expected to be similar under Alternative 3 compared to the No Action Alternative. Differences in monthly average temperature between Alternative 3 and the No Action Alternative would be less than 0.5°F for all months of the year (Figure O.3-113). Modeled maximum temperatures in the Trinity River in July, September, and November are approximately 2°F to 5°F higher under Alternative 3 compared to the No Action

Alternative and approximately 1°F lower in February, with similar maximum temperatures in the remaining months. Maximum temperatures under Alternative 3 from August to October exceed the NCRWQCB (2018) objectives for the Trinity River and may limit the success of juvenile rearing Steelhead compared to conditions under the No Action Alternative.

Green Sturgeon

Green Sturgeon occur within the lower 43 miles of the Trinity River, approximately 70 miles downstream of Lewiston Dam. Water temperature and habitat conditions within this section of the Trinity River are heavily influenced by several large tributaries that enter the Trinity River (e.g., the North Fork Trinity River, New River, and the South Fork Trinity River). As a result, minor changes in reservoir operations are likely to be undetectable this far downstream. Results of previous water temperature modeling for the Trinity River (USFWS 1999) predicted a difference of approximately 1°F in water temperature for flows of 300 cfs and 450 cfs near RM 43 with smaller temperature differences expected downstream of RM 43 to the confluence of the Trinity and Klamath Rivers. Therefore, changes in water temperature under Alternative 2 would not affect Green Sturgeon.

White Sturgeon

White Sturgeon would not be affected by changes in reservoir operations under Alternative 2 compared to the No Action Alternative due to their limited distribution in the lower Klamath River, primarily in the estuary.

Pacific Lamprey

Model results predict that water temperatures in the Trinity River below Lewiston Dam would be similar under Alternative 3 compared to the No Action Alternative. Differences in monthly average temperature between Alternative 3 and the No Action Alternative would be less than 0.5°F for all months of the year (Figure O.3-113). Modeled maximum temperatures in the Trinity River in July, September, and November would be approximately 2°F to 5°F higher under Alternative 3 compared to the No Action Alternative and approximately 1°F lower in February, with similar maximum temperatures in the remaining months. Maximum temperatures under Alternative 3 from August to October exceed the NCRWQCB (2018) objectives for the Trinity River. Under the No Action Alternative and Alternative 3 water temperatures exceed the NCRWQCB objectives during this time. However, larger increases in temperature that would occur under Alternative 3 may further reduce Pacific Lamprey juvenile rearing success compared to the No Action Alternative.

American Shad

American Shad are primarily found in the lower Klamath River but may occur in the lower sections of the Trinity River up to approximately RM 24 at the town of Willow Creek. Water temperature and habitat conditions within this section of the Trinity River are heavily influenced by several large tributaries that enter the Trinity River (e.g., the North Fork Trinity River, New River, and the South Fork Trinity River). As a result, minor changes in reservoir operations are likely to be undetectable this far downstream. Results of previous water temperature modeling for the Trinity River (USFWS 1999) predicted a difference of approximately 1°F in water temperature for flows of 300 cfs and 450 cfs near RM 24 with smaller temperature differences expected downstream to the confluence of the Trinity and Klamath Rivers. Therefore, changes in water temperature under Alternative 3 would not affect American Shad.

O.3.7.1.2 Trinity River Record of Decision

The Trinity River ROD is being implemented under both Alternative 3 and the No Action Alternative. Therefore, implementation of the variable annual flow regime, restoration actions, and monitoring and adaptive management, per the Trinity River ROD under Alternative 3 would have similar effects as the No Action Alternative on Coho Salmon, Chinook Salmon (Spring- and Fall-Run), Steelhead (Winter- and Summer-Run), Green Sturgeon, White Sturgeon, Pacific Lamprey, and American Shad.

O.3.7.1.3 Grass Valley Creek Flows

Grass Valley Creek Flows are being implemented under both Alternative 3 and Alternative 1. Therefore, Alternative 3 and Alternative 1 are likely to have similar effects on aquatic resources.

O.3.7.2 *Sacramento River*

Potential changes to aquatic resources in the Sacramento River from seasonal operations.

Under all the Project alternatives, flows in the upper Sacramento River result from controlled releases from Shasta and Keswick reservoirs, as well as transfers from the Trinity River and natural accretions. Dry hydrologic conditions often lead to inadequate storage in Shasta Reservoir for operators to provide suitable conditions for salmonids and other native species in the upper Sacramento River. In most cases, water temperature rather than flow is the limiting factor creating unsuitable conditions, as discussed below. The primary differences between the No Action Alternative (No Action Alternative) and Alternative 3 for the Sacramento River flow and water tempearture management upstream of the Delta is that the No Action Alternative includes NMFS's 2009 BO RPAs to operate Shasta Reservoir for management of cold water in the reservoir and river to protect anadromous salmonids, and includes requirements for Fall X2 flow releases, but Alternative 3 includes neither requirement. A minimum flow of 3,250 cfs is required from Keswick Dam to the RBDD during October through March under the No Action Alternative and during October through February under Alternative 3 (NCWA 2014).

CalSim II modeling indicates that average flow released at Keswick Dam under Alternative 3 would generally be higher than or similar to flow under No Action Alternative, except in wet and above normal water years during September and November, when the Alternative 3 flows would be substantially lower than the No Action Alternative flows (Table Sac-3-1). The higher September and November flows under the No Action Alternative result from Fall X2 releases, which are not included in Alternative 3. Table O.3-43 shows that the highest mean monthly flows for both alternatives occur primarily during winter of wet and above normal water years and during summer of all water year types. Flow releases are high during summer to satisfy downstream demands of water users and Delta water quality and to meet water temperature requirements of incubating Winter-Run Chinook Salmon eggs and alevins downstream of Keswick Dam.

Table O.3-43. CalSim II Monthly Average Flow (cfs) by Water Year Type and Month below Keswick Dam for No Action Alternative, Alternative 3 and Differences between Them

Alternative[1,2,3] Water Year Type[4]	Monthly Flow (cfs)											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
No Action Alternative												
Wet (32%)[5]	7,908	9,796	7,444	17,876	19,288	16,127	8,458	8,662	8,940	13,440	10,474	14,063
Above Normal (16%)	7,054	10,124	6,406	7,629	16,401	8,534	5,221	7,925	10,359	15,316	10,494	9,972
Below Normal (13%)	5,842	4,960	7,558	3,285	7,149	3,925	3,803	7,867	10,930	14,421	10,624	5,493
Dry (24%)	5,660	5,111	8,652	3,697	3,564	3,961	3,719	7,014	10,368	12,658	8,608	4,995
Critically Dry (15%)	4,829	3,755	3,251	3,392	3,580	3,509	4,065	6,895	8,984	10,947	7,793	4,729
Alternative 3												
Wet (32%)	7,989	6,310	9,404	18,174	19,555	16,272	8,739	8,800	9,868	13,374	11,111	7,933
Above Normal (16%)	7,419	7,008	6,967	8,552	17,410	8,984	5,287	8,742	12,699	15,337	10,986	6,088
Below Normal (13%)	6,410	5,043	7,003	4,495	7,253	4,813	4,472	9,460	13,093	14,731	11,723	6,770
Dry (24%)	6,565	5,011	8,211	3,762	3,295	3,667	3,908	8,470	11,590	12,580	8,597	5,565
Critically Dry (15%)	5,076	3,815	3,252	3,548	3,440	4,141	4,350	7,469	9,807	11,080	8,079	5,019
Alternative 3 minus No Action Alternative[6]												
Wet (32%)	81	-3,486	1,960	299	267	144	281	137	928	-66	636	-6,130
Above Normal (16%)	365	-3,116	560	923	1,009	450	67	817	2,340	20	492	-3,884
Below Normal (13%)	568	82	-555	1,210	104	888	670	1,593	2,163	310	1,099	1,277
Dry (24%)	905	-100	-441	65	-269	-294	188	1,455	1,222	-78	-11	570
Critically Dry (15%)	247	60	1	156	-140	632	284	574	823	134	286	290

1 Results based on the 82-year simulation period.
2 Results displayed with calendar year - year type sorting.
3 All scenarios are simulated at ELT (Early Long-Term) Q5 with 2025 climate change and 15 cm sea level rise.
4 Water year types as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999).
5 Percent of years of each type given in parentheses.
6 Bold green font indicates greater than 5% increase in flow; bold red font indicates greater than 5% reduction in flow.

HEC-5Q modeling was used to compare water temperature effects of the No Action Alternative and Alternative 3. Based on recent investigations of Winter-Run Chinook Salmon mortality in the upper Sacramento River (Martin et al. 2017; Anderson 2018), this effects analyses uses an upper water temperature threshold of 53.5°F for suitable salmonid spawning and egg and alevin incubation in the Sacramento River. An important caution regarding the HEC-5Q water temperature modeling results, particularly with regard to meeting water temperature criteria (e.g., 56°F water temperature at Bend Bridge criterion), relates to the time step used in the modeling. HEC-5Q, like the CalSim II model on which it relies for flow data, has a monthly time step and provides estimates of monthly mean water temperatures. However, most of the regulatory requirements to meet water temperature criteria apply to daily mean (or shorter duration) water temperatures. Daily means are almost always much more variable than monthly means and, therefore, the monthly mean water temperature estimates provided by HEC-5Q are not directly comparable to the regulatory criteria. For example, even with constant flows releases, downstream daily water temperatures would fluctuate around the mean in response to variation in solar radiation and other meteorological conditions within a given month. In view of this limitation, it is helpful to consider the comparisons of temperature effects among the alternatives as indicating the relative likelihoods of exceeding temperature criteria, rather than whether or not the criteria are actually met.

These considerations apply to the CalSim II flow data as well, but are less important for flow because there are fewer regulatory criteria for flow and, except during storm events, flow tends to be less variable than water temperature.

During the summer and much of the fall, water released from Keswick Dam warms downstream resulting in warmer water temperatures in more downstream habitats. Therefore, the effects of the alternatives on fish populations depend on the habitat distributions of the populations as well as the results of temperature management operations. Winter-Run Chinook Salmon mostly spawn from Keswick Dam to about 6 miles downstream of the Clear Creek temperature gage, Spring-Run Chinook Salmon from Keswick Dam to about Balls Ferry, Fall-Run Chinook Salmon from Keswick Dam to about RBDD, Late Fall-Run Chinook Salmon spawning distribution is similar to that of Winter-Run, and Green Sturgeon spawn downstream of the Cow Creek confluence to the GCID oxbow near Hamilton City (NMFS 2018b). Steelhead spawning areas in the upper Sacramento River are poorly known.

Based on the HEC-5Q modeling, the mean monthly water temperatures at Keswick Dam are roughly equal under the No Action Alternative and Alternative 3, except for September of above normal water years, which has a 1.2°F higher mean water temperatures under Alternative 3 than under the No Action Alternative (Table O.3-44). Summer mean monthly water temperatures are consistently below the 53.5°F temperature threshold, except in critically dry water years during July through September. The October and November mean water temperatures under Alternative 3 are similar to those under the No Action Alternative and are just above the 53.5°F temperature threshold, except for critically dry water years, when those for both alternatives are well above the threshold (Table O.3-44). For October, the mean water temperature for critically dry water years is 1.0°F higher under Alternative 3 than that under the No Action Alternative. Although the difference in mean October critically dry water year water temperatures between the No Action Alternative and Alternative 3 is not large, it occurs under highly stressful temperature conditions for salmonids eggs and alevins. The largest predicted increase in mean water temperature under Alternative 3 is 1.2°F for September of above normal water years (Table O.3-44). This increase occurs over a range well below the critical temperature threshold and is therefore unlikely to have a large effect on the salmonids. The differences between the No Action Alternative and Alternative 3 in September water temperatures at Keswick Dam are small (Figure O.3-20) relative to those at more downstream locations, as described below.

Table O.3-44. HEC-5Q Monthly Average Water Temperature (°F) by Water Year Type and Month at Keswick Dam for No Action Alternative, Alternative 3 and Differences between Them

Alternative[1,2,3] Water Year Type[4]	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
	Monthly Temperature (°F)											
No Action Alternative												
Wet (32%)[5]	54.3	55.4	52.0	47.3	45.9	46.3	47.8	48.7	49.6	50.4	51.4	51.0
Above Normal (16%)	53.9	54.9	51.4	47.6	46.0	46.5	48.1	48.6	49.3	50.0	51.1	51.0
Below Normal (13%)	54.2	54.3	51.3	48.2	46.9	47.8	49.1	49.4	49.7	50.8	52.0	52.8
Dry (24%)	54.5	54.4	50.8	48.4	47.3	47.8	49.1	49.5	50.1	51.4	53.0	53.2
Critically Dry (15%)	58.9	56.3	51.5	48.2	47.1	48.1	49.5	50.7	52.3	53.9	56.2	58.4
Alternative 3												
Wet (32%)	53.8	54.5	51.5	47.3	45.9	46.4	47.8	48.7	49.5	50.5	51.4	51.8
Above Normal (16%)	53.8	54.4	51.1	47.4	45.9	46.6	48.1	48.5	49.1	50.2	51.2	52.2
Below Normal (13%)	54.5	54.9	51.7	48.1	46.8	47.8	49.1	49.2	49.7	51.0	51.8	52.8
Dry (24%)	54.5	54.8	51.0	48.4	47.3	47.9	49.1	49.1	49.9	51.5	53.0	53.1
Critically Dry (15%)	59.9	56.6	51.5	48.3	47.1	48.0	49.4	50.7	52.4	54.1	56.6	59.2
Alternative 3 minus No Action Alternative[6]												
Wet (32%)	-0.5	-0.9	-0.5	0.0	0.0	0.0	-0.1	0.0	0.0	0.1	0.0	0.7
Above Normal (16%)	-0.1	-0.5	-0.3	-0.2	-0.1	0.0	0.0	-0.1	-0.2	0.2	0.1	**1.2**
Below Normal (13%)	0.4	0.6	0.4	-0.2	-0.1	0.0	0.0	-0.2	0.0	0.2	-0.2	-0.1
Dry (24%)	0.0	0.4	0.2	0.0	0.0	0.1	0.0	-0.3	-0.2	0.1	0.0	-0.1
Critically Dry (15%)	1.0	0.3	0.0	0.1	0.1	-0.1	-0.1	-0.1	0.1	0.2	0.3	0.8

1 Results based on the 82-year simulation period.

2 Results displayed with calendar year - year type sorting.

3 All scenarios are simulated at ELT (Early Long-Term) Q5 with 2025 climate change and 15 cm sea level rise.

4 Water year types as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999).

5 Percent of years of each type given in parentheses.

6 Bold green font indicates greater than 1°F reduction in temperature, bold red font indicates greater than 1°F increase in temperature.

The HEC-5Q results indicate that late spring through early fall water temperatures in the Sacramento River at Clear Creek are slightly warmer than those at Keswick Dam, with larger increases in September water temperature differences between the No Action Alternative and Alternative 3 (Table O.3-45). Summer mean monthly water temperatures are below the 53.5°F temperature threshold, except in drier water years, especially in August and September. All mean temperatures for October and November are above the threshold for both alternatives. At Balls Ferry, the temperatures are warmer still and the September increases are larger (Table O.3-46). The mean September water temperatures for wet and above normal water years at Balls Ferry exceed the critical water temperature threshold under Alternative 2, but not under the No Action Alternative (Table O.3-46). As discussed previously, the monthly mean water temperatures provide a rough estimate of the probability of mean daily water temperatures exceeding a temperature threshold. Because the mean monthly water temperatures are higher under Alternative 3, the probability or frequency of the threshold being exceeded in September of wet and above normal water years is expected to be higher under Alternative 3 than under the No Action Alternative.

Table O.3-45. HEC-5Q Monthly Average Water Temperature (°F) by Water Year Type and Month at Clear Creek Confluence for No Action Alternative, Alternative 3 and Differences between Them

Alternative[1,2,3] Water Year Type[4]	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
No Action Alternative												
Wet (32%)[5]	54.7	55.3	51.6	47.3	46.2	47.0	49.2	50.3	51.4	51.9	52.9	51.9
Above Normal (16%)	54.4	54.7	51.0	47.7	46.4	47.4	49.9	50.3	51.0	51.3	52.6	52.1
Below Normal (13%)	54.7	54.2	51.0	48.1	47.4	49.0	51.1	51.0	51.3	52.1	53.5	54.5
Dry (24%)	55.2	54.3	50.6	48.3	47.9	49.1	51.0	51.2	51.7	52.8	54.6	55.0
Critically Dry (15%)	59.4	56.1	51.2	48.2	47.8	49.5	51.4	52.4	54.0	55.5	57.8	59.8
Alternative 3												
Wet (32%)	54.3	54.5	51.3	47.3	46.2	47.1	49.2	50.3	51.3	52.0	52.8	53.2
Above Normal (16%)	54.4	54.3	50.9	47.6	46.3	47.5	49.9	50.1	50.6	51.5	52.6	53.8
Below Normal (13%)	55.1	54.8	51.4	48.1	47.3	48.9	50.9	50.6	51.1	52.3	53.1	54.2
Dry (24%)	55.1	54.7	50.8	48.3	48.0	49.2	51.1	50.7	51.4	53.0	54.7	54.8
Critically Dry (15%)	60.3	56.5	51.3	48.3	48.0	49.3	51.4	52.3	53.9	55.7	58.1	60.5
Alternative 3 minus No Action Alternative[6]												
Wet (32%)	-0.4	-0.8	-0.3	0.0	0.0	0.1	-0.1	0.0	-0.2	0.1	-0.1	**1.3**
Above Normal (16%)	0.0	-0.5	-0.1	-0.1	-0.1	0.1	0.1	-0.2	-0.4	0.2	0.0	**1.8**
Below Normal (13%)	0.4	0.6	0.4	-0.1	-0.1	0.0	-0.1	-0.4	-0.2	0.2	-0.3	-0.3
Dry (24%)	0.0	0.4	0.2	0.1	0.1	0.2	0.0	-0.5	-0.3	0.1	0.0	-0.2
Critically Dry (15%)	0.9	0.4	0.1	0.1	0.1	-0.2	-0.1	-0.1	0.0	0.2	0.3	0.7

1 Results based on the 82-year simulation period.

2 Results displayed with calendar year - year type sorting.

3 All scenarios are simulated at ELT (Early Long-Term) Q5 with 2025 climate change and 15 cm sea level rise.

4 Water year types as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999).

5 Percent of years of each type given in parentheses.

6 Bold green font indicates greater than 1°F reduction in temperature, bold red font indicates greater than 1°F increase in temperature.

Table O.3-46. HEC-5Q Monthly Average Water Temperature (°F) by Water Year Type and Month at Balls Ferry for No Action Alternative, Alternative 3 and Differences between Them

Alternative[1,2,3] / Water Year Type[4]	Monthly Temperature (°F)											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
No Action Alternative												
Wet (32%)[5]	55.1	54.9	50.7	46.9	46.4	47.7	50.8	52.5	53.6	53.3	54.2	52.6
Above Normal (16%)	54.9	54.4	50.2	47.0	46.6	48.2	51.6	52.3	52.7	52.4	53.8	53.0
Below Normal (13%)	55.3	53.8	50.2	47.4	47.6	49.8	52.9	52.6	52.8	53.3	54.6	55.8
Dry (24%)	55.7	53.8	49.8	47.7	47.9	49.8	52.8	53.0	53.2	54.1	55.9	56.4
Critically Dry (15%)	59.7	55.7	50.1	47.9	48.2	50.4	53.0	54.0	55.4	56.7	59.1	60.8
Alternative 3												
Wet (32%)	54.7	54.1	50.6	46.9	46.4	47.7	50.7	52.5	53.4	53.4	54.1	54.4
Above Normal (16%)	54.9	53.8	50.1	47.0	46.5	48.3	51.7	52.0	52.1	52.6	53.8	55.2
Below Normal (13%)	55.6	54.4	50.5	47.4	47.5	49.7	52.6	52.0	52.5	53.4	54.2	55.3
Dry (24%)	55.6	54.1	50.0	47.8	48.0	50.0	52.8	52.4	52.8	54.2	56.0	56.1
Critically Dry (15%)	60.6	56.1	50.1	48.0	48.3	50.2	52.9	53.8	55.3	56.9	59.3	61.5
Alternative 3 minus No Action Alternative[6]												
Wet (32%)	-0.4	-0.8	-0.1	0.0	0.0	0.1	-0.1	0.0	-0.2	0.1	-0.2	**1.8**
Above Normal (16%)	0.0	-0.6	-0.1	0.0	-0.1	0.1	0.1	-0.3	-0.6	0.2	0.0	**2.2**
Below Normal (13%)	0.4	0.5	0.3	0.0	-0.1	-0.1	-0.2	-0.6	-0.3	0.2	-0.4	-0.5
Dry (24%)	-0.1	0.3	0.2	0.0	0.1	0.2	0.0	-0.7	-0.4	0.1	0.0	-0.3
Critically Dry (15%)	0.8	0.3	0.1	0.1	0.1	-0.2	-0.1	-0.2	-0.1	0.2	0.2	0.7

1 Results based on the 82-year simulation period.

2 Results displayed with calendar year - year type sorting.

3 All scenarios are simulated at ELT (Early Long-Term) Q5 with 2025 climate change and 15 cm sea level rise.

4 Water year types as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999).

5 Percent of years of each type given in parentheses.

6 Bold green font indicates greater than 1°F reduction in temperature, bold red font indicates greater than 1°F increase in temperature.

The downstream trends in water temperature conditions noted for Keswick Dam, Clear Creek and Balls Ferry continue to RBDD, with little difference in water temperatures between the alternatives, except for substantially warmer temperatures in September of wet and above normal water years under Alternative 3 (Table O.3-47). The growing downstream differences in wet and above normal water year temperatures for September can be seen in Figures O., 3-20, O.3-31 and O.3-22. The temperature differences are largely limited to the cooler 50% of years. Under both the No Action Alternative and Alternative 3, the mean water temperatures at RBDD for April through October are above the 53.5°F critical water temperature threshold in all water year types. The pattern of increasing water temperatures differences in September of wet and above normal water years between the No Action Alternative and Alternative 3 continues downstream to Hamilton City and Knights Landing, (Tables O.3-48 and O.3-49; Figures O.3-23 and O.3-24). However, at these locations there are also water temperature reductions of 1°F to 2°F between the No Action Alternative and Alternative 3 during May, June, and September of above normal, below normal or dry water years, depending on the month (Table O.3-48 and O.3-49; Figure O.3-23 and O.3-24). These reductions result from increases in flow under Alternative 3 relative to the No Action Alternative (Tables O.3-51 and O.3-52).

The reduced downstream warming of the river in September of wet and above normal under the No Action Alternative relative to the Alternative 3 is due, at least in part, to the much higher flow releases for Fall X2, as noted above (Table O.3-43). Note that November Fall X2 flow releases under the No Action Alternative do not result in higher water temperatures under Alternative 3 (e.g., Table O.3-49), presumably because November air temperatures would, on average, be similar to or lower than the water temperatures.

Table O.3-47. HEC-5Q Monthly Average Water Temperature (°F) by Water Year Type and Month at Red Bluff Diversion Dam for No Action Alternative, Alternative 2 and Differences between Them

Alternative[1,2,3]	Monthly Temperature (°F)											
Water Year Type[4]	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
No Action Alternative												
Wet (32%)[5]	56.2	54.3	49.3	46.5	47.0	49.3	53.7	56.7	59.1	58.1	58.9	55.4
Above Normal (16%)	56.2	53.7	48.8	46.6	47.1	50.0	54.9	56.9	57.8	56.5	58.3	56.3
Below Normal (13%)	56.6	53.3	48.9	46.7	48.0	51.7	56.4	56.7	57.4	57.4	58.8	60.1
Dry (24%)	57.1	53.0	48.5	46.9	48.3	51.5	56.1	57.5	57.9	58.5	60.6	60.9
Critically Dry (15%)	60.6	54.7	48.6	47.3	49.0	52.4	56.6	58.0	60.0	61.2	63.3	64.3
Alternative 1												
Wet (32%)	55.3	53.6	49.4	46.6	47.0	49.4	53.7	56.5	59.0	58.2	58.7	58.0
Above Normal (16%)	55.3	52.7	48.8	46.8	47.1	50.0	55.0	56.6	57.7	56.6	58.5	59.9
Below Normal (13%)	56.4	53.6	49.2	46.9	48.0	51.5	56.1	56.0	56.9	57.3	58.4	59.5
Dry (24%)	56.3	53.2	48.9	47.0	48.3	51.5	56.2	56.9	57.3	58.4	59.8	60.6
Critically Dry (15%)	60.7	54.9	48.7	47.5	49.2	52.4	56.7	57.7	59.2	61.0	63.0	64.8
Alternative 1 minus No Action Alternative[6]												
Wet (32%)	-0.9	-0.7	0.1	0.1	0.0	0.0	0.0	-0.2	0.0	0.1	-0.2	**2.6**
Above Normal (16%)	-0.9	-1.0	-0.1	0.1	0.0	0.0	0.0	-0.3	-0.1	0.1	0.2	**3.6**
Below Normal (13%)	-0.3	0.3	0.3	0.2	0.0	-0.2	-0.3	-0.7	-0.5	-0.1	-0.4	-0.6
Dry (24%)	-0.9	0.2	0.3	0.1	0.0	0.0	0.0	-0.5	-0.6	-0.1	-0.8	-0.4
Critically Dry (15%)	0.1	0.2	0.1	0.2	0.2	0.0	0.1	-0.3	-0.7	-0.2	-0.3	0.5

1 Results based on the 82-year simulation period.

2 Results displayed with calendar year - year type sorting.

3 All scenarios are simulated at ELT (Early Long-Term) Q5 with 2025 climate change and 15 cm sea level rise.

4 Water year types as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999).

5 Percent of years of each type given in parentheses.

6 Bold green font indicates greater than 1°F reduction in temperature, bold red font indicates greater than 1°F increase in temperature.

Table O.3-48. HEC-5Q Monthly Average Water Temperatures (degree Fahrenheit) by Water Year Type and Month below Hamilton City for No Action Alternative, Alternative 3 and Differences between Them

Alternative[1,2,3] Water Year Type[4]	Monthly Temperature (°F) Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
No Action Alternative												
Wet (32%)[5]	57.8	54.3	48.9	46.5	47.4	50.4	55.4	60.2	64.1	63.0	63.7	58.2
Above Normal (16%)	58.0	53.6	48.6	46.7	47.6	51.1	56.8	61.0	62.8	61.0	62.9	59.6
Below Normal (13%)	58.5	53.5	48.5	46.7	48.6	53.1	58.9	60.7	62.0	61.8	63.2	64.2
Dry (24%)	59.1	53.3	48.3	46.9	49.0	52.8	58.5	61.5	62.7	63.1	65.3	65.1
Critically Dry (15%)	62.2	54.8	48.3	47.4	50.0	54.2	59.6	62.1	64.5	65.9	67.9	67.9
Alternative 3												
Wet (32%)	57.8	53.7	48.9	46.5	47.4	50.4	55.3	60.2	63.5	63.1	63.2	62.3
Above Normal (16%)	58.0	53.0	48.5	46.7	47.6	51.1	56.8	60.4	61.3	61.1	62.6	63.5
Below Normal (13%)	58.5	53.9	48.5	46.8	48.6	52.9	58.4	59.7	60.8	61.8	62.4	62.9
Dry (24%)	58.8	53.4	48.4	47.0	49.0	53.0	58.4	60.4	61.8	63.2	65.5	64.5
Critically Dry (15%)	62.6	55.0	48.3	47.4	50.1	54.0	59.4	61.7	64.0	65.9	67.8	68.0
Alternative 3 minus No Action Alternative[6]												
Wet (32%)	-0.1	-0.6	0.0	0.0	0.0	0.0	-0.1	0.0	-0.6	0.1	-0.5	**4.1**
Above Normal (16%)	0.0	-0.6	-0.1	0.0	0.0	0.0	0.0	-0.6	**-1.5**	0.1	-0.3	**4.0**
Below Normal (13%)	0.0	0.4	0.1	0.1	0.0	-0.2	-0.5	**-1.1**	**-1.2**	0.0	-0.8	**-1.2**
Dry (24%)	-0.3	0.2	0.1	0.0	0.0	0.2	0.0	**-1.1**	-0.9	0.1	0.1	-0.6
Critically Dry (15%)	0.4	0.2	0.0	0.1	0.1	-0.3	-0.2	-0.4	-0.5	0.0	0.0	0.1

1 Results based on the 82-year simulation period.

2 Results displayed with calendar year - year type sorting.

3 All scenarios are simulated at ELT (Early Long-Term) Q5 with 2025 climate change and 15 cm sea level rise.

4 Water year types as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999).

5 Percent of years of each type given in parentheses.

6 Bold green font indicates greater than 1°F reduction in temperature, bold red font indicates greater than 1°F increase in temperature.

Table O.3-49. HEC-5Q Monthly Average Water Temperature (°F) by Water Year Type and Month at Knights Landing for No Action Alternative, Alternative 3 and Differences between Them

Alternative[1,2,3] Water Year Type[5]	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
	Monthly Temperature (°F)											
No Action Alternative												
Wet (32%)[5]	61.0	55.1	48.8	46.5	48.0	51.9	57.4	65.0	70.9	71.8	72.4	63.9
Above Normal (16%)	61.6	54.3	48.5	47.0	48.3	52.5	59.1	66.6	70.8	69.7	71.6	65.8
Below Normal (13%)	62.7	55.1	48.4	46.9	49.2	55.1	62.0	67.1	69.9	70.5	71.4	70.5
Dry (24%)	63.2	54.9	48.4	46.9	49.7	54.5	61.1	68.0	71.3	71.9	73.6	71.7
Critically Dry (15%)	65.9	56.9	48.5	47.5	51.1	56.5	63.2	68.6	72.4	74.3	75.5	73.3
Alternative 3												
Wet (32%)	61.5	55.1	48.8	46.5	48.0	51.9	57.3	64.9	70.2	71.9	71.8	68.7
Above Normal (16%)	61.9	54.4	48.4	47.0	48.3	52.5	59.1	66.0	69.0	69.6	71.2	69.6
Below Normal (13%)	62.3	55.3	48.5	46.9	49.2	54.8	61.6	66.0	68.3	70.4	70.5	69.1
Dry (24%)	62.7	55.0	48.5	46.9	49.8	54.7	61.1	66.9	70.1	72.0	73.8	71.2
Critically Dry (15%)	66.0	57.0	48.5	47.5	51.1	56.3	63.0	68.1	71.6	74.2	75.3	73.1
Alternative 3 minus No Action Alternative[6]												
Wet (32%)	0.5	-0.1	0.0	0.0	0.0	0.0	-0.1	0.0	-0.7	0.1	-0.6	**4.7**
Above Normal (16%)	0.3	0.1	-0.2	0.0	0.0	0.0	0.0	-0.6	**-1.8**	-0.1	-0.3	**3.9**
Below Normal (13%)	-0.4	0.2	0.1	0.1	0.0	-0.3	-0.4	**-1.1**	**-1.7**	-0.1	-0.9	**-1.4**
Dry (24%)	-0.5	0.1	0.1	0.0	0.0	0.1	0.0	**-1.2**	**-1.2**	0.0	0.1	-0.5
Critically Dry (15%)	0.1	0.1	0.0	0.0	0.1	-0.2	-0.2	-0.5	-0.7	-0.1	-0.2	-0.2

1 Results based on the 82-year simulation period.

2 Results displayed with calendar year - year type sorting.

3 All scenarios are simulated at ELT (Early Long-Term) Q5 with 2025 climate change and 15 cm sea level rise.

4 Water year types as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999).

5 Percent of years of each type given in parentheses.

6 Bold green font indicates greater than 1°F reduction in temperature, bold red font indicates greater than 1°F increase in temperature.

Table O.3-50. CalSim II Monthly Average Flow (cfs) by Water Year Type and Month at Red Bluff Diversion Dam for No Action Alternative, Alternative 3 and Differences between Them

Alternative[1,2,3]	Monthly Flow (cfs)											
Water Year Type[4]	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
No Action Alternative												
Wet (32%)[5]	8,728	12,255	12,422	29,982	31,345	25,200	14,018	11,059	9,426	12,709	9,781	14,320
Above Normal (16%)	7,927	12,554	11,235	16,772	26,458	16,158	9,459	9,611	10,203	14,275	9,759	10,210
Below Normal (13%)	6,820	6,705	11,915	7,608	12,849	7,303	6,118	8,845	10,980	13,721	10,131	5,837
Dry (24%)	6,538	7,784	15,279	7,303	9,573	9,042	6,326	8,214	10,498	12,221	8,358	5,349
Critically Dry (15%)	5,338	5,218	6,394	6,318	6,527	5,955	5,159	7,866	9,252	10,848	7,654	4,954
Alternative 3												
Wet (32%)	8,695	8,660	14,302	30,175	31,510	25,240	14,177	11,073	10,170	12,566	10,355	8,075
Above Normal (16%)	8,167	9,328	11,718	17,597	27,358	16,499	9,408	10,283	12,299	14,151	10,141	6,193
Below Normal (13%)	7,216	6,689	11,268	8,713	12,847	8,077	6,650	10,110	12,767	13,721	10,986	6,963
Dry (24%)	7,299	7,592	14,755	7,270	9,206	8,652	6,392	9,517	11,512	12,032	8,258	5,804
Critically Dry (15%)	5,526	5,231	6,323	6,399	6,313	6,513	5,355	8,351	9,999	10,927	7,893	5,187
Alternative 3 minus No Action Alternative[6]												
Wet (32%)	-33	**-3,595**	**1,880**	193	165	40	158	14	**744**	-144	**574**	**-6,245**
Above Normal (16%)	240	**-3,226**	484	825	900	341	-51	**672**	**2,096**	-124	382	**-4,016**
Below Normal (13%)	**395**	-15	**-647**	**1,105**	-1	**773**	**532**	**1,265**	**1,787**	0	**855**	**1,126**
Dry (24%)	**761**	-192	-524	-33	-366	-390	65	**1,304**	**1,014**	-189	-100	**456**
Critically Dry (15%)	187	13	-71	81	-214	**558**	195	**485**	**747**	79	240	232

1 Results based on the 82-year simulation period.

2 Results displayed with calendar year - year type sorting.

3 All scenarios are simulated at ELT (Early Long-Term) Q5 with 2025 climate change and 15 cm sea level rise.

4 Water year types as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999).

5 Percent of years of each type given in parentheses.

6 Bold green font indicates greater than 5% increase in flow; bold red font indicates greater than 5% reduction in flow.

Table O.3-51. CalSim II Monthly Average Flow (cfs) by Water Year Type and Month at Hamilton City for No Action Alternative, Alternative 3 and Differences between Them

Alternative[1,2,3] / Water Year Type[4]	Monthly Flow (cfs) Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
No Action Alternative												
Wet (32%)[5]	8,219	12,548	13,755	33,783	35,092	28,342	16,376	11,144	8,207	10,450	7,770	13,867
Above Normal (16%)	7,425	12,867	12,385	19,430	29,641	18,802	11,052	8,831	8,368	11,840	7,780	9,701
Below Normal (13%)	6,440	6,788	13,003	8,908	14,535	8,530	7,083	7,429	8,757	11,240	8,168	5,345
Dry (24%)	5,989	8,176	17,167	8,112	11,042	10,647	7,244	6,779	8,089	9,728	6,468	4,801
Critically Dry (15%)	4,854	5,153	7,089	6,934	7,312	6,875	5,290	6,238	7,000	8,573	5,874	4,436
Alternative 3												
Wet (32%)	8,186	8,953	15,635	33,976	35,257	28,382	16,534	11,157	8,948	10,317	8,338	7,622
Above Normal (16%)	7,665	9,647	12,872	20,256	30,541	19,143	11,001	9,500	10,446	11,723	8,147	5,685
Below Normal (13%)	6,835	6,772	12,357	10,013	14,534	9,303	7,615	8,679	10,536	11,204	9,042	6,474
Dry (24%)	6,750	7,984	16,643	8,080	10,676	10,257	7,309	8,065	9,104	9,535	6,376	5,260
Critically Dry (15%)	5,042	5,166	7,018	7,015	7,097	7,433	5,485	6,711	7,742	8,652	6,114	4,698
Alternative 3 minus No Action Alternative[6]												
Wet (32%)	-33	**-3,595**	**1,881**	193	165	40	158	13	**741**	-133	**568**	**-6,245**
Above Normal (16%)	240	**-3,220**	487	825	900	341	-51	**669**	**2,078**	-117	367	**-4,016**
Below Normal (13%)	**395**	-15	-647	**1,105**	-1	**773**	**532**	**1,250**	**1,780**	-37	**874**	**1,129**
Dry (24%)	**761**	-192	-524	-33	-366	-390	65	**1,286**	**1,016**	-192	-93	**459**
Critically Dry (15%)	188	13	-71	81	-214	**558**	195	**473**	**742**	79	240	**262**

1 Results based on the 82-year simulation period.

2 Results displayed with calendar year - year type sorting.

3 All scenarios are simulated at ELT (Early Long-Term) Q5 with 2025 climate change and 15 cm sea level rise.

4 Water year types as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999).

5 Percent of years of each type given in parentheses.

6 Bold green font indicates greater than 5% increase in flow; bold red font indicates greater than 5% reduction in flow.

Table O.3-52. CalSim II Monthly Average Flow (cfs) by Water Year Type and Month at Wilkins Slough for No Action Alternative, Alternative 3 and Differences between Them

Alternative[1,2,3] / Water Year Type[4]	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
No Action Alternative												
Wet (32%)[5]	7,511	12,176	11,622	18,870	19,567	17,810	14,598	9,612	6,426	7,574	5,293	13,916
Above Normal (16%)	6,711	11,184	11,185	16,976	18,484	17,432	12,412	7,174	6,171	8,650	5,448	9,654
Below Normal (13%)	6,046	6,466	11,361	10,381	13,627	9,842	7,454	5,489	5,958	7,948	5,637	5,132
Dry (24%)	5,215	8,027	12,724	9,098	12,422	12,174	8,077	4,381	5,159	6,678	4,291	4,665
Critically Dry (15%)	4,072	4,733	7,847	8,021	8,590	8,066	5,306	3,683	4,176	5,648	3,817	4,154
Alternative 3												
Wet (32%)	7,728	8,481	12,451	18,865	19,581	17,783	14,758	9,616	7,172	7,412	5,883	7,648
Above Normal (16%)	7,129	7,637	11,394	17,419	19,027	17,396	12,379	7,851	8,217	8,460	5,866	5,639
Below Normal (13%)	6,417	6,436	11,016	11,068	13,824	10,527	7,977	6,718	7,695	7,867	6,563	6,243
Dry (24%)	5,958	7,982	12,741	9,034	12,260	11,964	8,156	5,659	6,106	6,465	4,241	5,144
Critically Dry (15%)	4,258	4,753	7,795	8,089	8,374	8,642	5,473	4,159	4,904	5,707	4,079	4,440
Alternative 3 minus No Action Alternative[6]												
Wet (32%)	217	**-3,695**	**828**	-4	14	-27	159	4	**745**	-162	**590**	**-6,268**
Above Normal (16%)	**417**	**-3,547**	210	443	543	-36	-33	**677**	**2,047**	-190	**418**	**-4,014**
Below Normal (13%)	**372**	-30	-345	**687**	197	**685**	**523**	**1,229**	**1,737**	-81	**926**	**1,111**
Dry (24%)	**743**	-46	17	-65	-161	-210	79	**1,278**	**947**	-213	-50	**480**
Critically Dry (15%)	186	20	-52	68	-216	**576**	167	**476**	**729**	60	**262**	**285**

1 Results based on the 82-year simulation period.

2 Results displayed with calendar year - year type sorting.

3 All scenarios are simulated at ELT (Early Long-Term) Q5 with 2025 climate change and 15 cm sea level rise.

4 Water year types as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999).

5 Percent of years of each type given in parentheses.

6 Bold green font indicates greater than 5% increase in flow; bold red font indicates greater than 5% reduction in flow.

It is expected that, in general, water temperatures between the No Action Alternative and Alternative 3 would be largely similar, with the exception of September of wet and above normal water years, when water temperatures are warmer under the Alternative 3 because this alternative would not include the Fall X2 flows that reduce downstream warming under the No Action Alternative, and with the exception of May, June, and September of various water year types at the most downstream locations, when water temperatures are cooler under Alternative 3 because of higher flows.

O.3.7.2.1 Sacramento River Winter-Run Chinook Salmon

Spawning and Egg/Alevin Incubation

Winter-Run Chinook Salmon adults spawn from May through August with peak spawning during June and July (Section O.2.4.2.1, *Winter-Run Chinook Salmon*). Fry emergence occurs up to 3 months after eggs are spawned, so effects of flow and water temperature on Winter-Run eggs and alevins may occur from May through November, but primarily occur during June through October.

As previously noted, CalSim II modeling indicates that mean monthly flow released at Keswick Dam under Alternative 3 would generally be higher than or similar to flow under No Action Alternative, except in wet and above normal water years during September and November, when the Alternative 3 flows would be substantially lower than the No Action Alternative flows (Table O.3-43). By September in most years, a large proportion of Winter-Run Chinook Salmon redds still contain incubating alevins. Assuming flows are stable enough to avoid dewatering the redds, which is generally true in September, the most important effect of flows on alevins is to transport dissolved oxygen to the developing alevins and to flush potentially toxic metabolites out of the redds. Although the mean September wet and above normal water year flows are substantially lower under Alternative 3 than under the No Action Alternative, the flows under Alternative 3 flows remain moderately high (>6,000 cfs) (Figure O.3-25). Flows at this level are expected to provide sufficient flow velocity to keep the redds clean and well oxygenated. With regard to redd dewatering, there are some reductions in mean monthly flows below Keswick Dam during the fall under Alternative 3, but these are similar to the fall reductions expected under the No Action Alternative (Table O.3-43). Therefore, differences in flow between the No Action Alternative and Alternative 3 are expected to have little effect on Winter-Run Chinook Salmon spawning and incubation habitat.

As noted in the previous section, there are few differences between the No Action Alternative and Alternative 3 in the HEC-5Q water temperature results for the Winter-Run Chinook Salmon spawning period (Table O.3-44). The largest difference for the Keswick Dam location, a 1.2°F increase in September of above normal water years under Alternative 3, would occur within a range of temperature well below the 53.5°F water temperature threshold, and therefore would not affect Winter-Run eggs or alevins. The mean October water temperatures at Keswick are predicted to be above the water temperature threshold in about 85% of years under both the No Action Alternative and Alternative 3 (Figure O.3-18). September mean monthly water temperatures exceed the threshold in critically dry water years under both alternatives (Table O.3-44). At the more downstream Winter-Run Chinook Salmon spawning locations, the September water temperatures exceed the threshold for more of the water year types (Tables O.3-45 and O.3-46). At these locations, water temperature increases between the No Action Alternative and Alternative 3 for September of wet and above normal water years result in water temperatures approaching or exceeding the 53.5°F temperature threshold under Alternative 3, but not under the No Action Alternative, which would result in adverse effects on Winter-Run Chinook Salmon eggs and alevins under Alternative 3.

Recent investigations of Winter-Run Chinook Salmon mortality in the upper Sacramento River (Martin et al. 2017; Anderson 2018) yielded models for estimating mortality of Winter-Run Chinook Salmon eggs and alevins under different water temperature conditions. These models, referred to hereinafter as the Martin and Anderson models, were used to compare water-temperature-related mortality of Winter-Run Chinook Salmon eggs and alevins under Alternative 3 and the No Action Alternative. The modeling was based on the HEC-5Q water temperature estimates for the years used in the HEC-5Q modeling (1922 to 2002). The results for all water year types combined show no consistent differences in egg/alevin mortality between Alternative 3 and the No Action Alternative (Figure O.3-115). Figure O.3-115 combines results for all water year types, including wet years, when there is little temperature-related mortality. This obscures the modeling results for drier years, when egg/alevin mortalities are especially high. For critically dry water years, the mortality modeling shows similar mortality between Alternative 3 and the No Action Alternative or slightly higher mortality under Alternative 3 (Figure O.3-116).

The flow effects resulting from Alternative 3 would have a less-than-significant effect relative to the No Action Alternative on Winter-Run Chinook Salmon spawning and the egg and alevin life stages, but the water temperature effects would have a significant adverse impact relative to the No Action Alternative because of the temperature increases in September of wet and above normal water years.

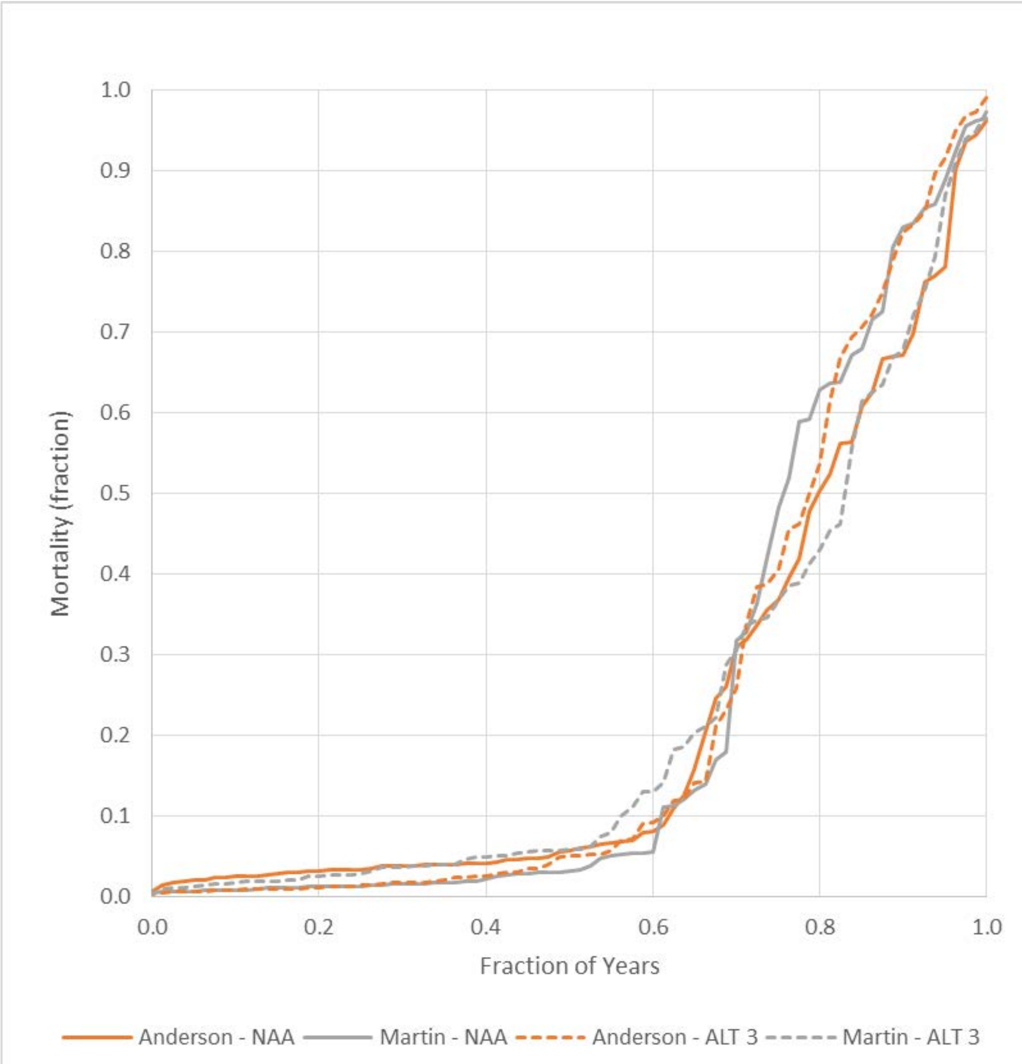


Figure O.3-115. Exceedances of Winter-Run Chinook Salmon Temperature-Dependent Egg Mortality, Alternative 3 vs. No Action Alternative; All Water Year Types.

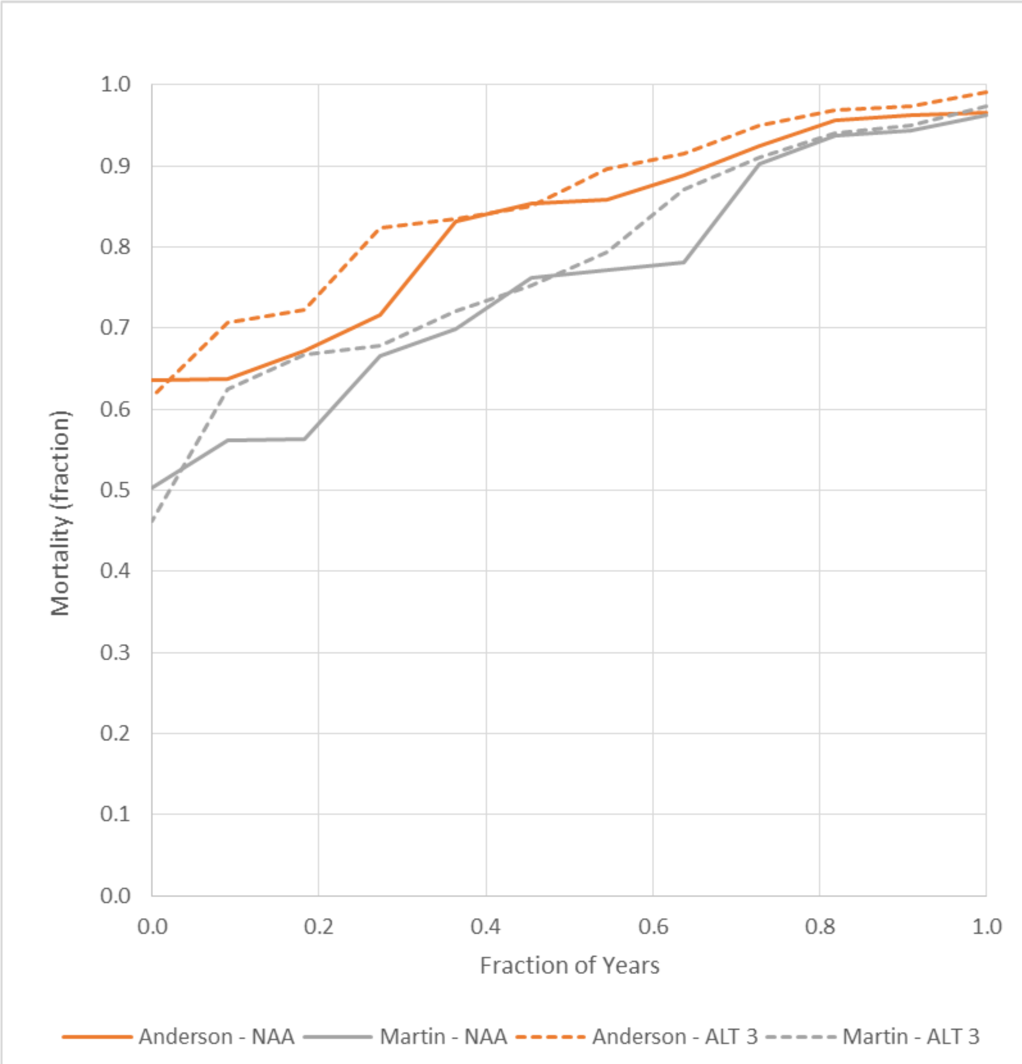


Figure O.3-116. Exceedances of Winter-Run Chinook Salmon Temperature-Dependent Egg Mortality, Alternative 3 vs. No Action Alternative; Critically Dry Water Years

Juvenile Rearing and Emigration

Winter-Run Chinook Salmon juveniles rear in the Sacramento River primarily from late summer to late winter, and emigrate from the river to the Delta beginning in November (see Section O.2.4.2.1, *Winter-Run Chinook Salmon*). The proportion of juveniles surviving to emigrate to the Delta depends largely on habitat conditions, including flow and water temperature. Inundated floodplain habitat has been shown to benefit growth and survival of juvenile salmon (Sommer et al. 2001, 2005; Katz et al. 2017), but natural flood flows largely determine the availability of this habitat, rather than operations of the CVP and SWP dams.

Sacramento River flow during the Winter-Run juvenile rearing and emigration period differs substantially between the No Action Alternative and Alternative 3, especially during September and November of wet and above normal water years (Tables O.3-43, O.3-50 through O.3-52). The juveniles rear primarily in the upper and middle Sacramento River until about October, when they begin to appear in the lower river (e.g., Knights Landing) (del Rosario et al. 2013). As noted previously, because the No Action Alternative includes Fall X2 releases but not Alternative 3 does not, the mean monthly flows during September and November are much lower under Alternative 3 than under the No Action Alternative, which would potentially reduce suitable rearing habitat for juveniles (Tables O.3-43 and O.3-50 through O.3-52; Figures O.3-25, O.3-28 and O.3-29).

Emigration of juvenile Winter-Run Chinook Salmon from the Sacramento River is triggered by pulse flows of about 14,000 cfs and above (at Wilkins Slough) (del Rosario et al. 2013). CalSim II September flows at Wilkins Slough exceed this threshold in about 18% of years under the No Action Alternative and never exceed it under Alternative 3, but September is too early for juvenile Winter-Run Chinook Salmon to emigrate to the Delta (del Rosario et al. 2013). For November, when Winter-Run juveniles are ready to emigrate, monthly mean flow at Wilkins Slough is much higher under the No Action Alternative than under Alternative 3, but remains below the 14,000 cfs threshold for both alternatives, except for the highest 9% of flows (Figure O.3-29). There are no differences between the alternatives at these highest flows. An important limitation with this analysis is that the CalSim II flow estimates are monthly averages and Winter-Run Chinook Salmon emigration can be triggered by flow pulses that exceed 14,000 cfs for only a few days (del Rosario et al. 2013), so the flow differences in Figure O.3-29 incompletely represent the likelihood of triggering pulse flows occurring under the two alternatives.

Results from a more recent analysis suggest that the reduction in November flows from the No Action Alternative to Alternative 3 during wet and above normal water years could adversely affect Winter-Run Chinook Salmon juveniles emigrating at that time. The NMFS Southwest Fisheries Science Center ran statistical models using 2012-2017 tagging data from Spring-Run Chinook Salmon and Fall-Run Chinook Salmon and found a significant increase in smolt survival when Sacramento River flow at Wilkins Slough was above 9,100 cfs during the smolts out-migration period (Cordoleani et al. 2019). The CalSim II results for November at Wilkins Slough indicate that, under the No Action Alternative, 50% of years would have mean monthly flows that exceed the 9,100 cfs threshold, but that under Alternative 3 only 20% of years would exceed the threshold (Figure O.3-29). If these results apply to Winter-Run juveniles emigrating in November, they indicate a potential adverse effect of Alternative 3 on emigrating Winter-Run juveniles. The applicability of the results to Winter-Run Chinook Salmon are currently unknown, so the effect on Winter-Run is uncertain.

The USEPA (2003) gives 61°F as the critical 7 day average daily maximum (7DADM) water temperature for Winter-Run Chinook Salmon juveniles rearing in the upper Sacramento River and 64°F (7DADM) for those rearing in the middle Sacramento River (Knights Landing). Under the No Action Alternative, NMFS's RPA 1.2.4 requires Reclamation to maintain water temperature from May 15 through October 31 in the Sacramento River at no more than 56°F at compliance locations between Ball's Ferry and Red Bluff Diversion Dam. Under Alternative 3, SWRCB's WRO 90-5 has similar but more flexible water temperature requirements for Reclamation. Therefore, under both alternatives, juveniles rearing in the upper Sacramento River are likely to be well protected from water temperature extremes through the end of October in all but the driest years.

Under the No Action Alternative and Alternative 3, mean monthly water temperatures at Keswick exceed the 61°F threshold in only about 5% of years in September and October, with no appreciable water temperatures differences between the alternatives for water temperatures greater than the 61°F threshold (Figures O.3-18 and O.3-20). The monthly average temperatures for these months should reasonably estimate daily mean temperatures because operations at Shasta and Keswick dams create relatively stable summer and fall flow and water temperature conditions in the upper Sacramento River. From November through March, by which months most juvenile Winter-Run Chinook Salmon have emigrated to the Delta, there are only minor differencs in mean water temperatures at all locations from Keswick Dam to Knights Landing (Tables O.3-26 through O.3-31).

The water temperature effects on juvenile Winter-Run Chinook Salmon rearing in or emigrating from the Sacramento River resulting from Alternative 3 would be less-than-significant relative to the No Action Alternative, but the flow effects are potentially significant because the reductions in September flows in wet and above normal water years could reduce rearing habitat and the reductions November flows in wet and above normal water years could reduce smolt survival.

Adult Upstream Migration and Holding

Winter-Run Chinook Salmon adults enter the Sacramento River from the Delta and make their way to the upper Sacramento River, beginning as early as December. They hold in the upper River within 10 to 15 miles of Keswick Dam until they are ready to spawn, which may extend through August (Windell et al. 2017).

There are no flow or temperature requirements for the middle Sacramento River designed to protect fish. However, releases from Shasta Reservoir during November through early May may be reduced to conserve water for the May through October Winter-Run and Spring-Run Chinook Salmon spawning and incubation periods, resulting in reduced flow in the middle river (NMFS 2011: RPA I.2.2; SWRCB 1990: WRO 90-5). Lower flow in the Sacramento River relative to flow from the lower Yolo and Sutter bypasses and agricultural drains may affect navigation cues and straying of Winter-Run adults into canals and behind weirs, increasing their stranding risk. Once the adults reach holding habitat in the upper Sacramento River, they are more directly affected by Shasta and Keswick reservoir operations designed to preserve cold water for the Winter-Run and Spring-Run Chinook Salmon spawning and incubation periods. During the December through August period of adult Winter-Run Chinook Salmon immigration and holding, the mean monthly flows under Alternative 3 at Keswick Dam, RBDD, Hamilton City and Wilkins Slough would generally be similar to or greater than flows under the No Action Alternative, except during December of below normal and dry water years at Keswick and December of below normal water years at RBDD (Tables O.3-43, O.3-50). The mean monthly CalSim II flows in December of below normal water years are greater than 6,500 cfs at all four sites for both alternatives, which is much higher than needed enough to allow upstream passage.

The USEPA (2003) gives 68°F as the critical 7DADM water temperature for Winter-Run Chinook Salmon adults migrating upstream in the Sacramento River and 61°F for adult Winter-Run Chinook Salmon holding in the upper river. There are no major differences in HEC-5Q water temperature estimates between the No Action Alternative and Alternative 3 during any of the months that adult Winter-Run Chinook Salmon migrate upstream in the Sacramento River or hold in the upper river (Tables O.3-44 through O.3-49). However, the monthly mean water temperatures are moderately cooler under Alternative 3 at Hamilton City and Knights Landing sites during May and June in some of the water year types (Tables O.3-48 and O.3-49). Under both alternatives, the mean monthly water temperatures in the middle Sacramento River (Knights Landing) would be below the 68°F threshold for immigrating adults from December through April, but would exceed the threshold in May of critically dry water years and June through August of all water year types (Table O.3-49). Most Winter-Run Chinook Salmon adults have migrated upstream of RBDD by late May (see Section O.2.4.2.1, *Winter-Run Chinook Salmon*) and would therefore not be adversely affected by the elevated downstream summer water temperatures. In the upper Sacramento River from Keswick to Balls Ferry, the mean water temperatures would be well below the 61°F threshold for holding adults from December through August under both alternatives (Table O.3-44, O.3-45, and O.3-46).

Alternative 3 is expected to have a less-than-signficant effect on Winter-Run Chinook Salmon adult upstream migration and holding relative to the No Action Alternative.

O.3.7.2.2 Central Valley Spring-Run Chinook Salmon

Spawning and Egg/Alevin Incubation

Spring-Run Chinook Salmon adults spawn from August through October with peak spawning in September (see Section O.2.4.2.2, *Spring-Run Chinook Salmon*). Monitoring Spring-Run spawning in the mainstem Sacramento River is complicated due to lack of spatial/geographic segregation and temporal isolation from Fall-Run Chinook Salmon. Most spring-sun spawning occurs between the Keswick Dam and Ball Ferry Bridge (NMFS 2017b). Fry emergence occurs up to 3 months after eggs are spawned (Moyle 2002), so effects of flow in the upper Sacramento River on incubating Spring-Run eggs and alevins potentially occur from August through January, peaking in December.

As previously noted, CalSim II modeling indicates that mean monthly flow released at Keswick Dam under Alternative 3 would generally be higher than or similar to flow under No Action Alternative, except in wet and above normal water years during September and November, when the Alternative 3 flows would be substantially lower (up to 44% lower) than the No Action Alternative flows (Table O.3-43). The higher September and November flows under the No Action Alternative result from Fall X2 releases, which are not included in Alternative 3. Spawning and incubating eggs and alevins could be negatively or positively affected by the flow reductions. Assuming flows are stable enough to avoid dewatering the redds, which as noted previously is an important criterion for operators of Shasta and Keswick dams, the most important effect of flows on eggs and alevins is to transport dissolved oxygen to the developing eggs and alevins and to flush potentially toxic metabolites out of the redds. Although the mean September and November wet and above normal water year flows are substantially lower under Alternative 3 than under the No Action Alternative, the flows under Alternative 3 flows remain sufficiently high (>6,000 and >7,400 cfs for September and November, respectively) to provide the flow velocity needed to keep most redds clean and well oxygenated (Figure O.3-25). Therefore, differences in flow between the No Action Alternative and Alternative 3 are expected to have little effect on Spring-Run Chinook Salmon spawning and incubation habitat.

Differences in water temperature during the Spring-Run Chinook Salmon spawning period may be important. As described previously, HEC-5Q mean October water temperatures at Keswick Dam under Alternative 3 are predicted to be largely similar to the No Action Alternative and above the 53.5°F water temperature threshold most years (Figure O.3-18; Tables O.3-44). Summer mean monthly water temperatures at Keswick Dam are roughly equal under the No Action Alternative and Alternative 3, except for September of above normal water years, which has a 1.2°F higher mean water temperatures under Alternative 3 than under the No Action Alternative (Table O.3-44). Summer mean monthly water temperatures are consistently below the 53.5°F temperature threshold, except in critically dry water years during July through September. The October and November mean water temperatures under Alternative 3 are similar to those under the No Action Alternative and are just above the 53.5°F temperature threshold, except for critically dry water years, when those for both alternatives are well above the threshold (Table O.3-44). For October, the mean water temperature for critically dry water years is 0.95°F higher under Alternative 3 than that under the No Action Alternative. Although the difference in mean October critically dry water year water temperatures between the No Action Alternative and Alternative 3 is not large, it occurs under highly stressful temperature conditions for salmonids eggs and alevins. The largest predicted increase in mean water temperature under Alternative 3 is 1.2°F for September of above normal water years (Table O.3-44). This increase occurs over a range well below the critical temperature threshold and is therefore unlikely to have a large effect on the salmonids. The differences between the No Action Alternative and Alternative 3 in September water temperatures at Keswick Dam are small in relation to downstream areas as described below (Figure O.3-20).

Between the Clear Creek confluence and Balls Ferry, where more of the Spring-Run Chinook Salmon spawning occurs, late spring through early fall water temperatures in the Sacramento River at Clear Creek are slightly warmer than those at Keswick Dam, with larger increases in September water temperature differences between the No Action Alternative and Alternative 3 (Table O.3-45). Summer mean monthly water temperatures are below the 53.5°F temperature threshold, except in drier water years, especially in August and September. At Balls Ferry, the temperatures are warmer still and the September increases are larger (Table O.3-46). The mean September water temperatures for wet and above normal water years at Balls Ferry exceed the critical water temperature threshold under Alternative 3 but not under the No Action Alternative (Table O.3-46). Because the mean monthly water temperatures are higher than the threshold under Alternative 3, the probability or frequency of the threshold being exceeded by daily mean temperatures in September of wet and above normal water years is expected to be higher under Alternative 3 than under the No Action Alternative. The critical temperature threshold for spawning adult Chinook Salmon in the Sacramento River is the same as that for eggs and alevins, 53.5°F (Martin et al. 2017) or 55.4°F (USEPA 2003).

The HEC-5Q modeling results, which show an increased exceedance of the 53.5°F water temperature threshold during September under Alternative 3 relative to the No Action Alternative, suggest that Alternative 3 would have a significant adverse impact on Spring-Run spawning and egg and alevin incubation. It is concluded that Alternative 3 would have a less-than-significant impact on Spring-Run Chinook Salmon spawning and egg and alevin incubation with respect to flow and water temperature.

Juvenile Rearing and Emigration

Spring-Run Chinook Salmon juveniles rear in the Sacramento River primarily from November through early May and most emigrate to the Delta during December and again in March and April (see Section O.2.4.2.2, *Spring-Run Chinook Salmon*). Migratory cues, such as increased flow and/or turbidity from runoff, may spur emigration of juveniles from the upper Sacramento River basin when they have reached the appropriate stage of maturation (NMFS 2009). Inundated floodplain habitats have been shown to benefit growth and survival of juvenile salmon (Sommer et al. 2001, 2005; Katz et al. 2017), but natural flood flows largely determine the availability of this habitat, rather than operations of the CVP and SWP dams.

Based on the CalSim II modeling results, during most of the Spring-Run juvenile rearing and emigration period, Sacramento River flow would be higher under Alternative 3 than under the No Action Alternative and many of the increases would be greater than 5% (Tables O.3-43 and O.3-50 through O.3-52). However, the mean monthly flows for November of wet and above normal water years would be much lower under Alternative 3, because of the Fall X2 flows that are included in the No Action Alternative but not Alternative 3. Despite the reductions, the wet and above normal water year November flows under Alternative 3 remain relatively high (Tables O.3-43, O.3-50 through O.3-52; Figures O.3-28 and O.3-29), so they are not expected to substantially affect rearing juveniles. Furthermore, as noted above, emigration occurs primarily in December and in the spring. Mean monthly flows would also be lower under Alternative 3 in December of below normal and dry water years and February and March of dry water years (Tables O.3-43 and O.3-50 through O.3-52).

Results from a recent study suggest that for Spring-Run Chinook Salmon that do emigrate as early as November, the Alternative 3 flow reductions in November of wet and above normal water years would have a potentially adverse effect. The NMFS Southwest Fisheries Science Center ran statistical models using 2012-2017 tagging data from Spring-Run Chinook Salmon and Fall-Run Chinook Salmon and found a significant increase in smolt survival when Sacramento River flow at Wilkins Slough was above 9,100 cfs during the smolts emigration period (Cordoleani et al. 2019). The CalSim II results for

November at Wilkins Slough indicate that 50% of years would have mean monthly flows that exceed the 9,100 cfs threshold under the No Action Alternative, and 20% of years would have flows that exceed the threshold under Alternative 3 (Figure (O.3-29). As shown by recent sampling at RBDD (Figure O.3-31-A), almost all Spring-Run juveniles emigrate from the upper Sacramento River after November, so the percentage of Spring-Run juveniles that would be affected by the expected reductions in November flows at Wilkins Slough would be small. Therefore changes in flow resulting from Alternative 3 are not expected to substantially affect rearing and emigrating juvenile Spring-Run Chinook Salmon.

The USEPA (2003) gives 61°F as the critical 7 day average daily maximum (7DADM) water temperature for Spring-Run Chinook Salmon juveniles rearing in the upper Sacramento River and 64°F (7DADM) for those rearing in the middle Sacramento River (Knights Landing). Under the No Action Alternative and Alternative 3, HEC-5Q estimates of mean monthly water temperatures from Keswick to RBDD do not exceed the 61°F threshold during any month and water year type during the November through May rearing period (Tables O.3-44 through O.3-47). The mean monthly water temperatures for Hamilton City do not exceed the 64°F threshold for the middle Sacramento River during any of the months, but the mean monthly water temperatures for May exceed the middle river threshold at Knights Landing in all water year types under both alternatives. However, the May temperatures are generally lower under Alternative 3 than the No Action Alternative, especially in below normal and dry water years (Table O.3-49). These results indicate that water temperature conditions would be too warm for juvenile Spring-Run Chinook Salmon rearing and emigrating in the middle Sacramento River during May, but would be modestly improved under Alternative 2 relative to the No Action Alternative. It should be noted that May is the last month during spring or summer that Spring-Run Chinook Salmon juveniles are found in the middle river, and it is likely that when water temperatures are too high they emigrate to the ocean before May. However, early emigration could have other adverse effects.

The flow and water temperature effects resulting from Alternative 3 would have a less-than-significant effect relative to the No Action Alternative on juvenile Spring-Run Chinook Salmon in the Sacramento River.

Adult Upstream Migration and Holding

Spring-Run Chinook Salmon adults enter the Sacramento River from the Delta as early as January and make their way to the upper Sacramento River beginning in February, where they hold until ready to spawn in late summer and early fall (Windell et al. 2017). Adults may continue migrating upstream until August, and holding continues until October when spawning is complete. There are no flow or temperature requirements for the middle Sacramento River designed to protect fish. Once the adults reach holding habitat in the upper Sacramento River, they are more directly affected by Shasta and Keswick reservoir operations designed to preserve cold water for the Winter-Run and Spring-Run Chinook Salmon spawning and incubation periods.

During the January through August period of adult Spring-Run Chinook Salmon immigration, the mean monthly CalSim II flows under Alternative 3 at Keswick, RBDD, Hamilton City, and Wilkins Slough would generally be similar to or greater than those under the No Action Alternative, except during February and March of dry water years (Tables O.3-43 and O.3-50 through O.3-52). During the holding period, September flow would be much lower under Alternative 3 than under the No Action Alternative (Tables O.3-43 and O.3-50 through O.3-52; Figure O.3-25), but the mean September Alternative 2 flows at Keswick Dam would not fall below 6,000 cfs over the range of flows for which the alternatives have major flow differences (i.e., upper 50% in Figure O.3-25). A flow of 6,000 cfs would presumably be sufficient to maintain good water quality conditions in the Spring-Run holding habitats. Note that monthly mean flows for these months should reasonably estimate daily mean flows because operations at

Shasta and Keswick dams create relatively stable summer and fall flow and water temperature conditions in the upper Sacramento River.

The USEPA (2003) gives 68°F as the critical 7DADM water temperature for Spring-Run Chinook Salmon adults migrating upstream in the Sacramento River and 61°F for adult Spring-Run Chinook Salmon holding in the upper river. Throughout the January through August period of Spring-Run upstream migration, HEC-5Q water temperatures for Alternative 3 are similar to or slightly lower than those for the No Action Alternative, including greater than 1°F reductions in mean monthly water temperature for May and June in various water year types at Hamilton City and t Knights Landing (Tables O.3-44 through O.3-49). Under both alternatives, the mean monthly water temperatures in the middle Sacramento River (Knights Landing) would be below the 68°F threshold for immigrating adults from December through April, but would exceed the threshold in May of critically dry water years and in June through August of all water year types (Table O.3-49). The high May through August water temperatures would be likely to adversely affect any Spring-Run Chinook Salmon adults that were migrating upstream in those months. High water temperatures were found to cause adult Spring-Run Chinook Salmon in Butte Creek to terminate their upstream migrations, which made them more susceptible to mortality from rising water temperatures (Mosser et al. 2012). The June temperature reductions under Alternative 3 occur in a range slightly above the 68°F threshold and, therefore, would likely have a beneficial effect on upstream migrating adults. In the upper Sacramento River at Keswick Dam to Balls Ferry, the mean water temperatures under both alternatives would be well below the 61°F threshold for holding adults from February through October (Tables O.3-44 through O.3-46). As previously noted, flow below Keswick Dam is relatively stable during the summer and fall months, so monthly mean flows and temperatures are likely to be fairly representative of daily means in those months.

May through August water temperature reductions under Alternative 3, especially in the middle Sacramento River, are expected to have a beneficial effect on adult Spring-Run Chinook Salmon migrating upstream to spawn. Temperatures in the upper River under Alternative 3 and changes in flow in the upper and middle River are expected to have a less-than-significant impact on migrating and holding adults. Therefore, Alternative 3 is expected to have a less-than-significant effect relative to the No Action Alternative on Spring-Run Chinook Salmon with respect to flow, and a minor beneficial effect with respect to water temperature.

O.3.7.2.3 Central Valley Steelhead

Spawning and Egg Incubation

CV steelhead adults spawn from November through April with peak spawning from January through March. Based on the general timing of hatching and fry emergence, eggs and alevins may occur from November through May. Little is known about steelhead spawning locations in the Sacramento River, but it is generally assumed that spawning occurs primarily between Keswick Dam and RBDD.

During the steelhead spawning and incubation period, CalSim II modeling indicates that Alternative 3 flows in wet and above normal years would be substantially lower in November, and generally higher during the winter and spring months (Table O.3-43). Based on PHABSIM results (flow versus weighted usable area [WUA]) developed by the USFWS (2003) for the Sacramento River between Keswick Dam and Battle Creek, changes in flow in wet and above normal years would result in a 14% increase in spawning WUA in November, and less than a 10% decrease in spawning WUA in subsequent months (Figure WUA-SH-S). The differences in flow in other water years would have relatively small, variable effects on the availability of spawning habitat. Therefore, changes in flows under Alternative 3 would have both positive and negative effects on the availability of steelhead spawning habitat relative to the No Action Alternative.

HEC-5Q modeling for Alternative 3 indicates that the water temperatures in the upper Sacramento River during the steelhead spawning and incubation period (November through May) would be similar to those under the No Action Alternative (Tables O.3-44 through O.3-47). Based on the steelhead spawning and incubation threshold of 53°F (see O.3.3 Alternative 1, Central Valley Steelhead Spawning and Egg Incubation), both alternatives would maintain suitable water temperatures for spawning and incubation through April or May in the reach between Keswick Dam and Clear Creek, and there would be no major differences in the frequency and magnitude of water temperatures exceeding 53°F in other months or locations with the primary spawning (Keswick Dam to RBDD). Therefore, changes in water temperatures under Alternative 3 would not likely have significant effects on spawning adults, eggs, and alevins relative to the No Action Alternative.

Juvenile Rearing and Emigration

CV steelhead rear year-round in the Sacramento River, and use the river downstream from spawning areas as both a rearing and migration corridor. The timing of downstream migration is variable but generally peaks in the upper river at RBDD in spring and summer (March through June) and in the lower river at Knights Landing in winter and spring (January through May) (NMFS 2009). The peak migration of yearling and older juveniles through the Delta occurs in March and April (NMFS 2009).

CalSim II modeling indicates that the largest differences in Sacramento River flows between Alternative 3 and the No Action Alternative would occur in the late summer and fall (September and November) of above normal and wet years, and in late spring (most notably May and June) of most water year types, potentially affecting fry and juvenile rearing habitat (Table O.3-43). Based on the flow-habitat relationships for Late Fall-Run Chinook Salmon fry and juvenile life stages (see O.3.3 Alternative 1, Central Valley Steelhead Juvenile Rearing and Emigration), lower flows under Alternative 3 in the fall of wet and above normal water years would increase the amount of juvenile rearing habitat (as measured by WUA), while higher flows in spring of most water year types would have variable effects on fry and juvenile rearing habitat (Figures O.3-39 and O.3-40). For example, in wet years, reductions in average flows of approximately 6,100 cfs in September and 3,500 cfs in November would increase juvenile WUA by 30% to 40% relative to the No Action Alternative. In below normal years, increases in average flows of approximately 1,600 cfs in May and 2,200 cfs in June would reduce juvenile WUA by approximately 10% relative to the No Action Alternative. These same flow increases would reduce fry WUA by 4% in May and increase fry WUA by 6% in June. Therefore, changes in flows under Alternative 3 would have both positive and negative effects on the availability of steelhead rearing habitat relative to the No Action Alternative.

In the upper Sacramento River, HEC-5Q modeling for Alternative 3 and the No Action Alternative indicates that average water temperatures between Keswick Dam and RBDD would be maintained at or below the "core rearing area threshold" of 61°F (see O.3.3 Alternative 1, Central Valley Steelhead Juvenile Rearing and Emigration) throughout the year except in summer (July through September) of critically dry water years (Tables O.3-44 through O.3-47). During summer, water temperatures under Alternative 3 would be similar to those under the No Action Alternative except in September of wet and above normal years when average water temperatures would be 0.7 to 3.2°F higher (Tables O.3-44 to O.3-47); however, there would be no major differences in the frequency and magnitude of temperatures above 61°F (Figure O.3-22). Similarly, water temperatures during the steelhead emigration season (January through June) are expected to similar or cooler than those under the No Action Alternative (Table O.3-47 to O.3-49). For example, although water temperatures at Knights Landing would frequently exceed the 64°F "non-core rearing area" threshold in May under both alternatives (e.g., Figure O.3-41), higher spring flows under Alternative 3 would reduce average water temperature by up to 1.2°F (dry water years) (Table O.3-49). Therefore, changes in water temperature under Alternative 3 would not likely have significant effects on rearing and emigrating steelhead relative to the No Action Alternative.

Adult Upstream Migration and Holding

Adult steelhead immigration into Central Valley streams potentially occurs during all months of the year but typically begins in August and continues through March or April (McEwan 2001; NMFS 2014a). In the Sacramento River, adults migrate upstream past RBDD during all months of the year, but primarily during September and October (NMFS 2009). Adults may hold until the spawning season which generally extends from November through April.

During the steelhead immigration and holding period, lower flows in September and November of wet and above normal water years under Alternative 3 could affect immigrating and holding adults. However, mean monthly flows would be maintained at a minimum of 3,250 under both alternatives, and would not differ substantially in frequency and magnitude between the alternatives until flows exceed approximately 5,000 cfs (Figures O.3-25, O.3-27, and O.3-29). Within this flow range (>5,000 cfs), no adverse effects on migrating and holding adults would be expected; flows of this magnitude would presumably be sufficient to maintain suitable passage and holding conditions under both alternatives.

Under both Alternative 3 and the No Action Alternative, HEC-5Q modeling indicates that suitable water temperatures for steelhead immigration in the Sacramento River (based on the immigration threshold of 68°F; see O.3.3 Alternative 1, Central Valley Steelhead Adult Upstream Migration and Holding) would generally not occur until September or October (Table O.3-49). However, under Alternative 3, substantially lower flows in September of wet and above normal water years would increase the frequency of water temperatures exceeding this threshold, resulting in potential delays in migration or adverse physiological effects on migrating adults relative to the No Action Alternative. For example, at Knights Landing, mean monthly water temperatures in September exceeded 68°F approximately 80% of the time compared to 52% of the time under the No Action Alternative (Figure O.3-24). Therefore, changes in water temperatures under Alternative 3 in September would have a potentially adverse effect on immigrating adult steelhead in the Sacramento River relative to the No Action Alternative. Lower flows in September would also result in higher water temperatures in the upper Sacramento River, potentially affecting holding adults. However, no major differences would be expected to occur in the frequency and magnitude of water temperatures exceeding the threshold for holding adults (61°F; see O.3.3 Alternative 1, Central Valley Steelhead Adult Upstream Migration and Holding) (Figure O.3-22).

O.3.7.2.4 <u>Southern DPS Green Sturgeon</u>

Spawning and Egg Incubation

Green Sturgeon spawn in deep pools (averaging about 28 feet deep) (NMFS 2018b). Eggs from spawning Southern DPS Green Sturgeon have been found in the middle and upper Sacramento River from the GCID oxbow (RM 207) to Inks Creek (RM 265) and spawning is believed to extend upstream to the confluence with Cow Creek (RM 277) (Heublein et al. 2017b). Green Sturgeon spawn primarily from April through July, although they periodically spawn in late summer and fall (as late as October) (Heublein et al. 2009, 2017b, NMFS 2018b). Eggs hatch about a week after fertilization (at 60ºF) (Heublein et al. 2017b). Because the incubation time for Green Sturgeon is so short, the effects analysis period for incubating eggs is considered to be the same as the spawning period. Based on laboratory studies for Northern DPS Green Sturgeon, Heublein et al. 2017b) concluded that the optimal range for normal embryo development of Southern DPS Green Sturgeon is 53 to 64°F, and impaired fitness occurs below 52°F and above 71°F.

During the April through July Green Sturgeon spawning period, CalSim II estimates of mean monthly flows at RBDD (RM 244) under the No Action Alternative and Alternative 3 range from about 5,000 cfs for April of critically dry water years to about 14,300 cfs in July of above normal water years (Table O.3-50). Mean flows during most of this period are moderate (~8,000 cfs to ~12,000 cfs). These flow levels are likely to be suitable for Green Sturgeon spawning and egg incubation, and no adverse effects are expected to result.

Differences in flows between Alternative 3 and the No Action Alternative are small in most months, but flows are moderately higher for Alternative 3 in May and June of all water years, except May of wet years (Table O.3-50). During the August through October period, when Green Sturgeon spawning occurs in occasional years, the flows under both alternatives tend to be lower than those in April through July, but the mean flows would be close to or above 5,000 cfs for all water year types in all three months, which is expected to be adequate for Green Sturgeon spawning and egg incubation. Large reductions in mean flows from the No Action Alternative to Alternative 3 are predicted for September of wet and above normal water years and, although the resulting Alternative 3 mean flows are greater than 5,000 cfs, the flow reductions are so large (45 and 41%, respectively) that conditions for Green Sturgeon spawning and egg incubation are likely to be adversely affected (Table O.3-50). However, September spawning occurs only sporadically so any effect on the Green Sturgeon population would be minor (NMFS 2018b). Therefore, the September flow reductions are expected to have a minor adverse impact on Green Sturgeon.

Based on the HEC-5Q modeling, mean water temperatures during the April through July primary spawning period of Green Sturgeon are below the 53°F and 52°F lower temperature thresholds for Green Sturgeon egg development at Clear Creek and Balls Ferry during many of the months and water year types (Tables O.3-45 and O.3-46). As discussed previously, daily water temperatures are likely to be more variable than monthly mean temperatures, so the reductions of the mean temperatures below the 52 and 53°F thresholds probably underestimate the largest daily reductions below the thresholds.

The HEC-5Q modeling results show little difference in Clear Creek confluence mean water temperatures between Alternative 3 and the No Action Alternative during the April through July primary Green Sturgeon spawning and incubation period (Table O.3-45). Therefore, Alternative 3 is unlikely to cause a reduction in water temperatures relative to the No Action Alternative and thereby would not adversely affect Green Sturgeon spawning and egg incubation.

Larval and Juvenile Rearing and Emigration

As discussed under Alternative 1 (Section O.3.3, *Alternative 1*), the larval period for Green Sturgeon is considered to be April through September. The downstream distribution of Green Sturgeon larvae in the Sacramento River is uncertain, but is estimated to extend to the Colusa area, at RM 157 (Heublein et al. 2017b). The upstream limit is the Cow Creek confluence. Green Sturgeon juveniles rear in the Sacramento River from about May through December (NMFS 2017b). During most of this period, the juveniles are likely to be found anywhere from the upstream spawning habitat near the Cow Creek confluence to the Delta.

CalSim modeling for the Sacramento River at RBDD indicates that mean monthly flows during the April through September period of larval rearing are generally similar between the No Action Alternative and Alternative 3 in April, July and August but would be greater in May (all water years except wet), June (all water years) and September (below normal and dry years) (Table O.3-50). The September reductions in flow from the No Action Alternative to Alternative 3 during wet and above normal years would potentially affect Green Sturgeon larvae adversely because, as discussed above, there appears to be a positive relationship between annual outflow and abundance of White Sturgeon larvae and juveniles, but the applicability of the relationship to Green Sturgeon is uncertain.

CalSim modeling for the Sacramento River at Hamilton City indicates that mean monthly flows during the period of juvenile rearing and emigration, May through December, are generally similar between the No Action Alternative and Alternative 3 except for higher flows under Alternative 3 during May (all years except wet), June (all years), and September (below normal to critically dry) (Table O.3-50). Reductions in flows occur in September and November (wet and above normal years). These reductions in flow could adversely affect Green Sturgeon juveniles under Alternative 3 because, as noted above, there may be a positive relationship between annual outflow and abundance of Green Sturgeon.

There are few notable differences in the HEC-5Q mean monthly water temperature estimates at RBDD or Hamilton City between the No Action Alternative and Alternative 3 during the Green Sturgeon larval and juvenile rearing and emigration period in any month, except for September (Tables O.3-47 and O.3-48). During over half of the years in September, the Alternative 3 water temperature at RBDD is greater than the No Action Alternative temperature, with a maximum difference of about 3°F (Figure O.3-22). Over the range of years for which there are temperature differences, the water temperatures of both the No Action Alternative and Alternative 3 are under the 63°F lower limit of the optimal range for larvae. However, the Alternative 3 water temperatures are closer to the optimal range and therefore would potentially provide more favorable conditions for larval growth and survival. For the juveniles at RBDD, the September water temperatures under the No Action Alternative are below the 59°F lower limit of the optimal temperature range in about half of the years, and under Alternative 3 they are below the optimal range in about a third of the years (Figure O.3-22). The September HEC-5Q temperature estimates for Hamilton City also fall within or are closer to the optimal ranges of Green Sturgeon larvae and juveniles in more years under the Alternative 3 than the No Action Alternative, however overall temperatures are slightly lower in the other months (Table O.3-48; Figure O.3-23).

The CalSim II flow results indicate that Alternative 3 would have a less-than-significant impact on rearing larval and juvenile southern DPS Green Sturgeon relative to the No Action Alternative, and the HEC-5Q water temperature modeling results indicate that Alternative 3 would provide a minor potential benefit to rearing larval and juvenile Green Sturgeon relative to the No Action Alternative.

Adult Upstream Migration and Holding

Green Sturgeon adults enter the Sacramento River from the Delta as early as February and ultimately make their way upstream to spawn in deep pools from the GCID oxbow (near Hamilton City) to the Cow Creek confluence (Heublein et al. 2017b). After spawning, the adults hold in the river for varying amounts of time, but typically emigrate back to the San Francisco Estuary and the ocean from about October through December (Heublein et al. 2017b).

Flows during the February through December period of Green Sturgeon immigration, spawning and holding would generally be similar between Alternative 3 and the No Action Alternative at RBDD, Hamilton City, and Wilkins Slough (Tables O.3-50 through O.3-52). Exceptions include moderately higher mean monthly flows under Alternative 3 at all locations during May and June, and in September during below normal to critically dry years. Substantially lower flows under Alternative 3 occur during September and November during wet and above normal years. All of the more notable flow differences occur within a range of river flows (~5,000 cfs to 14,000 cfs) that are not expected to substantially affect upstream passage of migrating Green sturgeon, but the September and November flow reductions under Alternative 3 at Hamilton City and RBDD could result in reduced habitat quality in holding pool habitats, adversely affecting holding adults.

There are few major differences in mean monthly water temperatures between the No Action Alternative and Alternative 3 in the Sacramento River at Knights Landing during the February through April period that most adult Green Sturgeon migrate upstream or during the later months (through December) when the sturgeon migrate downstream after spawning (Table O.3-49). Temperatures are lower during May and June which would benefit migrating adults by bringing temperatures closer to the 66 degree threshold. However, increases of more than 4°F are expected in September of wet and above normal water years. The means exceed the 66°F threshold for migrating Green Sturgeon adults in both water year types under Alternative 3 and in neither water year type under the No Action Alternative. The mean monthly water temperatures at Knights Landing also exceed the 66°F threshold under both alternatives during June through August of all water year types and May of all but wet years (Table O.3-49). Adults migrating downstream from May through September would potentially be adversely affected by the high water temperatures. However, adults migrating upstream would be less affected because most upstream immigration occurs before late spring (Heublein et al. 2009), when water temperatures are below the 66°F threshold.

During the May through December spawning and post-spawn holding period for Green Sturgeon, the HEC-5Q mean monthly water temperatures at Hamilton City are generally similar between the No Action Alternative and Alternative 3, except for higher temperatures under Alternative 3 in September (Table O.3-48). The mean monthly water temperatures during the hottest months of this period, July through September, range from 58 to 68°F (both in September). The temperatures frequently exceed the 63°F threshold for spawning adults and the 61°F threshold for holding adults during these months. During September, the mean water temperatures only exceed the 63 and 61°F thresholds in wet and above normal years under Alternative 3 but not under the No Action Alternative and the mean water temperatures in the remaining water years are slightly lower under Alternative 3 than under the No Action Alternative. September water temperatures are cooler at RBDD and there is no difference at this location between Alternative 3 and the No Action Alternative in the frequency of the threshold exceedances (Figure O.3-22). During October through December, the mean monthly water temperatures stay below both thresholds in every water year type.

The CalSim II modeling results indicate that for adult southern DPS Green Sturgeon holding in September or November, reduced flows under Alternative 3 would have a potentially significant adverse impact on holding habitat relative to the No Action Alternative. The HEC-5Q modeling results indicate that the water temperatures for September of wet and above normal water years would be substantially higher under Alternative 3 than under the No Action Alternative and would exceed the 61°F thresholds for migrating, spawning and holding adult Green Sturgeon only under Alternative 3. In conclusion, the HEC-5Q results for Alternative 3 are expected to result in substantially less favorable water temperatures for Green Sturgeon in September of wet and above normal water years and moderately more favorable water temperatures in a number of other water year types and months. In combination, the reduced flows in September and November of wet and above normal water years and increased water temperatures in September of wet and above normal water years are expected to have a significant adverse impact on southern DPS Green Sturgeon adults.

O.3.7.2.5 Fall-Run Chinook Salmon

Spawning and Egg/Alevin Incubation

Fall-Run Chinook Salmon migrate upstream past RBDD on the Sacramento River between July and December, typically spawning in upstream reaches from October through January, with a peak in October and November. Eggs and alevins are present from October through April. The primary spawning area used by Fall-Run Chinook Salmon in the Sacramento River is the area from Keswick Dam downstream to RBDD. Spawning densities for all Chinook Salmon runs are highest in this reach, but the distribution of spawning fall-run generally extends downstream to spawning areas below RBDD (Gard 2013).

During the Fall-Run Chinook Salmon spawning and incubation period, relatively large reductions in flows in November of wet and above normal water years under Alternative 3 (averaging over 3,000 cfs lower than No Action Alternative flows) would increase the amount of available spawning habitat, while moderate increases in flow in subsequent months (averaging 500 to 2,000 cfs higher than No Action Alternative flows) would decrease available spawning habitat. For example, in wet years, a reduction in average flow of approximately 3,500 cfs in November would increase the amount of available spawning habitat (as measured by WUA) by 72%, while an increase in average flow of approximately 2,000 cfs in December would decrease available spawning habitat by 26% (Figure O.3-35). In above normal years, a reduction in average flow of approximately 3,100 cfs in November would increase the amount of available spawning habitat by 63%, while increases in average flow of 600 cfs in December and 900 cfs in January would decrease available spawning habitat by 8% and 13%, respectively. Therefore, changes in flows under Alternative 3 would have both positive and negative effects on the availability of spawning habitat relative to the No Action Alternative.

HEC-5Q modeling indicates that Alternative 3 would not substantially affect the frequency of water temperatures exceeding the 53.5°F threshold (see O.3.3.1.2, Sacramento River, *Potential changes to aquatic resources in the Sacramento River from seasonal operations*) during the fall-run Chinook Salmon spawning and incubation period (Table O.3-44). Both alternatives would maintain suitable water temperatures for spawning and incubation through April in the reach between Keswick Dam and Clear Creek, and there would be little or no difference in the frequency and magnitude of water temperatures exceeding 53.5°F in other months or locations within the primary spawning area (Keswick Dam to RBDD) (e.g., Figure O.3-117). Therefore, changes in water temperatures under Alternative 3 are not likely to have significant effects on steelhead spawning and incubation relative to the No Action Alternative.

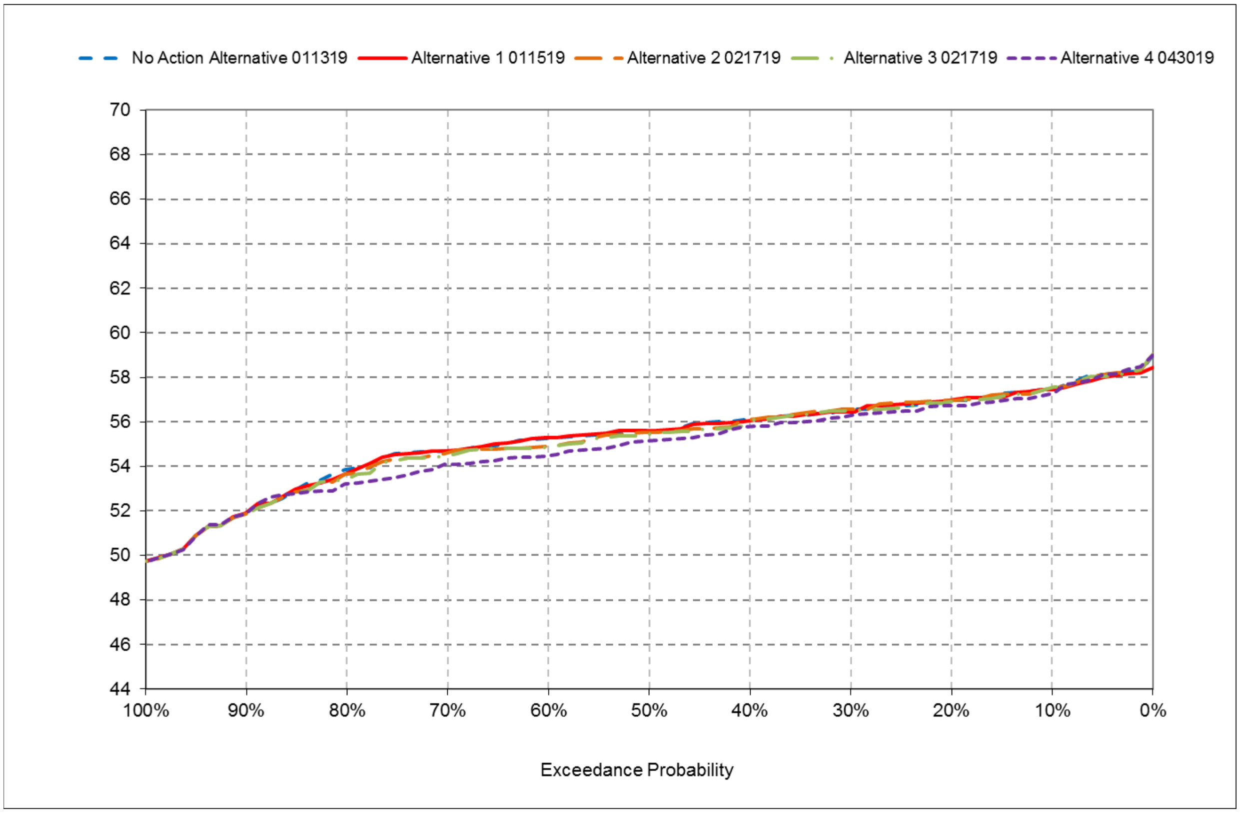


Figure O.3-117. HEC-5Q Sacramento River Water Temperatures at Red Bluff Diversion Dam under the No Action Alternative, Alternative 1, Alternative 2, Alternative 3 and Alternative 4; April

Juvenile Rearing and Emigration

Fall-Run Chinook Salmon juveniles rear in the Sacramento River primarily from December through May. Following emergence, juveniles rear for variable lengths of time in the Sacramento River before entering the Delta and estuary, and may emigrate as fry, parr, or smolts. The timing of emigration is variable but generally peaks in the upper river from January through April and in the lower river from January through May (NMFS 2009).

Under Alternative 3, higher winter and spring flows in the Sacramento River relative to the No Action Alternative could affect rearing and emigrating fall-run Chinook Salmon. Based on the flow-habitat relationships for Fall-Run Chinook Salmon fry and juvenile life stages (see O.3.3 Central Valley Fall-Run Chinook Salmon, Juvenile Rearing and Emigration), higher winter and spring flows under Alternative 3 would generally reduce the amount of available fry and juvenile rearing habitat in the upper Sacramento River (Figures O.3-39 and O.3-40). CALSIM II modeling indicates that the largest differences in flows between Alternative 3 and the No Action Alternative would occur in December of wet years (averaging approximately 2,000 cfs) and in May of below normal and dry water years (averaging approximately 1,500 cfs). Based on the flow-habitat relationships, these flow increases correspond to a 7% reduction in fry WUA in December of wet years, a 13% reduction in juvenile WUA in May of below normal years, and a 12% reduction in juvenile WUA in May of dry years. While these results indicate that Alternative 3 would potentially reduce the availability of suitable rearing habitat for Fall-Run Chinook Salmon relative to the No Action Alternative, uncertainty exists in the importance of this reduction relative to other factors that affect the quantity and quality of rearing habitat for juvenile Chinook Salmon in the Sacramento River.

In the upper Sacramento River, HEC-5Q modeling for Alternative 3 and the No Action Alternative indicates that both alternatives would maintain suitable water temperatures (≤ 61°F; see O.3.3 Alternative 1, Central Valley Steelhead Juvenile Rearing and Emigration) between Keswick Dam and RBDD during the Fall-Run Chinook Salmon fry and juvenile rearing period (December through May) (Tables O.3-44 through O.3-47). Farther downstream, mean monthly water temperatures in the lower river at Knights Landing would be similar or slightly cooler under Alternative 4 (Table O.3-49), but there would be no differences in the frequency and magnitude of temperatures exceeding the 64°F “non-core rearing area threshold” (Table O.3-49). Therefore, changes in Sacramento River water temperatures under Alternative 3 would not likely have significant effects on rearing and emigrating juvenile Fall-Run Chinook Salmon relative to the No Action Alternative.

Adult Upstream Migration and Holding

Fall-Run Chinook Salmon migrate upstream past RBDD on the Sacramento River between July and December. Adults may hold until the spawning season, which occurs primarily from October through January.

CALSIM II modeling indicates that mean monthly flows in the Sacramento River under Alternative 3 would be substantially lower in September and November of wet and above normal water years relative to the No Action Alternative (Tables O.3-43, O.3-50, and O.3-51), potentially affecting immigrating and holding adults. However, flows under both alternatives would be maintained at or above 3,250 cfs throughout the immigration and holding period. Although flows would differ substantially in September and November, the differences would be limited to flows exceeding approximately 5,000 cfs (Figures O.3-25, O.3-27, and O.3-29). Within this range (>5,000 cfs), no adverse effects on migrating and holding adults would be expected; flows of this magnitude would presumably be sufficient to maintain suitable passage and holding conditions under both alternatives.

Under both Alternative 3 and the No Action Alternative, HEC-5Q modeling indicates that suitable water temperatures for Fall-Run Chinook Salmon immigration in the Sacramento River (based on the immigration threshold of 68°F; see O.3.3 Alternative 1, Central Valley Fall-Run Adult Upstream Migration and Holding) would generally not occur until September or October (Table O.3-49). However, under Alternative 3, substantially lower flows in September would increase the frequency of water temperatures exceeding this threshold, resulting in potential delays in migration or adverse physiological effects on migrating adults relative to the No Action Alternative. For example, at Knights Landing, mean monthly water temperatures in September exceeded 68°F approximately 80% of the time under Alternative 3 compared to 52% of the time under the No Action Alternative (Figure O.3-24). Therefore, changes in water temperatures under Alternative 3 in September would have a potentially adverse effect on immigrating adult Fall-Run Chinook Salmon in the Sacramento River relative to the No Action Alternative. Lower flows in September would also result in higher water temperatures in the upper Sacramento River, potentially affecting holding adults. However, no major differences would be expected to occur in the frequency and magnitude of water temperatures exceeding the threshold for holding adults (61°F; see O.3.3 Alternative 1, Central Valley Fall-Run Adult Upstream Migration and Holding) (Figure O.3-22).

O.3.7.2.6 Late Fall-Run Chinook Salmon

Spawning and Egg/Alevin Incubation

Late Fall-Run Chinook Salmon spawn primarily from December through April, and eggs and alevins are present in the gravel from December through June. In the Sacramento River, most adults spawn upstream of Red Bluff Diversion Dam, with the majority spawning between Keswick Dam and the ACID Dam.

CALSIM II modeling indicates that Sacramento River flows under Alternative 3 would generally be higher than or similar to the flows under the No Action Alternative during the Late Fall-Run Chinook Salmon spawning and incubation period (December through June) (Table O.3-43). The largest increases in flow are expected to occur in the winters of wet, above normal, and below normal years, averaging approximately 1,000 cfs to 2,000 cfs higher than flows under the No Action Alternative. Based on PHABSIM results (flow-habitat relationships) developed by the USFWS for the Sacramento River between Keswick Dam and Battle Creek (USFWS 2003a), higher flows under Alternative 3 would reduce the amount of available spawning habitat for Late Fall-Run Chinook Salmon (as measured by WUA) (Figure O.3-38). For example, spawning habitat WUA would be reduced by approximately 16% in December of wet years and 10% in January and February of above normal years. While these results indicate that Alternative 3 would potentially reduce the availability of suitable spawning habitat for Late Fall-Run Chinook Salmon relative to the No Action Alternative, uncertainty exists in the importance of this reduction relative to other factors that affect the quantity and quality of spawning and incubation habitat for Late Fall-Run Chinook Salmon in the Sacramento River.

Similar to Alternative 1, HEC-5Q modeling for Alternative 3 indicates that the water temperatures in the upper Sacramento River during the Late Fall-Run Chinook Salmon spawning and incubation period (December through June) would be similar to those under the No Action Alternative (Tables O.3-44 through O.3-47). Based on the spawning and incubation threshold of 53.5°F (see O.3.3.1.2, Sacramento River, *Potential changes to aquatic resources in the Sacramento River from seasonal operations*), both alternatives would maintain suitable water temperatures from spawning and incubation through May or June in the primary spawning reach (Keswick Dam and Clear Creek), and there would be no major differences in frequency and magnitude of water temperatures exceeding this threshold (Table O.3-44 to O.3-45). Therefore, changes in water temperatures under Alternative 3 are unlikely to have significant effects on spawning adults, eggs, and alevins relative to the No Action Alternative.

Juvenile Rearing and Emigration

Late fall–run Chinook Salmon fry generally emerge from March through June, and juveniles rear in the Sacramento River through the summer before emigrating at a relatively large size (150- to 170-mm fork length) primarily from November through May.

CalSim II modeling indicates that Sacramento River flows under Alternative 3 would generally be higher than or similar to flows under the No Action Alternative during the Late Fall-Run Chinook Salmon rearing period except in September and November of wet and above normal water years when flows would be substantially lower (Table O.3-43). Based on PHABSIM results (flow-habitat relationships) for Late Fall-Run Chinook Salmon fry (<60 mm) and juveniles (≥60 mm) in the upper Sacramento River between Keswick Dam and Battle Creek (USFWS 2005), higher flows during spring and summer would generally reduce the amount of available fry and juvenile rearing habitat (Figures O.3-39 and O.3-40). For example, in below normal water years, higher spring flows under Alternative 3 would reduce fry WUA by 4% to 10% (March to May), increase fry WUA by 8% in June, and reduce juvenile WUA by 9% to 12% in May and June. In September and November of wet and above normal water years, substantially lower flows under Alternative 3 would increase juvenile WUA by 30% to 40% relative to the No Action Alternative. Therefore, changes in flows under Alternative 3 would have both positive and negative effects on the availability of rearing habitat relative to the No Action Alternative.

In the upper Sacramento River, HEC-5Q modeling for Alternative 3 and the No Action Alternative indicates that average water temperatures between Keswick Dam and RBDD would be maintained at or below the "core rearing area threshold" of 61°F (see O.3.3 Alternative 1, Central Valley Steelhead Juvenile Rearing and Emigration) throughout the year except in the summer (July through September) of critically dry water years (Tables O.3-44 through O.3-47). During summer, water temperatures under Alternative 3 would be similar or cooler than those under the No Action Alternative except in September of wet and above normal years when average water temperatures would be 0.7°F to 3.2°F higher (Tables O.3-44 to O.3-47); however, there would be no major differences in the frequency and magnitude of temperatures above 61°F (Figure O.3-22). Similarly, water temperatures during the Late Fall-Run Chinook Salmon emigration season (November through May) are expected to similar or cooler than those under the No Action Alternative (Table O.3-47 to O.3-49). Although water temperatures would frequently exceed the 64°F "non-core rearing area" threshold by May under both alternatives (e.g., Figure O.3-41), water temperatures at Hamilton City and Knights Landing would average up to 1.2°F cooler in May (Tables O.3-48 and O.3-49). Therefore, changes in water temperature under Alternative 3 would not likely have significant effects on rearing and emigrating Late Fall-Run Chinook Salmon relative to the No Action Alternative.

Adult Upstream Migration and Holding

In the Sacramento River, adult Late Fall-Run Chinook Salmon migrate from October through April, with a peak during January through March (NMFS 2009). Adults hold for 1 to 3 months prior to spawning, which occurs primarily from December through April.

Under Alternative 2, CALSIM II modeling indicates that flows in the Sacramento River during the Late Fall-Run Chinook Salmon immigration period would be similar or higher than those under the No Action Alternative except in November of wet and above normal water years when flows would be substantially reduced relative to the No Action Alternative (Tables O.3-43, O.3-50, and O.3-51). However, flows under both alternatives would be maintained at or above 3,250 cfs throughout the immigration and holding period. Although flows would differ substantially in November, the differences would be limited to flows exceeding approximately 5,000 cfs (Figures O.3-25, O.3-27, and O.3-29). Within this range (>5,000 cfs), no adverse effects on migrating and holding adults would be expected; flows of this magnitude would presumably be sufficient to maintain suitable passage and holding conditions under both alternatives.

Based on the water temperature thresholds for immigration (68°F) and holding (61°F) (see O.3.3 Alternative 1, Central Valley Fall-Run Adult Upstream Migration and Holding), Alternative 3 and the No Action Alternative would maintain suitable water temperatures for Late Fall-Run Chinook Salmon throughout the immigration and holding period (October through April) (Tables O.3-47 and-O.3-49). Therefore, changes in water temperatures under Alternative 3 would not likely have significant effects on immigrating and holding Late Fall-Run Chinook Salmon in the Sacramento River relative to the No Action Alternative.

O.3.7.2.7 White Sturgeon

Spawning and Egg Incubation

White sturgeon spawn in deep water in the middle and lower Sacramento River from Verona (RM 80) to just upstream of Colusa (~RM 156) from late February to early June, but primarily during March and April, (Moyle et al. 2015; Heublein et al. 2017). The adults typically return promptly to the Delta/Estuary after spawning.

During the March and April spawning and egg incubation period of White Sturgeon, CalSim II estimates of mean monthly flows at Wilkins Slough under the No Action Alternative and Alternative 3 range from about 5,300 cfs for April of critically dry water years to about 17,800 cfs for March of wet water years (Table O.3-34). These flow levels are likely to be adequate for White Sturgeon spawning and egg incubation, so no adverse effects are expected to result. Differences in flows between Alternative 3 and the No Action Alternative are small in both months, but flows are moderately higher for Alternative 3 in March of below normal and critically dry water years and April of below normal years (Table O.3-34). It is concluded that Alternative 2 would have no flow effect on White Sturgeon eggs and embryos relative to the No Action Alternative.

The HEC-5Q water temperature modeling results for March and April indicate that mean monthly water temperatures at Knights Landing are below the 63°F threshold for optimal temperatures (see Section O.3.3.1.2, *Sacramento River*), except in April of critically dry water years (Table O.3-49). As noted earlier, the mean monthly water temperatures for water year types combine water temperatures for many years and therefore mask individual year variations. The monthly means for individual years show that April water temperatures exceed the 63°F threshold in 15% of years, but lie below the 68°F lethal temperature in all years (Figure O.3-43). There are no appreciable differences in water temperatures between Alternative 3 and No Action Alternative in March or April (Table O.3-31; Figures O.3-43).

During June, the warmest month of the full spawning and egg incubation period, the mean monthly water temperatures are predicted to exceed the 68°F lethal temperature in all water year types, but the water temperatures are lower for Alternative 3 than for the No Action Alternative, especially in drier water years (Table O.3-49). It is concluded that Alternative 3 would have no water temperature effect on White Sturgeon eggs and embryos relative to the No Action Alternative.

Larval and Juvenile Rearing and Emigration

During the March through June larval period, water temperature modeling indicates that water temperatures frequently exceed water temperature thresholds (61 and 68°F, see Section O.3.3.1.2, *Sacramento River*) at Knights Landing under the No Action Alternative and Alternative 3 (Table O.3-31), especially in June. Such high levels of temperature threshold exceedances suggest that typical water temperature conditions in the lower Sacramento River may be highly stressful for White Sturgeon larvae. In any case, the water temperatures, especially in June, are lower under Alternative 3 than under the No Action Alternative (Table O.3-31). It is concluded that Alternative 3 compared to the No Action Alternative will not have an adverse effect on larval and juvenile rearing.

During the of White Sturgeon juvenile emigration period, approximately April to July, CalSim II results indicate that flows at Wilkins Slough during May and June would increase with Alternative 3 compared to No Action Alternative (Table O.3-14). Alternative 3 may have a beneficial effect on juvenile White Sturgeon.

Adult Upstream Migration and Holding

White Sturgeon adults to initiate their upstream spawning migrations during late winter and early spring, presumably in response to elevated flows (Heublein et al. 2017). CalSim II flows at Wilkins Slough for December through February are not much different between Alternative 3 and No Action Alternative for all water year types. There are a few months and water year types when flows are higher under Alternative 3, such as December during wet years and January during below normal years. Increased flows potentially benefit White Sturgeon migration, but all flows are between 7,700 and 18,900 cfs, which are suitable for migration. There are no temperature differences from December through February for Knights Landing. Alternative 3 would have no flow or water temperature effects on White Sturgeon adults.

O.3.7.2.8 <u>Sacramento Splittail</u>

Sacramento Splittail occur in the Sacramento River upstream of the Delta from about December through May. The adults spawn in river-margin and inundated floodplain habitats in February through April (Feyrer et al. 2005, 2006; Sommer et al. 2007; Moyle et al. 2015). The larvae hatch several days after spawning then rear for about a month in habitat similar to the spawning habitat (Moyle et al. 2004). The juveniles rear upstream and then begin their downstream migration during April and May, as the river level recedes back to the channel (Moyle et al. 2004; Feyrer et al. 2005). Floodplain spawning in wet years overwhelmingly dominates production, but spawning in side channels and channel margins is important during low-flow years when floodplains are not inundated. In the Sacramento River drainage, splittail spawn from Colusa to Knights Landing, but the most important spawning areas are the inundated floodplains of the Yolo and Sutter bypasses (Feyrer et al. 2005).

High flows benefit adults migrating upstream (Feyrer et al. 2006), and greatly enhance spawning and rearing habitat for larvae and early juveniles (Crain et al. 2004). Mean monthly flows at Wilkins Slough during January through March of wet and above normal water years consistently equal or exceed 17,000 cfs under both alternatives (Table O.3-43). Figure O.3-44 shows the expected mean February flows for each year of the CalSim II record. About 15% of the years have mean February flows greater than 22,500 cfs, which is the approximate flow at which the Tisdale Weir begins to spill into the Sutter Bypass (DWR 2010b). In any case, differences between Alternative 3 and the No Action Alternative in flows at Wilkins Slough during December through May are relatively minor, and generally result from higher flow under the Alternative 3, especially in May during all water year types except wet years (Table O.3-52). It is concluded that Alternative 3 would have no flow effects on Sacramento Splittail relative to the No Action Alternative.

Preferred water temperature for Sacramento splittail ranges from about 66°F for adults to about 75°F for juveniles, and the “upper limit of safe temperatures” ranges from about 75°F for adults and 81°F for juveniles (Young and Cech 1996). Mean monthly water temperatures during December through May at Knights Landing, which is at the approximate downstream limit of splittail spawning in the Sacramento River, range up to 68°F under both alternatives in May of critically dry water years (Table O.3-49). There are no meaningful water temperature differences between the alternatives at Knights Landing during the December through May period that Sacramento Splittail occupy the river upstream of the Delta, except in May of below normal and dry water years when water temperatures are just over 1°F lower under Alternative 3 than the No Action Alternative (Table O.3-49). There is evidence that some juvenile splittail remain in the Sacramento River well upstream of the Delta through the entire year (Feyrer et al. 2005), but summer water temperatures in the more upstream locations where they have been found are considerably cooler than those at Knights Landing (compare Tables O.3-48 and O.3-49). Therefore, Alternative 3 is considered to have no adverse water temperature effects on splittail relative to the No Action Alternative.

The CalSim II flow results for Wilkins Slough and the HEC-5Q water temperature results for Knight Landing indicate that Alternative 3 would not have an adverse impact on Sacramento Splittail relative to the No Action Alternative.

O.3.7.2.9 Pacific Lamprey

Sacramento River Pacific Lamprey adults enter the Sacramento River from the Delta primarily during about March through June and hold in the river for about a year prior to spawning (Moyle et al. 2015). Spawning occurs in gravel redds in the upper river from March through July. The eggs and pro-larvae incubate for about 1 to 1.5 months. After the larvae (ammocoetes) emerge, they drift downstream and burrow into fine sediments primarily in off-channels habitats, where they rear (Schultz et al. 2014; Moyle et al. 2015). After 5 or more years, the ammocoetes metamorphose to the macropthalmia (juvenile) stage and migrate downstream to the Delta and ocean, typically migrating from March through June during pulse flow events (Moyle et al. 2015).

River flow potentially affects survival of Pacific Lamprey eggs and larvae, and migratory habitat of the juveniles and adults. Pacific lamprey build their spawning redds in shallow water (about 0.5 to 3.5 feet) (Gunckel et al. 2009; Schultz et al. 2014; Moyle et al. 2015), so reductions in water level can dewater the redds. The larvae select habitats, often off-channel, with fine sediments, low flow velocity, and shallow depths (~1 ft), so they are vulnerable to stranding by reductions in water level. Migrations of the juveniles and adults may be triggered by surges in flow (Moyle et al. 2015).

The types of variations in flow that potentially affect Pacific Lamprey, as described above, often occur on a time scale of hours or days, and therefore may not be detectable using the CalSim II monthly time-step modeling results. However, the CalSim II results mostly show no large difference in Sacramento River flow between the No Action Alternative and Alternative 3, so there is no reason to expect much difference in short period flow fluctuations between the alternatives. The biggest differences in monthly mean flows occur in September and November of wet and above normal water years, when flows are much lower under Alternative 3 than the No Action Alternative because Alternative 3 operations do not include releases for Fall X2 flows (Table O.3-50; Figures O.3-25 and O.3-28). Pacific lamprey are generally done spawning by late July and the prelarvae have finished emerging from their redds by early September. In contrast, the larvae are present in the river yearround and so could be vulnerable to flow reductions during September and November. However, water levels during these months are generally relatively stable because they are largely determined by Shasta and Keswick dam releases rather than runoff. The adults and juveniles carry out their migrations primarily during March through June. CalSim II modeling flow results for these months are generally higher under Alternative 3 than under the No Action Alternative (Tables O.3-13 and O.3-14). Therefore, Alternative 3 and the No Action Alternative are expected to similarly affect Pacific Lamprey with respect to flow in the Sacramento River.

As described for Alternative 1, laboratory studies conducted on Columbia River Pacific Lamprey indicated that survival of incubating eggs and pre-larvae and of young larvae was greatest at a water temperature of 64°F and lowest at the highest water temperature included in the study, 72°F (Meeuwig et al. 2005). HEC-5Q modeling results indicate that mean monthly water temperatures in the Sacramento River between Keswick and RDBB during the March through August spawning and egg/prelarvae incubation period would be consistently below 64°F, with minor differences between the alternatives (Tables O.3-26 through O.3-29). During September, when Pacific Lamprey larvae would be present in the river, mean water temperatures would exceed the 64°F optimal temperature at RBDD in critically dry water years. September has the highest water temperatures of the year upstream of RBDD. Mean September water temperatures at RBDD for individual years exceed 64°F in about 7% of years for both alternatives, but are below 72°F for all years (Figure O.3-22). The downstream distribution of Pacific Lamprey larvae is uncertain, but if the larvae drift well downstream of RBDD or enter the Sacramento River from downstream tributaries, they would be subject to higher water temperatures, especially during July and August. However, there are few differences between July and August water temperatures at the lower temperature modeling sites, except in below normal water years when water temperatures are about 1°F cooler under Alternative 3, which would likely benefit the larvae (Table O.3-48 and O.3-49; Figure O.3-45). There are no biologically meaningful differences in water temperature conditions for Pacific Lamprey between the No Action Alternative and Alternative 3.

The CalSim II flow results and the HEC-5Q water temperature results indicate that Alternative 3 would have a less-than-significant impact on Pacific Lamprey relative to the No Action Alternative.

O.3.7.2.10 River Lamprey

River Lamprey adults migrate from the ocean to spawning areas during the fall and late winter (Beamish 1980). Spawning is believed to occur from February through May in small tributary streams (Moyle 2002). The redds are built at the upstream end of small riffles (Moyle 2002). After the larvae (ammocoetes) emerge, they drift downstream and burrow into sediments in pools or side channels where they rear. After several years, the larvae metamorphose in late July and the juvenile (macrothalmia) migrate downstream in the following year from May to July (Moyle 2002).

River flow potentially affects survival of River Lamprey eggs and larvae, and migratory habitat of the juveniles and adults. River lamprey build their spawning redds in shallow water (Moyle et al. 2015), so reductions in water level can dewater the redds. Assuming River Lamprey larvae habitat requirements are similar to those of Pacific Lamprey, the larvae select habitats, often off-channel, with low flow velocity and shallow depths, so they are vulnerable to stranding by reductions in water level.

The types of variations in flow likely to cause redd dewatering and stranding of larvae often occur on a time scale of hours or days and, therefore, may not be detectable using the CalSim II monthly time-step modeling results. However, the CalSim II results mostly show no large differences in Sacramento River flow between the No Action Alternative and Alternative 2, so there is no reason to expect much difference in short period flow fluctuations between the alternatives. The biggest differences in monthly mean flows occur in September and November of wet and above normal water years, when flows are lower under Alternative 3 than the No Action Alternative because Alternative 3 operations do not include releases for Fall X2 flows (Table O.3-50; Figures O.3-25 and O.3-28). River lamprey are generally done spawning by May and, assuming their incubation times are similar to those of Pacific Lamprey, the prelarvae complete their emergence from redds by June or July. In contrast, the larvae are present in the river yearround and so could be vulnerable to flow reductions during September and November. However, water levels during these months are generally relatively stable because they are largely determined by Shasta and Keswick dam releases rather than runoff.

The juveniles carry out their migrations during May through July. CalSim II modeling flow results for May and June at Hamilton City and Wilkins Slough are higher under Alternative 3 than under the No Action Alternative, except in May of wet years, but flows for July are generally slightly lower (Tables O.3-51 and O.3-52). The adults migrate upstream primarily in the fall and winter and could be adversely affected by the September and November reductions in flow under Alternative 3 relative to the No Action Alternative (Table O.3-52), but little is know about flow needs of migrating adult River Lamprey.

Overall, Alternative 3 and the No Action Alternative are expected to similarly affect River Lamprey with respect to flow in the Sacramento River.

The water temperature requirements of River Lamprey have not been studied, but they are assumed to be similar to those of Columbia River Pacific Lamprey with 64°F for maximum survival of eggs and prelavae and 72°F and above for minimum survival (Meeuwig et al. 2005). HEC-5Q modeling results indicate that mean monthly water temperatures in the Sacramento River between Keswick and RDBB during the February through May spawning and egg/prelarvae incubation period would be consistently below 64°F, with minor differences between the alternatives (Tables O.3-44 through O.3-47). It should be noted that River Lamprey are believed to spawn in tributary streams rather than the mainstem, but this is uncertain (Moyle et al. 2015). During September, when River Lamprey larvae would be present in the river, mean water temperatures would exceed the 64°F optimal temperature at RBDD in critically dry water years. September has the highest water temperatures of the year upstream of RBDD. Mean September water temperatures at RBDD for individual years exceed 64°F in about 7% of years for both alternatives, but are below 72°F for all years (Figure O.3-22). The downstream distribution of River Lamprey larvae is uncertain, but if the larvae drift well downstream of RBDD or enter the Sacramento River from downstream tributaries, they would subject to higher water temperatures, especially during July and August. However, there are few differences between July and August water temperatures at the downstream temperature modeling sites, except in below normal water years when water temperatures are about 1 dgree Fahrenheit cooler under Alternative 3, which would likely benefit the larvae (Table O.3-48 and O.3-49; Figure O.3-45). There are no biologically meaningful differences in water temperature conditions for River Lamprey between the No Action Alternative and Alternative 3.

The CalSim II flow results and the HEC-5Q water temperature results indicate that Alternative 1 would have a less-than-signficant impact on River Lamprey relative to the No Action Alternative.

O.3.7.2.11 Hardhead

Hardhead are believed to spawn in riffles, runs, and heads of pools, primarily during April and May (Moyle et al. 2015). Most spawning probably occurs in tributaries rather than in the Sacramento River mainstem (Moyle et al. 2015). Larvae and juveniles likely inhabit stream margins with abundant cover, and move into deeper habitats as they grow larger. Adults occupy the deepest part of pools. Juvenile and adult Hardhead are present in the Sacramento River year-round. They tend to prefer water temperatures near 67°F (Thompson et al. 2012), but have been captured at RBDD, where water temperatures are generally much cooler (USFWS 2002) (Table O.3-9).

Spawning success of Hardhead in the lower Tuolumne River is highest when there are higher flows during in April and May (Brown and Ford 2002), which is likely true for the Sacramento River Hardhead as well. The CalSim II results for Keswick, Red Bluff, Hamilton City, and Wilkins Slough indicate that monthly mean flow would be moderately higher under Alternative 3 than under the No Action Alternative during the April and May peak spawning months (Tables O.3-43, O.3-50 through O.3-52). During most of the other months, flows would generally be similar between Alternative 3 and the No Action Alternative, but, from Keswick Dam to Wilkins Slough, they would be 9 to 33% higher under Alternative 3 in June of all water year types and would be 25% to 36% lower in September and November of wet and above normal water years. The large flow reductions in September and November would likely have little effect on hardhead because they are predicted for wet and above normal years, when flows are generally high, and because by September and November, hardhead hatched in the spring would be well developed and have gravitated to deeper water. Similarly, the large flow increases in June would likely have little effect because June flows are adequate under both alternatives. The flow effects of Alternative 3 are not expected to substantially affect hardhead.

Hardhead juveniles and adults performed well in laboratory tests at water temperatures from about 61 to 70°F (Thompson et al. 2012). They consistently preferred a mean water temperature of 67°F and avoided temperatures above about 79°F. HEC-5Q modeling results indicate that mean monthly water temperatures in the Sacramento River would be below 79°F at all locations under both alternatives (Tables O.3-44 through O.3-49). There would be only minor differences in mean water temperatures between the alternatives, except for moderate increases under Alternative 3 during September of wet and above normal water years. However, these mean water temperatures would be only slightly warmer than the Hardhead preferred temperature, and only at Knights Landing (Table O.3-49). There are no biologically meaningful differences in water temperature conditions for Hardhead between the No Action Alternative and Alternative 3.

The CalSim II flow results and the HEC-5Q water temperature results indicate that Alternative 3 would have no impact on Hardhead relative to the No Action Alternative.

O.3.7.2.12 Central California Roach

Given that most Central California Roach inhabit tributary streams rather than the mainstem Sacramento River and have a broad range of habitat types and temperature tolerances, as discussed under Alternative 1, it is unlikely that flow or water temperature conditions under Alternative 3 would adversely affect California Roach. Therefore, Alternative 3 is expected to have no impact on Central California Roach relative to the No Action Alternative.

O.3.7.2.13 Striped Bass

Striped Bass spawn in the Sacramento River primarily between about Verona (RM 78) and Wilkins Slough (RM 121) during April through June (Moyle 2002). No spawning occurs until water temperature reaches 57 degrees Fahrenheit (Moyle 2002). The eggs are free-floating and negatively buoyant and hatch in about two days after spawning (at 66°F) as they drift downstream. Low flows can result in eggs settling on the bottom, which they cannot survive for long. The larvae may inhabit shallow, open water of the lower river from April to mid-June and then are carried by flows to the Delta and Suisun Bay (Stevens 1966; Moyle 2002). Adult striped bass are found in the upper Sacramento River at RBDD and upstream, primarily from late spring through early fall, where they forage heavily on juvenile salmon and other fish (Tucker et al. 1998).

High flows in April through June benefit striped bass eggs because they help prevent them from settling to the river bottom. High flows likely also accelerate transport of Striped Bass larvae to their nursery habitats in the Delta and Suisun Bay (Moyle 2002). CalSim II flow results for Wilkins Slough indicate that mean monthly flow during April through June under Alternative 3 would be similar to or higher than flow under the No Action Alternative, with higher flow especially in May and June, which would potentially benefit conditions for eggs and larvae drifting downstream (Table O.3-34). The greatest reductions in flow resulting from Alternative 3 would occur in September and November of wet and above normal water years. Adult Striped Bass may reside throughout the Sacramento River in September (Tucker et al. 1998). However, although the Alternative 3 mean monthly flows are reduced from the No Action Alternative flows in wet and above normal years, they remain close to or well above 5,000 cfs (Table O.3-50 through O.3-52), which is likely adequate for foraging Striped Bass.

Optimal spawning temperature range for Striped Bass is 59 to 68°F and spawning ceases at about 70°F (Moyle 2002). The eggs can withstand temperatures of about 54 to 75°F, with the optimum being about 64°F (Emmett et al. 1991). Larvae tolerate temperatures of 50 to 77°F, but optimal temperatures for survival are 59 to 72°F (Emmett et al. 1991). Striped Bass adults and juveniles are tolerant of a wide range and rapid swings of water temperatures. The adults appear to prefer water temperatures ranging from about 68 to 75°F (Emmett et al., 1991) and juveniles prefer rearing temperatures of 61 to 66°F (Hasler 1988). Adults are under stress at temperatures over 77°F, and temperatures over 86°F are lethal (Moyle 2002).

HEC-5Q modeling results indicate that mean monthly water temperatures in the Sacramento River at Knights Landing during the April through June spawning period would be within the optimal range for spawning in April of all but wet years and in May of all but critically dry years, but would be above the optimal range in June during all water year types (Table O.3-49). The mean monthly temperatures would be below the optimal range for adults during April and May of all water year types except critically dry years in May, but would be within this range in all water year types in June. The temperatures would be acceptable for eggs and optimal for larvae throughout the spawning period (Table O.3-49). Juvenile striped bass generally do not occur in the Sacramento River upstream of the Delta. The adults, as noted earlier, may forage in the river upstream to and above RBDD from about May through early October. Mean monthly water temperatures at RBDD throughout this period would be well below the optimal range for adults (Table O.3-47).

The largest difference in water temperatures between the No Action Alternative and Alternative 3 at Knights Landing during the Striped Bass spawning season are moderate reductions in May of below normal and dry years and June of above normal, below normal and dry water years (Table O.3-31). With these reductions, water temperatures under Alternative 3 would be closer to the optimal range for spawning than those under the No Action Alternative, providing a minor benefit. The largest temperature differences at any time of year are substantial increases under Alternative 3 for September of wet and above normal water years. These increases would be potentially beneficial for foraging Striped Bass adults because the No Action Alternative water temperatures for these months and water year types would be well below the optimal range for adults throughout the river (Tables O.3-47 through O.3-49).

The CalSim II flow results and the HEC-5Q water temperature results indicate that Alternative 3, with regard to flow and water temperature, would have a less-than-significant impact on Striped Bass relative to the No Action Alternative.

O.3.7.2.14 American Shad

American shad migrate upstream in the Sacramento River starting in March, and typically spawn from April to June. Water temperature influences the timing of runs, with peak runs and spawning usually occurring at water temperatures of 62 to 75°F (Moyle 2002). Shad eggs drift downstream from spawning areas and hatch in 3 to 12 days, depending on water temperature (MacKenzie et al. 1985). However, more rapid development at higher temperatures appears to be associated with lower survival rates of embryos (Moyle 2002). Larval shad are planktonic for about 4 weeks, after which they metamorphose to actively swimming juveniles. Juveniles spend the next several months in freshwater, and seem to prefer temperatures of 63 to 77°F. In the Sacramento River, summer rearing habitat occurs in the main river from Colusa to the north Delta (Stevens et al. 1987). As the season progresses, juvenile shad move downstream and enter salt water primarily during September through November (Moyle 2002). In general, variations in river discharge and temperature during early larval development are considered important regulators of year-class strength and recruitment of American shad (Hinrichsen et al. 2013). Although the importance of various potential mechanisms is unknown, the abundance of juvenile American shad in the Sacramento-San Joaquin Delta has been shown to be positively correlated with freshwater inflow during the April through June spawning and nursery periods (Stevens et al. 1987, Kimmerer 2002, Kimmerer et al. 2009).

During the spawning and larval rearing period (April through June), CalSim II modeling results at Wilkins Slough indicates that average monthly flows in May and June under Alternative 3 would be higher than those under the No Action Alternative, which may have positive effects on spawning and early rearing success of American shad (Table O.3-52). In addition, with higher flows under Alternative 3, HEC-5Q modeling results indicate that mean monthly temperatures in the lower Sacramento River (Knights Landing) during May and June would be lower on average, which may improve water temperatures for developing embryos and larvae (Table O.3-49; Figures O.3-41 and O.3-91). The largest differences in flows and water temperatures in the Sacramento River under Alternative 3 and the No Action Alternative would occur in September and November of wet and above normal water years (Table O.3-49 and O.3-52). However, the importance of river inflows and river temperatures for juvenile shad in September and November is unknown. Correlations between Delta inflows and abundance of juvenile shad have been demonstrated for the months of April through August, with the highest correlations in April through June, suggesting that the principal factors influencing abundance occur during periods of larval dispersal and transport. Sacramento River flows and temperatures under Alternative 3 may have minor benefits to American Shad relative to the No Action Alternative, but because the potential effects are highly uncertain, Alternative 3 is considered to have a less-than-significant effect on American Shad.

O.3.7.2.15 Largemouth Bass

The Sacramento River above the Delta generally provides poor habitat conditions for Largemouth Bass because of large seasonal flow fluctuations, relatively cold water, and lack of suitable nesting and rearing habitat. Consequently, Largemouth Bass populations in the Sacramento River above the Delta are largely dependent on upstream sources, including reservoirs, floodplain ponds and sloughs, and irrigation canals that provide suitable conditions for spawning and rearing during the late spring and summer months.

Largemouth bass spawning activity typically starts in April when water temperatures reach 59 to 61°F, and continues through June (Moyle 2002). Nests are typically constructed at a depth of about 3 feet (Brown et al. 2009a). Optimal temperatures for successful spawning and incubation are 68 to 70°F, although spawning is generally observed over a range of 55°F to 79°F (Stuber et al. 1982). Eggs hatch in 2 to 7 days after spawning and the sac fry usually spend 5 to 8 days in the nest until they begin actively feeding (Moyle 2002). Optimal temperatures for growth of juvenile and adult bass range from 77 to 86°F, although growth will occur over a much wider range (50°F to 95°F) (Moyle 2002).

The CALSIM II and HEC-5Q modeling results for Alternative 3 indicate that Sacramento River flows would be higher and water temperatures would be lower in May and June relative to the No Action Alternative, potentially affecting largemouth bass spawning and incubation (Tables O.3-49 and O.3-52). However, based on modeled mean monthly water temperatures in the lower Sacramento River at Knights Landing, no substantial changes would be expected to occur in the frequency of suitable water temperatures for spawning and incubation (Figures O.3-41 and O.3-91). The relatively large changes in flows and water temperatures in September and November of wet and above normal years under Alternative 3 (Tables O.3-49 and O.3-52) could also affect habitat conditions for juvenile and adult bass, but water temperatures would remain below optimum levels for growth under both alternatives. Consequently, the generally poor habitat conditions for largemouth bass in the Sacramento River under the No Action Alternative would persist under Alternative 3. Therefore, changes in Sacramento River flows and water temperatures associated with Alternative 3 would have a less-than-significant effect on largemouth bass in the Sacramento River relative to the No Action Alternative.

O.3.7.2.16 Smallmouth Bass

The temperature optimal range for Smallmouth Bass spawning is 55 to 70°F (Brown et al. 2009b) and the optimal for adult growth is approximately 77 to 80°F, but rapid growth of has been seen in the wild at temperatures as high as 84°F, providing prey is abundant (Moyle 2002). Young-of-year Smallmouth Bass will select temperatures as high as 84 to 87°F. Populations are rarely established in water temperatures that do not exceed 66°F in summer for extended periods, and most smallmouth populations in California are present where summer temperatures are typically 69 to 71°F. In northern California reservoirs most spawning takes place in May and June, but spawning in streams may occur into July, depending on flows and temperatures. Males start making nest depressions when water temperatures reach 55°F to 61°F. The nests are typically built at depths of about 3 to 8 feet (Brown et al. 2009). In streams, nesting and reproduction can be disrupted by flow reductions that lead to nest dewatering, or elevated flows that wash embryos and fry out of nests or lower water temperatures excessively (Graham and Orth 1986; Lukas and Orth 1995).

CalSim II results for Wilkins Slough flow for Alternative 3 compared to No Action Alternative during the May through July spawning season indicate moderately increased flow during May and June of all of the water year types, except May of wet years, and slightly reduced flow in July, except in critically dry water years (Table O.3-52). Higher flows could adversely affect embryos and fry by dewatering nests or washing them out of the nests, but it is unknown what magnitude of flows would have these effects.

HEC-5Q monthly mean water temperatures at Hamilton City consistently fall within the 55°F to 70°F optimal spawning range during the spawning season of May through July under both Alternative 3 and the No Action Alternative (Table O.3-48). At Knights Landing, however, the temperatures fall within the optimal range during May of all water year types, but lie above the range during June and July of most water year types (Table O.3-49). The water temperatures under Alternative 3 are generally similar or moderately lower than those under the No Action Alternative. The monthly mean summer water temperatures at Hamilton City consistently fall below the 66°F threshold that has been found to be a minimum for Smallmouth Bass to establish populations in California (Moyle 2002), except for critically dry water years in August and September (Table O.3-48). At Knights Landing, however, the 66°F threshold is exceeded in all summer months and water year types except September of wet and above normal years under the No Action Alternative (Table O.3-49). Note that the large wet-and-above-normal-year September water temperature increases under Alternative 3 result in water temperatures exceeding the threshold, which may benefit Smallmouth Bass. The mean water temperatures are consistently well below the optimal range for adult growth, 77 to 80°F, at both locations.

The CalSim II flow and HEC-5Q water temperature results indicate that Alternative 3 would have a less-than-significant impact on Smallmouth Bass relative to the No Action Alternative with regard to flow and water temperature.

O.3.7.2.17 <u>Spotted Bass</u>

Spotted Bass inhabit streams and reservoirs and prefer moderate-size, clear, low-gradient sections of rivers and reservoirs (McKechnie 1966). They prefer pool habitat and slower, more turbid water than Smallmouth Bass but faster water than Largemouth Bass (Moyle 2002). Their summer water temperature preference is 75 to 87°F (Moyle 2002). In streams, nests are constructed in low-current areas on bottoms ranging from debris to gravel (Moyle 2002). Spawning depths are deeper than those of largemouth bass (Aasen and Henry 1981). They spawn in the spring when water temperatures rise to 59°F to 64°F (Aasen and Henry 1981; Howland 1931). Spawning continues through late May and early June, until temperatures reach 71 to 73°F.

During the spring (April through June) spawning season, CalSim II results for Wilkins Slough monthly mean flows under Alternative 3 are mostly higher than the No Action Alternative flows (Table O.3-52). Higher flows could adversely affect embryos and fry by dewatering nests or washing them out of the nests, but it is unknown what magnitude of flows would have these effects.

HEC-5Q monthly mean water temperatures at Knights Landing during the spawning season of April through June would largely be within the 59°F to 64°F spawning range in April under Alternative 3 and the No Action Alternative, but would exceed the range in May and June under both alternatives. The preferred summer water temperatures range of 75 to 87°F would be available only in critically dry years, especially in August, under both Alternative 3 and the No Action Alternative (Table O.3-49).

The CalSim II flow results and the HEC-5Q water temperature results indicate that Alternative 3, with regard to flow and water temperature, would have a less-than-significant impact on Spotted Bass relative to the No Action Alternative.

Potential changes to aquatic resources in the Sacramento River from Shasta cold water pool management

Shasta Cold Water Pool Management will not occur under either Alternative 3 or the No Action Alternative. Therefore, Alternative 3 and the No Action Alternative are likely to have similar effects on aquatic resources with respect to some potential effects of this action. However, the No Action Alternative includes NMFS's 2009 BO RPAs to operate Shasta Reservoir for management of cold water in the reservoir and river for protection of anadromous salmonids, and includes requirements for Fall X2 flow releases, but Alternative 3 includes neither requirement. The effects of these differences in operations on water temperatures and flows in the Sacramento River and potential effects on water temperature and flow differences on the focal fish species in the river are discussed above in the assessments for the individual fish species in the section *Potential changes to aquatic resources in the Sacramento River from seasonal operations* under Alternative 3.

Potential changes to aquatic resources in the Sacramento River from spring pulse flows.

Spring Pulse Flows for fish will not occur under either Alternative 3 or the No Action Alternative. Therefore, Alternative 3 and the No Action Alternative are likely to have similar effects on aquatic resources with respect to potential effects of this action.

Potential changes to aquatic resources in the Sacramento River from fall and winter refill and redd maintenance.

Fall and winter refill and redd maintenance will not occur under either Alternative 3 or the No Action Alternative. Therefore, Alternative 3 and the No Action Alternative are likely to have similar effects on aquatic resources with respect to potential effects of this action.

Potential changes to aquatic resources in the Sacramento River from rice decomposition smoothing.

Rice decomposition smoothing will not occur under either Alternative 3 or the No Action Alternative. Therefore, Alternative 3 and the No Action Alternative are likely to have similar effects on aquatic resources with respect to potential effects of this action.

Potential changes to aquatic resources in the Sacramento River from spring management of spawning locations.

Rice decomposition smoothing will not occur under either Alternative 3 or the No Action Alternative. Therefore, Alternative 3 and the No Action Alternative are likely to have similar effects on aquatic resources with respect to potential effects of this action.

O.3.7.3 *Clear Creek*

O.3.7.3.1 Whiskeytown Reservoir Operations

Alternative 3 would incorporate the same flow and operations as described in Alternative 2 to meet requirements in D-1641 and other legal requirements and would incorporate habitat restoration and intervention measures. Under both the No Action Alternative and Alternative 3, flows from Whiskeytown Dam to Clear Creek would be managed for base flow of 50 cfs to 100 cfs based on downstream water rights and the 1963 Reclamation proposal to USFWS and NPS. Unlike the No Action Alternative, there would be no planned channel maintenance flows or pulse flows released from Whiskeytown Dam under Alternative 3.

Under current operations and the No Action Alternative, Whiskeytown Lake is annually drawn down 13 feet (approximately 35 TAF) between November and April for flood control purposes, although it can be lowered as much as 30 feet as needed for maintenance. Model output for Whiskeytown Lake predicts that compared to the No Action Alternative, minimum reservoir volumes would be lower under Alternative 3 during the months of May and June (1.3 TAF and 0.1 TAF lower, respectively) (Figure O.3-118, Table 0.3-53). During those two months, water surface elevations would also be lower under Alternative 3 compared to the No Action Alternative. In April, water surface elevations would be 1.6 TAF higher under Alternative 3 compared to the No Action Alternative. In all other months, Whiskeytown Lake storage volume under Alternative 3 would be either identical or 0.1 TAF to 0.2 TAF higher than under the No Action Alternative.

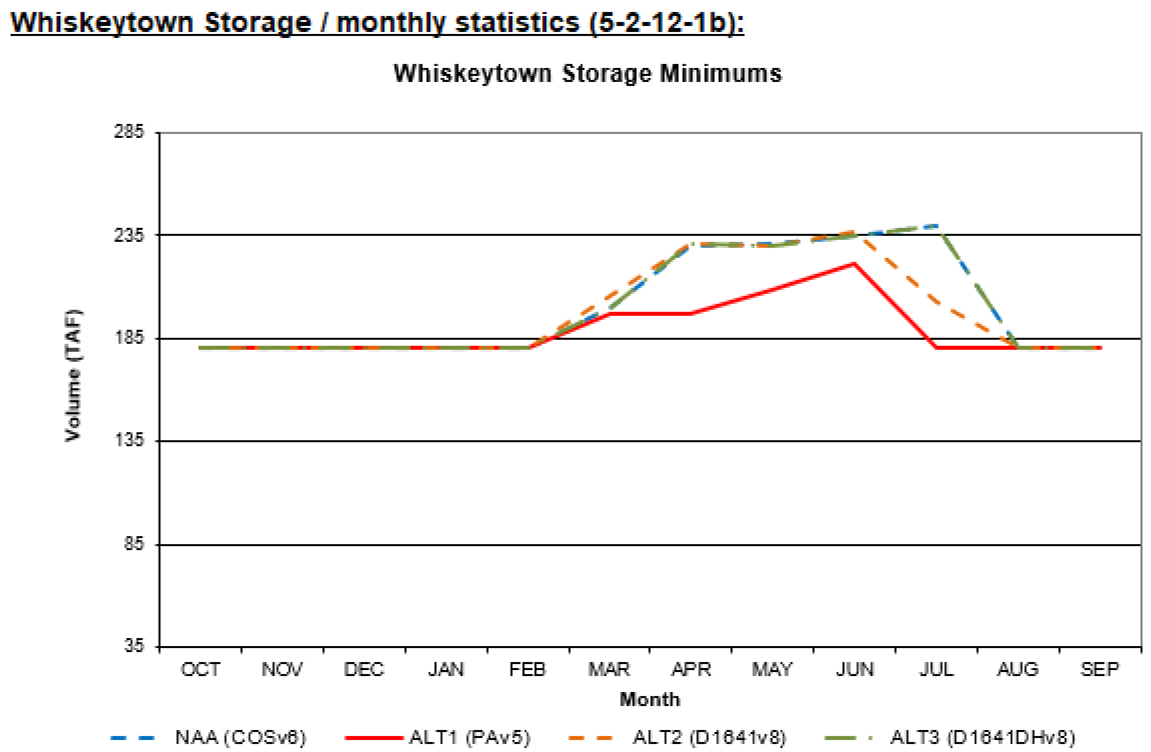


Figure O.3-118. Modeled Whiskeytown Lake Monthly Minimum Storage Volume under the No Action Alternative, Alternative 1, Alternative 2, and Alternative 3 during all Water Year Types

Table 0.3-53. Modeled differences in Whiskeytown Lake monthly minimum storage volumes from March to July under Alternative 3 relative to the No Action Alternative.

Month	Change in Volume from No Action Alternative (TAF)
March	0.2
April	1.6
May	-1.3
June	-0.1
July	0.0

The proposed additional seasonal draw-downs in May and June under Alternative 3 could cause an increase in bank and bed erosion in newly exposed areas of tributary stream mouths where they are devoid of stabilizing riparian vegetation. This scour could cause channel incision (i.e., down-cutting) and result in increased lake water turbidity. Channel incision can create erosional nick points that propagate upstream until they encounter scour-resistant grade-controlling materials such as bedrock, at which point a cascade can form. However, annual minimum storage volume is not expected to change under this alternative. The additional draw-downs therefore represent a change in timing and duration of lower water surface elevation, not a new type or mechanism of disturbance, and channel incision may have already occurred and stabilized as a result of past operations.

Potential changes to aquatic resources in Clear Creek from seasonal variation in water surface elevation

Hardhead

Hardhead migrate from the reservoir into tributaries in April and May to spawn upstream of Whiskeytown Lake. The timing of proposed increased draw-downs from March through July under Alternative 3 could affect Hardhead if the lower water surface elevations in May expose any previously submerged cascades at tributary mouths or create new ones. No such cascades have been documented, but if they are present or created by tributary incision at low water, they could present barriers to migration that would prevent reservoir-dwelling adult Hardhead from spawning in tributary streams. Alternately, higher water surface elevation in April may benefit migrating Hardhead at the start of their upstream migration season.

Hardhead are not a cold-water species, so drawing additional cold water from the bottom layers of the reservoir would not be expected to affect them directly. Hardhead have shown sensitivity to high sediment loads (Gard 2002), so increased reservoir turbidity due to varial zone erosion during draw-down periods could reduce suitability of reservoir and downstream waters for Hardhead persistence.

The increased annual variations in reservoir water surface elevation under Alternative 3 could cause Hardhead to be affected by reducing habitat connectivity and increasing water turbidity. However, changes to storage volume and water surface elevation in Whiskeytown Lake are relatively small under Alternative 3 compared to the No Action Alternative, and higher water surface elevation in April could benefit migrating Hardhead at the start of their upstream migration season.

Other Fish Species

Central California Roach are not likely to be affected by changes in reservoir operations because, although they are found in upstream tributaries, they do not reside in Whiskeytown Lake, having likely been extirpated from the reach after the reservoir was originally filled in 1963. Future operations of Whiskeytown Dam under Alternative 3 are therefore unlikely to affect either individuals or populations.

Increased annual variations in reservoir water surface elevation under Alternative 3 compared to the No Action Alternative could cause varying effects to stocked and introduced nonnative game species in Whiskeytown Lake. Stocked species would not be expected to be affected by changes in reservoir operations. Rainbow Trout, Brown Trout, Kokanee Salmon, and Brook Trout typically spawn in tributary streams, but they are capable of spawning in lakes if they are unable to access moving water. Whiskeytown Lake Kokanee spawn in the fall, a period when no differences in water levels are expected under Alternative 3 compared to the No Action Alternative. Pond species such as Largemouth Bass, Smallmouth Bass, Spotted Bass, Bluegill, Black Crappie, Channel Catfish, and Brown Bullhead are able to tolerate a wide range of conditions, but the basses and panfish spawn in relatively shallow lake areas when water warms to at least 50°F in late spring or summer. Reducing reservoir volume in May and June could put some of their nests at risk of being dewatered in years when springtime conditions are warm. However, these species have rapid reproductive rates which can enable them to recover from episodic recruitment failures.

O.3.7.3.2 Clear Creek Flows

Potential changes to aquatic resources in Clear Creek from variation in flow

Under Alternative 3 Reclamation proposes minimum base flows in Clear Creek of 50 cfs to100 cfs in normal water years and 30 cfs to 70 cfs in critically dry water years, based on downstream water rights and the 1963 Reclamation proposal to USFWS and NPS, as described in the No Action Alternative (Table 3). Alternative 3 flows do not include predetermined CVPIA 3406(b)(2) flows and NMFS BO Action I.1.1, which are included in the No Action Alternative. Additionally, under Alternative 3 there are no channel maintenance flows or pulse flows, whereas under the No Action Alternative channel maintenance flows occur when flood operations occur and 2 pulse flows are released in May and June of at least 600 cfs for at least 3 days for each pulse per year.

Modeling results show that flows and temperatures in Clear Creek downstream of Whiskeytown Dam would be the same under Alternative 3 as those described under Alternative 2. Effects of flow and water temperature in Clear Creek downstream of Whiskeytown Dam to listed species would be the same under Alternative 3 and Alternative 2.

O.3.7.3.3 Spring Creek Debris Dam

Existing operations of the SCDD will continue under both Alternative 3 and the No Action Alternative. Therefore, Alternative 3 and the No Action Alternative are likely to have similar effects on aquatic resources.

O.3.7.3.4 Clear Creek Restoration Program

The Clear Creek Restoration Program is being implemented under both Alternative 3 and the No Action Alternative. Therefore, Alternative 3 and the No Action Alternative are likely to have similar effects on aquatic resources.

O.3.7.4 *Feather River*

O.3.7.4.1 <u>FERC Project #2100-134</u>

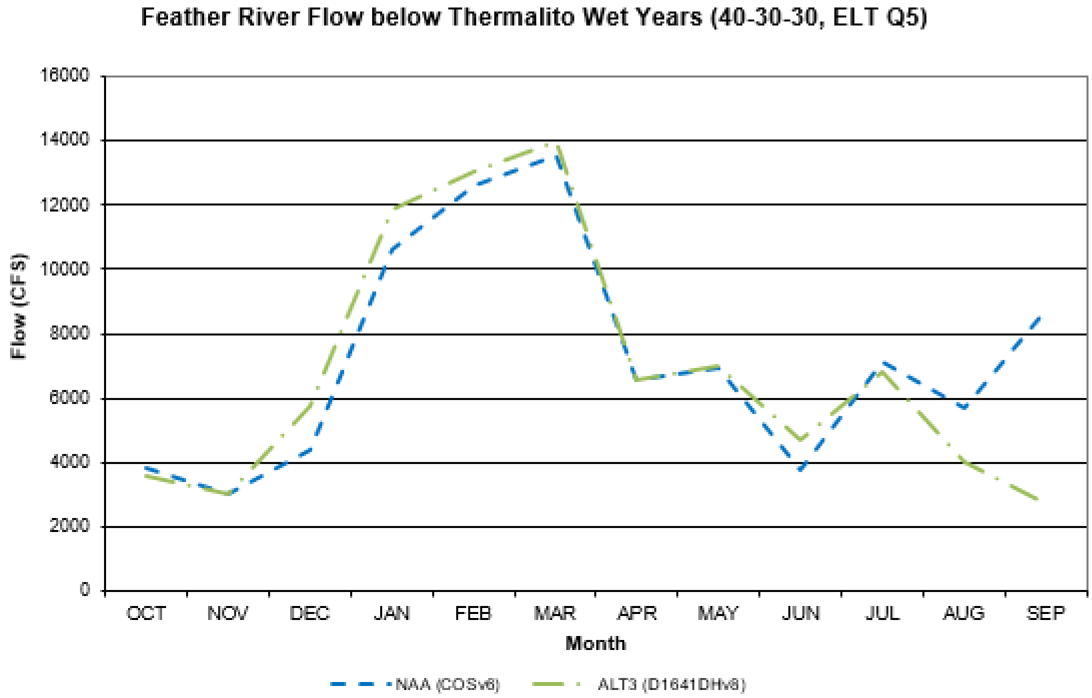
DWR, under Alternative 3, would operate Oroville Dam consistent with the NMFS, USFWS, and CDFW environmental requirements applicable for the current FERC License for the Oroville Complex (FERC Project #2100-134). Reclamation would operate Oroville Dam with minimum flows of 700 cfs to 800 cfs below the Thermalito Diversion Dam in the low flow channel (2006 Settlement Agreement), 750 cfs to 1,700 cfs below the Thermalito Afterbay outlet (1983 DWR-CDFG Agreement), and the DFG/DWR operation objective of 2,800 cfs at the mouth of the Feather River from April through September, with options to vary flow depending on year types. Under the No Action Alternative, DWR would operate Oroville Dam in accordance with ongoing management policies, criteria, and regulations, including water right permits and licenses issued by the SWRCB and operational requirements of the 2008 USFWS BO and the 2009 NMFS BO. Under the No Action Alternative, DWR typically releases water from Lake Oroville to meet the requirements of instream flows and D-1641.

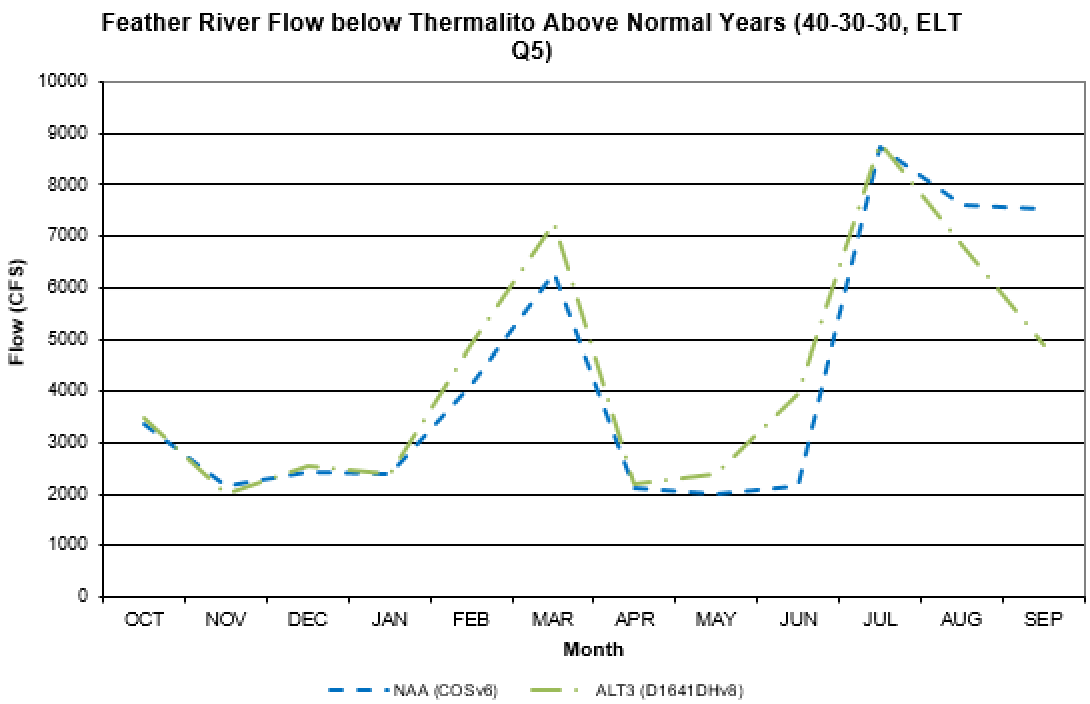
Potential changes to aquatic resources in the Feather River due to seasonal variation in flow

CalSim II model output shows that Feather River flows under Alternative 3 and the No Action Alternative would comply with Feather River HFC minimum instream flow requirements during all months in wet, above normal, and below normal water years. In dry years where the preceding April to July unimpaired runoff is less than 55% of normal, Alternative 3 and the No Action Alternative would comply with minimum instream flow requirements in the HFC; however, where the preceding April to July unimpaired runoff is greater than 55% of normal, Alternative 3 would not comply with minimum instream flow requirements from October through March (Figure O.3-119). In critically dry years where the preceding April to July runoff is 55% or greater of normal, Alternative 3 and the No Action Alternative would not comply with minimum instream flows from October to March; however, where the preceding April to July runoff is less than 55% of normal, Alternative 3 and the No Action Alternative would not comply with minimum instream flow requirements in the HFC only in November (Figure O.3-119).

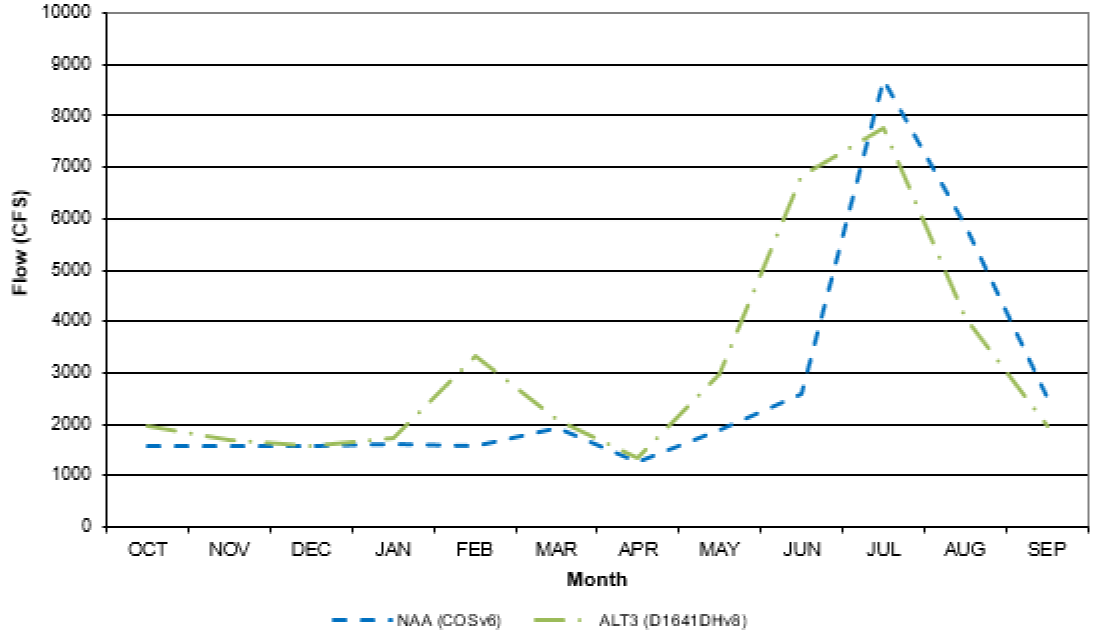
Overall, flows under Alternative 3 and the No Action Alternative are similar, but flows under the No Action Alternative are greater than flows under Alternative 3 from July through September of wet and above normal, and below normal years, and flows under Alternative 3 are greater than under the No Action Alternative from April through June of below normal, and dry water years (Figure O.3-121). Flows under Alternative 3 are also much greater than under the No Action Alternative in February of below normal years.

Overall, flows under Alternative 3 and the No Action Alternative are similar, but flows under the No Action Alternative are greater than flows under Alternative 3 from July through September of wet and above normal, and below normal years, and flows under Alternative 3 are greater than under the No Action Alternative from April through June of below normal, and dry water years (Figure O.3-121). Flows under Alternative 3 are also much greater than under the No Action Alternative in February of below normal years.

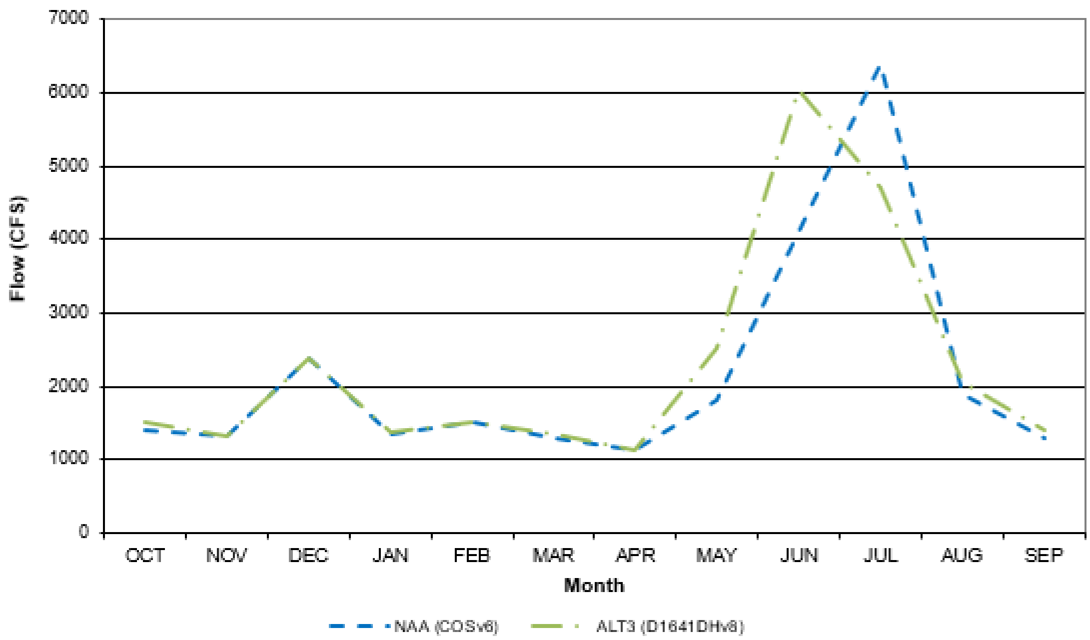

Feather River Flow below Thermalito Wet Years (40-30-30, ELT Q5)
Flow (CFS)
16000
14000
12000
10000
8000
6000
4000
2000
0
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
Month
NAA (COSv6)
ALT3 (D1641DHv8)


Feather River Flow below Thermalito Above Normal Years (40-30-30, ELT Q5)
Flow (CFS)
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
Month
NAA (COSv6)
ALT3 (D1641DHv8)

Feather River Flow below Thermalito Below Normal Years (40-30-30, ELT Q5)



Feather River Flow below Thermalito Dry Years (40-30-30, ELT Q5)



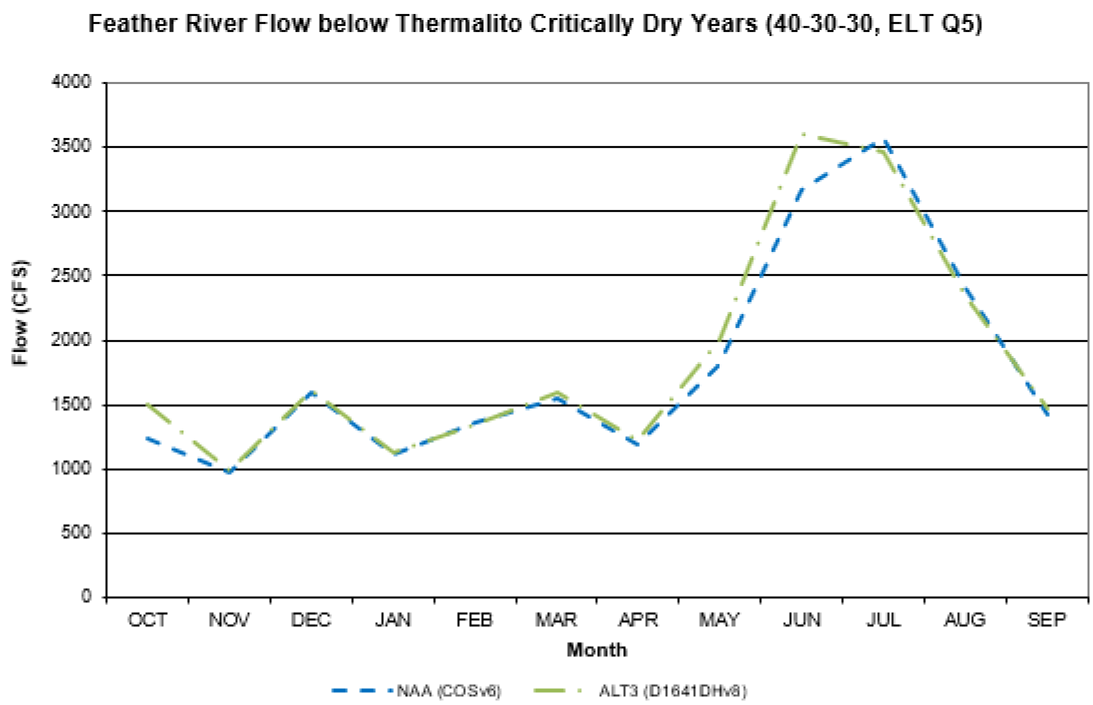


Figure O.3-119. CalSim II Estimates of Feather River Long-Term Average Flow below Thermalito, All Scenarios in Wet, Above Normal, Below Normal, Dry, and Critically Dry Water Years

Winter-Run Chinook Salmon

Winter-Run Chinook Salmon are not likely to be affected by changes in flow under Alternative 3 compared to the No Action Alternative due to their limited distribution in the Feather River.

Spring-Run Chinook Salmon

Spring-Run Chinook Salmon would be exposed to the effects of Alternative 3 based on their seasonal occurrence in the Feather River, minimum instream flow requirements in the HFC, and compliance with D-1641. Eggs and emerging fry of Spring-Run Chinook Salmon occur in the Feather River from September through February (NMFS 2016a); juvenile Spring-Run Chinook Salmon occur in the Feather River year-round, with peak abundance from November through May; and adult Spring-Run Chinook Salmon have a peak abundance in the Feather River from March through June. All life stages would thus be exposed to the effects of Alternative 3.

Spring-Run Chinook Salmon eggs and emerging fry would potentially benefit from increased Alternative 3 flows, leading to increased dissolved oxygenand decreased temperature in February of dry years when Alternative 3 flows are significantly higher than No Action Alternative flows (Figure O.3-119). Juvenile Spring-Run Chinook Salmon would benefit from increased Alternative 3 flows relative to No Action Alternative flows from November through March of wet years, January through April of above normal years, and February of below normal years when the increased flows could result in increased rearing and foraging habitat, higher dissolved oxygencontent, and reduced water temperatures (Figure O.3-119). Adult Spring-Run Chinook Salmon would benefit from increased Alternative 3 flows relative to No Action Alternative flows from April through June of below normal, dry, and critically dry years due to the resulting increased attraction flows and holding habitat (Figure O.3-119). Because Alternative 3 flows are higher than No Action Alternative flows during key months of all Spring-Run Chinook Salmon life stages, Alternative 3 may provide benefits for Spring-Run Chinook Salmon.

Fall-Run Chinook Salmon

Fall-Run Chinook Salmon would be exposed to the effects of Alternative 3 based on their seasonal occurrence in the Feather River, minimum instream flow requirements in the HFC, and compliance with D-1641. Fall-Run Chinook Salmon occur in the Feather River year-round, with eggs and emerging fry occurring between January and April, juveniles out-migrating year-round with peaks from January to April and August to November, and holding and migrating adults occurring between April and July (NMFS 2016a). All life stages would thus be exposed to the effects of Alternative 3.

Fall-Run Chinook Salmon eggs and emerging fry would benefit from increased dissolved oxygenand decreased temperatures due to higher Alternative 3 flows from January to April of wet and above normal years and in February of below normal years (Figure O.3-119). Juvenile Fall-Run Chinook Salmon could benefit from increased Alternative 3 flows relative to No Action Alternative flows from January to April of wet and above normal years and in February of below normal years when increased flows result in increased rearing and foraging habitat, higher DO, and reduced water temperatures (Figure O.3-119). Migrating adult Fall-Run Chinook Salmon would benefit from increased Alternative 3 flows relative to No Action Alternative flows from April to July of below normal, dry, and critically dry years due to increased attraction flows and holding habitat (Figure O.3-119). Because Alternative 3 flows are higher than No Action Alternative flows during key months of all Fall-Run Chinook Salmon life stages, Alternative 3 may provide benefits for Fall-Run Chinook Salmon.

Central Valley Steelhead

Central Valley Steelhead would be exposed to the effects of Alternative 3 based on their seasonal occurrence in the Feather River, minimum instream flow requirements in the HFC, and compliance with D-1641. Central Valley Steelhead eggs and fry occur in the Feather River from December to May; juveniles typically migrate to the ocean from January to May after spending 1 to 3 years in freshwater (CDFG 1996); peak adult migration occurs in September and October; and adult holding occurs December to March (NMFS 2016a).

Alternative 3 flows can affect Central Valley Steelhead by influencing water temperature, DO, sedimentation, substrate composition, habitat, food availability, predation, entrainment and stranding risk, habitat availability, and migration cues. Differences in flow under Alternative 3 and the No Action Alternative are minimal during the January to May period in which Central Valley Steelhead juveniles are out-migrating in all but below normal water years when Alternative 3 flows are considerably higher than No Action Alternative flows from mid-January through mid-March and can benefit juveniles via increased rearing and foraging habitat, higher dissolved oxygencontent, and reduced water temperatures (Figure O.3-119). The same is true for the December to May period in which Central Valley Steelhead eggs and fry are present in the Feather River. During the September and October adult peak migration period, No Action Alternative flows are considerably higher than Alternative 3 flows in September in wet and above normal water years, causing higher levels of flow attraction (Figure O.3-119); there are minimal differences in all other water years. During adult holding from December to March, differences between Alternative 3 and No Action Alternative flows are minimal except for in February of below normal water years when increased flows could increase available habitat. Because Alternative 3 flows are higher than No Action Alternative flows during key months of all Central Valley Steelhead life stages, Alternative 3 may provide benefits for Central Valley Steelhead.

North American Green Sturgeon

North American Green Sturgeon would be exposed to the effects of Alternative 3 based on their seasonal occurrence in the Feather River, minimum instream flow requirements in the HFC, and compliance with D-1641. Green Sturgeon eggs and larvae occur in the Feather River from March to July; larvae and juveniles occur from April to August; subadults occur year-round; and adults occur from March to August (NMFS 2016a).

Differences in flow under Alternative 3 and the No Action Alternative are minimal during all water years in the March to August period in which Green Sturgeon eggs, larvae, juveniles, and adults occur in the Feather River; subadults occur year-round. Thus, only subadults would be exposed to the larger differences between Alternative 3 and the No Action Alternative in February of below normal water years when Alternative 3 flows are greater than they are under the No Action Alternative and in September of above normal and wet water years when No Action Alternative flows are greater than they are under Alternative 3. Because flow differences between Alternative 3 and the No Action Alternative during key periods of Green Sturgeon presence in the Feather River are minimal flow-related actions under Alternative 3 are not anticipated to substantially affect North American Green Sturgeon.

Potential changes to aquatic resources in the Feather River due to changes in water temperature from differences in flow

Water flow combines with other environmental drivers to affect aspects of water quality such as temperature. Water temperatures influence the condition and survival of fish species during all stages of their life cycle. Optimal water temperatures can facilitate physiological responses including faster growth rates, reduced stress, and heightened immunity to disease, leading to a higher likelihood of survival. In contrast, effects of elevated water temperatures include an inability to satisfy metabolic demand and acute to chronic physiological stress, possibly leading to mortality (Stillwater Sciences 2006; Martin et al. 2017).

Water temperatures in the Feather River HFC at Gridley Bridge follow a seasonal pattern with a high point around 72°F in July or August and a low point around 47°F in January (Figure O.3-120). Flow releases from Oroville facilities primarily influence Feather River water temperatures in summer and fall when these releases can help alleviate elevated water temperatures. Minimum water temperatures in the Feather River do not change substantially between water year type, but water temperatures can reach a maximum up to 4°F warmer (approximately 75°F) in critically dry years than in wet years (approximately 71°F; Figure O.3-121). Effects of water temperature on fish in the Feather River vary among species and life stages. Temperatures surpass suboptimal levels for all species and life stages at 68°F and stress-inducing levels at 75.2°F (Table O.3-54). There is, therefore, potential for adverse temperature-related effects on Feather River fish species.

Alternative 3 was designed to follow flow regulation procedures similar to procedures under the No Action Alternative as a way to minimize potential adverse temperature-related effects on various fish species in the Feather River. Certain water temperature objectives were developed to aid the development of Alternative 3 operations (Table O.3-55).

Table O.3-54. Water temperatures suitable for Spring- and Fall-Run Chinook, Central Valley Steelhead, and Green Sturgeon by life stage

Life Stage	Peak Occurrence	Optimal	Suboptimal	Stress-inducing
Spring-Run Chinook				
Eggs to fry	September to October	< 54°F	54°F to 58°F	> 58°F
Rearing to out-migrating	November to May	< 60°F	60°F to 65°F	> 65°F
Migrating adults	March to June	< 56°F	56°F to 65°F	> 65°F
Adult holding	May to August	< 60.8°F	60.8°F to 66.2°F	> 66.2°F
Fall-Run Chinook				
Eggs to fry	October to April	48.2°F to 55.4°F	55.4°F to 62.6°F	> 62.6°F
Rearing to out-migrating	April to June	55.4°F to 68°F	68°F to 75.2°F	> 75.2°F
Migrating adults	June to April	50°F to 68°F	68°F to 69.8°F	> 69.8°F
Central Valley Steelhead				
Eggs to fry	January	46°F to 52°F	52°F to 55°F	> 55°F
Rearing to out-migrating	January to May	< 65°F	65°F to 68°F	> 68°F
Migrating adults	September to October	< 52°F	52°F to 70°F	> 70°F
Adult holding	December to March	< 60.8°F	60.8°F to 66.2°F	> 66.2°F
Green Sturgeon				
Eggs to fry	May to July	53°F to 65°F	65°F to 66°F	> 66°F
Rearing to out-migrating	May to October	58°F to 66°F	66°F to 69°F	> 69°F
Migrating adults	March to May	53°F to 64°F	64°F to 66°F	> 66°F
Post-spawn adults	March to August	46°F to 68°F	68°F to 70°F	>70°F

Sources: NMFS 2016a; Stillwater Sciences 2006; CDFG 2012a, 2012b.

Table 0.3-55. Maximum Daily Mean Water Temperature Objectives for the Feather River HFC

Period	Temperature (°F)
January 1 to March 31	56
April 1 to 30	61
May 1 to 15	64
May 16 to 31	64
June 1 to August 31	64
September 1 to 8	61
September 9 to 30	61
October 1 to 31	60
November 1 to December 31	56

Source: NMFS 2016a.

Modeled average water temperatures under both Alternative 3 and the No Action Alternative (Figure O.3-120) exceed the daily average water temperature objectives of 64°F from June 1 to August 31 and 61°F from September 1 to 30 (Table O.3-120). There is, therefore, potential for adverse temperature-related effects on Feather River anadromous fish species, although the presence and magnitude of these effects would vary between the different species and life stages. In particular, these modeled average temperatures would reach suboptimal or stress-inducing levels for Spring-Run Chinook eggs, fry, and adults, migrating Central Valley Steelhead, and Green Sturgeon eggs, fry, and post-spawn adults.

Modeling results indicate that water temperatures under Alternative 3 operations would be similar to temperatures under the No Action Alternative for much of the year (Figures O.3-120 and O.3-121). In August and September water temperatures in the Feather River at Gridley Bridge are projected to be, on average, up to 1°F warmer than under the No Action Alternative (Figure O.3-120). The most pronounced difference in August and September water temperatures between Alternative 3 and No Action Alternative scenarios would occur in wet years when this temperature difference could reach as much as 3°F and 1°F warmer in below normal years, whereas no difference is projected in dry or critically dry water years (Figure O.3-121). In below normal to dry water years, a notable difference in water temperature between Alternative 3 and No Action Alternative scenarios would occur instead in June, when Alternative 3 water temperatures would be lower than No Action Alternative temperatures by approximately 4°F (Figure O.3-121). In below normal to dry water years, a small difference in water temperature between Alternative 2 and No Action Alternative scenarios would also occur in July, when Alternative 2 water temperatures would surpass No Action Alternative temperatures by approximately 1°F (Figure O.3-121). These differences in water temperature between Alternative 3 and the No Action Alternative would therefore predominantly occur in summer months when water temperatures are higher (> 60°F) and more likely to lead to physiological stress and mortality.

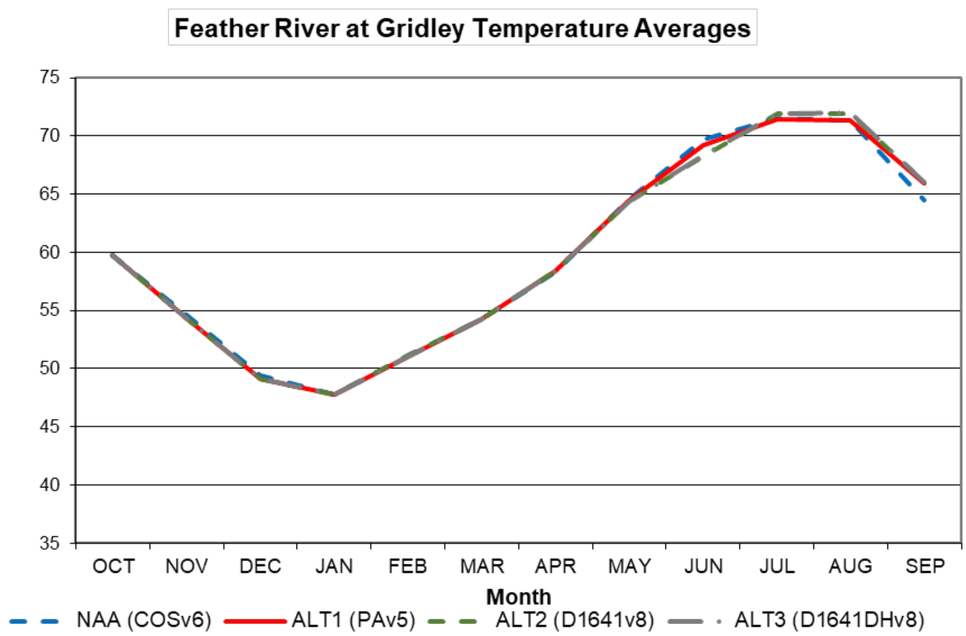


Figure O.3-120. RecTemp average Feather River water temperatures at Gridley Bridge under the No Action Alternative, Alternative 1, Alternative 2, and Alternative 3 scenarios.

Figure O.3-121. RecTemp Average Estimated Feather River Water Temperatures at Gridley Bridge in Wet, Above Normal, Below Normal, Dry, and Critically Dry Water Year Types under the No Action Alternative, Alternative 1, Alternative 2, and Alternative 3 Scenarios

Winter-Run Chinook Salmon

Winter-Run Chinook are not likely to be affected by changes in flow under Alternative 3 compared to the No Action Alternative due to their limited distribution in the Feather River.

Spring-Run Chinook

Effects of water temperature on Spring-Run Chinook have been heavily studied in the Feather River, resulting in an understanding of the optimal (beneficial), suboptimal, and stress-inducing (adverse) temperature ranges for each life stage (Table O.3-54).

In the Feather River, Spring-Run Chinook eggs and emerging fry occur from September to February, peaking in abundance from September to October (NMFS 2016a). The only difference in water temperature between Alternative 3 and No Action Alternative scenarios during this period would occur in September of wet to dry water years when temperatures under Alternative 3 flows would be higher than temperatures under No Action Alternative flows (Figure O.3-121). This would result in potentially adverse effects from the slightly higher water temperatures under Alternative 3 than under the No Action Alternative, yet water temperatures under both scenarios would fall in the stress-inducing range for this life stage (Table O.3-54). The slightly higher water temperatures in September under Alternative 3 in wet and above normal water years, therefore, would result in a negligible adverse effect on Spring-Run Chinook eggs and emerging fry relative to the effect of the No Action Alternative.

The occurrence of rearing juvenile Spring-Run Chinook in the Feather River is possible year-round, but peak abundance is usually between November and May. During this period of peak abundance, there is little to no projected difference between water temperatures under Alternative 3 and the No Action Alternative (Figure O.3-120); therefore, the effect of water temperatures on juvenile Spring-Run Chinook would be negligible under Alternative 3 operations relative to operations under No Action Alternative.

Migrating adult (ocean to river) Spring-Run Chinook reach the Feather River between March and June at generally consistent levels across all four months. During the first three months of this time span, water temperatures would be nearly identical under Alternative 1 and the No Action Alternative (Figure O.3-120). In June of above normal and dry water years, however, water temperatures under Alternative 2 could be up to 4°F lower than under the No Action Alternative (Figure O.3-121), yet modeled water temperatures are above the threshold for stress-inducing temperatures for migrating adults under both Alternative 2 and the No Action Alternative (Table O.3-54). Effects of water temperature on this life stage, therefore, are anticipated to be slightly less severe under Alternative 3 than under the No Action Alternative.

Holding adult Spring-Run Chinook have the potential to occur in the Feather River from March to September with peak abundance between May and August. As indicated by the RecTemp model, Feather River water temperatures would be similar under Alternative 3 and the No Action Alternative during peak abundance and the majority of the possible time range (Figures O.3-120 and O.3-121) but would differ in June and September of wet to normal water years when temperatures under Alternative 3 flows could be up to 3°F higher than temperatures under No Action Alternative flows (Figure O.3-121). Additionally, water temperatures in normal to dry water years would also differ when temperatures under Alternative 3 flows would be up to 4°F lower than temperatures under No Action Alternative flows (Figure O.3-121). Water temperatures in most water type years would then remain at stress-inducing levels for holding adults for an additional month under Alternative 3 than under the No Action Alternative when they would drop to the suboptimal range in September and June (Table O.3-54). Alternative 3 operations would therefore result in slightly adverse temperature-related effects on holding adult Spring-Run Chinook relative to the effects under the No Action Alternative in September and slightly lower adverse effects in June.

Alternative 3 has the potential for slightly adverse water temperature-related effects on eggs and fry, but very slightly beneficial effects on migrating adults and holding adults, so its overall effect on Spring-Run Chinook relative to the No Action Alternative is slightly adverse.

Fall-Run Chinook Salmon

Effects of water temperature on Fall-Run Chinook have been heavily studied in the Feather River, resulting in an understanding of the optimal (beneficial), suboptimal, and stress-inducing (adverse) temperature ranges for each life stage (Table O.3-54).

In the Feather River, Fall-Run Chinook eggs and emerging fry occur from October to April (CDFG 2012c). During this period there is no projected difference between water temperatures under Alternative 3 and the No Action Alternative (Figures O.3-120 and O.3-121); therefore, the effect of water temperatures on Fall-Run Chinook eggs and fry would be negligible under Alternative 2 operations relative to under No Action Alternative operations.

Juvenile Fall-Run Chinook typically occur in the Feather River from April to June. During the first two months of this time span, water temperatures would be essentially identical under Alternative 3 and the No Action Alternative (Figures O.3-120 and O.3-121). In June of below normal and dry water years, however, water temperatures under Alternative 3 could be up to 4°F lower than under the No Action Alternative (Figure O.3-121). The effect of this temperature difference would be slightly beneficial as temperature in these years would likely rise to suboptimal levels for juvenile Fall-Run Chinook under Alternative 3 and the No Action Alternative.

Migrating adult (ocean to river) Fall-Run Chinook reach the Feather River between June and April. This time span includes the slightly higher August and September water temperatures under Alternative 3 in wet and above normal years as well as the slightly lower June water temperatures in normal to dry years (Figure O.3-121). For migrating adult Fall-Run Chinook, water temperatures under Alternative 3 would then reach suboptimal and stress-inducing levels a couple of weeks more in summer of wet and above normal water than under the No Action Alternative but would drop to suboptimal and optimal levels approximately a couple of weeks more than under the No Action Alternative scenario in early summer of years below normal and dry water years (Figure O.3-121 and Table O.3-54). The net effect of Alternative 3 water temperatures on migrating adult Fall-Run Chinook relative to the No Action Alternative would be expected to be slightly adverse overall but would ultimately depend on rainfall levels experienced in the watershed.

Alternative 3 has the potential for slightly beneficial water temperature-related effects on juveniles and slightly adverse on migrating adults. Overall effect on Fall-Run Chinook relative to the No Action Alternative is slightly beneficial.

Central Valley Steelhead

Effects of water temperature on Central Valley Steelhead have been heavily studied, resulting in an understanding of the optimal (beneficial), suboptimal, and stress-inducing (adverse) temperature ranges for each life stage (Table O.3-54).

Central Valley Steelhead eggs and emerging fry occur in the Feather River from December to May, peaking in abundance in January (NMFS 2016a). Under Alternative 2 and the No Action Alternative, water temperature estimates for all water year types are essentially identical throughout this time period (Figure O.3-121), so no effect of Alternative 3 relative to the No Action Alternative is expected for Central Valley Steelhead eggs and fry.

Rearing juveniles typically migrate to the ocean from January to May after spending 1 to 3 years in freshwater (CDFG 1996). Under Alternative 3 and the No Action Alternative, water temperature estimates for all water year types are nearly identical throughout this time period (Figure O.3-121). Therefore, no effect of Alternative 3 relative to the No Action Alternative is expected for juvenile Central Valley Steelhead.

Migrating adult (ocean to river) Central Valley Steelhead reach the Feather River between September and October. Modeled water temperatures for Alternative 3 and the No Action Alternative differ in September of wet and above normal water years when temperatures under Alternative 3 could be up to 3°F higher than temperatures under No Action Alternative flows (Figure O.3-121), yet water temperatures would remain in the suboptimal range for migrating adults under Alternative 3 and the No Action Alternative (Table O.3-54). Adverse effects of water temperature on this life stage are therefore anticipated to be slightly less severe under the No Action Alternative than under Alternative 3.

Holding adult Central Valley Steelhead have the potential to occur in the Feather River from December to March. Under Alternative 3 and the No Action Alternative, water temperature estimates for all water year types are essentially identical throughout this time period (Figure O.3-121), and no effect of Alternative 3 relative to the No Action Alternative is expected for Central Valley Steelhead eggs and fry.

Alternative 3 has the potential for slightly adverse water temperature-related effects on migrating adults. Overall effects on Central Valley Steelhead under Alternative 3 relative to the No Action Alternative is slightly adverse.

North American Green Sturgeon

Effects of water temperature on North American Green Sturgeon have been heavily studied in the Feather River, resulting in an understanding of the optimal (beneficial), suboptimal, and stress-inducing (adverse) temperature ranges for each life stage (Table O.3-54).

Green Sturgeon eggs and emerging fry occur in the Feather River from May to July (NMFS 2016a). During May, water temperatures would be essentially identical under Alternative 3 and the No Action Alternative (Figures O.3-120 and O.3-121). In June of below normal and dry water years, however, water temperatures under Alternative 3 could be up to 4°F lower than under the No Action Alternative (Figure O.3-121), yet modeled water temperatures are above the threshold for stress-inducing temperatures for eggs and fry under both Alternative 3 and the No Action Alternative (Table O.3-54). However, in July of below normal and dry water years, water temperatures would be up to 1°F higher under Alternative 3 than under the No Action Alternative (Figure O.3-121), and similarly to June would have stress-inducing temperatures for eggs and fry under both Alternative 3 and the No Action Alternative (Table O.3-54). Effects of water temperature on this life stage of Green Sturgeon are therefore anticipated to be slightly less severe under Alternative 3 than under the No Action Alternative.

Rearing juvenile Green Sturgeon are present in the Feather River from May to October, with abundance peaking in September. During May and October, water temperatures would be essentially identical under Alternative 3 and the No Action Alternative (Figures O.3-120 and O.3-121). In June of below normal and dry water years, however, water temperatures under Alternative 3 could be up to 4°F lower than under the No Action Alternative (Figure O.3-121). This would result in water temperatures reaching suboptimal stress-inducing levels for juveniles later in June under Alternative 3 than under the No Action Alternative (Table O.3-54). However, in July of below normal and dry water years, water temperatures would be up to 1°F higher under Alternative 3 than under the No Action Alternative (Figure O.3-121), which would likely have stress-inducing temperatures for juveniles under both Alternative 3 and the No Action

Alternative (Table O.3-54). Water temperatures would differ in August and September of wet and above normal water years when temperatures under Alternative 3 flows could be up to 3°F higher than temperatures under No Action Alternative flows (Figure O.3-121). Water temperatures in wet and above normal years would drop from stress-inducing levels for juveniles to suboptimal levels and again to optimal levels later in the month under Alternative 3 than under the No Action Alternative (Figure O.3-121, Table O.3-54). The effects of water temperature on juvenile Green Sturgeon under Alternative 3 would then be dependent on water year types with slightly beneficial effects in below normal and dry water years and slightly adverse effects in wet and above normal water years; therefore, the net effect would be slightly adverse under Alternative 3 than under the No Action Alternative.

Migrating adult (ocean to river) Green Sturgeon reach the Feather River between March and May and, upon spawning, can remain in the vicinity until August. From March to May, water temperatures would be essentially identical under Alternative 3 and the No Action Alternative (Figures O.3-120 and O.3-121). In June of below normal and dry water years, however, water temperatures under Alternative 3 could be up to 4°F lower than under the No Action Alternative (Figure O.3-121). Modeled June water temperatures are above the threshold for stress-inducing temperatures for migrating adults under both Alternative 3 and the No Action Alternative (Table O.3-54). However, water temperatures would reach the suboptimal threshold for post-spawn adults later in below normal and dry years under the No Action Alternative and optimal levels under Alternative 3. Water temperatures would differ in August of wet and above normal water years when temperatures under Alternative 3 flows could be up to 1°F higher than temperatures under No Action Alternative flows (Figure O.3-121), which would likely result in stress-inducing levels in migrating adults under both Alternative 3 and the No Action Alternative; yet these temperatures could reach stress inducing temperatures for post-spawn adults a couple of weeks more under Alternative 3 than under the No Action Alternative. Effects of water temperature on this life stage, therefore, are anticipated to be slightly less severe under Alternative 3 than under the No Action Alternative.

Alternative 3 has the potential for slightly adverse water temperature-related effects on juveniles in wet and above normal years but slightly beneficial effects on eggs, fry, and post-spawn adults in below normal and dry years. Overall, effect on North American Green Sturgeon under Alternative 3 relative to the No Action Alternative is minor and dependent on annual rainfall totals.

O.3.7.5 *American River*

Potential changes to aquatic resources in the American River from flood control

Flood Control for the American River at Folsom Dam would be the same under the Alternative 3 would be the same compared the No Action Alternative, since flood control follows the USACE Water Control Manual and flow management for Alternative 2 is according to the American River 2006 Flow Management Standard (Water Forum 2006), the same as the No Action Alternative. The Water Control Manual has been updated over time, and a new Water Control Manual was developed that utilizes forecasted inflow as the criteria for determining flood control releases. The new manual looks ahead five days and considers the forecasted inflow volume for the total of those five days. If that volume exceeds a threshold, a flood control release is specified. The concept is to pre-emptively draw the reservoir down in anticipation of high inflows, thus providing space to store the rain event when it arrives. This will allow Reclamation to pass higher precipitation events with lower peak releases which relieves stress on the downstream levees and provides a higher level of flood protection to downstream areas.

Potential changes to aquatic resources from Folsom Reservoir operations in the American River to meet Delta salinity requirements

Folsom Reservoir operations to address Delta water quality requirements under D-1641 would not change under Alternative 3, compared to the No Action Alternative. Folsom Reservoir flow requirements includes releases to meet Delta standards under D-1641, as needed. Since Folsom Reservoir is the closest reservoir to the Delta, releases from Folsom can more quickly address Delta water quality requirements. Releases to address Delta water quality objectives would be conducted, as needed, in coordination with the American River stakeholders. Releases to address Delta water quality objectives would improve water quality conditions, and thus habitat conditions for fish and other aquatic species in the Delta when hydrologic conditions are negatively affecting salinity levels.

Potential changes to aquatic resources from flows in the American River

Flows in the American River would be the same under Alternative 3, compared to the No Action Alternative, since flow management for Alternative 3 is according to the American River 2006 Flow Management Standard (Water Forum 2006), the same as the No Action Alternative. Under the Alternative 3, flow releases are managed according to the American River 2006 Water Forum Lower American Flow Management Standard, with the objective of providing suitable conditions for Fall-Run Chinook Salmon and Steelhead. Under the Flow Management Standard, flows are managed according to the Minimum Flow Requirements (MFR), which establishes minimum flows, as measured by the total release at Nimbus Dam, which vary throughout the year in response to the hydrology of the Sacramento and American River basins. The October 1 through December 31 MFR range between 800 and 2,000 cfs. The January 1 through Labor Day MFR range between 800 and 1,750 cfs. The post Labor Day through September MFR range between 800 and 1,500 cfs. As a general rule, the MFR must equal or exceed 800 cfs year round. Narrowly defined exceptions to this rule allow Nimbus releases to drop below 800 cfs to avoid depletion of water storage in Folsom Reservoir when dry or critically dry hydrologic conditions are forecasted to occur. These narrowly defined exceptions to the MFR are an important component of the Flow Management Standard. Since the No Action Alternative follows the existing condition implementation of the Alternative 2 would result in no change to flows in the lower American River.

Potential changes to aquatic resources in the American River due to changes in water temperature

Alternative 3 does not include water temperature objectives. However, water temperature modeling indicates that differences in water temperatures are more a function of hydrologic conditions than operations to meet objectives, water temperatures in the American River would be similar for Alternative 3, compared to the No Action Alternative (Figure 8). Since flow objectives are the same for Alternative 3 as for the No Action Alternative and follow the American River 2006 Flow Management Standard (Water Forum 2006), the flow conditions in the American River remain the same, and thus water temperatures no change in water temperatures are expected under Alternative 3. Temperature modeling indicates that there would be no change average water temperatures in the American River (Figure 8), or in wet years (Figure 9) and dry years (Figure 10).

Potential changes to aquatic resources in the American River from habitat restoration

Habitat for Chinook Salmon and Steelhead in the lower American River would be improved under Alternative 3, compared to the No Action Alternative. Alternative 3 includes implementation of spawning and rearing habitat projects in the American River and its tributaries. This action will likely result in long-term improvements to the habitat and conditions for Fall-Run Chinook Salmon, Steelhead, and other aquatic inhabitants. The spawning and rearing habitat projects would result in increased total spawning habitat area, increased and improved side channel habitat, improved intragravel incubation conditions, increased and improved total rearing habitat area, improved overall habitat complexity, and cover and refugia.

O.3.7.6 *Stanislaus River*

Potential changes to aquatic resources in the Stanislaus River due to changes in flows.

Similar to the previous discussion for Alternative 2 for flows below Goodwin Dam and at the mouth of the Stanislaus River, decreases in flow could affect various salmonid life stages, reduce suitable habitat for to varying degree by salmonid life stages, or have other undesirable results.

Like Alternative 1, Alternative 3 proposes spawning and rearing habitat restoration to offset effects related to changes in flow. As previously described under Alternative 1, the habitat restoration would result in increased survival of juvenile salmonids in the Stanislaus River.

The following effects would be expected to be similar under Alternative 3 to the potential effects as previously described for Alternative 2:

Potential changes to aquatic resources in the Stanislaus River due to changes in water temperature

The following effects would be expected to be similar under Alternative 3 to the potential effects as previously described for Alternative 1:

O.3.7.7 *San Joaquin River*

The following effects would be expected to be similar under Alternative 3 to the potential effects as previously described for the No Action Alternative:

Potential changes to aquatic resources in the San Joaquin River due to changes in flow

Potential changes to aquatic resources in the San Joaquin River due to changes in water temperature

O.3.7.8 *Bay-Delta*

O.3.7.8.1 Delta Smelt

Potential changes to Delta Smelt due to seasonal operations

Water operations criteria under Alternative 3 would be the same as under Alternative 2, i.e., largely governed by adherence to D-1641 criteria and other legal requirements, but the potential negative effects of these operations on Delta Smelt may differ between the alternatives. These differences may arise because of inclusion of a greater extent of programmatic intervention measures such as tidal habitat restoration and food subsidies to offset (or potentially more than offset) the negative effects of Alternative 3 on food availability and potentially habitat for Delta Smelt occupancy, as well as the *Delta Smelt Habitat Operations* conservation measure (which is the same as included in Alternative 1); such components would tend to make the difference between the No Action Alternative and Alternative 3 less than the difference between the No Action Alternative and Alternative 2. However, there could also be negative effects from tidal restoration such as changed hydrodynamics, as discussed below in *Potential changes to Delta Smelt from additional habitat restoration (25,000 acres within the Delta).*

Potential changes to Delta Smelt due to changes from Tracy and Skinner fish facilities improvements

Alternative 3 would include the carbon dioxide injection device previously described for Alternative 1 and therefore could have a positive effect on salvage efficiency relative to the No Action Alternative in this respect. However, given the potential increase in entrainment from seasonal operations (as discussed for Alternative 2) as a result of the No Action Alternative's OMR criteria from the USFWS (2008) BO not being included in Alternative 3, the negative effects from salvage at the Tracy and Skinner fish facilities could outweigh any increases in salvage efficiency at Tracy.

The following project-level effects would be expected to be similar under Alternative 3 to the potential effects as previously described for Alternative 1 because the operations are similar:

Potential changes to Delta Smelt from Clifton Court aquatic weed removal and algal bloom management

Potential changes to Delta Smelt from North Bay Aqueduct operations

The following project-level effects would be expected to be similar under Alternative 3 to the potential effects as previously described for Alternative 2 because of limited potential for effect or because the operations are similar:

Potential changes in Delta Smelt survival related to the Temporary Barriers Project

Potential changes to Delta Smelt from Contra Costa Water District operations

Potential changes to Delta Smelt from water transfers

Potential changes to Delta Smelt due to changes in Delta Cross Channel operations

Potential changes to Delta Smelt due to changes from Suisun Marsh facilities

O.3.7.8.2 Longfin Smelt

Potential changes to Longfin Smelt due to seasonal operations

Under Alternative 3, seasonal operations generally would be expected to have similar effects on Longfin Smelt as previously described for Alternative 2. However, Alternative 3 may have more potential to offset these effects given the larger extent of tidal habitat restoration that is included (see *Potential changes to Longfin Smelt from addtional habitat restoration (25,000 acres within the Delta)*).

Potential changes to Longfin Smelt due to changes from Tracy and Skinner fish facilities improvements

Alternative 3 would include the carbon dioxide injection device previously described for Alternative 1 and therefore could have a positive effect on Longfin Smelt salvage efficiency relative to the No Action Alternative in this respect. Given the potential increase in entrainment from seasonal operations (as discussed for Alternative 2), the negative effects from salvage at the Tracy and Skinner fish facilities could outweigh any increases in salvage efficiency at Tracy. However, as previously discussed for Alternative 2, the population-level effects may be limited given historically low entrainment loss during management under D-1641, as proposed under Alternative 3.

The following project-level effects would be expected to be similar under Alternative 3 to the potential effects as previously described for Alternative 1 because the operations are similar:

Potential changes to Longfin Smelt from Clifton Court aquatic weed and algal bloom management

Potential changes to Longfin Smelt from North Bay Aqueduct operations

The following project-level effects would be expected to be similar under Alternative 3 to the potential effects as previously described for Alternative 2 because of limited potential for effect or because the operations are similar:

Potential changes in Longfin Smelt survival due to the Temporary Barriers Project

Potential changes to Longfin Smelt from Contra Costa Water District operations

Potential changes to Longfin Smelt from water transfers

Potential changes to Longfin Smelt due to changes in Delta Cross Channel operations

Potential changes to Longfin Smelt due to changes from Suisun Marsh facilities

O.3.7.8.3 Sacramento Winter-Run Chinook Salmon

Potential changes to aquatic resources due to seasonal operations

Rearing Winter-Run Chinook Salmon are present in the Delta between October and May. Key habitat attributes relevant to seasonal operations in the Delta include out-migration cues and entrainment risk.

Hydrodynamic changes associated with river inflows and South Delta exports have been suggested to adversely affect juvenile Chinook Salmon in two distinct ways: 1) “near-field” mortality associated with entrainment to the export facilities, and 2) “far-field” mortality resulting from altered hydrodynamics. Near-field or entrainment effects of proposed seasonal operations can be assessed by examining patterns of proportional population entrainment available from decades of coded wire tag studies (e.g., Zeug and Cavallo 2014). A foundation for assessing far-field effects has been provided by work of the Collaborative Adaptive Management Team’s (CAMT) Salmonid Scoping Team (SST). The SST completed a thorough review of this subject and defined a driver-linkage-outcome (DLO) framework for specifying how water project operations (the “driver”) can influence juvenile salmonid behavior (the “linkage”) and potentially cause changes in survival or routing (the “outcome”). The SST concluded altered “Channel Velocity” and altered “Flow Direction” were the only two hydrodynamic mechanisms by which exports and river inflows could affect juvenile salmonids in the Delta. Figure O.3-122 provides a simplified conceptual model of the DLO defined by the CAMT SST.

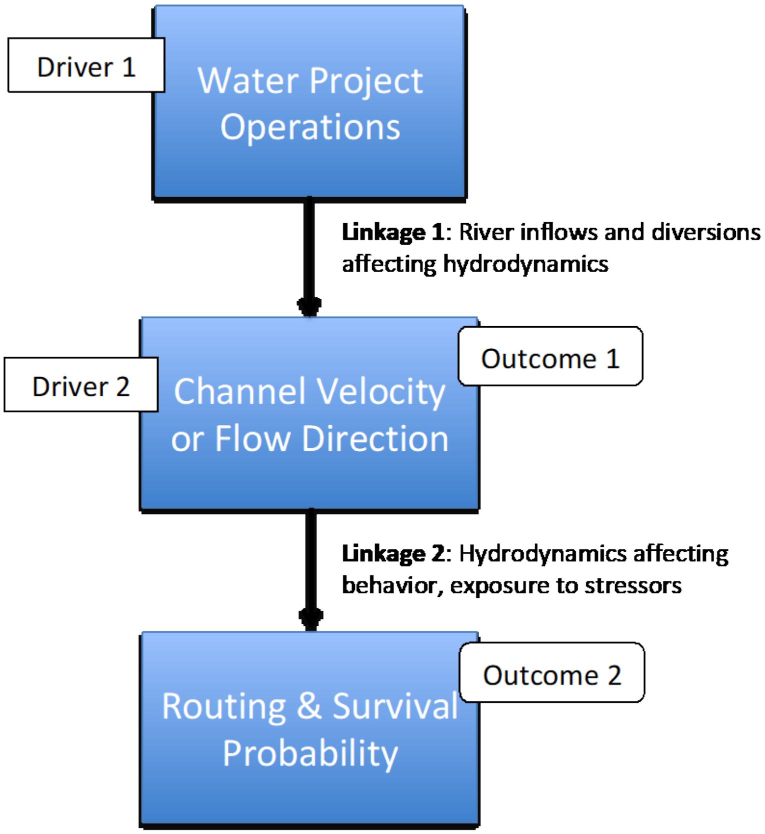


Figure O.3-122. Conceptual Model for Far-field Effects of Water Project Operations on Juvenile Salmonids in the Delta. This CM is a Simplified Version of the Information Provided by the CAMT SST.

To assess the potential for water project operations to influence survival and routing, Reclamation and DWR analyzed Delta hydrodynamic conditions by creating maps from DSM2 Hydro modeling. The maps are based on a comparative metric, proportion overlap (more below), to capture channel-level hydrodynamic details as a single number for color-scale mapping of Delta channels.

The objective of the comparative metric is to summarize the water velocity time series for each channel and scenario such the channel-level comparison is captured in a single number. For the proportion overlap metric, kernel density estimates are calculated on each time series. The kernel density estimates represent a non-parametric smoothing of the empirical distribution of time series values. The proportion overlap of two kernel density estimates is calculated with the following steps: 1) calculate the total area under the curve (AUC_t) as the sum of the AUC for each density estimate, 2) calculate the AUC of the overlapping portions (AUC_o) of the two density distributions being compared, and 3) calculate the overlapping proportion of the density distributions as AUC_o/AUC_t. Proportion overlap is naturally bound by zero and one; a value of zero indicates no overlap and a value of one indicates complete overlap. Lower values of proportion overlap identify channels demonstrating larger differences in a scenario comparison.

The proportion overlap metric is best applied over relatively short time periods because seasonal and annual variation in water velocity can overwhelm differences between scenarios. Thus, Reclamation calculated proportion overlap for every DSM2 channel for two seasons (Dec-Feb, Mar-May) in each water year (1922–2003). DSM2 output was excluded from water year 1921 to allow for an extensive burn-in period. The proportion overlap was calculated based on hourly DSM2 output. Because each season was roughly 90 days, each comparison involved roughly 4,300 DSM2 values (2 scenarios * 24 hours * 90 days) for each channel.

Because the proportion overlap was calculated for each channel in each water year, the proportion overlap values were summarized prior to mapping (i.e., not feasible to map proportion overlap for every comparison in every water year). To summarize, the minimum proportion overlap for each channel for each water year type for each comparison were found. The minimum values represent the maximum expected effect. Note that the year with the minimum proportion overlap for one channel might not be the same year as for another channel.

Entrainment

In the December through June period, the average total export rate, under Alternative 3, is higher than the export rate under No Action Alternative. Therefore, higher entrainment is expected compared to the No Action Alternative.

Zeug and Cavallo (2014) analyzed more than 1,000 release groups representing more than 28 million coded wire tagged juvenile fish including winter, late fall and Fall-Run Chinook Salmon. This data represents large release groups of tagged smolts where the number of fish representing each release group lost to entrainment at the export facilities has been estimated. Cavallo (2016) provided a supplemental assessment of Winter-Run Chinook Salmon entrainment risk (building upon Zeug and Cavallo 2014) that showed total CVP and SWP exports described entrainment risk better than OMR or other flow metrics. Entrainment loss results as reported below represents the proportion of coded wire tagged Winter-Run Chinook Salmon released upstream of the Delta which were entrained at South Delta export facilities. This proportion accounts for and includes expansion for sampling effort at the salvage facilities and also prescreen mortality. For December through February, Alternative 3 has an average total export rate greater than No Action Alternative (10,173 and 7,617 cfs respectively; Figure O1-1 in Appendix O, Attachment 1), and will therefore have greater entrainment risk. However, entrainment losses should average 0.8% and not exceed 2.2%. In the March through June period, total exports for Alternative 3 increase entrainment risk relative to No Action Alternative (6,782 vs. 4,164 cfs, respectively; Figure O1-2 in Appendix O, Attachment 1), but entrainment losses should average 0.4% and not exceed 1.5%.

Routing

Routing of juvenile Chinook Salmon into alternative migration routes is closely related to hydrodynamics (Perry et al. 2015; Cavallo et al. 2015; Steel et al. 2012). Changes to hydrodynamics in Delta channels resulting from Alternative 3 were evaluated using DSM2. Juvenile Winter-Run Chinook Salmon are present in the Sacramento River at Sherwood Harbor upstream of the first distributary junctions between November and March with peak abundance in February and March (Reclamation 2019).

In the December to February period, velocity overlap between Alternative 3 and No Action Alternative in the Sacramento River mainstem between the Sutter-Steamboat and DCC/Georgiana Slough Junctions, was more than 83%, 79%, 68%, 70%, and 54% in critically dry, dry, below normal, above normal, and wet years, respectively (Figure O1-37 in Appendix O, Attachment 1). During the December through February period, velocities were higher under Alternative 3 in below normal, above normal, and wet years and slightly lower in critically dry and dry years indicating routing into the interior Delta would be lower relative to No Action Alternative in normal and wet years and slightly higher relative to No Action Alternative in dry years (Perry et al. 2015; Figure O1-41 in Appendix O, Attachment 1). During the March to May period, velocity overlap between No Action Alternative and Alternative 3 was more than

82%, 75%, 70%, 60%, and 79% in critically dry, dry, below normal, above normal, and wet years, respectively (Figure O1-38 in Appendix O, Attachment 1).

Abundance of juvenile Winter-Run Chinook Salmon at Chipps Island peaks in March and April but fish are collected between December and May (Reclamation 2019). During this time period, Winter-Run Chinook Salmon originating from the Sacramento River that enter the interior Delta via Georgiana Slough and the Delta Cross Channel can potentially be exposed to hydrodynamic effects associated with the CVP and SWP that could affect routing. Once these fish arrive at the junction of the Mokelumne River and the San Joaquin River, they can move south toward the export facilities or west toward the ocean. In the December through February period analysis of DSM2 data indicates that there is little change to velocities in the region of the junction of the Mokelumne and San Joaquin Rivers between Alternative 3 and the No Action Alternative (Figure O1-39 in Appendix O, Attachment 1). Similar results were obtained when comparing Alternative 3 to the No Action Alternative in the March to May period (Figure O1-40 in Appendix O, Attachment 1).

Through-Delta Survival

Perry et al. (2018) found that the effect of flow on survival is not uniform throughout the Delta. Relationships between flow and survival were significant only in reaches where flow changes from bi-directional to unidirectional when discharge increases.

To examine potential effects of Alternative 3, changes in velocity distributions were examined for the Sacramento River at Walnut Grove and Steamboat Slough which are both in this “transitional” region. During the December to February period at Walnut Grove, there are higher velocities under Alternative 3 than the No Action Alternative in wet, above normal, and below normal years. Velocities were lower in critically dry and dry years but overlap was high (>84%; Figure O1-41 in Appendix O, Attachment 1). At Steamboat Slough in the December through February period, there are higher velocities under Alternative 3 than the No Action Alternative in wet and below normal years. Velocities were lower in critically dry, dry, and above normal years but overlap was high (>83%; Figure O1-42). In the March through May period at Walnut Grove, when Alternative 3 was compared to the No Action Alternative, velocity overlap ranged from 78.5-87.5% (Figure O1-43 in Appendix O, Attachment 1). Velocity overlap at Steamboat Slough in the March through May period ranged from 76.6% to 82.6% (Figure O1-44 in Appendix O, Attachment 1).

Overall, Alternative 3 results in similar or higher velocities in the Delta in the spring than under No Action Alternative, during the outmigrating juvenile time period. Survival probabilities are non-linear; however, the similar or higher discharge at Freeport in the spring under Alternative 3 results in similar or higher survival in the transition reaches. Higher flows also lead to lower probability of routing into the interior Delta, which has the lowest survival probability regardless of flow.

Potential changes to aquatic resources due to OMR management

See section on seasonal operations above which integrate OMR management.

Potential changes to aquatic resources due to Delta Cross Channel operations

Under Alternative 3, the DCC may be closed for up to 45 days from November through January for fishery protection purposes. From February 1 through May 20, the gates are closed for fishery protection purposes. The gates may also be closed for 14 days from May 21 through June 15 for fishery protection purposes. The peak migration of juvenile Winter-Run Chinook Salmon in the Sacramento River at Sherwood Harbor, which is near the DCC, occurs from February through March (Reclamation 2019).

Therefore, the DCC is closed for the majority of the juvenile Winter-Run Chinook Salmon migration period in the Sacramento River and as such the proportion of juvenile Winter-Run Chinook Salmon exposed to an open DCC would be negligible. Juvenile Chinook Salmon entrained into an open DCC and transported to the interior Delta have reduced survival (Perry et al. 2010; Perry et al. 2018).

Potential changes to aquatic resources due to the Temporary Barriers Project

Juvenile Winter-Run Chinook Salmon are not expected to co-occur in space or time with the agricultural barriers indicating no potential impacts.

Potential changes to aquatic resources due to Contra Costa Water District operations

CCWD's operations in Alternative 3 are consistent with the operational criteria specified in separate biological opinions and permits that govern operations at CCWD's intakes and Los Vaqueros Reservoir (NMFS 1993, 2007, 2010, 2017; USFWS 1993a, 1993b, 2000, 2007, 2010, 2017; CDFG 1994, 2009a) and remain unchanged from the No Action Alternative.

The Contra Costa Canal Rock Slough Intake is located on a dead-end slough, far from the main migratory route for Winter-Run Chinook Salmon (NMFS 2017c), approximately 18 miles from the Sacramento River via the shortest route. Designated critical habitat for Winter-Run Chinook Salmon does not occur within Rock Slough, but is present further to the north in the Delta (NMFS 2017c; NMFS 2014c). Salmonids are expected to avoid the area of the Rock Slough Intake during certain times of the year based on historical water temperatures.

Fish monitoring prior to the construction of the Rock Slough Fish Screen (RSFS) indicates the timing and magnitude of Winter-Run Chinook Salmon presence near the Rock Slough Intake. Since 1994, fish monitoring has been conducted by CDFW and CCWD consistent with the separate biological opinions and permits that govern CCWD's operations. From 1994 through 1999, CDFW conducted fish monitoring at the Rock Slough Intake and in the Contra Costa Canal up to the first pumping plant. Over this 6-year period, CDFW captured a total of 13 juvenile Winter-Run Chinook Salmon from January through May (CDFG 2002c; NMFS 2017c). From 1999 to 2009, the 11 years prior to construction of the RSFS, CCWD's Fish Monitoring Program collected no juvenile or adult Winter-Run Chinook Salmon at the Rock Slough Headworks (Reclamation 2016; NMFS 2017c).

Since construction of the RSFS, operation of the hydraulic rake cleaning system has been shown to trap and kill adult Chinook Salmon and other non-listed fish (Reclamation 2016). From 2011-2018, 47 Salmon were recovered at the RSFS (Reclamation 2016, Appendix A; Tenera Environmental 2018a), but none of the captured fish were identified as Winter-Run Chinook Salmon (NMFS 2017c).

NMFS issued a biological opinion in 2017 (NMFS 2017c) that considered improvements to the RSFS facility including the hydraulic rake cleaning system, operations and maintenance (O&M) of the RSFS and associated appurtenances, and administrative actions such as the transfer of O&M activities from Reclamation to CCWD. NMFS determined that the O&M of RSFS may result in the incidental take of juvenile Winter-Run Chinook Salmon and provided an incidental take limit based upon the number of listed fish collected in the pre and post-construction RSFS monitoring (NMFS 2017c). The incidental take provided in NMFS 2017c is five juvenile Winter-Run Chinook Salmon per year.

CCWD's Fish Monitoring Program also samples behind the fish screens at CCWD's other south Delta intakes. Since the intakes have been in operation, CCWD's Fish Monitoring Program has never collected Winter-Run Chinook Salmon at CCWD's Old River Intake or Middle River Intake (CCWD 2019).

CCWD’s operations, including operation of the Rock Slough, Old River, and Middle River intakes and Los Vaqueros Reservoir, are simulated in the CalSim model. Thus, CalSim results discussed throughout this appendix include the effects of CCWD’s operations in combination with all other water diversions and reservoir operations. A further analysis was undertaken to isolate the maximum possible effects of CCWD’s operations on Delta hydrodynamics by determining the effect that CCWD pumping at maximum capacity would have on Delta channel water velocity. Results of this analysis are shown below; in all cases the maximum possible effect of CCWD's operations is de minimis.

Due to the location of the Rock Slough Intake near the end of a dead-end slough, far from the main migratory routes, juvenile Winter-Run Chinook Salmon are not likely to be in the vicinity of the Rock Slough Intake. However, according to NMFS (2017), juvenile Salmon can be “drawn” into the south Delta under reverse flows and high CVP and SWP pumping rates. One indicator of reverse flows is the net flow in Old and Middle Rivers (OMR). Rock Slough Intake is located on Rock Slough, approximately 3.5 miles west of the junction of Rock Slough and Old River, which is over 12 river miles north of the gates to the SWP Clifton Court Forebay. Given its location, the Rock Slough Intake does not affect OMR, and any effect that diversions at Rock Slough Intake would have in the Old and Middle River corridor would be to increase the northerly (positive) flow away from the Banks and Jones Pumping Plants.

However, diversions at the Rock Slough Intake could affect flows in the San Joaquin River at Jersey Point, which is approximately 14 river miles from the Rock Slough Intake (via the shortest route through Franks Tract). Mean velocity in a river channel can be calculated by dividing the flow rate by the cross-sectional area of the channel. The maximum effect of Rock Slough diversions on the channel velocity would be the maximum diversion rate (350 cfs) divided by the minimum cross-sectional area of the channel. This calculation assumes that all water diverted at Rock Slough comes from the San Joaquin River at Jersey Point, which is a conservative assumption (i.e., overestimates the effect on velocity). The cross-sectional area of the San Joaquin River at Jersey Point is approximately 60,500 square feet (sf), but varies depending on the tidal stage from approximately 56,000 sf (at low tide and low San Joaquin River flow) to 68,000 sf (at high tide and high San Joaquin River flow) as shown in Figure O.3-123.

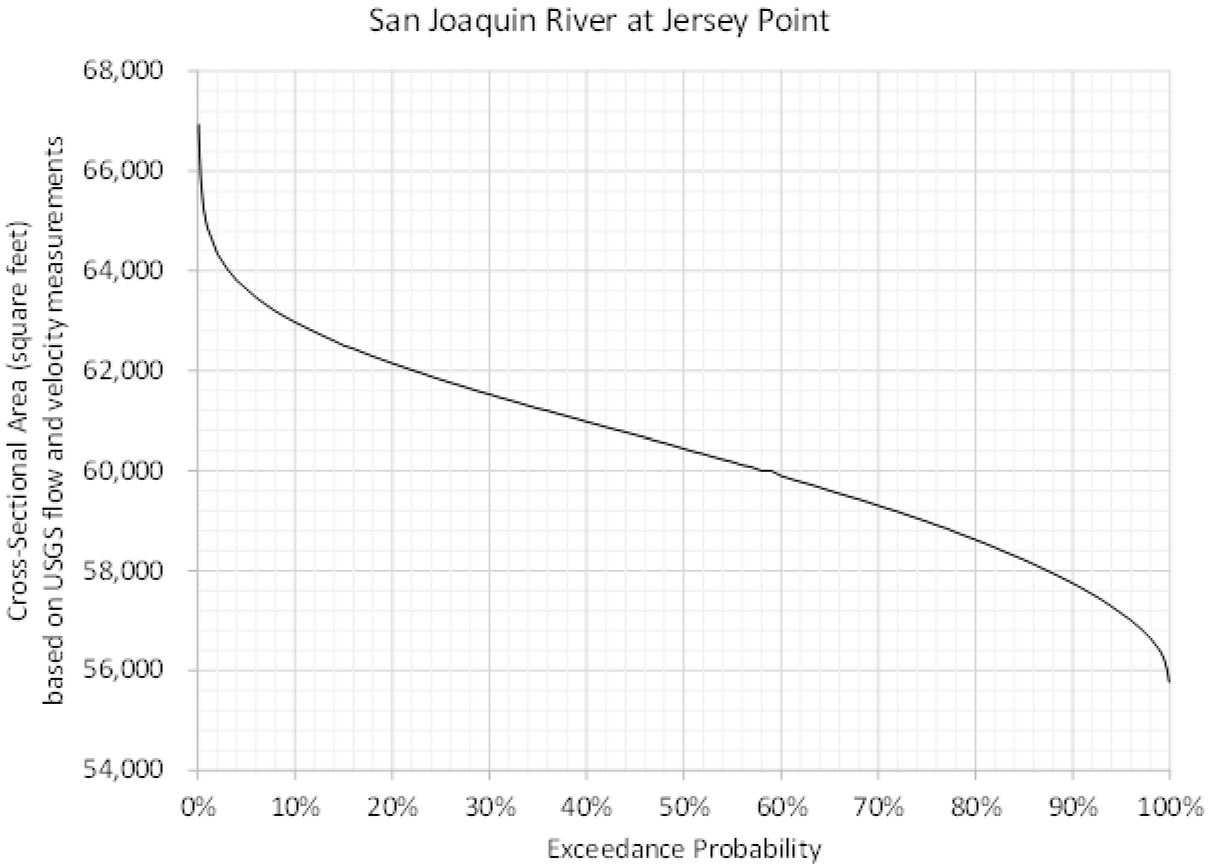


Figure O.3-23. Cross-sectional area of the San Joaquin River at Jersey Point (Station: 11337190) Calculated from USGS Measurements of Flow and Velocity every 15 Minutes for Water Years 2014 through 2018.

The maximum effect of water diversions at Rock Slough Intake on velocity in the San Joaquin River at Jersey Point is calculated as 350 cfs divided by 56,000 square feet; resulting in 0.00625 feet per second (ft/sec). For comparison, the velocity threshold for design of fish screens to prevent impingement of salmonids is 0.33 ft/sec, which is 50 times the maximum possible contribution from Rock Slough diversions. Furthermore, the actual effect is likely to be much lower than 0.00625 ft/sec because the water diverted at the Rock Slough Intake does not all come from the San Joaquin River west of Jersey Point.

Recognizing that CCWD owns and operates two additional intakes in the south Delta, the combined effect of all three intakes is examined. CCWD's Old River Intake and Middle River Intake have a physical capacity of 250 cfs at each intake. If CCWD were to divert at all three intakes at the maximum capacity at the same time, total CCWD diversions would be 850 cfs. The corresponding effect on velocity in the San Joaquin River at Jersey Point would be 0.015 ft/sec. The velocity threshold used to protect salmonids from diversions in the vicinity of fish screens (0.33 ft/sec) is over 21 times greater than the maximum possible contribution from CCWD's combined physical capacity. The water diversions at the Rock Slough Intake when combined with diversions at CCWD's Old River Intake and Middle River Intake have a negligible effect on velocity along the migratory path for juvenile Winter-Run Chinook Salmon and are not likely to affect the movement of juvenile salmonids.

Nonetheless, even extremely small changes in velocity can affect the movement of neutrally buoyant

particles such as phytoplankton. To examine the effect on neutrally buoyant particles, the distance that a particle would travel due to the maximum permitted Rock Slough diversions over the course of a day is calculated. A change in velocity of 0.00625 ft/sec could move a neutrally buoyant particle approximately 540 ft over the course of the day (0.00625 ft/sec * 86,400 sec/day). For comparison, the tidal excursion on the San Joaquin River at Jersey Point during a flood tide (i.e., the distance a particle will travel tidally upstream during a flood tide) is about 34,000 ft on average (or 6.4 miles), which is about 63 times the distance that diversions at Rock Slough could move a particle at the same location over the course of a full day. Therefore, the maximum possible contribution of diversions at Rock Slough on movement of neutrally buoyant particles such as phytoplankton is not significant in comparison to the tidal excursion and mixing at this location.

In summary, CCWD's operations under Alternative 3 would remain consistent with the operational criteria specified in separate biological opinions and permits that govern operations at CCWD's intakes and Los Vaqueros Reservoir, and as shown above, the effect of CCWD's operations on Delta hydrodynamics is negligible.

Potential changes to aquatic resources due to North Bay Aqueduct operations

Alternative 3 includes the North Bay Aqueduct (NBA) intake in the North Delta and operation of the Barker Slough Pumping Plant. Listed salmonids may be present in the waterways adjacent to the Barker Slough Pumping Plant (monitoring data is available at https://www.wildlife.ca.gov/Regions/3). There should be no discernable effect to the Winter-Run Chinook Salmon due to the operations of the Barker Slough Pumping Facility. This is due to the infrequent presence of Winter-Run Chinook Salmon in the monitoring surveys indicating a low risk of entrainment. Further, Barker Slough Pumping Facility fish screens are designed to protect juvenile salmonids per NMFS criteria and should prevent entrainment while greatly minimizing any impingement of fish against the screen.

Alternative 1 also includes sediment removal with a suction dredge that could entrain Winter Run individuals occurring near the suction dredging. In addition, aquatic weed removal with a grappling system could disturb Winter Run occurring near the removal. The low occurrence of Chinook Salmon in monitoring efforts suggest that any potential imacts from sediment and aquatic weed removal would be limited.

Potential changes to aquatic resources due to water transfers

Under Alternative 3, Reclamation is extending the water transfer window until November, from the current July through September window. This extension could result in increased flows entering the Delta and increased pumping at Jones and Banks Pumping Plants.

Egg, alevin, and fry lifestages of Winter-Run Chinook Salmon do not occur in the Delta, and therefore would not be affected by this action. Winter-Run Chinook Salmon juveniles enter the Delta starting in December, and therefore would be unlikely to be exposed to increased pumping of water transfers through November. Adults returning from the ocean could possibly be in the Delta in July; however, they are strong swimmers, large fish that can avoid predators, and are unlikely to have impacts associated with direct entrainment of the pumping plants.

Potential changes to aquatic resources from Clifton Court aquatic weed removal

Few if any juvenile Winter-Run Chinook Salmon would be expected to be exposed to the Clifton Court Forebay Aquatic Weed Control Program. Juvenile Winter-Run Chinook Salmon are present in the Delta between December and May with a peak in March and April (Reclamation 2019). The application of aquatic herbicide to the waters of CCF will occur between 28 June and 31 August. Treatment could occur prior to 28 June at tempertures ≥ 25˚C; however, Winter-Run Chinook Salmon would not be expected to occur at these temperatures. Treatment could also occur after 31 August if protective measures have not been triggered but few if any Winter-Run Chinook Salmon would be expected in the Delta during that time period. Thus, the probability of exposing Winter-Run Chinook Salmon to the herbicide is very low. Based on typical water temperatures in the vicinity of the salvage facilities during this period, the water temperatures would be incompatible with salmonid life history preferences, generally exceeding 70°F by mid-June.

As discussed in Appendix D, treatment of harmful algal blooms with peroxide-based algaecide is proposed to occur as needed, year-round, but there are no anticipated impacts to fish because the oxidation reaction occurs immediately upon contact with the water, destroying algal cell membranes and chlorophyll, with hydrogen peroxide and oxygen as byproducts.

Potential changes to aquatic resources due to changes from Tracy and Skinner fish facilities improvements

A small proportion of juvenile Winter-Run Chinook Salmon are expected to be exposed to the Tracy Fish Facility (Zeug and Cavallo 2014). However, for fish that arrive at the facility, the proposed improvements are likely to increase survival through the facility. Winter-Run Chinook Salmon adults would not be expected to be exposed to the effects of construction of the carbon dioxide injection device proposed for the Tracy Fish Facility, based on the timing of in-water construction (August to October) and the typical seasonal occurrence of this life stage in the Delta (Reclamation 2019).

Few if any juvenile Winter-Run Chinook Salmon would be expected to be exposed to construction of the carbon dioxide injection device proposed for the Tracy Fish Facility Improvements based on lack of observed salvage during the August to October in-water work window (see Figures F.2.7, F.2.8, and F.2.9 in Appendix Fof the ROC LTO BA). However, a few early migrants could occur during the in-water work window based on occurrence in the north Delta (see Figures WR_Seines and WR_Sherwood in Appendix F of the ROC LTO BA).

To the extent that the construction affects the ability of juvenile Winter-Run Chinook Salmon to be efficiently salvaged (as part of the entrainment risk habitat attribute in the SAIL conceptual model; Figure 5.6-44), there could be a minor effect to a small number of individuals, although risk would be minimized through appropriate mitigation measures for aquatic resources (Appendix E, *Mitigation Measures*). There is low potential exposure because of the in-water work window, the application of mitigation measures, and the small scale of the in-water construction.

Skinner Fish Facility improvements from predator control efforts to reduce predation on listed fishes following entrainment into CCF could reduce pre-screen loss of juvenile Chinook Salmon entrained into CCF. It is important to note that only small proportions of Winter-Run Chinook Salmon are lost at the SWP (Zeug and Cavallo 2014).

Potential changes to aquatic resources due to changes from Suisun Marsh facilities

Operation of the SMSCG from October through May to meet salinity standards set by the State Water Resources Control Board and Suisun Marsh Preservation Agreement provides water quality benefits to Winter-Run Chinook Salmon habitat. This beneficial operation coincides with downstream migration of juvenile Winter-Run Chinook Salmon (Reclamation 2019). Montezuma Slough provides an alternative route to their primary migration corridor through Suisun Bay. No data are available to estimate the abundance of juvenile Winter-Run Chinook Salmon in Montezuma Slough thus, the proportion of the total run utilizing this route is unknown. Winter-Run Chinook Salmon typically migrate through the estuary several months before spawning, but an extended delay in the estuary may affect their ability to access their natal spawning streams. Winter-Run generally utilize high stream flow conditions to assist their upstream migration. Rapid upstream movement may be needed to take advantage of a short duration high stream flow event, particular in dry years when high flow events may be uncommon. NMFS (2009) determined that operation of the SWSCG is unlikely to impede migration of juvenile salmonids or produce conditions that support unusually high numbers of predators.

As described by NMFS (2009: 437-438), the Roaring River Distribution System (RRDS)'s water intake (eight 60-inch-diameter culverts) is equipped with fish screens (3/32-inch opening, or 2.4 mm) operated to maintain screen approach velocity of 0.7 ft/s, so that juvenile Winter-Run Chinook Salmon would be excluded from entrainment.

The Morrow Island Distribution System (MIDS) diverts water from Goodyear Slough through three 48-inch diameter culverts during high tide. Although the MIDS intakes do not currently have fish screens, its unlikely juvenile Winter-Run Chinook Salmon will be entrained into the water distribution system, since Winter-Run Chinook have not be caught in past surveys. Also, the large size and better swimming ability of juvenile listed salmonids in the Delta allow these fish to avoid entrainment at MIDS. In addition, the location of the MIDS intake on Goodyear Slough further reduces the risk of entrainment. Goodyear Slough is not a migratory corridor Winter-Run Chinook Salmon.

Goodyear Slough Outfall improves water circulation in the marsh. This structure consists of four 48-inch diameter culverts with flap gates designed to drain water from the southern end of Goodyear Slough into Suisun Bay. On flood tides, the gates reduce the amount of tidal inflow into Goodyear Slough. Due to its location and design, Winter-Run Chinook Salmon are not likely to encounter this structure or be negatively affected by its operation. Improved water circulation by the operation of the Goodyear Slough Outfall likely benefits juvenile Winter-Run Chinook Salmon in Suisun Marsh by improving water quality and increasing foraging opportunities.

Potential changes to aquatic resources due to changes from Delta Smelt summer-fall habitat operations

No Winter-Run Chinook Salmon are detected in the Delta between June and September. Therefore, no effects would occur as a result of the Suisun Marsh Salinity Control Gate operation.

Potential changes to aquatic resources due to changes from Clifton Court predator management

Clifton Court predator management efforts could reduce predation on listed fishes following entrainment into CCF, reducing pre-screen loss.

Potential changes to aquatic resources due to the San Joaquin Basin Steelhead Telemetry Study

Potential changes to aquatic resources due to reintroduction changes from the fish conservation and culture laboratory

Potential changes to aquatic resources from monitoring

A number of monitoring activities described in Appendix C - Real Time Water Operations Charter, in section Routine Operations and Maintenance on CVP Activities would have the potential to capture Winter-Run Chinook Salmon. Not all the existing IEP monitoring programs that target pelagic fish identify Chinook Salmon race. Of the programs that target and identify Winter-Run Chinook Salmon, collective catches are less than 1% of the Winter-Run JPE (Reclamation 2019). Because such a small percentage of the total JPE is captured in the monitoring programs, the effects of the monitoring programs are not likely to have effects to the Winter-Run Chinook Salmon population. These monitoring programs are important for understanding entry and residence time of Winter-Run Chinook Salmon into the Delta and San Francisco Estuary.

O.3.7.8.4 Central Valley Spring-Run Chinook Salmon

Potential changes to aquatic resources due to seasonal operations

Reclamation and DWR propose to operate the C.W. Bill Jones Pumping Plant and the Harvey O. Banks Pumping Plant. These pumping plants affect the hydrodynamics of the south and central Delta resulting in effects to Spring-Run Chinook Salmon entrainment, routing and through Delta survival. Hydrodynamic changes associated with river inflows and South Delta exports have been suggested to negatively impact juvenile Chinook Salmon in two distinct ways: 1) "near-field" mortality associated with entrainment to the export facilities, 2) "far-field" mortality resulting from altered hydrodynamics. See Winter-Run Chinook Salmon effects section for more detail concerning "far-field" and "near-field."

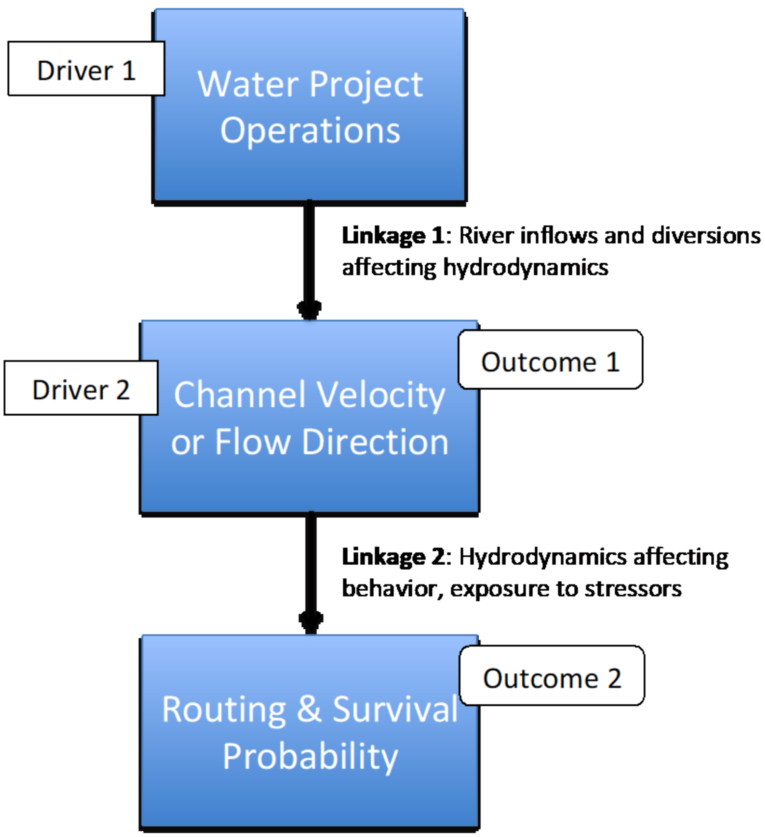


Figure O.3-124. Conceptual model for far-field effects of water project operations on juvenile salmonids in the Delta. This CM is a simplified version of the information provided by the CAMT SST.

Entrainment

Among 6.8 million tagged natural origin and 2.8 million tagged hatchery origin Spring-Run Chinook Salmon juveniles, entrainment loss averaged less than 0.0005% (Zeug and Cavallo 2014). Although data for juvenile Spring-Run Chinook Salmon originating from the San Joaquin River are limited, Zeug and Cavallo (2014) analyzed salvage of San Joaquin River-origin Fall-Run juvenile Chinook Salmon that are found in the Delta at a similar time as Spring-Run Chinook Salmon. Salvage of Fall-Run Chinook Salmon originating from the San Joaquin River averaged 1.4% and increased with export rate at the CVP and SWP (Zeug and Cavallo 2014). However, there were few observations at export rates greater than 3,000 cfs. Average mortality at the facilities represents < 5% total juvenile mortality for San Joaquin River-origin populations but can range as high as 17.5% (Zeug and Cavallo 2014).

In the December through February period, Alternative 3 proposes an average total export rate higher than No Action Alternative (2,556 cfs; Figure O1-1 in Appendix O, Attachment 1) and will, therefore, have a higher entrainment risk. Total exports proposed for Alternative 3 in March-June (2,618 cfs higher than No Action Alternative; Appendix O, Attachment 1, Figure O1-2), when juvenile Spring-Run Chinook Salmon are most abundant in the Delta, will increase entrainment risk relative to No Action Alternative. Recent acoustic studies of juvenile Fall-Run Chinook Salmon in the San Joaquin River revealed that when the Head of Old River Barrier is out, >60% of fish detected at Chipps Island came through CVP, indicating that salvage is a higher survival route than volitional migration.

Routing

As stated in the Sacramento Winter-Run Chinook effects section, routing of juvenile Chinook Salmon into alternative migration routes is closely related to hydrodynamics (Perry et al. 2015; Cavallo et al. 2015; Steel et al. 2012). Juvenile Spring-Run Chinook Salmon are present in the Delta between November and early June with a peak in April (Reclamation 2019). In the December to February period, velocity overlap between Alternative 3 and No Action Alternative in the Sacramento River mainstem between the Sutter-Steamboat and DCC/Georgiana Slough Junctions, was more than 83%, 79%, 68%, 70%, and 54% in critically dry, dry, below normal, above normal, and wet years, respectively (Figure O1-37 in Appendix O, Attachment 1). During the December through February period, velocities were higher under Alternative 3 in below normal, above normal, and wet years and slightly lower in critically dry and dry years indicating routing into the interior Delta would be lower relative to No Action Alternative in normal and wet years and slightly higher relative to No Action Alternative in dry years (Perry et al. 2015; Figure O1-41 in Appendix O, Attachment 1). During the March to May period, velocity overlap between No Action Alternative and Alternative 3 was more than 82%, 75%, 70%, 60%, and 79% in critical, dry, below normal, above normal, and wet years, respectively (Figure O1-38 in Appendix O, Attachment 1).

Spring-Run Chinook Salmon originating from the Sacramento River that enter the interior Delta via Georgiana Slough and the Delta Cross Channel can be exposed to hydrodynamic project effects that could affect routing. Once these fish arrive at the junction of the Mokelumne River and the San Joaquin River, they can move south toward the export facilities or west toward the ocean. In the December through February period analysis of DSM2 data indicates that there is little change to velocities in the region of the junction of the Mokelumne and San Joaquin Rivers between Alternative 1 and both the No Action Alternative scenarios (Figure O1-5 in Appendix O, Attachment 1). Similar results were obtained when comparing Alternative 1 to No Action Alternative in the March to May period (Figure O1-6 in Appendix O, Attachment 1).

Juvenile Spring-Run Chinook Salmon are present in the Delta between November and early June with a peak in April (Reclamation 2019). Early studies using coded wire tags indicated that survival of San Joaquin River-origin juvenile Chinook Salmon was lower in the Old River Route relative to the San Joaquin main stem (Newman 2008). This finding led to strategies designed to keep larger proportions of fish in the San Joaquin River main stem including the Head of Old River rock barrier and non-physical barriers. Recent studies using acoustic technology have indicated that differences in survival among the two routes are not significant (Buchanan et al. 2013; Buchanan et al. 2018). Thus, fish that enter Old River are unlikely to experience reduced survival.

Spring–run Chinook Salmon originating from the San Joaquin River that remain in the San Joaquin River main stem at the Head of Old River are exposed to additional junctions that lead into the interior Delta including; Turner Cut, Columbia Cut, Middle River, Old River, Fisherman's Cut and False River. In the December through February period analysis of DSM2 data indicates that there is little change to velocities in the region of the junctions with San Joaquin Rivers between Alternative 1 and No Action Alternative scenarios (Figure O1-5 in Appendix O, Attachment 1). Similar results were obtained when comparing Alternative 1 to No Action Alternative in the March to May period (Figure O1-6 in Appendix O, Attachment 1).

In the December through February period, velocity overlap between Alternative 2 and No Action Alternative in the channel upstream of the Head of Old River was 92.8%, 84.8%, 55.1%, 65.6%, and 53.8% in critically dry, dry, below normal, above normal, and wet years, respectively (Figure O1-23 in Appendix O, Attachment 1). In the March to May period, velocity overlap was 83.1%, 62.9%, 61.8%, 64.3%, and 43.1% in critical, dry, below normal, above normal, and wet years, respectively (Figures O1-24 in Appendix O, Attachment 1).

Through-Delta Survival

To examine potential effects of Alternative 3, changes in velocity distributions were examined for the Sacramento River at Walnut Grove and Steamboat Slough which are both in this "transitional" region. During the December to February period at Walnut Grove, velocity distributions for Alternative 3 relative to No Action Alternative were most different in wet years (72.5%) with higher velocities in Alternative 3. Velocities were also greater for Alternative 3 relative to No Action Alternative in below normal and above normal years although overlap was greater (>78%; Figure O1-41 in Appendix O, Attachment 1). In critically dry and dry years, velocity distributions were more similar (>84%; Figure O1-41 in Appendix O, Attachment 1). At Steamboat Slough in the December to February period, velocities under Alternative 3 were higher than No Action Alternative in wet and below normal years and similar in above normal, dry, and critically dry years (Figure O1-42 in Appendix O, Attachment 1).

In the March through May period at Walnut Grove, velocity overlap between Alternative 3 and No Action Alternative was >78% across all water year types with similar velocities under Alternative 3 (Figure O1-43 in Appendix O, Attachment 1). At Steamboat Slough in the March through May period, overlap between Alternative 3 and No Action Alternative scenarios was >76% with similar velocities under Alternative 3 (Figure O1-44 in Appendix O, Attachment 1).

A recent study by Perry et al. (2018) found that the effect of flow on survival is not uniform throughout the Delta. Relationships between flow and survival were significant only in reaches where flow changes from bi-directional to unidirectional when discharge increases. To examine potential effects of Alternative 3, changes in velocity distributions were examined for the San Joaquin River at Highway 4 and the Head of Middle River which are both in the "transitional" region of the San Joaquin River. During the December to February period at the San Joaquin River at Highway 4, velocity distributions for Alternative 3 relative to No Action Alternative exhibited high overlap in all water year types (≥81.3%; Figure O1-45 in Appendix O, Attachment 1). At the Head of Middle River during the December through February period, overlap was high between Alternative 3 and No Action Alternative in critically dry and dry water years (≥77%) and moderate in wet, above normal, and below normal years (65%; Figure O1-46 in Appendix O, Attachment 1).

In the March to May period in the San Joaquin River at Highway 4, velocity overlap was high between Alternative 3 and No Action Alternative (≥80%; Figure O1-47 in Appendix O, Attachment 1). Velocities were similar in all water year types (Figure O1-47). At the Head of Middle River in the March –May period, overlap between Alternative 3 and No Action Alternative was moderate in all water year types (41-65%) and higher in critically dry years >78% (Figure O1-48 in Appendix O, Attachment 1). Velocities were generally lower under Alternative 3 than No Action Alternative (Figure O1-48 in Appendix O, Attachment 1).

Potential changes to aquatic resources due to OMR management

See section on seasonal operation above which integrates OMR management

Potential changes to aquatic resources due to Delta Cross Channel operations

The Delta Cross Channel may be closed for up to 45 days from November through January for fishery protection purposes. From February 1 through May 20, the gates are closed for fishery protection purposes. Significant amounts of flow and many juvenile Spring-Run Chinook Salmon enter the DCC (when the gates are open) and Georgiana Slough, especially during increased Delta pumping. Mortality of juvenile Salmon entering the central Delta is higher than for those continuing downstream in the Sacramento River. Juvenile Chinook Salmon that are entrained into an open DCC and transported to the interior Delta have reduced survival (Perry et al. 2010) The gates may also be closed for 14 days from May 21 through June 15 for fishery protection purposes. The peak migration of juvenile Spring-Run Chinook Salmon in the Sacramento River past Knights Landing, which is upstream of the DCC, occurs from March-April (Reclamation 2019). Therefore, the DCC is closed to protect the majority of the juvenile Spring-Run Chinook Salmon migration period in the Sacramento River and reduce the proportion of fish exposed to an open DCC.

Potential changes to aquatic resources due to the Temporary Barriers Project

The agricultural barriers at Middle River and Old River near Tracy can begin operating as early as April 15 but the tide gates are tied open from May 16 to May 31. After May 31, the barriers in Middle River, Old River near Tracy, and Grant Line Canal are permitted to be operational until they are completely removed by November 30.

The proportion of juvenile Spring-Run Chinook Salmon exposed to the agricultural barriers (Temporary Barrier Program, TBP) depends on their annual timing of installation and removal. Due to their location, primarily migrants originating from the San Joaquin River would be exposed to the TBP. The peak relative abundance of juvenile Spring-Run Chinook Salmon in the Delta is March and April (Reclamation 2019). If the agricultural barriers are operating as early as April 15 then they have the potential to expose a large proportion of the juvenile Spring-Run Chinook Salmon migrating down the San Joaquin River. When the Head of Old River barrier is not in place, acoustically tagged juvenile Chinook Salmon have demonstrated a high probability of selecting the Old River route (Buchanan 2018), which would expose them to the agricultural barriers. When the agricultural barriers are operating with tidal flap gates down, a significant decline in passage and reach survival of acoustically tagged juvenile Chinook Salmon migrating past the barrier has been observed compared to when the barrier is not present (DWR 2018). When flap gates are tied up, Chinook Salmon passage past the agricultural barrier was improved (DWR 2018). Flap gates tied up on agricultural barriers from May 16 to May 31 would help to reduce the negative effect of the barriers during this period. However, juveniles migrating before or after this period could be exposed to the agricultural barriers with flaps down which apparently decreases passage success and survival (DWR 2018).

Potential changes to aquatic resources due to Contra Costa Water District operations

CCWD's operations in Alternative 3 are consistent with the operational criteria specified in separate biological opinions and permits that govern operations at CCWD's intakes and Los Vaqueros Reservoir (NMFS 1993, 2007, 2010, 2017; USFWS 1993a, 1993b, 2000, 2007, 2010, 2017; CDFG 1994, 2009a). Therefore, CCWD's operation, including operation of the Rock Slough Intake, for Alternative 3 remain unchanged from the current operations.

The Contra Costa Canal Rock Slough Intake is located on a dead-end slough, far from the main migratory route for Central Valley Spring-Run Chinook Salmon (NMFS 2017c), approximately 18 miles from the Sacramento River and 10 miles from the San Joaquin River via the shortest routes. Designated critical habitat for Spring-Run Chinook Salmon does not occur within Rock Slough, but is present further to the north in the Delta (NMFS 2017c; NMFS 2014c). Salmonids are expected to avoid the area of the Rock Slough Intake during certain times of the year based on historical water temperatures, which range from lows of about 45°F in winter (December and January) to over 70°F beginning in May and continuing to October (Reclamation 2016).

Fish monitoring prior to the construction of the Rock Slough Fish Screen (RSFS) indicates the timing and magnitude of Central Valley Spring-Run Chinook Salmon presence near the Rock Slough Intake. Since 1994, fish monitoring has been conducted by CDFW and CCWD consistent with the separate biological opinions and permits that govern CCWD's operations. From 1994 through 1999, CDFW conducted fish monitoring at the Rock Slough Intake and in the Contra Costa Canal up to the first pumping plant. Over this 6-year period, CDFW captured a total of 108 juvenile Central Valley Spring-Run Chinook Salmon from March through May (CDFG 2002c; NMFS 2017c). From 1999 to 2009, the 11 years prior to construction of the RSFS, CCWD's Fish Monitoring Program collected a total of 11 juvenile Central Valley Spring-Run Chinook Salmon from March through May at the Rock Slough Headworks (Reclamation 2016; NMFS 2017c) and 4 juvenile Central Valley Spring-Run at Pumping Plant #1 (CCWD 2019). No adult Spring-Run Chinook Salmon were collected in the vicinity of the Rock Slough Intake from 1994 through 2009 (CDFG 2002c; Reclamation 2016; NMFS 2017c). No juvenile or adult Central Valley Spring-Run Chinook Salmon have been collected in CCWD's Fish Monitoring Program at the Rock Slough Intake since 2008.

Since construction of the RSFS, operation of the hydraulic rake cleaning system has been shown to trap and kill adult Chinook Salmon and other non-listed fish (Reclamation 2016). From 2011-2018, 47 Salmon were recovered at the RSFS (Reclamation 2016, Appendix A; Tenera Environmental 2018a), but none of the captured fish were identified as Spring-Run Chinook Salmon (NMFS 2017c).

CCWD's Fish Monitoring Program also samples behind the fish screens at CCWD's other south Delta intakes. Since the intakes have been in operation, CCWD's Fish Monitoring Program has never collected Spring-Run Chinook Salmon at CCWD's Old River Intake or Middle River Intake (CCWD 2019).

CCWD's operations, including operation of the Rock Slough, Old River, and Middle River intakes and Los Vaqueros Reservoir, are simulated in the CalSim model. Thus, CalSim results discussed throughout this appendix include the effects of CCWD's operations in combination with all other water diversions and reservoir operations. A further analysis was undertaken to isolate the maximum possible effects of CCWD's operations on Delta hydrodynamics by determining the effect that CCWD pumping at

maximum capacity would have on Delta channel water velocity. Results of this analysis are shown below; in all cases the maximum possible effect of CCWD's operations is de minimis.

Due to the location of the Rock Slough Intake near the end of a dead-end slough, far from the main migratory routes (i.e., 10 miles from the San Joaquin River and 18 miles from the Sacramento River), juvenile Spring-Run Chinook Salmon are not likely to be in the vicinity of the Rock Slough Intake. However, according to NMFS (2017), juvenile Spring-Run can be “drawn” into the south Delta under reverse flows and high CVP and SWP pumping rates.

One indicator of reverse flows is the net flow in OMR. Rock Slough Intake is located on Rock Slough, approximately 3.5 miles west of the junction of Rock Slough and Old River, which is over 12 river miles north of the gates to the SWP Clifton Court Forebay. Given its location, the Rock Slough Intake does not affect net reverse flow in OMR, and any effect that diversions at Rock Slough Intake would have in the OMR corridor would be to increase the northerly (positive) flow away from the Banks and Jones Pumping Plants. For juveniles that migrate down the OMR corridor that are not salvaged at TFCF or Skinner Fish Facility, any effect of Rock Slough Intake diversions would be a positive effect on OMR.

For juveniles that migrate down the mainstem of the Sacramento River or the San Joaquin River and for juveniles that were salvaged, trucked, and released in the western Delta, the potential effect of Rock Slough diversions on the net reverse flow in San Joaquin River may be relevant. The effect of water diversions at Rock Slough Intake on the velocity in the San Joaquin River at Jersey Point is presented in the effects analysis for juvenile Winter-Run Chinook Salmon. As detailed in that section, the maximum potential effect of water diversions at Rock Slough Intake (assuming diversions at the maximum permitted capacity of 350 cfs and all water diverted by the Rock Slough Intake comes from the San Joaquin River at Jersey Point) is 0.00625 ft/sec in the San Joaquin River at Jersey Point. For comparison, the velocity threshold for design of fish screens to prevent impingement of salmonids is 0.33 ft/sec, which is 50 times the maximum possible contribution from the Rock Slough diversions.

Recognizing that CCWD owns and operates two additional intakes in the south Delta, we examine the combined effect of all three intakes. CCWD’s Old River Intake and Middle River Intake have a physical capacity of 250 cfs at each intake. If CCWD were to divert at all three intakes at the maximum capacity at the same time, total CCWD diversions would be 850 cfs. The corresponding effect on velocity in the San Joaquin River at Jersey Point would be 0.015 ft/sec. The velocity threshold used to protect salmonids from diversions in the vicinity of fish screens (0.33 ft/sec) is over 21 times greater than the maximum possible contribution from CCWD’s combined physical capacity. The water diversions at the Rock Slough Intake when combined with diversions at CCWD’s Old River Intake and Middle River Intake have a negligible effect on velocity along the migratory path for juvenile Spring-Run Chinook Salmon and are not likely to affect the movement of juvenile salmonids.

Nonetheless, even extremely small changes in velocity can affect the movement of neutrally buoyant particles such as phytoplankton. As shown in the Winter-Run Chinook Salmon section, the diversions at the Rock Slough Intake could move a neutrally buoyant particle in the San Joaquin River at Jersey Point approximately 540 ft over the course of the day. For comparison, the tidal excursion on the San Joaquin River at Jersey Point during a flood tide (i.e., the distance a particle will travel tidally upstream during a flood tide) is about 34,000 ft on average (or 6.4 miles), which is about 63 times the distance that diversions at Rock Slough could move a particle at the same location over the course of a full day. Therefore, the maximum possible contribution of diversions at Rock Slough on movement of neutrally buoyant particles such as phytoplankton is insignificant in comparison to the tidal excursion and mixing at this location.

In summary, CCWD's operations under Alternative 3 would remain consistent with the operational criteria specified in separate biological opinions and permits that govern operations at CCWD's intakes and Los Vaqueros Reservoir, and as shown above, the effect of CCWD's operations on Delta hydrodynamics is negligible.

Potential changes to aquatic resources due to North Bay Aqueduct operations

Alternative 3 includes the North Bay Aqueduct (NBA) intake in the North Delta and operation of the Barker Slough Pumping Plant. Listed salmonids may be present in the waterways adjacent to the Barker Slough Pumping Plant (monitoring data is available at https://www.wildlife.ca.gov/Regions/3). The NBA is located within designated critical habitat for Spring-Run Chinook Salmon. There should be no discernable effect to the Spring-Run Chinook Salmon due to the operations of the Barker Slough Pumping Facility. This is due to the infrequent presence of Spring-Run Chinook Salmon in the monitoring surveys indicating a low risk of entrainment. Further, Barker Slough Pumping Facility fish screens are designed to protect juvenile salmonids per NMFS criteria and should prevent entrainment while greatly minimizing any impingement of fish against the screen.

Alternative 1 also includes sediment removal with a suction dredge that could entrain Spring Run individuals occurring near the suction dredging. In addition, aquatic weed removal with a grappling system could disturb Spring Run occurring near the removal. The low occurrence of Chinook Salmon in monitoring efforts suggest that any potential imacts from sediment and aquatic weed removal would be limited.

Potential changes to aquatic resources due to water transfers

Under Alternative 3, Reclamation is expanding the transfer window to November from the current July to September. Expanding the transfer window could lead to increased pumping at Jones and Banks Pumping Plants, when capacity is available. The Figures below show when capacity is available under Alternative 1 and the No Action Alternative, in terms of exceedances, years in the model period of record, and average by water year types. These values are total available, and are not filtered for the pattern on which water might be acquired for transfer. The pattern of acquisition could decrease these values, as well as reoperation of storage that might be required, or the water cost of meeting D-1641. Prior estimates indicate that approximately 50% of the capacity in the figures below would be useful for water transfers given these timing and upstream considerations. In addition, a 20-30% surcharge on acquisition might be necessary to accommodate the salinity related inefficiencies that arise in operations. Based on the figures below and these additional estimates, expanding the water transfer window could result in an additional approximately 50 TAF of pumping in most yeartypes. As more stored water is available from CVP and SWP reservoirs to pump in wetter yeartypes, most of the available capacity for transfers is in drier yeartypes (Figures O.3-125 through O.3-127).

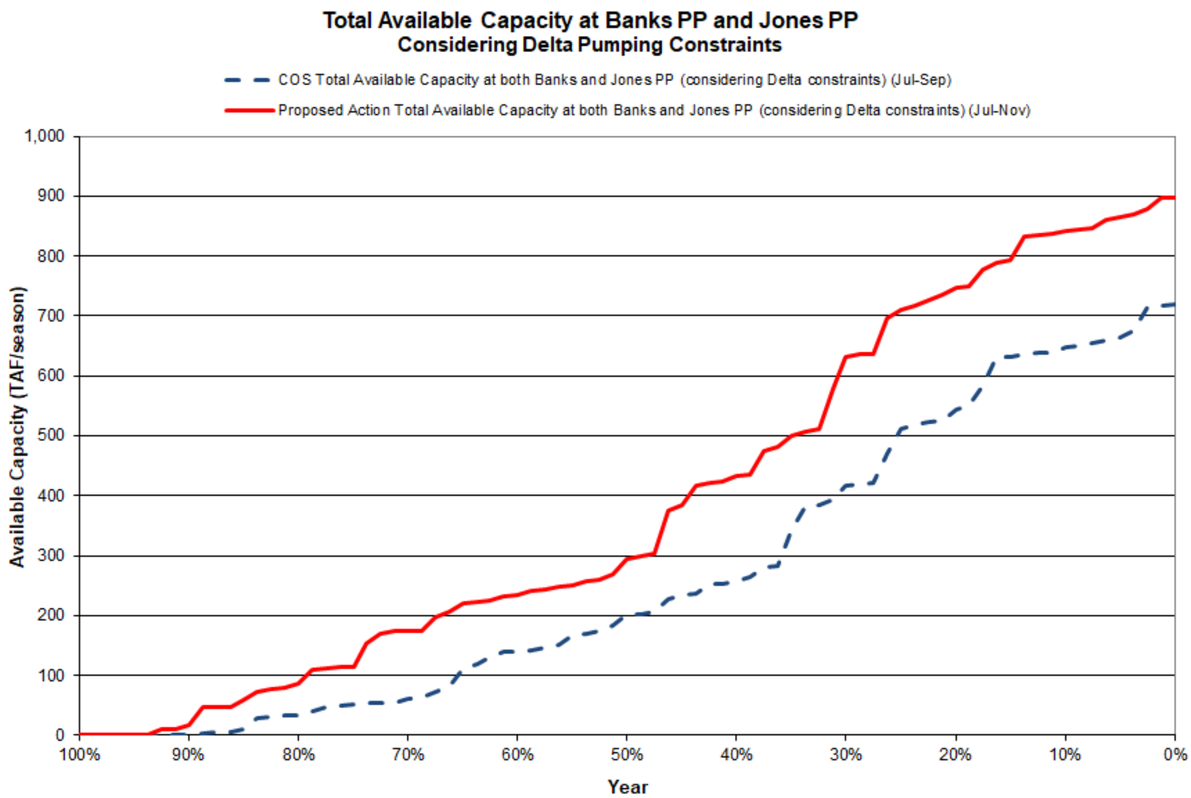


Figure O.3-125. Exceedance of Available Capacity for Transfers at Jones and Banks under the Alternative 1 and No Action Alternative

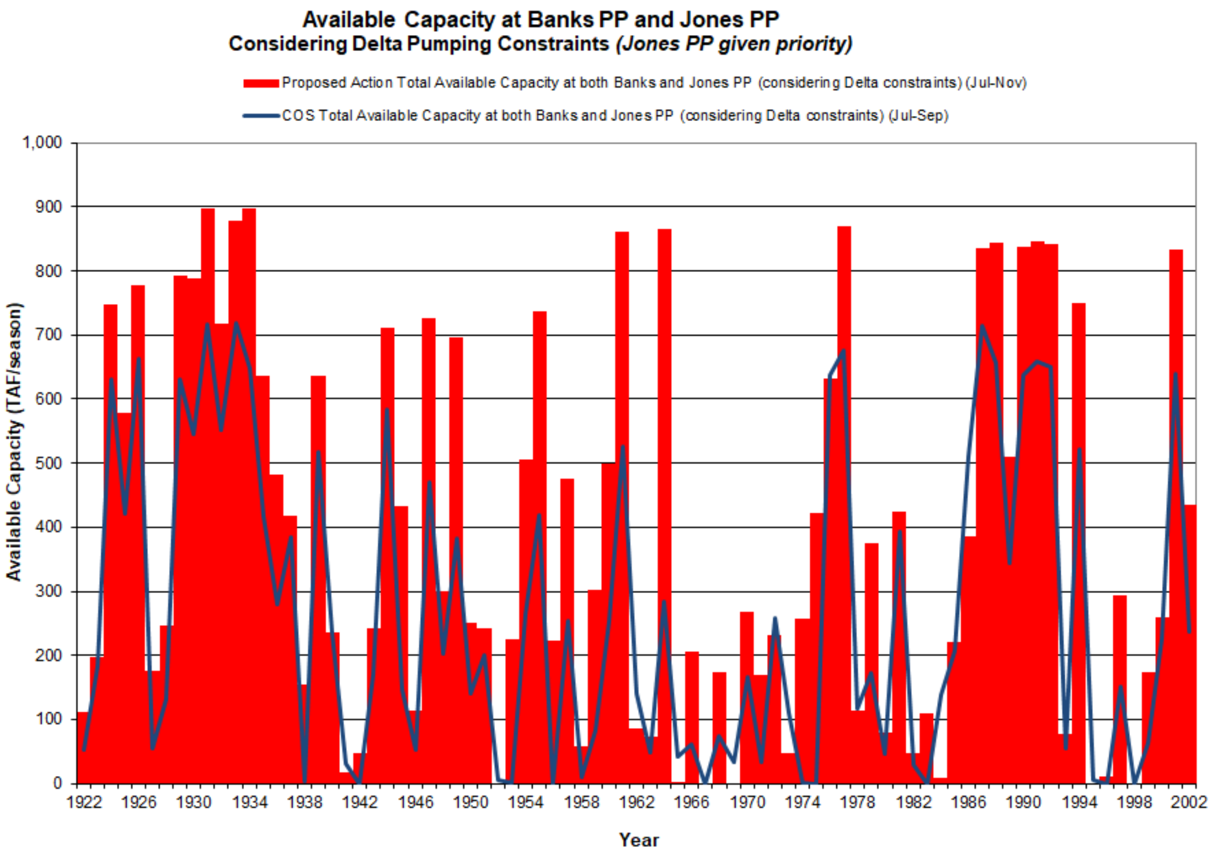


Figure O.3-126. Modeled Annual Maximum Available Capacity for Transfers under Alternative 1 and No Action Alternative, CalSim Period of Record (1922–2003)

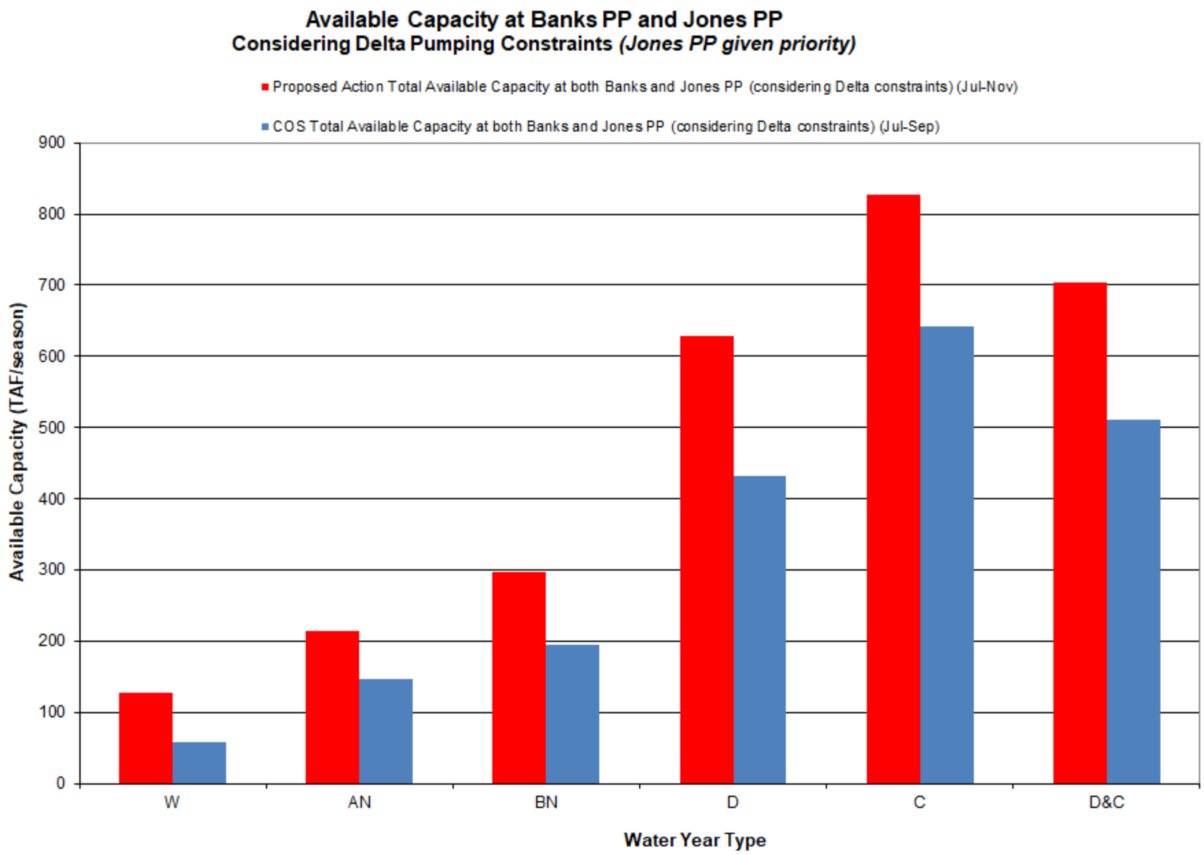


Figure O.3-127. Water Year Type average available capacity at Jones and Banks Pumping Plants

Egg, aelvin, fry, and adult lifestages of Spring-Run Chinook Salmon would not be exposed to the effects of increased water transfers as they do not occur in the Delta during July through November. Juvenile Central Valley Steelhead are detected at Chipps Island between December and July with the highest abundance in March to May (Reclamation 2019). Thus, only the very early or late migrants could potential be exposed to water transfers that occur during this time. These early or late migrant uvenile Spring-Run Chinook Salmon could be exposed to increased effects of entrainment, routing, and decreased Delta survival (see OMR management section) as a result of the expanded water transfer window. Increased flows during conveyance in the Sacramento River could provide small survival benefits to migrating juveniles (Perry et al. 2018).

Potential changes to aquatic resources from Clifton Court aquatic weed removal

Few if any juvenile Spring-Run Chinook Salmon would be expected to be exposed to the Clifton Court Forebay Aquatic Weed Control Program. Juvenile Spring-Run Chinook Salmon are present in the Delta between mid-November and early June with a peak in April (Table5.6-1). The application of aquatic herbicide to the waters of Clifton Court Forebay will occurbetween 28 June and 31 August. Treatment could occur prior to 28 June at tempertures ≥ 25˚C; however, Spring-Run Chinook Salmon would not be expected to occur at these temperatures. Treatment could also occur after 31 August if protective measures have not been triggered but few if any Spring-Run Chinook Salmon would be expected in the Delta during that time period.

Thus, the probability of exposing Spring-Run Chinook Salmon to the herbicide is very low. Based on typical water temperatures in the vicinity of the salvage facilities during this period, the temperatures would be incompatible with salmonid life history preferences, generally exceeding 70°F by mid-June.

As discussed in Appendix D, treatment of harmful algal blooms with peroxide-based algaecide is proposed to occur as needed, year-round, but there are no anticipated impacts to fish because the oxidation reaction occurs immediately upon contact with the water, destroying algal cell membranes and chlorophyll, with hydrogen peroxide and oxygen as byproducts.

Potential changes to aquatic resources due to changes from Tracy and Skinner fish facilities improvements

A number of programmatic actions are proposed to improve salvage efficiency of TFCF, including installing a carbon dioxide injection device to allow remote controlled anesthetization of predators in the secondary channels of the Tracy Fish Facility. These actions could potentially benefit juvenile Spring-Run Chinook Salmon through greater salvage efficiency.

Few if any juvenile Spring-Run Chinook Salmon would be expected to be exposed to construction of the CO_2 injection device proposed for the Tracy Fish Facility Improvements, based on lack of observed salvage during the August to October in-water work window (see figures in Appendix F of the ROC LTO BA: WR_salvage_unclipped_date, WR_salvage_clipped_date, and WR_salvage_clipped_CWT_race). Risks to these few individuals would be minimized through appropriate mitigation measures (Appendix E, *Mitigation Measures*), the selected in-water work window, and the small scale of the in-water construction. For juvenile Spring-Run Chinook Salmon that arrive at the facility, the proposed improvements are likely to increase survival through the facility.

Predator control efforts at Skinner Fish Facility under Alternative 3 to reduce predation on listed fishes following entrainment into Clifton Court Forebay could reduce pre-screen loss of juvenile Spring-Run Chinook Salmon entrained into Clifton Court Forebay. Spring-Run Chinook Salmon are unlikely to be in the area during predator control efforts.

Potential changes to aquatic resources due to changes from Suisun Marsh facilities

Operation of the SMSCG from October through May to meet salinity standards set by the State Water Resources Control Board and Suisun Marsh Preservation Agreement provides water quality benefits to Spring-Run Chinook Salmon habitat. This beneficial operation coincides with downstream migration of juvenile Spring-Run Chinook Salmon (Reclamation 2019). Montezuma Slough provides an alternative route to their primary migration corridor through Suisun Bay. No data are available to estimate the abundance of juvenile Spring-Run Chinook Salmon in Montezuma Slough thus, the proportion of the total run utilizing this route is unknown. Spring-Run Chinook Salmon typically migrate through the estuary several months before spawning, but an extended delay in the estuary may affect their ability to access their natal spawning streams. Spring-Run generally utilize high stream flow conditions during the spring snowmelt to assist their upstream migration. Rapid upstream movement may be needed to take advantage of a short duration high stream flow event, particular in dry years when high flow events may be uncommon. If the destination of a pre-spawning adult Salmon is among the smaller tributaries of the Central Valley, it may be important for migration to be unimpeded, since access to a spawning area could diminish with receding flows. However NMFS (2009) determined that operation of the SWSCG is unlikely to impede migration of juvenile salmonids or produce conditions that support unusually high numbers of predators.

As described by NMFS (2009: 437-438), the Roaring River Distribution System (RRDS)'s water intake (eight 60-inch-diameter culverts) is equipped with fish screens (3/32-inch opening, or 2.4 mm) operated to maintain screen approach velocity of 0.7 ft/s, so that juvenile Spring-Run Chinook Salmon would be excluded from entrainment.

The Morrow Island Distribution System (MIDS) diverts water from Goodyear Slough through three 48-inch diameter culverts during high tide. Although the MIDS intakes do not currently have fish screens, its unlikely juvenile Central Valley Spring-Run Chinook Salmon will be entrained into the water distribution system, since Spring-Run Chinook have not be caught in past surveys. Also, the large size and better swimming ability of juvenile listed salmonids in the Delta allow these fish to avoid entrainment at MIDS. In addition, the location of the MIDS intake on Goodyear Slough further reduces the risk of entrainment. Goodyear Slough is not a migratory corridor Spring-Run Chinook Salmon.

Goodyear Slough Outfall improves water circulation in the marsh. This structure consists of four 48-inch diameter culverts with flap gates designed to drain water from the southern end of Goodyear Slough into Suisun Bay. On flood tides, the gates reduce the amount of tidal inflow into Goodyear Slough. Due to its location and design, Spring-Run Chinook Salmon are not likely to encounter this structure or be negatively affected by its operation. Improved water circulation by the operation of the Goodyear Slough Outfall likely benefits juvenile Spring-Run Chinook Salmon in Suisun Marsh by improving water quality and increasing foraging opportunities.

Potential changes to aquatic resources from actions for Delta Smelt summer-fall habitat

No Spring-Run Chinook Salmon are detected in the Delta between June and September. Therefore, no effects would occur as a result of the Suisun Marsh Salinity Control Gate operation.

Potential changes to aquatic resources due to changes from Clifton Court predator management

Predator control efforts at Clifton Court Forebay under Alternative 3 could reduce pre-screen loss of juvenile Spring-Run Chinook Salmon entrained into Clifton Court Forebay. Spring-Run Chinook Salmon are unlikely to be in the area during predator control efforts during the summer in-water work window.

Potential changes to aquatic resources due to the San Joaquin Basin steelhead telemetry study

Potential changes to aquatic resources due to reintroduction changes from the fish conservation and culture laboratory

Potential changes to aquatic resources from monitoring

Less than 2% of the estimated Spring-Run Chinook Salmon population, as indexed by the Red Bluff Rotary Screw Trap data, is collectively captured by the salmonid monitoring programs that support CVP operations (Reclamation 2019). Because such a small percentage of the estimated Spring-Run Chinook Salmon juvenile production is captured in the monitoring programs, the effects of the monitoring programs are not likely to have effects to the Spring-Run population.

O.3.7.8.5 Central Valley Fall-Run Chinook Salmon

Potential changes to aquatic resources due to seasonal operations

Hydrodynamic changes associated with river inflows and South Delta exports have been hypothesized to adversely affect juvenile Chinook Salmon in two distinct ways: 1) "near-field" mortality associated with entrainment to the export facilities, 2) “far-field” mortality resulting from altered hydrodynamics. Near-field or entrainment effects of proposed seasonal operations can be most appropriately assessed by examining patterns of proportional population entrainment available from decades of coded wire tag studies (e.g., Zeug and Cavallo 2014). A foundation for assessing far-field effects has been provided by work of the Collaborative Adaptive Management Team’s (CAMT) Salmonid Scoping Team (SST). The SST completed a thorough review of this subject and defined a driver- linkage-outcome (DLO) framework for specifying how water project operations (the “driver”) can influence juvenile salmonid behavior (the “linkage”) and potentially cause changes in survival or routing (the “outcome”). The SST concluded altered “Channel Velocity” and altered “Flow Direction” were the only two hydrodynamic mechanisms by which exports and river inflows could affect juvenile salmonids in the Delta. Figure O.3-128 provides a simplified conceptual model of the DLO defined by the CAMT SST.

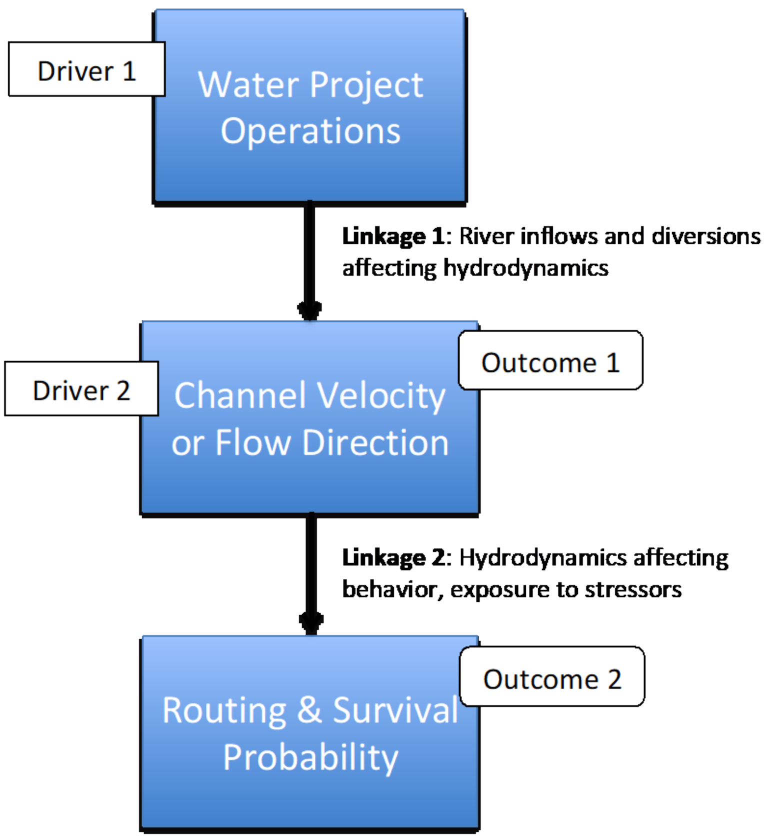


Figure O.3-128. Conceptual model for far-field effects of water project operations on juvenile salmonids in the Delta. This CM is a simplified version of the information provided by the CAMT SST.

Though many juvenile salmonid tagging studies have been conducted in the Delta, the focus has primarily been on estimating reach survival and routing- not assessing export-related hydrodynamic mechanisms defined by the SST’s DLO. In fact, most tagging studies have targeted areas of the Delta where “Channel Velocity” and “Flow Direction” may not be appreciably affected by exports (e.g., Newman and Brandes 2010; Perry et al. 2010; Perry et al. 2012; Perry et al. 2015; Michel et al. 2013).

In order to assess the potential for water project operations to influence survival and routing, we analyzed Delta hydrodynamic conditions by utilizing outputs from DSM2 Hydro modeling. Our analysis of DSM2 output is based on our previous work creating map-based visualizations of spatial hydrodynamic patterns at the scale of the Delta. The map-based approach allows us to identify a 'footprint' of the hydrodynamic differences between scenarios. The maps are based on a comparative metric, proportion overlap (more below), to capture channel-level hydrodynamic details as a single number for color-scaled mapping of Delta channels. Our previous work made clear that spatial patterns were more easily discerned by mapping comparative metrics than by mapping descriptive metrics in multiple panels.

The objective of the comparative metric is to summarize the water velocity time series for each channel and scenario such the channel-level comparison is captured in a single number. For the proportion overlap metric, kernel density estimates are calculated on each time series. The kernel density estimates represent a non-parametric smoothing of the empirical distribution of time series values. The proportion overlap of two kernel density estimates is calculated with the following steps: 1) calculate the total area under the curve (AUC_t) as the sum of the AUC for each density estimate, 2) calculate the AUC of the overlapping portions (AUC_o) of the two density distributions being compared, and 3) calculate the overlapping proportion of the density distributions as AUC_o/AUC_t. Proportion overlap is naturally bound by zero and one; a value of zero indicates no overlap and a value of one indicates complete overlap. Lower values of proportion overlap identify channels demonstrating larger differences in a scenario comparison.

The proportion overlap metric is best applied over relatively short time periods because seasonal and annual variation in water velocity can overwhelm differences between scenarios. Thus, we calculated proportion overlap for every DSM2 channel for two seasons (Dec-Feb, May-Mar) in each water year (1922–2003). We excluded DSM2 output from water year 1921 to allow for an extensive burn-in period. We calculated proportion overlap based on hourly DSM2 output. Because each season was roughly 90 days, each comparison involved roughly 4,300 DSM2 values (2 scenarios * 24 hours * 90 days) for each channel.

Because we calculated proportion overlap for each channel in each water year, we summarized the proportion overlap values prior to mapping (i.e., not feasible to map proportion overlap for every comparison in every water year). To summarize, we found the minimum proportion overlap for each channel for each water year type for each comparison. The minimum values represent the maximum expected effect. Note that the year with the minimum proportion overlap for one channel might not be the same year as for another channel.

Entrainment

Zeug and Cavallo (2014) analyzed > 1000 release groups representing, more than 28 million coded wire tagged juvenile fish including winter, late fall and Fall-Run Chinook Salmon. This data is extremely useful because it represents large release groups of tagged smolts where the number of fish representing each release group lost to entrainment at the export facilities has been estimated. Estimating loss from "raw" salvage is problematic because the actual stock or basin of origin is often unknown (e.g., poor performance of length-at-date curves). Furthermore, with "raw" salvage, the number of smolts produced and potentially exposed to entrainment is unknown. The CWT salvage data analyzed by Zeug and Cavallo (2014) overcomes these deficiencies and provides the most appropriate basis for defining stock-specific categories of entrainment risk.

The average proportion Sacramento River-origin Fall-Run Chinook salvaged over a 15-year period was 0.0001 and the proportion of mortality accounted for by entrainment averaged 0.0003 (Zeug and Cavallo 2014). Salvage increased with increasing exports but loss never exceeded 1% regardless of export rate.

Late Fall-Run juveniles were salvaged at a higher rate than any other race (0.02% of each release group) and entrainment related mortality accounted for almost 1% of total mortality on average (Zeug and Cavallo 2014). Proportional loss of Late-Fall remained low until exports exceeded ~9,000 cfs when proportional loss could approach 8% (Zeug and Cavallo 2014). In the December through February period when Late Fall-Run are most abundant, Alternative 2 proposes an average total export rate higher than No Action Alternative (2,556 cfs; Figure O1-1) and will therefore have a higher entrainment risk. Total exports proposed for Alternative 2 in March-June (2,618 cfs higher than No Action Alternative; Figure O1-2) when juvenile Fall-Run are most abundant in the Delta, will increase entrainment risk relative to No Action Alternative, but entrainment losses for Fall-Run Chinook Salmon will be extremely low. Entrainment risk will also increase for Late Fall-Run and losses will likely be higher relative to Fall-Run.

Routing

Routing of juvenile Chinook Salmon into alternative migration routes is closely related to hydrodynamics (Perry et al. 2015; Cavallo et al. 2015; Steel et al. 2012). Changes to hydrodynamics in Delta channels resulting from Alternative 1 were evaluated using DSM2 as described above. Juvenile Fall-Run Chinook Salmon abundance in the Delta is greatest between February and May and Late Fall-Run are present in the Delta between November and July with peaks in January through February and April through May (Table FR_1, LFR_1). In the December through February period, velocity overlap between Alternative 1 and No Action Alternative in the Sacramento River main stem between the Sutter-Steamboat and DCC/Georgiana Slough Junctions, was more than 83%, 79%, 68%, 70%, and 54% in critically dry, dry, below normal, above normal, and wet years, respectively (Figure O1-37 in Appendix O, Attachment 1). During the December through February period, velocities were higher under Alternative 3 in below normal, above normal, and wet years and slightly lower in critically dry and dry years indicating routing into the interior Delta would be lower relative to No Action Alternative in normal and wet years and slightly higher relative to No Action Alternative in dry years (Perry et al. 2015; Figure O1-41 in Appendix O, Attachment 1). During the March to May period, velocity overlap between No Action Alternative and Alternative 3 was more than 82%, 75%, 70%, 60%, and 79% in critically dry, dry, below normal, above normal, and wet years, respectively (Figure O1-38).

Fall-Run and Late Fall-Run Chinook Salmon juveniles originating from the Sacramento River that enter the interior Delta via Georgiana Slough and the Delta Cross Channel can be exposed to hydrodynamic project effects that could affect routing. Once these fish arrive at the junction of the Mokelumne River and the San Joaquin River, they can move south toward the export facilities or west toward the ocean. In the December through February period analysis of DSM2 data indicates that there is little change to velocities in the region of the junction of the Mokelumne and San Joaquin Rivers between Alternative 3 and the No Action Alternative (Figure O1-39 in Appendix O, Attachment 1). Similar results were obtained when comparing Alternative 3 to the No Action Alternative in the March to May period (Figure O1-40).

Through-Delta Survival

A recent study by Perry et al. (2018) found that the effect of flow on survival is not uniform throughout the Delta. Relationships between flow and survival were significant only in reaches where flow changes from bi-directional to unidirectional when discharge increases. To examine potential effects of the proposed project, changes in velocity distributions were examined for the Sacramento River at Walnut Grove and Steamboat Slough which are both in this “transitional” region. During the December to February period at Walnut Grove, velocity distributions for Alternative 3 relative to No Action Alternative were most different in wet years (72.5%) with higher velocities in Alternative 3. Velocities were also greater for Alternative 3 relative to No Action Alternative in below normal and above normal years although overlap was greater (>78%; Figure O1-41 in Appendix O, Attachment 1). In critically dry and dry years, velocity distributions were more similar (>84%; Figure O1-41 in Appendix O, Attachment 1). At Steamboat Slough in the December to February period, velocities under Alternative 3 were higher than No Action Alternative in wet and below normal years and similar in above normal, dry, and critically dry years (Figure O1-42 in Appendix O, Attachment 1).

In the March through May period at Walnut Grove, velocity overlap between Alternative 3 and No Action Alternative was >78% across all water year types with similar velocities under Alternative 3 (Figure O1-43 in Appendix O, Attachment 1). At Steamboat Slough in the March through May period, overlap between Alternative 3 and No Action Alternative scenarios was >76% with similar velocities under Alternative 3 (Figure O1-44 in Appendix O, Attachment 1).

A recent study by Perry et al. (2018) found that the effect of flow on survival is not uniform throughout the Delta. Relationships between flow and survival were significant only in reaches where flow changes from bi-directional to unidirectional when discharge increases. To examine potential effects of Alternative 3, changes in velocity distributions were examined for the San Joaquin River at Highway 4 and the Head of Middle River which are both in the “transitional” region of the San Joaquin River. During the December to February period at the San Joaquin River at Highway 4, velocity distributions for Alternative 3 relative to No Action Alternative exhibited high overlap in all water year types (≥81.3%; Figure O1-45 in Appendix O, Attachment 1). At the Head of Middle River during the December through February period, overlap was high between Alternative 3 and No Action Alternative in critically dry and dry water years (≥77%) and moderate in wet, above normal, and below normal years (65%; Figure O1-46 in Appendix O, Attachment 1).

In the March to May period in the San Joaquin River at Highway 4, velocity overlap was high between Alternative 3 and No Action Alternative (≥80%; Figure O1-47 in Appendix O, Attachment 1). Velocities were similar in all water year types (Figure O1-47). At the Head of Middle River in the March –May period, overlap between Alternative 3 and No Action Alternative was moderate in all water year types (41-65%) and higher in critically dry years >78% (Figure O1-48 in Appendix O, Attachment 1). Velocities were generally lower under Alternative 3 than No Action Alternative (Figure O1-48).

Potential changes to aquatic resources due to OMR management

See section on seasonal operations which includes OMR management.

Potential changes to aquatic resources due to Delta Cross Channel operations

The Delta Cross Channel may be closed for up to 45 days from November through January for fishery protection purposes. From February 1 through May 20, the gates are closed for fishery protection purposes. The gates may also be closed for 14 days from May 21 through June 15 for fishery protection purposes. The peak migration of juvenile Fall-Run Chinook Salmon in the Sacramento River past West Sacramento, which is near the DCC, occurs from February through May (Table FR_1). Therefore, the DCC is closed for the majority of the juvenile Fall-Run Chinook Salmon migration period in the Sacramento River and as such the proportion of fish exposed to an open DCC would be low. Juvenile Fall-Run Chinook Salmon that are entrained into an open DCC and transported to the interior Delta have reduced survival (Perry et al. 2010).

Potential changes to aquatic resources due to the Temporary Barriers Project

The Temporary Barriers Project (TBP) consists of three rock barriers across south Delta channels to improve water levels for agricultural diversions and one rock barrier to improve San Joaquin River salmonid migration in the south Delta. The temporary rock barriers are installed and removed at Middle River near Victoria Canal, Old River near Tracy, Grant Line Canal near Tracy Boulevard Bridge, and the head of Old River. The TBP is operated based on San Joaquin River flow conditions. The agricultural barriers at Middle River and Old River near Tracy can begin operating as early as April 15 but the tide gates are tied open from May 16 to May 31. After May 31, the barriers in Middle River, Old River near Tracy, and Grant Line Canal are permitted to be operational until they are completely removed by November 30. The head of Old River Barrier is only installed from September 16 to November 30 to improve flow and dissolved oxygenconditions in the San Joaquin River for the immigration of adult Fall-Run Chinook Salmon.

The proportion of juvenile Fall-Run Chinook Salmon exposed to the TBP depends on their annual timing of installation and removal. Due to their location, primarily migrants originating from the San Joaquin River would be exposed to the TBP. The peak relative abundance of juvenile Fall-Run Chinook Salmon in the Delta at Mossdale is February through May (Table FR_1). The Head of Old River Barrier would have no effect on juvenile Fall-Run Chinook Salmon if installed from September 16 to November 30 as juvenile Fall-Run are largely absent from this section of the San Joaquin River during this time period (FR_1). If the agricultural barriers are operating as early as April 15 then they have the potential to expose a large proportion of the juvenile Fall-Run Chinook Salmon migrating down the San Joaquin River. When the Head of Old River barrier is not in place, acoustically tagged juvenile Chinook Salmon have demonstrated a high probability of selecting the Old River route (Buchanan 2018), which would expose them to the agricultural barriers. When the agricultural barriers are operating with tidal flap gates down, a significant decline in passage and reach survival of acoustically tagged juvenile Chinook Salmon migrating past the barrier has been observed compared to when the barrier is not present (DWR 2018). When flap gates are tied up, Chinook Salmon passage past the agricultural barrier was improved (DWR 2018). Flap gates tied up on agricultural barriers from May 16 to May 31 would help to reduce the negative effect of the barriers during this period. However, juveniles migrating before or after this period could be exposed to the agricultural barriers with flaps down which apparently decreases passage success and survival (DWR 2018). Therefore, the potential negative effects of the agricultural barriers depends on when they are installed and whether the flap gates are down or tied up but overall would be medium to high.

Potential changes to aquatic resources due to Contra Costa Water District operations

CCWD's operations in Alternative 3 are consistent with the operational criteria specified in separate biological opinions and permits that govern operations at CCWD's intakes and Los Vaqueros Reservoir (NMFS 1993, 2007, 2010, 2017; USFWS 1993a, 1993b, 2000, 2007, 2010, 2017; CDFG 1994, 2009a). Therefore, CCWD's operations, including operation of the Rock Slough Intake, under Alternative 3 would remain unchanged from the current operations.

Fish monitoring prior to the construction of the Rock Slough Fish Screen (RSFS) indicates the timing and magnitude of Fall-Run/Late Fall-Run Chinook Salmon presence near the Rock Slough Intake. From 1999 to 2011, the 11 years prior to construction of the RSFS, CCWD's Fish Monitoring Program collected 23 juvenile Fall-Run/Late Fall-Run Chinook Salmon at the Rock Slough Headworks and Contra Costa Pumping Plant #1. Since construction of the Rock Slough Fish Screen in 2012, no Fall-Run/Late Fall-Run Chinook Salmon have been collected behind the fish screen. CCWD's Fish Monitoring Program also samples at CCWD's other south Delta intakes. Since the intakes have been in operation, CCWD's Fish Monitoring Program has never collected Fall-Run/Late Fall-Run Chinook Salmon at CCWD's Old River Intake or Middle River Intake (CCWD 2019).

CCWD’s operations, including operation of the Rock Slough, Old River, and Middle River intakes and Los Vaqueros Reservoir, are simulated in the CalSim model. Thus, CalSim results discussed throughout this appendix include the effects of CCWD’s operations in combination with all other water diversions and reservoir operations. A further analysis was undertaken to isolate the maximum possible effects of CCWD’s operations on Delta hydrodynamics by determining the effect that CCWD pumping at maximum capacity would have on Delta channel water velocity. Results of this analysis are shown below; in all cases the maximum possible effect of CCWD's operations is de minimis.

Due to the location of the Rock Slough Intake near the end of a dead-end slough, far from the main migratory routes, juvenile Central Valley Fall-Run/Late Fall-Run Chinook Salmon are not likely to be in the vicinity of the Rock Slough Intake. However, according to NMFS (2017), juvenile Salmon can be “drawn” into the south Delta under reverse flows and high CVP and SWP pumping rates.

One indicator of reverse flows is the net flow in Old and Middle Rivers (OMR). Rock Slough Intake is located on Rock Slough, approximately 3.5 miles west of the junction of Rock Slough and Old River, which is over 12 river miles north of the gates to the SWP Clifton Court Forebay. Given its location, the Rock Slough Intake does not affect net reverse flow in Old and Middle Rivers (OMR), and any effect that diversions at Rock Slough Intake would have in the Old and Middle River corridor would be to increase the northerly (positive) flow away from the Banks and Jones Pumping Plants. For juveniles that migrate down the Old and Middle River corridor that are not salvaged at TFCF or Skinner Fish Facility, any effect of Rock Slough Intake diversions would be a positive effect on OMR.

For juveniles that migrate down the mainstems of the Sacramento River or the San Joaquin River and for juveniles that were salvaged, trucked, and released in the western Delta, the potential effect of Rock Slough diversions on the net reverse flow in San Joaquin River may be relevant. The effect of water diversions at Rock Slough Intake on the velocity in the San Joaquin River at Jersey Point is presented in the effects analysis for juvenile Winter-Run. As detailed in that section, the maximum potential effect of water diversions at Rock Slough Intake (assuming diversions at the maximum permitted capacity of 350 cfs and all water diverted by the Rock Slough Intake comes from the San Joaquin River at Jersey Point) is 0.00625 ft/sec in the San Joaquin River at Jersey Point. For comparison, the velocity threshold for design of fish screens to prevent impingement of salmonids is 0.33 ft/sec, which is 50 times the maximum possible contribution from the Rock Slough diversions.

Recognizing that CCWD owns and operates two additional intakes in the south Delta, we examine the combined effect of all three intakes. CCWD’s Old River Intake and Middle River Intake have a physical capacity of 250 cfs at each intake. If CCWD were to divert at all three intakes at the maximum capacity at the same time, total CCWD diversions would be 850 cfs. The corresponding effect on velocity in the San Joaquin River at Jersey Point would be 0.015 ft/sec. The velocity threshold used to protect salmonids from diversions in the vicinity of fish screens (0.33 ft/sec) is over 21 times greater than the maximum possible contribution from CCWD’s combined physical capacity. The water diversions at the Rock Slough Intake when combined with diversions at CCWD’s Old River Intake and Middle River Intake have a negligible effect on velocity along the migratory path for juvenile Central Valley Fall-Run/Late Fall-Run Salmon and are not likely to affect the movement of juvenile salmonids.

Nonetheless, even extremely small changes in velocity can affect the movement of neutrally buoyant particles such as phytoplankton. As shown in the Winter-Run Chinook Salmon section, the diversions at the Rock Slough Intake could move a neutrally buoyant particle in the San Joaquin River at Jersey Point approximately 540 ft over the course of the day. For comparison, the tidal excursion on the San Joaquin River at Jersey Point during a flood tide (i.e., the distance a particle will travel tidally upstream during a flood tide) is about 34,000 ft on average (or 6.4 miles), which is about 63 times the distance that diversions at Rock Slough could move a particle at the same location over the course of a full day. Therefore, the maximum possible contribution of diversions at Rock Slough on movement of neutrally buoyant particles such as phytoplankton is not significant in comparison to the tidal excursion and mixing at this location.

In summary, CCWD’s operations under Alternative 3 would remain consistent with the operational criteria specified in separate biological opinions and permits that govern operations at CCWD’s intakes and Los Vaqueros Reservoir, and as shown above, the effect of CCWD’s operations on Delta hydrodynamics is negligible.

Potential changes to aquatic resources due to North Bay Aqueduct operations

Listed salmonids may be present in the waterways adjacent to the Barker Slough Pumping Plant, however several years of monitoring have failed to consistently capture any salmonids during the winter Delta Smelt surveys (1996 to 2004) in Lindsey Slough or Barker Slough. Captures of Chinook Salmon have usually occurred in the months of February and March and typically are only a single fish per net haul (http://www.delta.dfg.ca.goc/data/nba). Most Chinook Salmon captured have come from Miner Slough, which is a direct distributary from the Sacramento River via Steamboat and Sutter Sloughs. Few if any San Joaquin River-origin Fall-Run Chinook Salmon are expected to be exposed to the North Bay aqueduct because it is not on the migration route of this species.

Alternative 3 also includes sediment removal with a suction dredge that could entrain Fall Run individuals occurring near the suction dredging. In addition, aquatic weed removal with a grappling system could disturb Fall Run occurring near the removal. The low occurrence of Chinook Salmon in monitoring efforts suggest that any potential imacts from sediment and aquatic weed removal would be limited.

Potential changes to aquatic resources from Clifton Court aquatic weed removal

Few if any juvenile Fall-Run Chinook Salmon would be expected to be exposed to the Clifton Court Forebay Aquatic Weed Control Program. Juvenile Fall-Run are present in the Delta between mid-November and early June with a peak in April (Table_WR1). The application of aquatic herbicide to the waters of Clifton Court Forebay will occur during the summer months of July and August. Thus, the probability of exposing Spring-Run Chinook Salmon to the herbicide is very low. Based on typical water temperatures in the vicinity of the salvage facilities during this period, the temperatures would be incompatible with salmonid life history preferences, generally exceeding 70°F by mid-June. Mechanical harvesting would occur on an as-needed basis and therefore listed salmonids could be exposed to this action, if entrained into the Forebay. The overall effect of this action is low.

Potential changes to aquatic resources due to changes from Tracy and Skinner fish facilities improvements

Although actions at the Tracy facility could positively affect juvenile Fall-Run Chinook Salmon through greater salvage efficiency, only small proportions of Fall-Run Chinook Salmon are lost at the CVP (Zeug and Cavallo 2014).

Skinner Fish Facility improvements from predator control efforts to reduce predation on listed fishes following entrainment into Clifton Court Forebay could reduce pre-screen loss of juvenile Chinook Salmon entrined into Clifton Cout Forebay. However, given that only small proportions of Fall-Run Chinook Salmon are lost at the SWP (Zeug and Cavallo 2014), the population-level positive effect of this action would be low. Larger proportions of Late Fall-Run Chinook Salmon are lost at the facilities and this action would have a larger effect for this run.

Potential changes to aquatic resources due to changes from Suisun Marsh facilities

Operation of the SMSCG from October through May coincides with downstream migration of juvenile Fall-Run Chinook Salmon (Table FR_1). NMFS (2009) determined that operation of the SWSCG is unlikely to impede migration of juvenile salmonids or produce conditions that support unusually high numbers of predators.

As described by NMFS (2009: 437-438), the Roaring River Distribution System (RRDS)'s water intake (eight 60-inch-diameter culverts) is equipped with fish screens (3/32-inch opening, or 2.4 mm) operated to maintain screen approach velocity of 0.2 ft/s (for Delta Smelt protection), so that juvenile Fall-Run Chinook Salmon would be excluded from entrainment.

NMFS (2009: 438) considered it unlikely that juvenile Winter-Run Chinook Salmon, would be entrained by the three unscreened 48-inch culverts that form the Morrow Island Distribution System (MIDS) water intake, as a result of their larger size and better swimming ability relative to the size of Fall-Run Chinook Salmon observed to have been entrained (<45 mm), and also because the location of the MIDS intake on Goodyear Slough is not on a migratory corridor for listed juvenile salmonids. Although Fall-Run have been entrained at this facility, only a small proportion of total migrants are likely to encounter it.

NMFS (2009: 438) concluded that it would be unlikely that Chinook Salmon would encounter or be negatively affected by the Goodyear Slough outfall given its location and design, which is intended to improve water circulation in Suisun Marsh and therefore was felt by NMFS (2009: 438) to likely be of benefit to juvenile salmonids by improving water quality and increasing foraging opportunities.

Potential changes to aquatic resources from actions for Delta Smelt summer-fall habitat Juvenile Fall-Run Chinook Salmon are abundant in the Delta in December and January and April and May (Table FR_1). Late Fall-Run are most abundant from January through April. Small fractions of each run could be exposed to Fall Delta Smelt habitat actions. For fish that are exposed, increased turbidity may reduce susceptibility to predation and increase through-Delta survival.

Potential changes to aquatic resources due to changes from Clifton Court predator management

Pre-screen survival of juvenile Chinook Salmon has been shown to be low (Gingras 1997) and predation is thought to be a major source of mortality. Analyses by Zeug and Cavallo (2014) indicate that only small proportions of Sacramento River-origin Fall-Run Chinook Salmon arrive at the facilities. However, moderte proportions of San Joaquin River-origin Fall-Run Chinook Salmon arrive at the facilities. For fish that are entrained into Clifton Cout Forebay, predator control may increase pre-screen survival. The overall effect of the action is low for Sacramento River-Origin fish and moderte for San Joaquin River and Mokelumne River-origin fish

Potential changes to aquatic resources due to the San Joaquin Basin steelhead telemetry study

Potential changes to aquatic resources due to reintroduction changes from the fish conservation and culture laboratory

O.3.7.8.6 Central Valley Steelhead

Potential changes to aquatic resources due to seasonal operations

Entrainment

ICF (2018) analyzed salvage of Central Valley Steelhead at the CVP and SWP between 2003 and 2017 and found that salvage increased with export rate and decreased with San Joaquin River flow. Salvage also decreased with OMR flow. However, OMR is a metric comprised of both exports and San Joaquin River flow which complicates attempts to understand individual effects.

In the December through February period, Alternative 3 proposes an average total export rate slightly higher than the No Action Alternative (2,556 cfs; Figure O1-1 in Appendix O, Attachment 1) and will therefore have higher entrainment risk. Total exports proposed for Alternative 3 in March-June (2,618 cfs higher than No Action Alternative; Figure O1-2 in Appendix O, Attachment 1) when juvenile Central Valley Steelhead are most abundant in the Delta at Chipps Island (Reclamation 2019), will increase entrainment risk relative to No Action Alternative.

Routing

Routing of juvenile Central Valley Steelhead into alternative migration routes is closely related to hydrodynamics (Perry et al. 2015; Cavallo et al. 2015; Steel et al. 2012). Changes to hydrodynamics in Delta channels resulting from Alternative 3 were evaluated using DSM2. Juvenile Central Valley Steelhead are present in the Sacramento River at Hood upstream of the first distributary junctions between November and early June with peak abundance from February to early June (Reclamation 2019). In the December to February period, velocity overlap between Alternative 3 and No Action Alternative in the Sacramento River mainstem between the Sutter-Steamboat and DCC/Georgiana Slough Junctions, was more than 83%, 79%, 68%, 70%, and 54% in critically dry, dry, below normal, above normal, and wet years, respectively (Figure O1-37 in Appendix O, Attachment 1). During the December through February period, velocities were higher under Alternative 3 in below normal, above normal, and wet years and slightly lower in critically dry and dry years indicating routing into the interior Delta would be lower relative to No Action Alternative in normal and wet years and slightly higher relative to No Action Alternative in dry years (Perry et al. 2015; Figure O1-41 in Appendix O, Attachment 1). During the March to May period, velocity overlap between No Action Alternative and Alternative 3 was more than 82%, 75%, 70%, 60%, and 79% in critically dry, dry, below normal, above normal, and wet years, respectively (Figure O1-38 in Appendix O, Attachment 1).

Through-Delta Survival

A recent study by Perry et al. (2018) found that the effect of flow on survival is not uniform throughout the Delta. Relationships between flow and survival were significant only in reaches where flow changes from bi-directional to unidirectional when discharge increases. To examine potential effects of Alternative 3, changes in velocity distributions were examined for the Sacramento River at Walnut Grove and Steamboat Slough which are both in this “transitional” region. During the December to February period at Walnut Grove, velocity distributions for Alternative 3 relative to No Action Alternative were most different in wet years (72.5%) with higher velocities in Alternative 3. Velocities were also greater for Alternative 3 relative to No Action Alternative in below normal and above normal years although overlap was greater (>78%; Figure O1-41 in Appendix O, Attachment 1). In critically dry and dry years, velocity distributions were more similar (>84%; Figure O1-41 in Appendix O, Attachment 1). At Steamboat Slough in the December to February period, velocities under Alternative 3 were higher than

No Action Alternative in wet and below normal years and similar in above normal, dry, and critically dry years (Figure O1-42 in Appendix O, Attachment 1).

In the March through May period at Walnut Grove, velocity overlap between Alternative 3 and No Action Alternative was >78% across all water year types with similar velocities under Alternative 3 (Figure O1-43 in Appendix O, Attachment 1). At Steamboat Slough in the March through May period, overlap between Alternative 3 and No Action Alternative scenarios was >76% with similar velocities under Alternative 3 (Figure O1-44 in Appendix O, Attachment 1).

A recent study by Perry et al. (2018) found that the effect of flow on survival is not uniform throughout the Delta. Relationships between flow and survival were significant only in reaches where flow changes from bi-directional to unidirectional when discharge increases. To examine potential effects of Alternative 1, changes in velocity distributions were examined for the San Joaquin River at Highway 4 and the Head of Middle River which are both in the "transitional" region of the San Joaquin River. During the December to February period at the San Joaquin River at Highway 4, velocity distributions for Alternative 3 relative to No Action Alternative exhibited high overlap in all water year types (≥81.3%; Figure O1-45 in Appendix O, Attachment 1). At the Head of Middle River during the December through February period, overlap was high between Alternative 3 and No Action Alternative in critically dry and dry water years (≥77%) and moderate in wet, above normal, and below normal years (65%; Figure O1-46 in Appendix O, Attachment 1).

In the March to May period in the San Joaquin River at Highway 4, velocity overlap was high between Alternative 3 and No Action Alternative (≥80%; Figure O1-47 in Appendix O, Attachment 1). Velocities were similar in all water year types (Figure O1-47). At the Head of Middle River in the March –May period, overlap between Alternative 3 and No Action Alternative was moderate in all water year types (41-65%) and higher in critically dry years >78% (Figure O1-48 in Appendix O, Attachment 1). Velocities were generally lower under Alternative 3 than No Action Alternative (Figure O1-48).

Potential changes to aquatic resources due to OMR management

See section on Seasonal Operations which includes OMR management.

Potential changes to aquatic resources due to Delta Cross Channel operations

Significant flow and many juvenile Central Valley Steelhead enter the central Delta when the DCC gates are open. Mortality of juvenile Central Valley Steelhead entering the central Delta is higher than for those continuing downstream in the Sacramento River. The peak migration of juvenile Central ValleyV Steelhead in the Sacramento River past Knights Landing, which is upstream of the DCC, occurs from January through February (Table 5.10-1). Therefore under Alternative 2, the continued operation of the DCC to protect the majority of the juvenile Central Valley Steelhead during their migration period in the Sacramento River would reduce the proportion of fish exposed to an open DCC and result in beneficial impacts to this life stage when compared to the No Action Alternative.

Potential changes to aquatic resources due to the Temporary Barriers Project

The Temporary Barriers Project (TBP) consists of three rock barriers across south Delta channels to improve water levels for agricultural diversions and one rock barrier to improve San Joaquin River salmonid migration in the south Delta. The temporary rock barriers are installed and removed at Middle River near Victoria Canal, Old River near Tracy, Grant Line Canal near Tracy Boulevard Bridge, and the head of Old River. The TBP is operated based on San Joaquin River flow conditions. The agricultural barriers at Middle River and Old River near Tracy can begin operating as early as April 15 but the tide gates are tied open from May 16 to May 31. After May 31, the barriers in Middle River, Old River near Tracy, and Grant Line Canal are permitted to be operational until they are completely removed by November 30. The Head of Old River Barrier is only installed from September 16 to November 30 to improve flow and dissolved oxygenconditions in the San Joaquin River for the immigration of adult Fall-Run Chinook Salmon.

The proportion of juvenile Central Valley Steelhead exposed to the TBP depends on their annual timing of installation and removal. Due to their location, primarily juvenile Central Valley Steelhead migrants originating from the San Joaquin River would be exposed to the TBP. The peak relative abundance of juvenile Central Valley Steelhead in the San Joaquin River in the vicinity of the TBP (Mossdale) occurs in April and May (Reclamation 2019). If the agricultural barriers are operating as early as April 15, there is potential exposure to a large proportion of the juvenile Central Valley Steelhead migrating down the San Joaquin River.

When the Head of Old River barrier is not in place, acoustically tagged juvenile Central Valley Steelhead have demonstrated a high probability of selecting the Old River route (Buchanan 2018[PC1]), which would expose them to the agricultural barriers. When the agricultural barriers are operating with tidal flap gates down, a significant decline in passage and reach survival of acoustically tagged juvenile Central Valley Steelhead migrating past the barrier has been observed compared to when the barrier is not present (DWR 2018). When flap gates are tied up, Central Valley Steelhead passage past the agricultural barrier was improved (DWR 2018). Therefore, although Alternative 3 does not include HORB, which could result in negative impacts to Central Valley Steelhead juvenile migration, the improvements to the agricultural barriers (including flap gates tied up from May 16 to May 31) would help to reduce the negative effect of the barriers on migrating juvenile Central Valley Steelhead during this period relative to No Action Alternative. However, juvenile Central Valley Steelhead migrating before or after this period could be exposed to the agricultural barriers with flaps down, which apparently decreases passage success and survival (DWR 2018). Therefore, the potential negative effects of the agricultural barriers under Alternative 1 on juvenile Central Valley Steelhead depends on when they are installed and whether or not the flap gates are down.

Potential changes to aquatic resources due to Contra Costa Water District operations

CCWD’s operations in Alternative 3 are consistent with the operational criteria specified in separate biological opinions and permits that govern operations at CCWD’s intakes and Los Vaqueros Reservoir (NMFS 1993, 2007, 2010, 2017; USFWS 1993a, 1993b, 2000, 2007, 2010, 2017; CDFG 1994, 2009a). Therefore, CCWD’s operations, including operation of the Rock Slough Intake, under Alternative 3 would remain unchanged from the current operations.

Fish monitoring prior to the construction of the Rock Slough Fish Screen (RSFS) indicates the timing and magnitude of Central Valley Steelhead presence near the Rock Slough Intake. From 1999 to 2011, the 11 years prior to construction of the RSFS, CCWD’s Fish Monitoring Program collected 15 juvenile Central Valley Steelhead at the Rock Slough Headworks and Pumping Plant #1. Since construction of the Rock Slough Fish Screen, no Central Valley Steelhead have been collected behind the fish screen. CCWD’s Fish Monitoring Program also samples at CCWD’s other south Delta intakes. Since the intakes have been in operation, CCWD’s Fish Monitoring Program has never collected Central Valley Steelhead at CCWD’s Old River Intake or Middle River Intake (CCWD 2019).

CCWD’s operations, including operation of the Rock Slough, Old River, and Middle River intakes and Los Vaqueros Reservoir, are simulated in the CalSim model. Thus, CalSim results discussed throughout this appendix include the effects of CCWD’s operations in combination with all other water diversions and reservoir operations. A further analysis was undertaken to isolate the maximum possible effects of CCWD's operations on Delta hydrodynamics by determining the effect that CCWD pumping at maximum capacity would have on Delta channel water velocity. Results of this analysis are shown below; in all cases the maximum possible effect of CCWD's operations is de minimis.

Due to the location of the Rock Slough Intake near the end of a dead-end slough, far from the main migratory routes, juvenile Central Valley Steelhead are not likely to be in the vicinity of the Rock Slough Intake. However, according to NMFS (2017), juvenile salmonids can be "drawn" into the south Delta under reverse flows and high CVP and SWP pumping rates. One indicator of reverse flows is the net flow in OMR. Rock Slough Intake is located on Rock Slough, approximately 3.5 miles west of the junction of Rock Slough and Old River, which is over 12 river miles north of the gates to the SWP Clifton Court Forebay. Given its location, the Rock Slough Intake does not affect OMR, and any effect that diversions at Rock Slough Intake under Alternative 3 would have in the OMR corridor would be to increase the northerly (positive) flow away from the Banks and Jones Pumping Plants. For juveniles that migrate down the Old and Middle River corridor that are not salvaged at TFCF or Skinner Fish Facility, any effect of Rock Slough Intake diversions would be a positive effect on OMR.

For juveniles that migrate down the mainstems of the Sacramento or San Joaquin Rivers and for juveniles that were salvaged, trucked, and released in the western Delta, the potential effect of Rock Slough diversions on the net reverse flow in San Joaquin River may be relevant. The effect of water diversions at Rock Slough Intake on the velocity in the San Joaquin River at Jersey Point is presented in the effects analysis for juvenile Winter-Run. As detailed in that section, the maximum potential effect of water diversions at Rock Slough Intake (assuming diversions at the maximum permitted capacity of 350 cfs and all water diverted by the Rock Slough Intake comes from the San Joaquin River at Jersey Point) is 0.00625 ft/sec in the San Joaquin River at Jersey Point. For comparison, the velocity threshold for design of fish screens to prevent impingement of salmonids is 0.33 ft/sec, which is 50 times the maximum possible contribution from the Rock Slough diversions.

Recognizing that CCWD owns and operates two additional intakes in the south Delta, the combined effect of all three intakes was examined. CCWD's Old River Intake and Middle River Intake have a physical capacity of 250 cfs at each intake. If CCWD were to divert at all three intakes at the maximum capacity at the same time, total CCWD diversions would be 850 cfs. The corresponding effect on velocity in the San Joaquin River at Jersey Point would be 0.015 ft/sec. The velocity threshold used to protect salmonids from diversions in the vicinity of fish screens (0.33 ft/sec) is over 21 times greater than the maximum possible contribution from CCWD's combined physical capacity. The water diversions at the Rock Slough Intake when combined with diversions at CCWD's Old River Intake and Middle River Intake have a negligible effect on velocity along the migratory path for juvenile Central ValleySteelhead.

Nonetheless, even extremely small changes in velocity can affect the movement of neutrally buoyant particles such as phytoplankton. As shown in the Winter-Run Chinook Salmon section, the diversions at the Rock Slough Intake could move a neutrally buoyant particle in the San Joaquin River at Jersey Point approximately 540 ft over the course of the day. For comparison, the tidal excursion on the San Joaquin River at Jersey Point during a flood tide (i.e., the distance a particle will travel tidally upstream during a flood tide) is about 34,000 ft on average (or 6.4 miles), which is about 63 times the distance that diversions at Rock Slough could move a particle at the same location over the course of a full day. Therefore, the maximum possible contribution of diversions at Rock Slough on movement of neutrally buoyant particles such as phytoplankton is insignificant in comparison to the tidal excursion and mixing at this location. Although the diversions at Rock Slough Intake are not likely to impact juvenile Central Valley Steelhead, the aggregate effect of all water diversions in the Delta, including exports at Jones and Banks Pumping Plants can affect channel velocity.

In summary, CCWD's operations under Alternative 3 would remain consistent with the operational criteria specified in separate biological opinions and permits that govern operations at CCWD's intakes and Los Vaqueros Reservoir, and as shown above, the effect of CCWD's operations on Delta hydrodynamics is negligible.

Potential changes to aquatic resources due to North Bay Aqueduct operations

Under Alternative 3, there would be no changes to operational criteria at the NBA's BSPP relative to current op. Juvenile Central Valley Steelhead could occur in the vicinity of the BSPP; however, the fish screens used at the facility are designed to protect juvenile salmonids per NMFS criteria and should prevent entrainment and greatly minimize impingement of fish against the screen itself (NMFS 2009). In addition, the location of the facility is well off the typical migration corridor of juvenile Central Valley Steelhead (NMFS 2009: 417). No juvenile Central Valley Steelhead have been captured during CDFW monitoring surveys from 1996 to 2004 (http://www.delta.dfg.ca.goc/data/nba).

Alternative 3 also includes sediment removal with a suction dredge that could entrain Fall Run individuals occurring near the suction dredging. In addition, aquatic weed removal with a grappling system could disturb Fall Run occurring near the removal. The low occurrence of Chinook Salmon in monitoring efforts suggest that any potential imacts from sediment and aquatic weed removal would be limited.

Potential changes to aquatic resources due to water transfers

Central Valley Steelhead juveniles could be exposed to increased entrainment, predation, and decreased through-Delta survival as a result of the expanded transfer window under Alternative 3, but as the peak of the juvenile out-migration is in the spring, effects are anticipated to be minimal. No other lifestages of Central Valley Steelhead would co-occur in time and space with water transfers from the Delta.

Potential changes to aquatic resources from Clifton Court aquatic weed removal

Under Alternative 3, the application of aquatic herbicide to the waters of CCF will occur between 28 June and 31 August. Treatment could occur prior to 28 June at tempertures ≥ 25˚C; however, steelhead would not be expected to occur at these temperatures. Treatment could also occur after 31 August if protective measures have not been triggered but few if any steelhead would be expected in the Delta during that time period. Juvenile Central Valley Steelhead abundance in the Delta peaks between March and May (Reclamation 2019). Based on typical water temperatures in the vicinity of the salvage facilities during this period, the water temperatures would be incompatible with salmonid life history preferences, generally exceeding 70°F by mid-June. As such, it is unlikely that juvenile Central Valley Steelhead would be rearing near this location after mid-June and the potential application of aquatic herbicide would only occur well after the peak out-migration period (Reclamation 2019) and therefore Central Valley Steelhead are not expected to be exposed to herbicide application activities.

Mechanical harvesting would occur on an as-needed basis and therefore listed salmonids could be exposed to this action, if entrained into the CCF. Potential direct and indirect effects to listed fish species from mechanical weed harvesters include mortality or injury from harvester strikes, entanglement in weeds lifted from the water, reduction of aquatic prey species, and temporary disturbances. Increased boat noise and disturbance of the water during harvesting, the slow speed of the harvester (approximately 2 miles per hour), and beginning harvesting closest to the edge should allow fish to escape the area proposed for mowing. However, Central Valley Steelhead are unlikely to be present and exposed to the adverse effects due to extreme temperatures.

Potential changes to aquatic resources due to changes from Tracy and Skinner fish facilities improvements

Small proportions of Sacramento River-origin Central Valley Steelhead and moderate proportions of Mokelumne River and San Joaquin River-origin Central Valley Steelhead are expected to be exposed to the Tracy Fish Facility. However, for fish that arrive at the facility, the proposed improvements resulting in greater salvage efficiency under Alternative 3 are likely to increase survival of juvenile Central Valley Steelhead.

As previously described, juvenile Central Valley Steelhead are largely absent from the Delta between August and November (Reclamation 2019) and, therefore, none to a few late migrants or early migrants have the potential to be exposed to the effects of construction of the carbon dioxide injection device proposed for the Tracy Fish Facility Improvements. Risks of decrease Central Valley Steelhead juvenile salvage during construction would be minimized through appropriate mitigation measures for aquatic resources (Appendix E, Mitigation Measures).

Skinner Fish Facility improvements under Alternative 3 to reduce predation on listed fishes following entrainment into CCF could reduce pre-screen loss of juvenile Central Valley Steelhead entrained into CCF; therefore, providing a benefit for all life stages of Central Valley Steelhead.

Potential changes to aquatic resources due to changes from Suisun Marsh facilities

Operation of the SMSCG from October through May under Alternative 3 coincides with downstream migration of juvenile Central Valley Steelhead (Reclamation 2019). Montezuma Slough provides an alternative route to their primary migration corridor through Suisun Bay. No data are available to estimate the abundance of juvenile Central Valley Steelhead thus, the proportion of the total run utilizing this route is unknown. However NMFS (2009) determined that operation of the SWSCG is unlikely to impede migration of juvenile salmonids or produce conditions that support unusually high numbers of predators.

Under Alternative 3, the Roaring River Distribution System water diversion intake is equipped with fish screens (3/32-inch opening, or 2.4 mm) operated to maintain screen approach velocity of 0.2 ft/s (for Delta Smelt protection), excluding juvenile Central Valley Steelhead from entrainment (NMFS 2009: 437).

The MIDS diverts water from Goodyear Slough through three 48-inch diameter culverts during high tide. Although the MIDS intakes do not currently have fish screens, it is unlikely juvenile Central Valley Steelhead will be entrained into the water distribution system because Central Valley Steelhead have not been caught in past surveys. Also, the large size and better swimming ability of juvenile listed salmonids in the Delta allow these fish to avoid entrainment at MIDS. In addition, the location of the MIDS intake on Goodyear Slough further reduces the risk of entrainment. Goodyear Slough is not a migratory corridor for Central Valley Steelhead. The operation of the MIDS under Alternative 3 would not impact Central Valley Steelhead.

Goodyear Slough Outfall improves water circulation in the Suisun Marsh. This structure consists of four 48-inch diameter culverts with flap gates designed to drain water from the southern end of Goodyear Slough into Suisun Bay. On flood tides, the gates reduce the amount of tidal inflow into Goodyear Slough. Due to its location and design, Central Valley Steelhead are not likely to encounter this structure or be negatively affected by its operation. Improved water circulation by the operation of the Goodyear Slough Outfall likely benefits Central Valley Steelhead in Suisun Marsh by improving water quality and increasing foraging opportunities.

Potential changes to aquatic resources from actions for Delta Smelt summer-fall habitat Central Valley Steelhead juveniles are in the Delta in the spring. Reclamation proposes to conduct actions for Fall Delta Smelt Habitat in the fall, as adult Central Valley Steelhead are migrating upstream. Fall Delta Smelt Habitat actions are unlikely to affect adult Central Valley Steelhead.

Potential changes to aquatic resources due to changes from Clifton Court predator management

Clifton Court predator management under Alternative 3 could reduce pre-screen loss of juvenile Central Valley Steelhead entrained into CCF; therefore, providing a benefit for all life stages of Central Valley Steelhead.

Potential changes to aquatic resources due to the San Joaquin Basin steelhead telemetry study

Potential changes to aquatic resources due to reintroduction changes from the fish conservation and culture laboratory

Potential changes to aquatic resources from monitoring

Population estimates for wild Steelhead remain outstanding in the Central Valley, therefore it is difficult to quantify the effects of the monitoring on Steelhead populations. However, most existing monitoring programs in the Central Valley and Delta/SF Estuary are not designed to capture Steelhead, which are much larger than Chinook Salmon upon river and Delta entry. Existing programs likely have poor capture efficiency for collecting and retaining Steelhead. Therefore, it is unlikely the monitoring programs have any effects to the population.

O.3.7.8.7 North American Green Sturgeon Southern DPS

Potential changes to aquatic resources due to seasonal operations

Hydrodynamic changes associated with river inflows and South Delta exports have been suggested to negatively impact southern DPS Green Sturgeon in two distinct ways: 1) “near-field” mortality associated with entrainment to the export facilities, 2) “far-field” mortality resulting from altered hydrodynamics. The SST completed a thorough review of this subject and defined a driver- linkage-outcome (DLO) framework for specifying how water project operations (the “driver”) can influence juvenile salmonid behavior (the “linkage”) and potentially cause changes in survival or routing (the “outcome”). A similar analysis is not available for southern DPS Green Sturgeon.

Entrainment

As described by NMFS (2009: 386), impacts to the migratory corridor function of juvenile and subadult Green Sturgeon critical habitat from south Delta exports are less clear than for juvenile salmonids because Green Sturgeon spend 1 to 3 years rearing in the Delta environment before transitioning to their marine life history stage. During this Delta rearing phase, Green Sturgeon are free to migrate throughout the Delta. In the conceptual model, it is hypothesized that higher rates of exports may result in higher rates of entrainment. However, estimating entrainment risk from raw salvage data is not possible due to a lack of information on the number of juvenile Green Sturgeon potentially exposed to salvage.

Juvenile southern DPS Green Sturgeon (> 5 mo) are present in the Delta all year and subadults are most abundant from June through November. In the June through September period under Alternative 3 Reclamation proposes an average total export rate slightly higher than No Action Alternative (440 cfs; Figure O1-15 in Appendix O, Attachment 1) and are unlikely to measurably increase entrainment risk.

Total exports proposed for Alternative 3 in September-November (904 cfs higher than No Action Alternative; Figure O1-16 in Appendix O, Attachment 1) are unlikely to measurably increase entrainment risk relative to No Action Alternative.

Juvenile White and Green Sturgeon are infrequent at the TFCF, but may occur in the facility salvage year-round. Salvage is expected to be similar and slightly higher than No Action Alternative under Alternative 3.

Routing

Juvenile Green Sturgeon (>5 mo) are present in the Delta all year and subadults are most abundant from June to November (Reclamation 2019). Juvenile Green Sturgeon swim and behave quite differently and have distinct body morphologies and habitat associations in the Delta compared to outmigrating salmonids, so it is hypothesized that juvenile Green Sturgeon have different routing-hydrology survival relationships. Per NMFS (2009: 338), Green Sturgeon are likely to be found in the main channels of the Delta and the larger interconnecting sloughs and waterways, with western Delta waterways having a higher likelihood of presence than eastern Delta waterways. It is highly uncertain how Green Sturgeon routing would change with Alternative 3.

Through-Delta Survival

Little is known about the relationship between survival of juvenile Green Sturgeon and Delta hydrology. Green Sturgeon reside in the Delta for 1 to 3 years suggesting they encounter a variety of daily, seasonal, and annual hydrological conditions. The majority of Green Sturgeon in the Delta are likely not surviving through the Delta per se, but using these habitats for rearing and foraging. Per NMFS (2009: 338), Green Sturgeon are likely to be found in the main channels of the Delta and the larger interconnecting sloughs and waterways, with western Delta waterways having a higher likelihood of presence than eastern Delta waterways. For juvenile outmigrating Green Sturgeon present in these regions, increasing negative velocities under Alternative 3 may result in lower survival. However, as described above, there is a lower probability of juvenile Green Sturgeon residing in this area.

Potential changes to aquatic resources due to OMR management

See section above on Seasonal operations which includes OMR management

Potential changes to aquatic resources due to Delta Cross Channel operations

Delta Cross Channel operations under Alternative 3 are changed to allow Reclamation to predict water quality exceedances and open the DCC if D-1641 criteria are predicted to be exceeded. This results in greater opening times of the DCC.

Little is known about the migratory behavior of juvenile Green Sturgeon in the Sacramento River basin. It is likely that juvenile Green Sturgeon (larger than the 75 mm) will not enter the Delta prior to their first winter and thus would not be exposed to the open DCC gates. If juvenile Green Sturgeon are exposed to the open DCC gates, they could be entrained into the central / south Delta and exposed to biological and physical conditions in this area, including potentially greater predation. It is likely that these fish will enter the Delta sometime in the winter or spring following their hatching upriver and encounter both types of gate configurations as they enter the Delta.

Potential changes to aquatic resources due to the Temporary Barriers Project

Agricultural Barriers (Temporary Barriers Project, or TBP) are included in Alternative 3 and consists of three rock barriers across south Delta channels to improve water levels for agricultural diversions. The temporary rock barriers are installed and removed at Middle River near Victoria Canal, Old River near Tracy, and Grant Line Canal near Tracy Boulevard Bridge. The TBP is operated based on San Joaquin River flow conditions. The agricultural barriers at Middle River and Old River near Tracy can begin operating as early as April 15 but the tide gates are tied open from May 16 to May 31. After May 31, the barriers in Middle River, Old River near Tracy, and Grant Line Canal are permitted to be operational until they are completely removed by November 30.

Juvenile Green Sturgeon are present in the Delta in all months of the year. However, little is known about their spatial distribution. When the south Delta agricultural barriers are operating with tidal flap gates down, a significant decline in passage and reach survival of acoustically tagged juvenile Chinook Salmon migrating past the barrier has been observed compared to when the barrier is not present (DWR 2018). When flap gates are tied up (May 16 to May 31), outmigrating Chinook Salmon passage past the agricultural barrier was improved (DWR 2018). It could be inferred that passage of outmigrating juvenile Green Sturgeon may also be improved when flap gates are tied up. Therefore, the potential negative effects of the agricultural barriers under Alternative 3 depends on when they are installed and whether the flap gates are down or tied up.

Potential changes to aquatic resources due to Contra Costa Water District operations

CCWD’s operations in Alternative 3 are consistent with the operational criteria specified in separate biological opinions and permits that govern operations at CCWD’s intakes and Los Vaqueros Reservoir (NMFS 1993, 2007, 2010, 2017; USFWS 1993a, 1993b, 2000, 2007, 2010, 2017; CDFG 1994, 2009a). Therefore, CCWD’s operations, including operation of the Rock Slough Intake, for Alternative 3 remain unchanged from current conditions and the No Action Alternative.

The Contra Costa Canal Rock Slough Intake is located on a dead-end slough, far from the main migratory routes for southern DPS Green Sturgeon (NMFS 2017c), approximately 18 miles from the Sacramento River and 10 miles from the San Joaquin River via the shortest routes. Water temperatures in Rock Slough range from lows of about 40 degrees F in winter (December and January) to over 70 degrees F beginning in May and continuing through October (NMFS 2017c).

A review of the 24 years of fish monitoring data (1994–2018) near the Rock Slough Intake both pre- and post-construction of the Rock Slough Fish Screen (RSFS) showed that southern DPS Green Sturgeon have never been observed in Rock Slough (CDFG 2002c; Reclamation 2016; NMFS 2017c; Tenera Environmental 2018b, ICF 2018). CCWD’s Fish Monitoring Program also samples at CCWD’s other south Delta intakes. Since the intakes have been in operation, CCWD’s Fish Monitoring Program has never observed southern DPS Green Sturgeon at CCWD’s Old River Intake or Middle River Intake (CCWD 2019).

It is unlikely that juvenile, subadult, or adult Green Sturgeon would be present in Rock Slough due to the shallow depth, warm water temperatures, and low dissolved oxygenwhich make the area unsuitable habitat during most of the year. Therefore, it is unlikely that Green Sturgeon will be entrained at Rock Slough Intake and unlikely that Green Sturgeon would be impacted by CCWD operations.

Potential changes to aquatic resources due to North Bay Aqueduct operations

Overall, the modeled exports in Alternative 3 represent a significant increase in export levels and, thus, a greater risk to Green Sturgeon in the waters adjacent to the pumping facility compared to their historical vulnerability (NOAA 2009). However, Green Sturgeon are expected to be fully screened out of the facilities by the positive barrier fish screen in place at the pumping facility.

Alternative 3 also includes sediment removal with a suction dredge that could entrain Green Sturgeon individuals occurring near the suction dredging. In addition, aquatic weed removal with a grappling system could disturb Green Sturgeon occurring near the removal. The low occurrence of Green Sturgeon in monitoring efforts suggest that any potential imacts from sediment and aquatic weed removal would be limited.

Potential changes to aquatic resources due to water transfers

As discussed under the Spring-Run Chinook Salmon water transfer section, under Alternative 3 Reclamation proposes to expand the transfer window to November. This extended transfer window could result in approximately 50 TAF of additional pumping per year in most years, with associated entrainment, routing, and through-Delta survival impacts. Please see the OMR management section for a discussion of the effects of pumping.

Juveniles older than 5 months, subadults, and adult Green Sturgeon could be exposed to the effects of increased pumping due to water transfers. Although southern DPS Green Sturgeon are present in the Delta in all months of the year, Green Sturgeon are likely to be found in the main channels of the Delta and the larger interconnecting sloughs and waterways, with western Delta waterways having a higher likelihood of presence than eastern Delta waterways (NMFS 2009:338). Therefore, there are no negative impacts of increased pumping at Jones and Banks Pumping Plants due to water transfers under Alternative 3.

Juvenile southern DPS Green Sturgeon are present in the Delta in every month of the year (Reclamation 2019). Thus, some portion of the population would be exposed to this action. Increases in Delta inflow during water transfers may have benefits for juvenile Green Sturgeon. However, there is no information on relationships between flow and juvenile Green Sturgeon ecology.

Potential changes to aquatic resources from Clifton Court aquatic weed removal

Few southern DPS juvenile Green Sturgeon Salmon would be expected to be exposed to the Clifton Court Forebay Aquatic Weed Control Program as part of Alternative 3. Although southern DPS juvenile Green Sturgeon are present in the Delta in all months of the year, Green Sturgeon are likely to be found in the main channels of the Delta and the larger interconnecting sloughs and waterways, with western Delta waterways having a higher likelihood of presence than eastern Delta waterways (NMFS 2009:338). The application of aquatic herbicide to the waters of Clifton Court Forebay will occur between 28 June and 31 August. Treatment could occur prior to 28 June at tempertures ≥ 25˚C; however, Green Sturgeon would not be expected to occur at these temperatures. Treatment could also occur after 31 August if protective measures have not been triggered but few Green Sturgeon are collected at the facility indicating the impact would be minimal. Thus, the likelihood of exposing juvenile Green Sturgeon to the herbicide is very low. Mechanical harvesting would occur on an as-needed basis and, therefore, juvenile Green Sturgeon could be exposed to this action, if entrained into the Forebay.

Potential changes to aquatic resources due to changes from Tracy and Skinner fish facilities improvements

Upgrades to the TFCF under Alternative 3 will aim to minimize the effects of the salvage process on listed fishes, in particular juvenile salmonids and Green Sturgeon. Salvage improvements will improve survival of salvaged fish, and potentially allow reduction of the expansion factors used to extrapolate take estimates from observed salvage.

Upgrades to the TFCF will aim to minimize the effects of the salvage process on listed fishes, in particular juvenile salmonids and Green Sturgeon. Salvage improvements will improve survival of salvaged fish and potentially allow reduction of the expansion factors used to extrapolate take estimates from observed salvage.

As previously described, juvenile Green Sturgeon can occur in the Delta year-round (Reclamation 2019) and, therefore, have the potential to be exposed to the effects of construction of the CO_2 injection device proposed for the Tracy Fish Facility Improvements. If construction affects the efficiency of Green Sturgeon salvage (which is an element of entrainment risk. (Reclamation 2019)), there could be a minor effect to a small number of individuals, although risk would be minimized through appropriate mitigation measures (Appendix E, *Mitigation Measures*).

Skinner Fish Facility improvements under Alternative 3, which involve predator control efforts, can reduce predation on listed fish species, following their entrainment into Clifton Court Forebay. This could also reduce pre-screen loss of juvenile southern DPS Green Sturgeon. It is unknown what proportion of juvenile Green Sturgeon are entrained into CCF but individuals are salvaged infrequently. Thus, Alternative 3 is not likely to negatively impact juvenile Green Sturgeon.

Potential changes to aquatic resources due to changes from Suisun Marsh facilities

Operation of the SMSCG from June through September under Alternative 3 coincides with a portion of the downstream migration of juvenile southern DPS Green Sturgeon, as well as adult southern DPS Green Sturgeon. Montezuma Slough provides an alternative route to their primary migration corridor through Suisun Bay. During full gate operation, the flashboards are installed and the radial gates open and close twice each tidal day. Green Sturgeon are thought to successfully pass through either the boat lock or through the gates during periods when the gates are open. NMFS (2009) determined that operation of the SWSCG is unlikely to produce conditions that support unusually high numbers of predators, change habitat suitability or availability for rearing or migration of juvenile and adult Green Sturgeon. Green Sturgeon are strong swimmers and therefore the operation of the Suisun Marsh Salinity Control Gate will have no impact on adults or juvenile Green Sturgeon.

The low screen velocity at the intake culverts combined with a small screen mesh size are expected to successfully prevent Green Sturgeon from being entrained into the RRDS under Alternative 3. (NOAA 2009).

The MIDS intakes under Alternative 3 do not currently have fish screens, and juvenile Green Sturgeon are more prone to entrainment than other species such as White Sturgeon (Poletto et al. 2014). However, fisheries monitoring performed in 2004-05 and 2005-06 identified entrainment of 20 fish species, none of which were Green Sturgeon (NOAA 2009). Presence of Green Sturgeon in the area of the MIDS intake is not well studied or documented, but it if Green Sturgeon are present they may potentially avoid entrainment as they do not typically swim along the surface where the diversion is located.

Due to its location and design, Green Sturgeon are not likely to encounter this structure or be negatively affected by its operation. Improved water circulation by the operation of the Goodyear Slough Outfall under Alternative 3 likely benefits juvenile Green Sturgeon in Suisun Marsh by improving water quality and increasing foraging opportunities (NOAA 2009).

Potential changes to aquatic resources due to changes from Clifton Court predator management

Predator control efforts under Alternative 3 can reduce predation on listed fish species, following their entrainment into Clifton Court Forebay. This could also reduce pre-screen loss of juvenile southern DPS Green Sturgeon. It is unknown what proportion of juvenile Green Sturgeon are entrained into CCF but individuals are salvaged infrequently.

Potential changes to aquatic resources due to the San Joaquin Basin steelhead telemetry study

Potential changes to aquatic resources due to reintroduction changes from the fish conservation and culture laboratory

None of the Green Sturgeon life stages would benefit from the Delta Fish Species Conservation Hatchery under Alternative 3. As with the other proposed construction activities in the Delta, the year-round occurrence of juvenile Green Sturgeon in the Delta (Reclamation 2019) means that this life stage, as well as the timing of the adult Green Sturgeon occurring in the Delta during May to October, could be exposed to Delta Fish Species Conservation Hatchery construction under *Alternative 3*. The in-water work constructing the hatchery intake and outfall could result in a small number of individuals experiencing effects such as temporary loss of habitat leading to predation, degraded water quality, noise-related delay in migration, and direct effects from contact with construction equipment or isolation/stranding within enclosed areas. The risks from these potential effects would be minimized with through the application of mitigation measures (Appendix E, *Mitigation Measures*).

Potential changes to aquatic resources from monitoring

Population estimates for Green Sturgeon also remain outstanding in the Central Valley. Similar to Steelhead, the existing monitoring programs very rarely catch Green Sturgeon because most monitoring programs are not designed to capture them. Similar to Steelhead, it is unlikely the monitoring programs have an effect to the population.

O.3.7.9 *Nearshore Pacific Ocean on the California Coast*

O.3.7.9.1 Southern Resident Killer Whale

Potential changes to Southern Killer Whale from Chinook Salmon prey abundance

As with Alternative 2, Alternative 3 water operations would not include many of the criteria currently in place as a result of the NMFS (2009a) SWP/CVP BO’s RPA. Based on the same reasoning applied to Alternative 2, Alternative 3 therefore could result in potential negative effects to Central Valley Chinook Salmon stocks and Southern Resident Killer Whale. As with Alternative 2, there is some uncertainty in this conclusion given that effects are potentially limited by the medium importance of Central Valley Chinook Salmon stocks to Southern Resident Killer Whale diet and the relatively high representation of hatchery-origin juvenile Chinook Salmon, many of which are released downstream of the Delta (Reclamation 2019).

O.3.8 Alternative 3 – Program-Level Effects

O.3.8.1 *Sacramento River*

Potential changes to aquatic resources from Battle Creek restoration

Acceleration of the Battle Creek restoration program will be implemented under both Alternative 3 and Alternative 1. Therefore, Alternative 3 and Alternative 1 are likely to have similar effects on aquatic resources compared to the No Action Alternative with respect to this measure.

Potential changes to aquatic resources from lower intakes near Wilkins Slough

Lowering intakes of diversions near Wilkins Slough will be implemented under both Alternative 3 and Alternative 1. Therefore, Alternative 3 and Alternative 1 are likely to have similar effects on aquatic resources compared to the No Action Alternative with respect to this measure.

Potential changes to aquatic resources due to Shasta TCD Improvements

Improvement of the Shasta TCD will be implemented under both Alternative 3 and Alternative 1. Therefore, Alternative 3 and Alternative 1 are likely to have similar effects on aquatic resources compared to the No Action Alternative with respect to this measure.

Potential changes to aquatic resources from operation of the Livingston-Stone National Fish Hatchery (Winter-Run Chinook Salmon)

Increased production of Winter-Run Chinook Salmon at the Livingston-Stone National Fish Hatchery is being implemented under both Alternative 3 and Alternative 1. Therefore, Alternative 3 and Alternative 1 are likely to have similar effects on aquatic resources compared to the No Action Alternative with respect to this measure.

Potential changes to aquatic resources from small screen program installation

The construction and operation of fish screens on water diversions is being implemented under both Alternative 3 and Alternative 1. Therefore, Alternative 3 and Alternative 1 are likely to have similar effects on aquatic resources compared to the No Action Alternative with respect to this measure.

Potential changes to aquatic resources from spawning habitat restoration

Spawning habitat restoration is being implemented under both Alternative 3 and Alternative 1. Therefore, Alternative 3 and Alternative 1 are likely to have similar effects on aquatic resources compared to the No Action Alternative with respect to this measure.

Potential changes to aquatic resources from rearing habitat restoration

Rearing habitat restoration is being implemented under both Alternative 3 and Alternative 1. Therefore, Alternative 3 and Alternative 1 are likely to have similar effects on aquatic resources compared to the No Action Alternative with respect to this measure.

Potential changes to aquatic resources due to adult rescue activities

Adult rescue is being implemented under both Alternative 3 and Alternative 1. Therefore, Alternative 3 and Alternative 1 are likely to have similar effects on aquatic resources compared to the No Action Alternative with respect to this measure.

Potential changes to aquatic resources due to trap and haul activities

The juvenile trap and haul strategy is being implemented under both Alternative 3 and Alternative 1. Therefore, Alternative 3 and Alternative 1 are likely to have similar effects on aquatic resources compared to the No Action Alternative with respect to this measure.

O.3.8.2 *Bay-Delta*

O.3.8.2.1 Delta Smelt

The following potential program-level effects would be similar under Alternative 3 as under Alternative 1:

Potential changes to Delta Smelt from food subsidies (Sacramento Deepwater Ship Channel food study; North Delta food subsidies/Colusa Basin Drain study; Suisun Marsh Roaring River Distribution System food subsidies study)

Potential changes to Delta Smelt from tidal habitat restoration (complete 8,000 acres from 2008 BO)

Potential changes to Delta Smelt from predator hot spot removal

Potential changes to Delta Smelt from Delta Cross Channel gate improvement

Potential changes to Delta Smelt due to changes from Tracy and Skinner Fish Facility improvements

Potential changes to Delta Smelt from Delta fish species conservation hatchery

In addition to these potential effects that would be expected to be similar to the effects under Alternative 1, Alternative 3 would include the following:

Potential changes to Delta Smelt from additional habitat restoration (25,000 acres within the Delta)

Restoration of an additional 25,000 acres of Delta habitat under Alternative 3 would have the potential to provide a greater extent of positive effects to Delta Smelt as previously described for the completion of 8,000 acres of habitat required under the USFWS (2008) BO, i.e., increased food availability and habitat for Delta Smelt to occupy depending on provision of suitable habitat features. The additional 25,000 acres of habitat restoration has the potential to more than offset the negative effects of seasonal operations on food availability, which is intended to be offset by the 8,000 acres of tidal habitat restoration required by the USFWS (2008) BO. However, 25,000 acres of tidal habitat restoration in the north Delta would change hydrodynamics such that there would be a lower tidal range at the DCC and therefore potentially reduced magnitude of Sacramento River flow entering the DCC, which in turn could reduce lower San Joaquin River net flow and negatively affect the subsidy of *P. forbesi* to the low salinity zone (Figures SJR_jul, SJR_aug, SJR_sep; see also discussion by RMA 2010). As with the completion of 8,000 acres of habitat restoration, potential negative effects from contaminants would be managed with minimization measures, as described in the ROC LTO BA).

O.3.8.2.2 Longfin Smelt

The following potential program-level effects would be similar under Alternative 3 as under Alternative 1:

Potential changes to Longfin Smelt from food subsidies (Sacramento Deepwater Ship Channel food study; North Delta food subsidies/Colusa Basin Drain study; Suisun Marsh Roaring River Distribution System food subsidies study)

Potential changes to Longfin Smelt from tidal habitat restoration

Potential changes to Longfin Smelt from predator hot spot removal

Potential changes to Longfin Smelt from Delta Cross Channel gate improvement

Potential changes to Longfin Smelt due to changes from Tracy and Skinner Fish Facility improvements

Potential changes to Longfin Smelt from the small screen program

Potential changes to Longfin Smelt from Delta fish species conservation hatchery

In addition to these potential effects that would be expected to be similar to the effects under Alternative 1, Alternative 3:

Potential changes to Longfin Smelt from additional habitat restoration (25,000 acres within the Delta)

Restoration of an additional 25,000 acres of Delta habitat under Alternative 3 would have the potential to provide a greater extent of positive effects to Longfin Smelt as previously described for the completion of 8,000 acres of habitat required under the USFWS (2008) BO, i.e., increased food availability and habitat for occupancy by Longfin Smelt, albeit with perhaps limited effects given that most Longfin Smelt would tend to be downstream of restored areas. Potential negative effects from contaminants would be limited through application of appropriate mitigation measures for aquatic resources, as previously outlined for the 8,000 acres of tidal habitat restoration.

O.3.8.2.3 Sacramento Winter-Run Chinook Salmon

Potential changes to aquatic resources from the Sacramento Deepwater Ship Channel food study

This action would hydrologically connect the Sacramento River with the Sacramento Deepwater Ship Channel (SDWSC) via the Stone Lock facility from mid-spring to late fall. Juvenile Winter-Run Chinook Salmon may be exposed to the Sacramento Deepwater Ship Channel (SDWSC) component of Alternative 3. This action would hydrologically connect the Sacramento River with the SDWSC via the Stone Lock facility from mid-spring to late fall (Wood Rodgers 2018) to provide food web benefits to Delta Smelt. Juvenile Winter-Run Chinook Salmon abundance downstream of Stone Lock at Sherwood Harbor is highest in February and March, declines in April, and is moderate in November (Reclamation 2019). Juvenile Winter-Run Chinook Salmon passing the Stone Lock facility when there is a hydrologic connection between the waterways could potentially be routed into the SDWSC. Estimates of salmonid survival in the SDWSC are not available to compare with rates in the Sacramento River route. However, if survival rates are similar, fish entering the SDWSC would not be exposed to entrainment into the interior Delta through the DCC or Georgiana Slough which would provide a benefit associated with Alternative 3. A hydrologically connected SDWSC could potentially attract adult Winter-Run Chinook Salmon. If the connection is maintained there would likely not be impacts to adults. However, if the connection is not maintained there could be migratory delays and stranding.

Potential changes to aquatic resources from the North Delta food subsidies/Colusa Basin Drain study

Provision of north Delta food subsidies by routing Colusa Basin drain water to the Cache Slough area through the Yolo Bypass would occur in summer/fall and therefore would have limited effects on Winter-Run Chinook Salmon, who are in the Delta between December and May for juveniles, and December to July for adults.

Potential changes to aquatic resources from the Suisun Marsh Roaring River Distribution System food subsidies study

Under Alternative 3, provision of Suisun Marsh food subsidies through coordination of managed wetland flood and drain operations in Suisun Marsh and draining of RRDS to Grizzly Bay/Suisun Bay in conjunction with reoperation of the SMSCG would occur in summer/fall and therefore would have limited effects on Winter-Run Chinook Salmon, who are in the Delta between December and May for juveniles, and December to July for adults.

Potential changes to aquatic resources due to tidal habitat restoration

Although migration through the Delta represents a short period, a large proportion of juvenile Winter-Run Chinook Salmon are expected to be exposed to 8,000 acres of tidal habitat restoration in the Delta. Tidal habitat restoration is expected to benefit juvenile Winter-Run Chinook Salmon in several aspects represented by the Winter-Run Chinook Salmon conceptual model, (see Figure 5.6-4 of the ROC LTO BA) including increased food availability and quality and refuge habitat from predators. These benefits can manifest in higher growth rates and increased survival through the Delta. Reclamation and DWR will consult on future tidal habitat restoration with USFWS and NMFS on potential effects to fish from construction-related effects.

Potential changes to aquatic resources from the predator hot spot removal program

Predator hot spot removal is primarily focused on providing positive effects to downstream-migrating juvenile salmonids including Winter-Run Chinook Salmon. Although Alternative 3 would not be limited to existing identified hot spots (e.g., those identified by Grossman et al. 2013), the existing hotspots that may be representative of where removal efforts may be most concentrated are in the primary migratory routes of juvenile Winter-Run Chinook Salmon. All hotspots are limited in scale relative to overall available habitat and previous research has not found a consistent positive effect of predator removal on juvenile salmon survival (Cavallo et al. 2012; Michel et al. 2017; Sabal et al. 2016). Winter-Run Chinook Salmon juveniles in the Bay-Delta are unlikely to be exposed to the effects of construction at predator hot spot removal locations in the Sacramento River, as the in-water work window is in the summer / fall when Winter-Run Chinook Salmon juveniles are generally in the upper river.

Potential changes to aquatic resources from Delta Cross Channel gate improvements

The DCC is an older structure which requires manual operation and increased use could result in locks braking in either open or closed positions. Migrating Winter-Run Chinook Salmon would benefit from faster operations that prevent straying into the central Delta and catastrophic failure of the facility. Few Winter-Run Chinook Salmon are expected to be exposed to improvements to the Delta Cross Channel. Seasonal closure periods would still be in place to protect migrating salmonids. Potential diurnal operation during closure periods could increase exposure of Winter-Run Chinook Salmon juveniles to entrainment into the interior Delta. Improved biological and physical monitoring associated with improvements would likely minimize potentially increased routing into the interior Delta and subsequent entrainment. Greater operational flexibility and increased gate reliability resulting from improvements would reduce the risk of gate failure that could result in higher rates of entrainment.

Potential changes to aquatic resources due to changes from Tracy and Skinner Fish Facility improvements

A small proportion of juvenile Winter-Run Chinook Salmon are expected to be exposed to the Tracy Fish Facility (Zeug and Cavallo 2014). However, for fish that arrive at the facility, the proposed improvements are likely to increase survival through the facility. Winter-Run Chinook Salmon adults would not be expected to be exposed to the effects of construction of the carbon dioxide injection device proposed for the Tracy Fish Facility, based on the timing of in-water construction (August to October) and the typical seasonal occurrence of this life stage in the Delta (Reclamation 2019).

Few if any juvenile Winter-Run Chinook Salmon would be expected to be exposed to construction of the carbon dioxide injection device proposed for the Tracy Fish Facility Improvements based on lack of observed salvage during the August to October in-water work window (see Figures F.2.7, F.2.8, and F.2.9 in Appendix F of the ROC LTO BA). However, a few early migrants could occur during the in-water work window based on occurrence in the north Delta (see Figures WR_Seines and WR_Sherwood in Appendix F of the ROC LTO BA).

To the extent that the construction affects the ability of juvenile Winter-Run Chinook Salmon to be efficiently salvaged (as part of the entrainment risk habitat attribute in the SAIL conceptual model; Reclamation 2019), there could be a minor effect to a small number of individuals, although risk would be minimized through appropriate mitigation measures, including MM-AQUA-1, MM-AQUA-2, MM-AQUA-7, MM-AQUA-8, MM-AQUA-10 and MM-AQUA-12 (Appendix E, *Mitigation Measures*). There is low potential exposure because of the in-water work window, the application of mitigation measures, and the small scale of the in-water construction.

Skinner Fish Facility improvements from predator control efforts to reduce predation on listed fishes following entrainment into CCF could reduce pre-screen loss of juvenile Chinook Salmon entrained into CCF. It is important to note that only small proportions of Winter-Run Chinook Salmon are lost at the SWP (Zeug and Cavallo 2014).

Potential changes to aquatic resources from the small screen program

There may be some overlap Winter-Run Chinook Salmon with the main late spring-fall irrigation period for small diversions. Diversion screening could reduce entrainment of late migrating individuals. It is important to note that only a small proportion of the population would be exposed.

Few if any juvenile Winter-Run Chinook Salmon rearing and outmigrating in the Bay-Delta are expected to be exposed to the effects of construction of screens on water diversion intakes. Juvenile Winter-Run Chinook Salmon primarily migrate from November through early May (NMFS 2014c), largely outside of the timing of in-water construction (July 15 to October 15). In addition, the work area for these projects is small, limiting exposure to construction.

Potential changes to aquatic resources from the Delta fish species conservation hatchery

The operation of the Delta Fish Species Conservation Hatchery would not provide benefits to any life stage of Winter-Run Chinook Salmon. Potential negative effects of the Delta Fish Species Conservation Hatchery include inadvertent propagation and spread of invasive or nuisance species, which could affect juvenile Winter-Run Chinook Salmon through changes in food web structure, for example, in the case of invasive quagga and zebra mussels (Fera et al. 2017). Additional impacts could include reduced water quality resulting from hatchery discharge. Potential negative effects from discharged water are expected to be minimal due to the water treatment and the very small size of the discharge compared to flows in the

Sacramento River near the hatchery location. Mitigation and minimization measures detailed in the EIR/EIS for the facility (Horizon Water and Environment 2017) indicate that potential impacts are less than significant. Potential exposure of juvenile Winter-Run Chinook Salmon would be restricted to a small spatial area within the primary migration route.

As with the other proposed construction activities in the Bay-Delta, few if any juvenile Winter-Run Chinook Salmon would be expected to be exposed to the effects of construction of the Delta Fishes Conservation Hatchery based on the timing of in-water construction (August to October) and the typical seasonal occurrence of this life stage in the Delta (Reclamation 2019). There may be some exposure of early migrants to in-water and shoreline construction of the hatchery intake and outfall, as illustrated by timing of occurrence in Sacramento seines and trawls (see Figures F.2.4 and F.2.5 in Appendix F of the ROC LTO BA). The relatively few individuals occurring near the construction site could be subject to effects similar to those previously described for habitat restoration (e.g., temporary loss of habitat leading to predation, degraded water quality, reduced foraging ability caused by reduced visibility, noise-related delay in migration, and direct effects from contact with construction equipment or isolation/stranding within enclosed areas). The risk from these potential effects would be minimized through application of mitigation measures (Appendix E, *Mitigation Measures*). There is low potential exposure because of the in-water work window, the application of mitigation measures, and the small scale of the in-water construction.

Winter-Run Chinook Salmon adults would not be expected to be exposed to the effects of construction of construction of the Delta Fish Species Conservation Hatchery based on the timing of in-water construction (August to October) and the typical seasonal occurrence of this life stage in the Delta (Reclamation 2019).

O.3.8.2.4 Central Valley Spring-Run Chinook Salmon

Potential changes to aquatic resources from the Sacramento Deepwater Ship Channel food study

This action would hydrologically connect the Sacramento River with the Sacramento Deepwater Ship Channel (SDWSC) via the Stone Lock facility from mid-spring to late fall. Juvenile Spring-Run Chinook Salmon abundance in the Delta is moderate in March and peaks in April (Reclamation 2019). Juvenile Spring-Run Chinook Salmon passing the Stone Lock facility when there is a hydrologic connection between the waterways could potentially be enter into the SDWSC. There are potential benefits to Spring-Run Chinook Salmon from this action. Fish entering the SDWSC would not be exposed to entrainment into the interior Delta through the DCC or Georgiana Slough which would provide a benefit if survival rates are similar. However, estimates of salmonid survival in the SDWSC are not available to compare with rates in the Sacramento River route. Also, there is potential for decreased migration time to the ocean and exposure to larger food sources of Liberty Island, but this is currently uncertain.

Potential changes to aquatic resources from the North Delta food subsidies/Colusa Basin Drain study

Provision of north Delta food subsidies by routing Colusa Basin drain water to the Cache Slough area through the Yolo Bypass would occur in summer/fall and therefore would have limited effects on Spring-Run Chinook Salmon, who are in the Delta January through February for adults, and November through June for juveniles, with a peak of juvenile migration from March to April.

Potential changes to aquatic resources from the Suisun Marsh Roaring River Distribution System food subsidies study

Under Alternative 3, provision of Suisun Marsh food subsidies through coordination of managed wetland flood and drain operations in Suisun Marsh and draining of RRDS to Grizzly Bay/Suisun Bay in conjunction with reoperation of the SMSCG would occur in summer/fall and therefore would have limited effects on Spring-Run Chinook Salmon, who are in the Delta January through February for adults, and November through June for juveniles, with a peak of juvenile migration from March to April.

Potential changes to aquatic resources due to tidal habitat restoration

A large proportion of juvenile Spring-Run Chinook Salmon are expected to benefit from continuing to construct the 8,000 acres of tidal habitat restoration in the Delta under Alternative 3. Benefits include increased food availability and quality and refuge habitat from predators. These benefits can manifest in higher growth rates and increased survival through the Delta.

Few if any juvenile Spring-Run Chinook Salmon would be expected to be exposed to the effects of construction of 8,000 acres of tidal habitat restoration, based on the timing of in-water construction (August to October) and the typical seasonal occurrence of this life stage in the Delta (Reclamation 2019). There may be some exposure of yearling migrants that enter the Delta in the fall. Individuals being exposed to construction could experience risk of potential effects similar to those suggested in recent restoration projects such as the Lower Yolo Restoration Project (NMFS 2014c). This includes the following: temporary loss of aquatic and riparian habitat leading to increased predation, increased water temperature, and reduced food availability; degraded water quality from contaminant discharge by heavy equipment and soils, and increased discharges of suspended solids and turbidity, leading to direct toxicological impacts on fish health/performance, indirect impairment of aquatic ecosystem productivity, loss of aquatic vegetation providing physical shelter, and reduced foraging ability caused by decreased visibility; impediments and delay in migration caused by elevated noise levels from machinery; and direct injury or mortality from in-water equipment strikes or isolation/stranding within dewatered cofferdams. Many of these are elements highlighted in the SAIL conceptual model (Figure 5.6-4). The risk from these potential effects would be minimized through application of mitigation measures MM-AQUA-1, MM-AQUA-2, MM-AQUA-4 through MM-AQUA-12, and MM-AQUA-14 (Appendix E, *Mitigation Measures*).

Potential changes to aquatic resources from the predator hot spot removal program

Predator hot spot removal under Alternative 3 is primarily focused on providing positive effects to downstream-migrating juvenile salmonids including Spring-Run Chinook Salmon. Although the action would not be limited to existing identified hot spots (e.g., those identified by Grossman et al. 2013), the existing hotspots that may be representative of where removal efforts may be most concentrated are in the primary migratory routes of juvenile Spring-Run Chinook Salmon. All hotspots are limited in scale relative to overall available habitat and previous research has not found a consistent positive effect of predator removal on juvenile salmon survival (Cavallo et al. 2012; Michel et al. 2017; Sabal et al. 2016).

Potential changes to aquatic resources from Delta Cross Channel gate improvements

Greater operational flexibility and increased gate reliability resulting from improvements to the Delta Cross Channel under Alternative 3 would reduce the risk of gate failure that could result in higher rates of entrainment of Spring-Run Chinook Salmon, if left open. Few Spring-Run Chinook Salmon are expected to be exposed to in-water construction related improvements to the Delta Cross Channel due to observance of species protective work windows. Seasonal closure periods would still be in place to protect Spring-Run Chinook Salmon. The DCC is an older structure which requires manual operation and increased use could result in locks braking in either open or closed positions. Migrating Spring-Run

Chinook Salmon would benefit from faster operations that prevent straying into the central Delta and catastrophic failure of the facility. However, improved biological and physical monitoring associated with improvements would likely minimize potentially increased entrainment.

Potential changes to aquatic resources due to changes from Tracy and Skinner Fish Facility improvements

A number of programmatic actions are proposed to improve salvage efficiency of TFCF, including installing a carbon dioxide injection device to allow remote controlled anesthetization of predators in the secondary channels of the Tracy Fish Facility. These actions could potentially benefit juvenile Spring-Run Chinook Salmon through greater salvage efficiency.

Few if any juvenile Spring-Run Chinook Salmon would be expected to be exposed to construction of the CO_2 injection device proposed for the Tracy Fish Facility Improvements, based on lack of observed salvage during the August to October in-water work window (see figures in Appendix Fof the ROC LTO BA*:* WR_salvage_unclipped_date, WR_salvage_clipped_date, and WR_salvage_clipped_CWT_race). Risks to these few individuals would be minimized through appropriate mitigation measures including MM-AQUA-1, MM-AQUA-2, MM-AQUA-7, MM-AQUA-8, MM-AQUA-10 and MM-AQUA-12 (Appendix E, *Mitigation Measures*), the selected in-water work window, and the small scale of the in-water construction. For juvenile Spring-Run Chinook Salmon that arrive at the facility, the proposed improvements are likely to increase survival through the facility.

Predator control efforts at Skinner Fish Facility under Alternative 3 to reduce predation on listed fishes following entrainment into Clifton Court Forebay could reduce pre-screen loss of juvenile Spring-Run Chinook Salmon entrained into Clifton Court Forebay. Spring-Run Chinook Salmon are unlikely to be in the area during predator control efforts.

Potential changes to aquatic resources from the small screen program

Few if any juvenile Spring-Run Chinook Salmon rearing and outmigrating in the Bay-Delta are expected to be exposed to the effects of construction of screens on water diversion intakes. Juvenile Sacramento River Spring-Run Chinook Salmon primarily from November through early May (NMFS 2014c), largely outside of the timing of in-water construction (July 15 to October 15). In addition, the work area for these projects is small, limiting exposure to construction.

Potential changes to aquatic resources from the Delta fish species conservation hatchery

The operation of the Delta Fish Species Conservation Hatchery would not provide benefits to any life stage of Winter-Run Chinook Salmon. Potential negative effects of the Delta Fish Species Conservation Hatchery include inadvertent propagation and spread of invasive or nuisance species, which could affect juvenile Winter-Run Chinook Salmon through changes in food web structure, for example, in the case of invasive quagga and zebra mussels (Fera et al. 2017). Additional impacts could include reduced water quality resulting from hatchery discharge. Potential negative effects from discharged water are expected to be minimal due to the water treatment and the very small size of the discharge compared to flows in the Sacramento River near the hatchery location. Mitigation and minimization measures detailed in the EIR/EIS for the facility (Horizon Water and Environment 2017) indicate that potential impacts are less than significant. Potential exposure of juvenile Winter-Run Chinook Salmon would be restricted to a small spatial area within the primary migration route.

As with the other proposed construction activities in the Bay-Delta, few if any juvenile Winter-Run Chinook Salmon would be expected to be exposed to the effects of construction of the Delta Fishes

Conservation Hatchery based on the timing of in-water construction (August to October) and the typical seasonal occurrence of this life stage in the Delta (Reclamation 2019). There may be some exposure of early migrants to in-water and shoreline construction of the hatchery intake and outfall, as illustrated by timing of occurrence in Sacramento seines and trawls (see Figures F.2.4 and F.2.5 in Appendix F of the ROC LTO BA). The relatively few individuals occurring near the construction site could be subject to effects similar to those previously described for habitat restoration (e.g., temporary loss of habitat leading to predation, degraded water quality, reduced foraging ability caused by reduced visibility, noise-related delay in migration, and direct effects from contact with construction equipment or isolation/stranding within enclosed areas). The risk from these potential effects would be minimized through application of mitigation measures MM-AQUA-1, MM-AQUA-2, MM-AQUA-4 through MM-AQUA-14. (Appendix E, *Mitigation Measures*). There is low potential exposure because of the in-water work window, the application of mitigation measures, and the small scale of the in-water construction.

Winter-Run Chinook Salmon adults would not be expected to be exposed to the effects of construction of construction of the Delta Fish Species Conservation Hatchery based on the timing of in-water construction (August to October) and the typical seasonal occurrence of this life stage in the Delta (Reclamation 2019).

O.3.8.2.5 Central Valley Fall-Run Chinook Salmon

Potential changes to aquatic resources from the Sacramento Deepwater Ship Channel food study

Moderate to high proportions of juvenile Fall-Run Chinook Salmon are expected to be exposed to the Sacramento Deepwater Ship Channel (SDWSC) action. This action would hydrologically connect the Sacramento River with the SDWSC via the Stone Lock facility from mid-spring to late fall (Wood Rodgers 2018). Juvenile Fall-Run Chinook Salmon abundance in the Delta is moderate in peaks in April and May (Table FR_1). Juvenile Fall-Run Chinook Salmon passing the Stone Lock facility when there is a hydrologic connection between the waterways could potentially be entrained into the SDWSC. Estimates of salmonid survival in the SDWSC are not available to compare with rates in the Sacramento River route. However, fish entering the SDWSC would not be exposed to entrainment into the interior Delta through the DCC or Georgiana Slough which would provide a benefit if survival rates are similar. The effect of this action on juvenile Fall-Run Chinook Salmon is moderate.

No San Joaquin River-origin Fall-Run are expected to be exposed to the Sacramento Deepwater Ship Channel.

Potential changes to aquatic resources from the North Delta food subsidies/Colusa Basin Drain study

This action is proposed to occur in July or September which is largely outside of the migration period for juvenile Fall-Run and Late Fall-Run Chinook Salmon in the Delta (Table _FR1, Table LFR1). For fish that are exposed, increased food production could potentially enhance growth. The effect of this action is expected to be low.

Potential changes to aquatic resources from the Suisun Marsh Roaring River Distribution System food subsidies study

This action is proposed to occur in July or September which is largely outside of the migration period for juvenile Fall-Run and Late Fall-Run Chinook Salmon in the Delta (Table _FR1, Table LFR1). For fish that are exposed, increased food production could potentially enhance growth. The effect of this action is expected to be low.

Potential changes to aquatic resources due to tidal habitat restoration

A large proportion of juvenile Fall-Run and Late Fall-Run Chinook Salmon are expected to be exposed to 8,000 acres of tidal habitat restoration in the Delta. Tidal habitat restoration is expected to benefit juvenile Chinook Salmon in several aspects represented by the Winter-Run conceptual model (Figure WR_CM4) including, increased food availability and quality and refuge habitat from predators. These benefits can manifest in higher growth rates and increased survival through the Delta. Migration through the Delta represents a short period in the migration of juvenile Fall-Run and Late Fall-Run Chinook Salmon. Thus the total effect of this action is moderate.

Few juvenile Fall-Run or Late Fall-Run Chinook Salmon would be expected to be exposed to the effects of construction of 8,000 acres of tidal habitat restoration, based on the timing of in-water construction (August to October) and the typical seasonal occurrence of this life stage in the Delta (Reclamation 2019). Individuals being exposed to construction could experience risk of potential effects similar to those suggested in recent restoration projects such as the Lower Yolo Restoration Project (NMFS 2014c). This includes temporary loss of aquatic and riparian habitat leading to increased predation, increased water temperature, and reduced food availability; degraded water quality from contaminant discharge by heavy equipment and soils, and increased discharges of suspended solids and turbidity, leading to direct toxicological impacts on fish health/performance (e.g., gill damage and reduced ability to take in oxygen, increasing metabolic cost), indirect impairment of aquatic ecosystem productivity (e.g., reduction in benthic macroinvertebrate production and availability), loss of aquatic vegetation providing physical shelter, and reduced foraging ability caused by decreased visibility; impediments and delay in migration caused by elevated noise levels from machinery; and direct injury or mortality from in-water equipment strikes or isolation/stranding within dewatered cofferdams. Many of these are elements highlighted in the SAIL conceptual model (Reclamation 2019). The risk from these potential effects would be minimized through application of mitigation measures MM-AQUA-1, MM-AQUA-2, MM-AQUA-4 through MM-AQUA-12, and MM-AQUA-14 (Appendix E Miigation Measures).

Potential changes to aquatic resources from the predator hot spot removal program

Predator hot spot removal is primarily focused on providing positive effects to downstream-migrating juvenile salmonids including Fall-Run and Late Fall-Run Chinook Salmon. Although the action would not be limited to existing identified hot spots (e.g., those identified by Grossman et al. 2013), the existing hotspots that may be representative of where removal efforts may be most concentrated are in the primary migratory routes of juvenile Spring-Run Chinook. All hotspots are limited in scale relative to overall available habitat and previous research has not found a consistent positive effect of predator removal on juvenile salmon survival (Cavallo et al. 2012; Michel et al. 2017; Sabal et al. 2016).

Potential changes to aquatic resources from Delta Cross Channel gate improvements

Greater operational flexibility and increased gate reliability resulting from improvements to the Delta Cross Channel under Alternative 3 would reduce the risk of gate failure that could result in higher rates of entrainment of Fall-Run and Late Fall-Run Chinook Salmon, if left open. Few Fall-Run or Late fall-Run Chinook Salmon are expected to be exposed to in-water construction related improvements to the Delta Cross Channel due to observance of species protective work windows. Seasonal closure periods would still be in place to protect Chinook Salmon. The DCC is an older structure which requires manual operation and increased use could result in locks braking in either open or closed positions. Migrating Fall-Run and Late Fall-Run Chinook Salmon would benefit from faster operations that prevent straying into the central Delta and catastrophic failure of the facility. However, improved biological and physical monitoring associated with improvements would likely minimize potentially increased entrainment.

Potential changes to aquatic resources due to changes from Tracy and Skinner Fish Facility improvements

A small proportion of juvenile Fall-Run Chinook Salmon are expected to be exposed to the Tracy Fish Facility (Zeug and Cavallo 2014). However, for fish that arrive at the facility, the proposed improvements are likely to increase survival through the facility.

Few juvenile Fall-Run or Late Fall-Run Chinook Salmon would be expected to be exposed to construction of the CO_2 injection device proposed for the Tracy Fish Facility Improvements, based on lack of observed salvage during the August to October in-water work window (see Figures WR_salvage_unclipped_date, WR_salvage_clipped_date, and WR_salvage_clipped_CWT_race in Appendix F of the ROC LTO BA). To the extent that the construction affects the ability of juvenile Fall-Run, and Late Fall-Run Chinook Salmon to be efficiently salvaged (as part of the entrainment risk habitat attribute in the SAIL conceptual model; Figure WR_CM4), there could be a minor effect to a small number of individuals, although risk would be minimized through appropriate mitigation measures including MM-AQUA-1, MM-AQUA-2, MM-AQUA-7, MM-AQUA-8, MM-AQUA-10 and MM-AQUA-12 (Appendix E, *Mitigation Measures*). Given the low potential exposure because of the in-water work window, the application of mitigation measures, and the small scale of the in-water construction, it is concluded that the negative population-level effects of Tracy Fish Facility Improvements construction would be low on this life stage.

Skinner Fish Facility improvements from predator control efforts to reduce predation on listed fishes following entrainment into Clifton Court Forebay could reduce pre-screen loss of juvenile Chinook Salmon entrined into Clifton Cout Forebay. However, given that only small proportions of Fall-Run Chinook Salmon are lost at the SWP (Zeug and Cavallo 2014), the population-level positive effect of this action would be low. Larger proportions of Late Fall-Run Chinook Salmon are lost at the facilities and this action would have a larger effect for this run.

Potential changes to aquatic resources from the small screen program

Although there may be moderate overlap Fall-Late Fall-Run Chinook Salmon with the main late spring-fall irrigation period for small diversions, and small diversion screening could reduce entrainment of late migraing individuals, the potential population-level positive effect would be low because only a small proportion of the population would be exposed.

Few if any juvenile Fall- /Late Fall-Run Chinook Salmon rearing and outmigrating in the Bay-Delta are expected to be exposed to the effects of construction of screens on water diversion intakes. Juvenile Sacramento River Fall- /Late Fall-Run Chinook Salmon primarily migrate from November through early May (NMFS 2014c), largely outside of the timing of in-water construction (July 15 to October 15). In addition, the work area for these projects is small, limiting exposure to construction.

Potential changes to aquatic resources from the Delta fish species conservation hatchery

Potential effects of the Delta Fishes Conservation Hatchery include inadvertent propagation and release of nuisance species and reduced water quality resulting from hatchery discharge. Mitigation and minimization measures detailed in the EIR/EIS for the facility (Horizon Water and Environment 2017) indicate that potential impacts are less than significant. Potential exposure of juvenile Fall-Run Chinook Salmon would be restricted to a small spatial area within the primary migration route. The overall impact of the operation of this facility is low.

As with the other proposed construction activities in the Bay-Delta, few juvenile Fall-Run or Late Fall-Run Chinook Salmon would be expected to be exposed to the effects of construction of the Delta Fishes Conservation Hatchery based on the timing of in-water construction (August to October) and the typical seasonal occurrence of this life stage in the Delta (Table FR_1, LFR_1). The relatively few individuals occurring near the construction site could be subject to effects similar to those previously described for habitat restoration (e.g., temporary loss of habitat leading to predation, degraded water quality, reduced foraging ability caused by reduced visibility, noise-related delay in migration, and direct effects from contact with construction equipment or isolation/stranding within enclosed areas). The risk from these potential effects would be minimized through application of mitigation measures MM-AQUA-1, MM-AQUA-2 and MM-AQUA-4 through MM-AQUA-14. (Appendix E, *Mitigation Measures*). There is low potential exposure because of the in-water work window, the application of mitigation measures will reduce effects, and the in-water construction is of a small scale.

O.3.8.2.6 <u>Central Valley Steelhead</u>

Potential changes to aquatic resources from the Sacramento Deepwater Ship Channel food study

Moderate to high proportions of Central Valley Steelhead are expected to be exposed to the Sacramento Deepwater Ship Channel (SDWSC) conservation measure under Alternative 3. This conservation measure would hydrologically connect the Sacramento River with the SDWSC via the Stone Lock facility from mid-spring to late fall (Wood Rodgers 2018), allowing food to enter the Delta and an alternate migration pathway. Juvenile Central Valley Steelhead abundance in the Delta peaks in February through May (Reclamation 2019). Juvenile Central Valley Steelhead passing the Stone Lock facility when there is a hydrologic connection between the waterways could potentially be entrained into the SDWSC. Estimates of salmonid survival in the SDWSC are not available to compare with rates in the Sacramento River route. However, fish entering the SDWSC would not be exposed to entrainment into the interior Delta through the DCC or Georgiana Slough which would provide a benefit if survival rates are similar.

No Central Valley Steelhead are expected to be exposed to the Sacramento Deepwater Ship Channel construction, as the in-water work window does not overlap with their occurrence in the Delta.

Potential changes to aquatic resources from the North Delta food subsidies/Colusa Basin Drain study

Provision of north Delta food subsidies by routing Colusa Basin drain water to the Cache Slough area through the Yolo Bypass would occur in summer/fall, and does not overlap in time or space with juvenile Central Valley Steelhead occurrence in the Delta. There would not be any effect to Central Valley Steelhead adults.

Potential changes to aquatic resources from the Suisun Marsh Roaring River Distribution System food subsidies study

Under Alternative 3, provision of Suisun Marsh food subsidies through coordination of managed wetland flood and drain operations in Suisun Marsh and draining of RRDS to Grizzly Bay/Suisun Bay in conjunction with reoperation of the SMSCG would occur in summer/fall and therefore would have limited effects on Central Valley Steelhead juveniles, who are in the Delta between December and July. The action is not expected to have any effect on Central Valley Steelhead adults.

Potential changes to aquatic resources due to tidal habitat restoration

A large proportion of juvenile Central Valley Steelhead are expected to benefit from 8,000 acres of tidal habitat restoration in the Delta under Alternative 3. Tidal habitat restoration is expected to benefit juvenile

Central Valley Steelhead in several aspects represented by the Winter-Run Chinook Salmon conceptual model (Figure 5.6-4) including, increased food availability and quality and refuge habitat from predators. These benefits can manifest in higher growth rates and increased survival through the Delta; however, the Delta only represents a small fraction of the total migration route.

Few if any juvenile Central Valley Steelhead would be expected to be exposed to the effects of construction of 8,000 acres of tidal habitat restoration, based on the timing of in-water construction (August to October) and the typical seasonal occurrence of this life stage in the Delta (Reclamation 2019). There may be exposure of a few late migrants, as illustrated by timing of occurrence in Chipps mid-water trawls (Reclamation 2019). Individuals being exposed to construction could experience risk of potential effects similar to those suggested in recent restoration projects such as the Lower Yolo Restoration Project (NMFS 2014c). This includes temporary loss of aquatic and riparian habitat leading to increased predation, increased water temperature, and reduced food availability; degraded water quality from contaminant discharge by heavy equipment and soils, and increased discharges of suspended solids and turbidity, leading to direct toxicological impacts on fish health/performance (e.g., gill damage and reduced ability to take in oxygen, increasing metabolic cost), indirect impairment of aquatic ecosystem productivity (e.g., reduction in benthic macroinvertebrate production and availability), loss of aquatic vegetation providing physical shelter, and reduced foraging ability caused by decreased visibility; impediments and delay in migration caused by elevated noise levels from machinery; and direct injury or mortality from in-water equipment strikes or isolation/stranding within dewatered cofferdams. The risk from these potential effects would be minimized through application of MM-AQUA-1, MM-AQUA-2, MM-AQUA-4 – through MM-AQUA-12, and MM-AQUA-14.

Potential changes to aquatic resources from the predator hot spot removal program

Predator hot spot removal under Alternative 3 is primarily focused on providing positive effects to downstream-migrating juvenile salmonids, including Central Valley Steelhead. Although the action would not be limited to existing identified hot spots (e.g., those identified by Grossman et al. 2013), the existing hotspots that may be representative of where removal efforts may be most concentrated are in the primary migratory routes of Central Valley Steelhead. All hotspots are limited in scale relative to overall available habitat, and previous research has not found a consistent positive effect of predator removal on juvenile salmon survival (Cavallo et al. 2012; Michel et al. 2017; Sabal et al. 2016). However, implementation of this action would likely improve conditions for all life stages of Central Valley Steelhead.

Potential changes to aquatic resources from Delta Cross Channel gate improvements

Completion of DCC gate improvements would benefit Central Valley Steelhead of all life stages within the CVP watershed systems. The peak migration of juvenile Central Valley Steelhead in the Sacramento River past Hood, which is near the DCC, occurs from February through mid-June (Reclamation 2019). No San Joaquin River-origin Central Valley Steelhead are expected to be exposed to the DCC. As previously described, juvenile Central Valley Steelhead are largely absent from the Delta between August and November (Reclamation 2019) and, therefore, few late migrants or early migrants have the potential to be exposed to potential construction from improvements to the DCC under Alternative 3.

Potential changes to aquatic resources due to changes from Tracy and Skinner Fish Facility improvements

Small proportions of Sacramento River-origin Central Valley Steelhead and moderate proportions of Mokelumne River and San Joaquin River-origin Central ValleyV Steelhead are expected to be exposed to the Tracy Fish Facility. However, for fish that arrive at the facility, the proposed improvements resulting in greater salvage efficiency under Alternative 3 are likely to increase survival of juvenile Central Valley Steelhead.

As previously described, juvenile Central Valley Steelhead are largely absent from the Delta between August and November (Reclamation 2019) and, therefore, none to a few late migrants or early migrants have the potential to be exposed to the effects of construction of the carbon dioxide injection device proposed for the Tracy Fish Facility Improvements. Risks of decrease Central Valley Steelhead juvenile salvage during construction would be minimized through appropriate mitigation measures including MM-AQUA-1, MM-AQUA-2, MM-AQUA-7, MM-AQUA-8, MM-AQUA-10 and MM-AQUA-12.

Skinner Fish Facility improvements under Alternative 3 to reduce predation on listed fishes following entrainment into CCF could reduce pre-screen loss of juvenile Central Valley Steelhead entrained into CCF; therefore, providing a benefit for all life stages of Central Valley Steelhead.

Potential changes to aquatic resources from the small screen program

Fish screens under Alternative 3 would also benefit this lifestage in the same ways described above. Juvenile Central Valley Steelhead outmigrating in the Bay-Delta may be exposed to the effects of construction of screens since they migrate downstream during most months of the year, with a peak emigration period in the spring and a smaller peak in the fall (Hallock et al. 1961). Juvenile Central Valley Steelhead may be found in the work area of these projects; however, MM-AQUA-7 would minimize impacts.

Potential changes to aquatic resources from the Delta fish species conservation hatchery

Potential effects of the Delta Fishes Conservation Hatchery include inadvertent propagation and release of nuisance species and reduced water quality resulting from hatchery discharge. Mitigation and minimization measures detailed in the EIR/EIS for the facility (Horizon Water and Environment 2017) indicate that potential impacts are less than significant. Potential exposure of juvenile Central Valley Steelhead would be restricted to a small spatial area within the primary migration route.

As with the other proposed construction activities in the Delta under Alternative 3, juvenile Central Valley Steelhead are largely absent from the Delta between August and November (Reclamation 2019) which means that none to a few late or early migrants of this life stage could be exposed to Delta Fishes Conservation Hatchery construction. The in-water work constructing the hatchery intake and outfall could result in a small number of individuals experiencing effects such as temporary loss of habitat leading to predation, degraded water quality, noise-related delay in migration, and direct effects from contact with construction equipment or isolation/stranding within enclosed areas. The risk from these potential effects would be minimized through application of MM-AQUA-1, MM-AQUA-2, MM-AQUA-4 through MM-AQUA-14 (Appendix E, *Mitigation Measures*).

O.3.8.2.7 North American Green Sturgeon Southern DPS

Potential changes to aquatic resources from the Sacramento Deepwater Ship Channel food study

As described above, juvenile Green Sturgeon may potentially be entrained into the DWSC. Fish entering the SDWSC would not, however, be exposed to entrainment into the interior Delta through the DCC or Georgiana Slough which would provide a benefit if survival rates are similar between the SDWSC and the Sacramento main stem

Potential changes to aquatic resources from the North Delta food subsidies/Colusa Basin Drain study

Provision of north Delta or Suisun Marsh food subsidies by routing drain water would occur in summer/fall and therefore could provide food benefits to Green Sturgeon juveniles, who are in the Delta in the fall.

Potential changes to aquatic resources from the Suisun Marsh Roaring River Distribution System food subsidies study

Provision of north Delta or Suisun Marsh food subsidies by routing drain water would occur in summer/fall and therefore could provide food benefits to Green Sturgeon juveniles, who are in the Delta in the fall.

Potential changes to aquatic resources due to tidal habitat restoration

A large proportion of juvenile southern DPS Green Sturgeon are expected to be exposed to continuing to implement the 8,000 acres of tidal habitat restoration in the Delta under Alternative 3. Tidal habitat restoration is expected to benefit juvenile Green Sturgeon in several aspects represented by the Green Sturgeon juvenile conceptual model (Figure 5.12-3 of the ROC LTO BA) including, increased food availability and quality and refuge habitat from predators. These benefits can manifest in higher growth rates and increased survival through the Delta.

Potential changes to aquatic resources from the predator hot spot removal program

Predator hot spot removal under Alternative 3 is primarily focused on providing positive effects to downstream-migrating juvenile salmonids. It is currently unknown if predation on juvenile Green Sturgeon in the Delta is limiting their productivity. Although the action would not be limited to existing identified hot spots (e.g., those identified by Grossman et al. 2013), the existing hotspots that may be representative of where removal efforts may be most concentrated are in the rearing and migratory corridors of juvenile Green Sturgeon.

Potential changes to aquatic resources from Delta Cross Channel gate improvements

Little is known about the migratory behavior of juvenile Green Sturgeon in the Sacramento River basin. It is likely that juvenile Green Sturgeon (larger than the 75 mm) will not enter the Delta prior to their first winter and thus would not be exposed to the open DCC gates. It is likely that these fish will enter the Delta sometime in the winter or spring following their hatching upriver and encounter both types of gate configurations as they enter the Delta. More information is required to accurately assess the migratory movements of juvenile Green Sturgeon in the river system, as well as their movements within the Delta during their rearing phase in estuarine/Delta waters. Greater operational flexibility and increased gate reliability resulting from improvements would reduce the risk of gate failure that could result in higher rates of entrainment.

Potential changes to aquatic resources due to changes from Tracy and Skinner Fish Facility improvements

Upgrades to the TFCF will aim to minimize the effects of the salvage process on listed fishes, in particular juvenile salmonids and Green Sturgeon. Salvage improvements will improve survival of salvaged fish and potentially allow reduction of the expansion factors used to extrapolate take estimates from observed salvage.

As previously described, juvenile Green Sturgeon can occur in the Delta year-round (Reclamation 2019) and, therefore, have the potential to be exposed to the effects of construction of the CO_2 injection device proposed for the Tracy Fish Facility Improvements. If construction affects the efficiency of Green Sturgeon salvage (which is an element of entrainment risk; Figure 5.12-3), there could be a minor effect to a small number of individuals, although risk would be minimized through appropriate mitigation measures including MM-AQUA-1, MM-AQUA-2, MM-AQUA-7, MM-AQUA-8, MM-AQUA-10 and MM-AQUA-12 (Appendix E, *Mitigation Measures*).

Skinner Fish Facility improvements under Alternative 3, which involve predator control efforts, can reduce predation on listed fish species, following their entrainment into Clifton Court Forebay. This could also reduce pre-screen loss of juvenile southern DPS Green Sturgeon. It is unknown what proportion of juvenile Green Sturgeon are entrained into CCF but individuals are salvaged infrequently. Thus, Alternative 3 is not likely to negatively impact juvenile Green Sturgeon.

Potential changes to aquatic resources from the small screen program

Southern DPS Green Sturgeon are expected to be present in the Delta during the main irrigation period for small diversions (late spring-fall). Diversion screening under Alternative 3 could reduce entrainment of individual Green Sturgeon. However, there is currently no information on the proportion of juvenile Green Sturgeon that are entrained into small unscreened diversions. North American Green Sturgeon in the juvenile to subadult/adult life stage may be exposed to the effects of construction of screens since they are present in the Sacramento River year-round (Reclamation 2019). Effects are the same as described above for juveniles. MM-AQUA-7 would minimize risk.

Potential changes to aquatic resources from the Delta fish species conservation hatchery

None of the Green Sturgeon life stages would benefit from the Delta Fish Species Conservation Hatchery under Alternative 3. As with the other proposed construction activities in the Delta, the year-round occurrence of juvenile Green Sturgeon in the Delta (Reclamation 2019) means that this life stage, as well as the timing of the adult Green Sturgeon occurring in the Delta during May to October, could be exposed to Delta Fish Species Conservation Hatchery construction under Alternative 3. The in-water work constructing the hatchery intake and outfall could result in a small number of individuals experiencing effects such as temporary loss of habitat leading to predation, degraded water quality, noise-related delay in migration, and direct effects from contact with construction equipment or isolation/stranding within enclosed areas. The risks from these potential effects would be minimized with through the application of MM-AQUA-1, MM-AQUA-2, MM-AQUA-4 through MM-AQUA-14 (Appendix E, *Mitigation Measures*).

O.3.8.3 *Nearshore Pacific Ocean on the California Coast*

O.3.8.3.1 <u>Southern Resident Killer Whale</u>

Potential changes to Southern Killer Whale from Chinook Salmon prey abundance

Building on the analyses provided in Alternatives 1 and 2, given the medium priority of Central Valley Chinook Salmon stocks and the contribution of hatchery-origin Chinook Salmon released downstream of the potential proposed action influence, there may be limited effects of Alternative 3 programmatic activities on Southern Resident Killer Whale through changes in Chinook Salmon prey abundance. There is some uncertainty in this conclusion given the considerably greater extent of tidal habitat restoration (25,000 acres) compared to the other alternatives (i.e., the remainder of the 8,000 acres required under the

USFWS 2008 BO), which could lead to positive effects relative to the other alternatives, including the No Action Alternative.

O.3.9 Alternative 4 – Project-Level Effects

O.3.9.1 *Trinity River*

O.3.9.1.1 Seasonal Operations

Under Alternative 4, the Trinity River system would be operated according to the Trinity River ROD with lower Klamath River augmentation flows and unimpaired flow objectives in the Trinity River.

Potential changes to aquatic resources due to changes in reservoir storage

Model results predict that under Alternative 4, storage volume in Trinity Lake would increase throughout the entire year in most water year types compared to the No Action Alternative (Figure O.3-129). On average, storage is expected to increase by 47 TAF under Alternative 4 compared to the No Action Alternative.

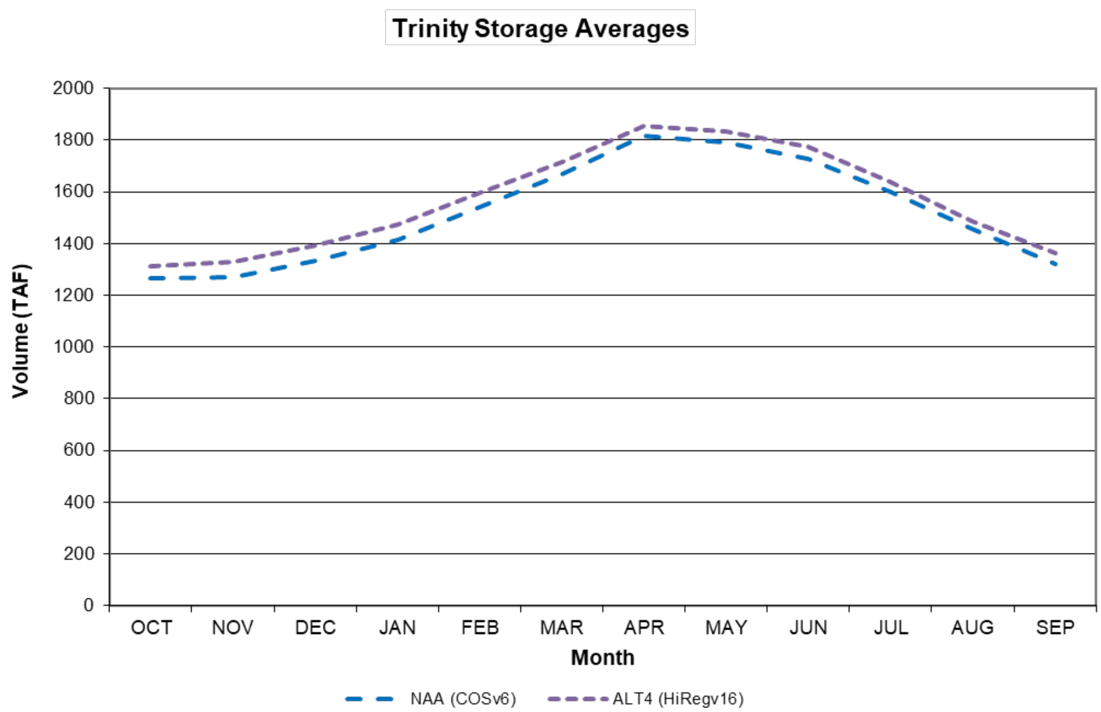


Figure O.3-129. Average Monthly Storage in Trinity Lake for the No Action Alternative and Alternative 4

The effects of changes in reservoir storage conditions as they relate to water temperature can be assessed by looking at temperatures in the Trinity River downstream of Trinity Dam. Average monthly water temperatures in the Trinity River downstream of Trinity Dam would remain similar under Alternative 4 compared to the No Action Alternative (Figure O.3-130). Maximum modeled water temperatures in the Trinity River downstream of Trinity Dam are generally similar under Alternative 4 compared to the No Action Alternative except in September when temperatures are approximately 8°F lower under

Alternative 4 and in October when temperatures are approximately 2°F lower under Alternative 4 compared to the No Action Alternative (Figure O.3-131).

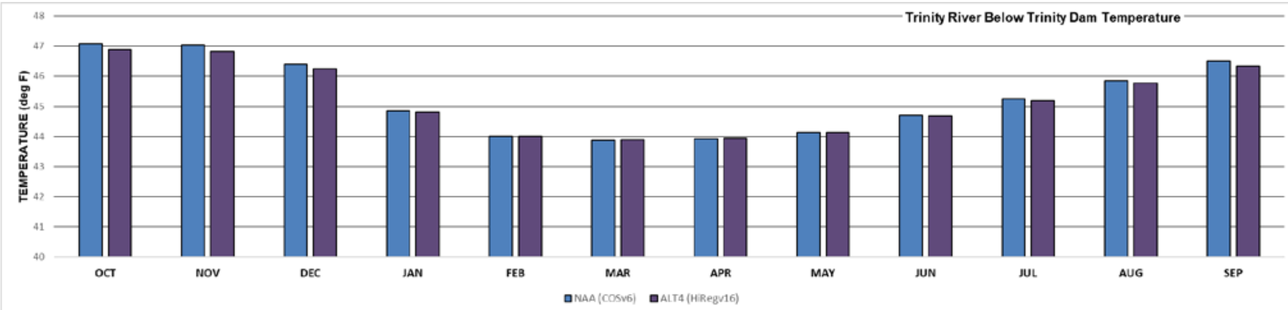


Figure O.3-130. Average Trinity River Water Temperatures below Trinity Dam for the period October to September, Average of All Water Year Types

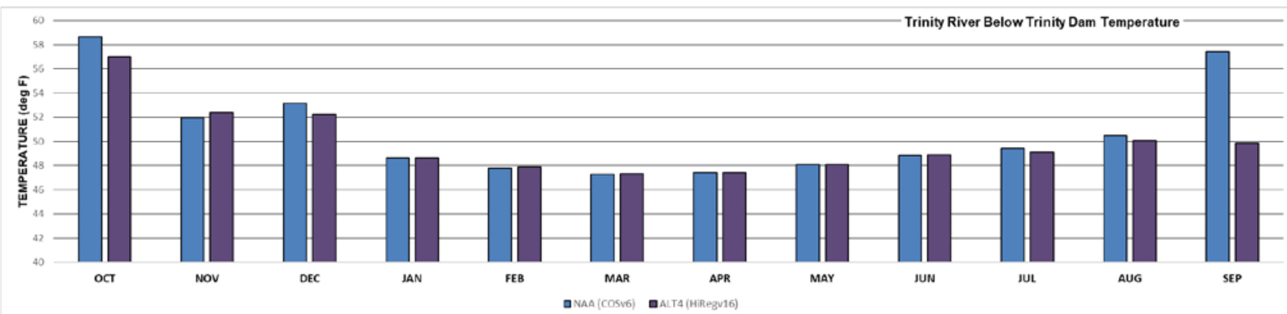


Figure O.3-131. Maximum Trinity River Water Temperatures below Trinity Dam for the Period October to September, Average of All Water Year Types

No focal fish species occur in Trinity Lake or in the Trinity River downstream of Trinity Dam. Effects of Trinity Reservoir storage on fish in the Trinity River downstream of Lewiston Dam are described below.

Potential changes to aquatic resources from variation in flow

Under Alternative 4 modeled average flows in the Trinity River downstream of Lewiston Dam are expected to be similar to flows under the No Action Alternative for the period of April through September with higher flows during October and December through March and either higher or lower flows in November and based on water year type. In wet years, flows would increase by between 7% and 11% during December through March under Alternative 4 compared to flows under the No Action Alternative (Figure O.3-132). In above normal water years, flows would decrease by 11% in November (603 cfs versus 678 cfs) and increase by 69% in February (894 cfs versus 528 cfs) under Alternative 4 compared to flows under the No Action Alternative. In critically dry years, flows would increase by 9% in October (342 cfs to 373 cfs) and November (275 cfs to 300 cfs) under Alternative 4 compared to flows under the No Action Alternative.

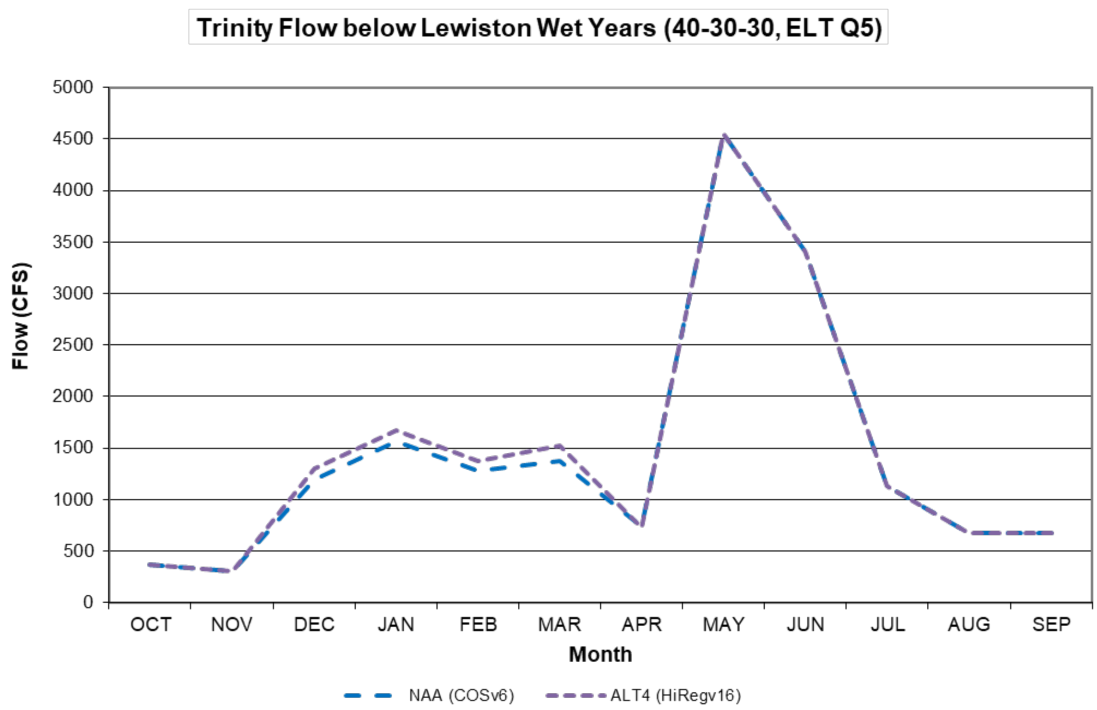


Figure O.3-132. Average Monthly Flow in the Trinity River downstream of Lewiston Dam for the No Action Alternative and Alternative 4 during Wet Years.

Coho Salmon

Flows in the Trinity River downstream of Lewiston Dam would generally be similar under Alternative 4 compared to the No Action Alternative. Minor differences (≤11%) from October through March of some water year types may affect spawning and juvenile rearing habitat for Coho Salmon. Based on previous flow habitat relationship studies in the Trinity River (USFWS 1999), these changes in flow are not expected to result in a detectable effect on Coho Salmon spawning or juvenile rearing habitat (USFWS 1999). Flows in February of above normal water years would increase by approximately 69% under Alternative 4 (894 cfs) compared to the No Action Alternative (528 cfs). This increase in flow could increase the likelihood of Coho Salmon egg mortality due to redd scour, potentially resulting in reduced incubation success in areas where local conditions contribute to substantial mobilization of gravel in the redds.

Spring-Run Chinook Salmon

Flows in the Trinity River downstream of Lewiston Dam would generally be similar under Alternative 4 compared to the No Action Alternative. Minor differences (≤11%) from October through March of some water year types may affect spawning and juvenile rearing habitat for Spring-Run Chinook Salmon. Based on previous flow habitat relationship studies in the Trinity River (USFWS 1999), these changes in flow are not expected to result in a detectable effect on Spring-Run Chinook Salmon spawning or juvenile rearing habitat (USFWS 1999). Flows in February of above normal water years would increase by approximately 69% under Alternative 4 (894 cfs) compared to the No Action Alternative (528 cfs). This increase in flow could increase the likelihood of Spring-Run Chinook Salmon egg mortality due to redd scour, potentially resulting in reduced incubation success in areas where local conditions contribute to substantial mobilization of gravel in the redds.

Fall-Run Chinook Salmon

Flows in the Trinity River downstream of Lewiston Dam would generally be similar under Alternative 3 compared to the No Action Alternative. Minor differences (≤11%) from October through March of some water year types may affect spawning and juvenile rearing habitat for Fall-Run Chinook Salmon. Based on previous flow habitat relationship studies in the Trinity River (USFWS 1999), these changes in flow are not expected to result in a detectable effect on Fall-Run Chinook Salmon spawning or juvenile rearing habitat (USFWS 1999). Flows in February of above normal water years would increase by approximately 69% under Alternative 4 (894 cfs) compared to the No Action Alternative (528 cfs). This increase in flow could increase the likelihood of Fall-Run Chinook Salmon egg mortality due to redd scour, potentially resulting in reduced incubation success in areas where local conditions contribute to substantial mobilization of gravel in the redds.

Steelhead (Winter- and Summer-Run)

Flows in the Trinity River downstream of Lewiston Dam would generally be similar under Alternative 3 compared to the No Action Alternative. Minor differences (≤11%) from November through March of some water year types may affect juvenile rearing habitat for Steelhead. Based on previous flow habitat relationship studies in the Trinity River (USFWS 1999), these changes in flow are not expected to result in a detectable effect on Steelhead juvenile rearing habitat (USFWS 1999). Flows in February of above normal water years would increase by approximately 69% under Alternative 4 (894 cfs) compared to the No Action Alternative (528 cfs). This increase in flow may increase the amount of spawning habitat for Steelhead. Based on previous flow habitat relationship studies in the Trinity River (USFWS 1999: 123), increasing flows from 500 cfs to 800 cfs showed little change in the amount of spawning habitat for Steelhead in the Trinity River from downstream of Lewiston Dam to the confluence with Dutch Creek.

Green Sturgeon

Green Sturgeon occur within the lower 43 miles of the Trinity River, approximately 70 miles downstream of Lewiston Dam. Water temperature and habitat conditions within this section of the Trinity River are heavily influenced by several large tributaries that enter the Trinity River (e.g., the North Fork Trinity River, New River, and the South Fork Trinity River). As a result, minor changes in reservoir operations are likely to be undetectable this far downstream. Therefore, changes in flow under Alternative 4 are not likely to affect Green Sturgeon.

White Sturgeon

White Sturgeon are not likely to be affected by changes in reservoir operations under Alternative 4 compared to the No Action Alternative due to their limited distribution in the lower Klamath River, primarily in the estuary.

Pacific Lamprey

Flows in the Trinity River downstream of Lewiston Dam would generally be similar under Alternative 4 compared to the No Action Alternative. However, minor differences (≤11%) in November and December of some water year types and a larger difference in February (69%) of above normal water years are expected. Increased flows in February overlap with the Pacific Lamprey adult migration period but are not expected to affect migration because Pacific Lamprey migration spans multiple seasons and associated flows. Although previous flow habitat relationship studies in the Trinity River (USFWS 1999) did not focus on Pacific Lamprey, results for salmonids suggest that changes in flow under Alternative 4 would not result in a detectable effect on juvenile rearing or adult holding habitat for Pacific Lamprey compared to the No Action Alternative.

American Shad

American Shad are primarily found in the lower Klamath River but may occur in the lower sections of the Trinity River up to approximately RM 24 at the town of Willow Creek. Water temperature and habitat conditions within this section of the Trinity River are heavily influenced by several large tributaries that enter the Trinity River (e.g., the North Fork Trinity River, New River, and the South Fork Trinity River). As a result, minor changes in reservoir operations are likely to be undetectable this far downstream. Therefore, changes in flow under Alternative 4 would not affect American Shad.

Potential changes to aquatic resources due to variation in temperature

Modeling results indicate that changes in monthly average water temperature in the Trinity River downstream of Lewiston Dam would be similar between Alternative 4 and the No Action Alternative. Differences in monthly average temperature between Alternative 4 and the No Action Alternative would be less than 0.5°F for all months of the year (Figure O.3-133). Modeled maximum temperatures in the Trinity River would be lower under Alternative 4 compared to the No Action Alternative in July, September, and October when the maximum temperature would be 1.5°F to 4.4°F lower. Maximum temperatures would be similar in the remaining months (Figure O.3-134 and Table O.3-56).

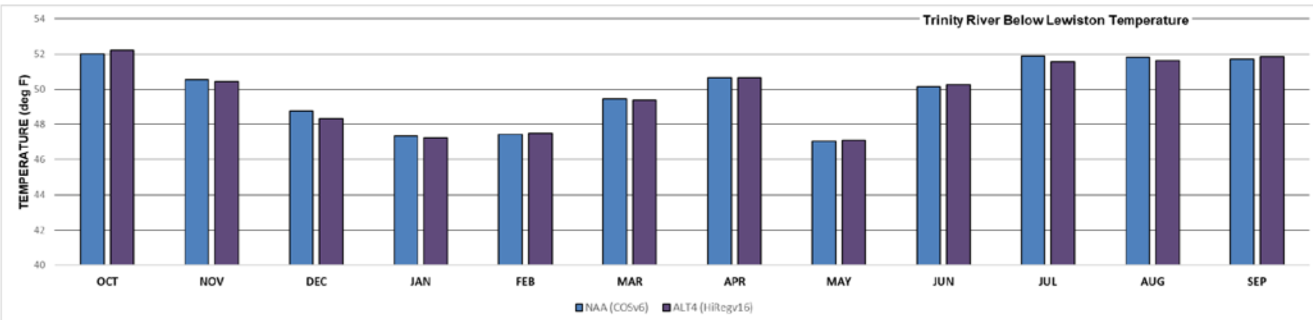


Figure O.3-133. Average Trinity River Water Temperatures below Lewiston Dam for the Period October to September, Average of All Water Year Types

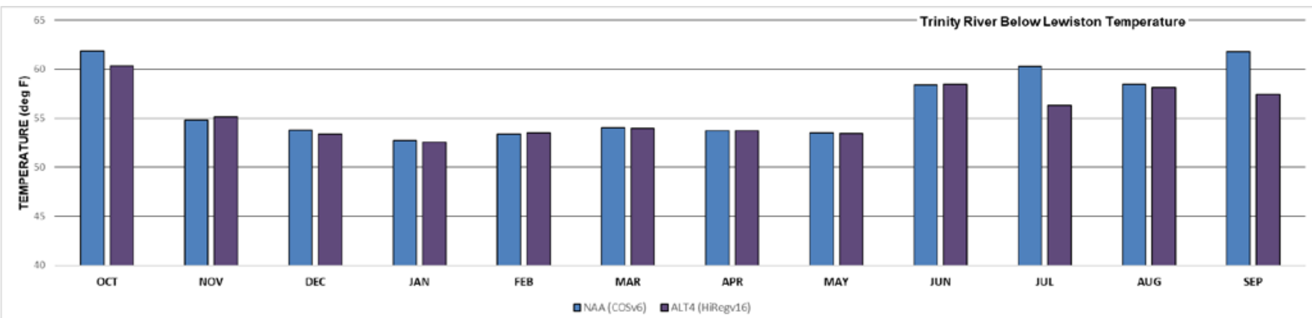


Figure O.3-134. Maximum Trinity River Water Temperatures below Lewiston Dam for the Period October to September, Average of All Water Year Types

Table O.3-56. Maximum Trinity River Water Temperatures below Trinity Dam for the Period October to September, Average of all Water Year Types (Differences >1°F Are Highlighted)

Alt	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
No Action Alternative	61.8	54.8	53.8	52.7	53.4	54.1	53.7	53.5	58.4	60.3	58.4	61.8
ALT 4	60.3	55.1	53.4	52.6	53.5	54.0	53.7	53.4	58.5	56.3	58.1	57.4

In a previous study that looked at flow and water temperatures in the Trinity River (USFWS 1999), results indicated that flow does not have a significant influence on water temperatures from mid-October through early April when cooler air temperatures help maintain cold water temperatures even when flow releases drop below 150 cfs. Once tributary influence begins to decrease and meteorological conditions warm from May to mid-July, flow releases become more influential on downstream temperatures, particularly during hot-dry conditions. Maintaining a flow of 450 cfs during the summer and early fall was found to meet the water temperature objectives for the Trinity River when water released from Lewiston Dam was 53°F or less (USFWS 1999: 203). Water temperatures are most influenced by flow releases from May through mid-October. Flow from May to October would be similar under Alternative 4 compared to the No Action Alternative in most water year types except in critically dry water years. In critically dry years, flow in October would increase by approximately 9% under Alternative 4 compared to the No Action Alternative, from 342 cfs to 373 cfs. Based on modeling results, changes in operations under Alternative 4 are expected to result in lower maximum water temperatures by 1.5°F during October in the Trinity River downstream of Lewiston Dam. Although flow would be similar under Alternative 4 compared to the No Action Alternative during July and September, maximum water temperatures are expected to decrease by 4.0°F and 4.4°F under Alternative 4 compared to the No Action Alternative during these months (Figure O.3-134 and Table O.3-56).

Coho Salmon

Water temperatures in the Trinity River below Lewiston Dam are generally expected to be similar under Alternative 4 compared to the No Action Alternative. Differences in monthly average temperature between Alternative 4 and the No Action Alternative would be less than 0.5°F for all months of the year (Figure O.3-133). Modeled maximum temperatures in the Trinity River in July, September, and October would be approximately 1.5°F to 4.4°F lower under Alternative 4 compared to the No Action Alternative with similar maximum temperatures during the remaining months (Figure O.3-134 and Table O.3-56). Although maximum water temperatures under Alternative 4 during September and October exceed the NCRWQCB (2018) objectives for the Trinity River, maximum temperatures are expected to be lower under Alternative 4 compared to the No Action Alternative during these months. Lower water temperatures during September and October under Alternative 4 may increase juvenile Coho Salmon rearing success compared to conditions under the No Action Alternative.

Spring-Run Chinook Salmon

Water temperatures in the Trinity River below Lewiston Dam are generally expected to be similar under Alternative 4 compared to the No Action Alternative. Differences in monthly average temperature between Alternative 4 and the No Action Alternative would be less than 0.5°F for all months of the year (Figure O.3-133). Modeled maximum temperatures in the Trinity River in July, September, and October would be approximately 1.5°F to 4.4°F lower under Alternative 4 compared to the No Action Alternative with similar maximum temperatures during the remaining months (Figure O.3-134 and Table O.3-56). Spring-Run Chinook Salmon spawning usually peaks in October but typically ranges from the third week of September through November. Although maximum water temperatures under Alternative 4 during September and October exceed the NCRWQCB (2018) objectives for the Trinity River, maximum temperatures are expected to be lower under Alternative 4 compared to the No Action Alternative during these months. Lower water temperatures during September and October under Alternative 4 may increase the success of adult migration, spawning, and juvenile rearing of Spring-Run Chinook Salmon compared to conditions under the No Action Alternative.

Fall-Run Chinook Salmon

Water temperatures in the Trinity River below Lewiston Dam are generally expected to be similar under Alternative 4 compared to the No Action Alternative. Differences in monthly average temperature between Alternative 4 and the No Action Alternative would be less than 0.5°F different for all months of the year (Figure O.3-133). Modeled maximum temperatures in the Trinity River in July, September, and October would be approximately 1.5°F to 4.4°F lower under Alternative 4 compared to the No Action Alternative with similar maximum temperatures during the remaining months (Figure O.3-134 and Table O.3-56). Fall-Run Chinook Salmon spawning usually occurs between October and December with peak spawning activity occurring in November Although maximum water temperatures under Alternative 4 during September and October exceed the NCRWQCB (2018) objectives for the Trinity River, maximum temperatures are expected to be lower under Alternative 4 compared to the No Action Alternative during these months. Lower water temperatures during September and October under Alternative 4 may increase the success of adult migration and spawning of Fall-Run Chinook Salmon compared to conditions under the No Action Alternative.

Steelhead (Winter- and Summer-Run)

Water temperatures in the Trinity River below Lewiston Dam are generally expected to be similar under Alternative 4 compared to the No Action Alternative. Differences in monthly average temperature between Alternative 4 and the No Action Alternative would be less than 0.5°F for all months of the year (Figure O.3-133). Modeled maximum temperatures in the Trinity River in July, September, and October are approximately 1.5°F to 4.4°F lower under Alternative 4 compared to the No Action Alternative with similar maximum temperatures during the remaining months. Although maximum water temperatures under Alternative 4 during September and October exceed the NCRWQCB (2018) objectives for the Trinity River, maximum temperatures are expected to be lower under Alternative 4 compared to the No Action Alternative during these months. Lower water temperatures during September and October under Alternative 4 may increase the success of juvenile rearing Steelhead compared to conditions under the No Action Alternative.

Green Sturgeon

Green Sturgeon occur within the lower 43 miles of the Trinity River, approximately 70 miles downstream of Lewiston Dam. Water temperature and habitat conditions within this section of the Trinity River are heavily influenced by several large tributaries that enter the Trinity River (e.g., the North Fork Trinity River, New River, and the South Fork Trinity River). As a result, minor changes in reservoir operations are likely to be undetectable this far downstream. Results of previous water temperature modeling for the Trinity River (USFWS 1999) predicted a difference of approximately 1°F in water temperature for flows of 300 cfs and 450 cfs near RM 43 with smaller temperature differences expected downstream of RM 43 to the confluence of the Trinity and Klamath Rivers. Therefore, changes in water temperature under Alternative 4 are not likely to affect Green Sturgeon.

White Sturgeon

White Sturgeon are not likely to be affected by changes in reservoir operations under Alternative 4 compared to the No Action Alternative due to their limited distribution in the lower Klamath River, primarily in the estuary.

Pacific Lamprey

Model results predict that water temperatures in the Trinity River below Lewiston Dam would be similar under Alternative 4 compared to the No Action Alternative. Differences in monthly average temperature between Alternative 4 and the No Action Alternative would be less than 0.5°F for all months of the year (Figure O.3-133). Modeled maximum temperatures in the Trinity River in July, September, and October would be approximately 1.5°F to 4.4°F lower under Alternative 4 compared to the No Action Alternative with similar maximum temperatures in the remaining months. Although maximum water temperatures under Alternative 4 during September and October exceed the NCRWQCB (2018) objectives for the Trinity River, maximum temperatures are expected to be lower under Alternative 4 compared to the No Action Alternative during these months. Lower water temperatures during September and October under Alternative 4 may increase Pacific Lamprey juvenile rearing success compared to the No Action Alternative.

American Shad

American Shad are primarily found in the lower Klamath River but may occur in the lower sections of the Trinity River up to approximately RM 24 at the town of Willow Creek. Water temperature and habitat conditions within this section of the Trinity River are heavily influenced by several large tributaries that enter the Trinity River (e.g., the North Fork Trinity River, New River, and the South Fork Trinity River). As a result, minor changes in reservoir operations are likely to be undetectable this far downstream. Results of previous water temperature modeling for the Trinity River (USFWS 1999) predicted a difference of approximately 1°F in water temperature for flows of 300 cfs and 450 cfs near RM 24 with smaller temperature differences expected downstream to the confluence of the Trinity and Klamath Rivers. Therefore, changes in water temperature under Alternative 4 would not affect American Shad.

O.3.9.1.2 Trinity River Record of Decision

The Trinity River ROD is being implemented under both Alternative 4 and the No Action Alternative. Therefore, implementation of the variable annual flow regime, restoration actions, and monitoring and adaptive management, per the Trinity River ROD under Alternative 4 would have similar effects as the No Action Alternative on Coho Salmon, Chinook Salmon (Spring- and Fall-Run), Steelhead (Winter- and Summer-Run), Green Sturgeon, White Sturgeon, Pacific Lamprey, and American Shad.

O.3.9.1.3 Grass Valley Creek Flows from Buckhorn Dam

A combination of a history of poor logging practices in the upper GVC basin and bedrock geology composed mainly of weathered quartz diorite (decomposed granite) resulted in increased deposition of fine sediments at critical spawning grounds in the Trinity River (Reclamation 2012a). In an effort to trap and, in turn, reduce fine sediment input into the Trinity River, Buckhorn Dam was constructed in 1991. Water from Buckhorn Reservoir is released from two sources: (1) the spillway, at an elevation of 2,803.13 ft; and (2) the outlet channel, which receives a constant flow of 6 cfs to 10 cfs that travels approximately 2,300 ft to its confluence with the spillway outlet.

GVC is an important spawning tributary for Coho Salmon, Steelhead, and Pacific Lamprey in the upper Trinity River basin. Restoration of the upstream 800 ft of outlet channel was performed in 2012 to enhance spawning and rearing within the outlet reach of GVC. Reclamation proposes flow releases of up to 100 cfs, lasting anywhere from a few hours to one week, from Buckhorn Dam down the outlet channel when the reservoir elevation exceeds 2,803.13 ft between March 1 and April 15. The primary objects of the proposed spring releases are: (1) to cue out-migration of juvenile salmonids residing in the outlet channel; and (2) to maintain habitat conditions through physical geomorphic processes (scour and deposition). Additional fall releases to the outlet channel during October and November are proposed to provide adult Coho Salmon sufficient flow for upstream migration and spawning. Proposed fall flows would provide ≥0.6 ft depth at riffle crests in the outlet channel for 600 ft downstream from the outlet works and a ≥10 cfs flow increase at USGS gage 11525630, located near the mouth of GVC.

Storage volume in Buckhorn Reservoir would likely remain the same or minimally decrease under Alternative 4 compared with the No Action Alternative during most water year types. Spring releases under both Alternative 4 and the No Action Alternative are only triggered when Buckhorn Dam is at capacity. Historically, flows from March 1 through April 15 at the GVC USGS gage have reached or exceeded 100 cfs (Table O.3-57 and Figure O.3-135). The main difference between Alternative 4 and the No Action Alternative is the location of flow releases; under Alternative 4 the outlet channel is the primary release point, and under the No Action Alternative the spillway is the primary release point. Since spring releases are dependent on the reservoir being at capacity, no effect on reservoir level is anticipated. However, fall releases during dry and critically dry years may have a minimal effect on reservoir levels if inflow to the reservoir is less than flow released from the reservoir.

Table O.3-57. Mean minimum and maximum discharges (cfs) in Grass Valley Creek at USGS gage 11525630 from March 1 through April 15, 2005 to 2018

Year	Mean (cfs)	Minimum (cfs)	Maximum (cfs)	Water Year Type
2005	106	66	263	Wet
2006	176	99	841	Extremely Wet
2007	36.2	27	49	Dry
2008	63.6	40.8	104	Dry
2009	91.5	47.1	961	Dry
2010	104	68.2	548	Wet
2011	159	42.4	581	Wet
2012	73.9	19	533	Normal
2013	37.1	29.3	74.5	Dry
2014	25.5	9.76	138	Critically Dry
2015	29.5	22	40.6	Dry
2016	130	36.5	585	Wet
2017	117	94.3	206	Extremely Wet
2018	27.1	14	202	Critically Dry
Average:	84	44	366.2	NA

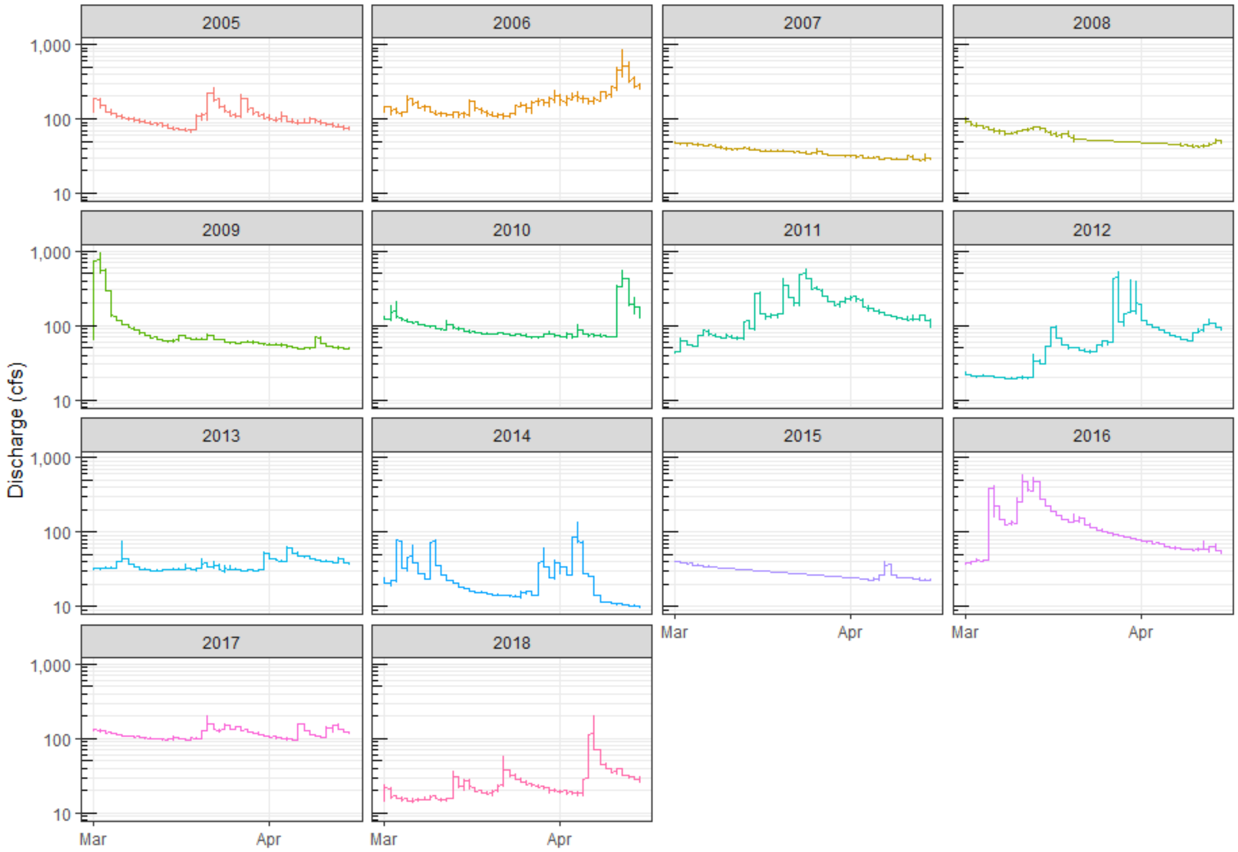


Figure O.3-135. Discharge (cfs) in Grass Valley Creek at USGS Gage 11525630 from March 1 through April 15, 2005 to 2018

Under Alternative 4, spring releases in the outlet channel will include pulse flows for channel maintenance and promotion of juvenile out-migration. Maintenance of the outlet channel through spring pulse flow releases of up to 100 cfs will promote natural geomorphic processes of erosion and deposition, control riparian vegetation, maintain spawning habitat quality by periodically mobilizing spawning gravel deposits and removing fine sediments, and transport and deposition of sands and fines. Under the No Action Alternative, flows in the outlet channel would remain at 6 cfs to 10 cfs year-round.

Water temperature effects on GVC under Alternative 4 compared with the No Action Alternative are anticipated to be minimal during spring releases for all water year types, as spring snowmelt and run-off dominate inflow into the reservoir, keeping water temperatures low. Fall flow releases to facilitate upstream migration and spawning of Coho Salmon would occur during October and November, typically a period when low flow and potentially high water temperature could occur in GVC (Table O.3-58 and Figure O.3-136). Water temperatures in dry and critically dry water year types in the Trinity River below Lewiston Dam are highest during June through October (Figure O.3-137). Given that high water temperatures typically extend through October in the Trinity River, similar conditions are likely to be present in GVC and Buckhorn Reservoir. Fall flow releases from Buckhorn Reservoir into the outlet channel are expected to increase flow at the USGS gage 11525630 to ≥10 cfs under Alternative 4 and range from 6 cfs to 10 cfs under the No Action Alternative during October and November, with the potential to affect water temperature in GVC; however, the intake for the outlet works is located approximately 58 ft below the spillway crest, providing cooler than surface water temperatures. Overall, no effect on water temperature in GVC is anticipated under Alternative 4 compared with the No Action Alternative.

Table O.3-58. Mean, Minimum, and Maximum Discharge (cfs) in Grass Valley Creek at USGS Gage 11525630 from October through November, 2004–2018

Year	Mean (cfs)	Minimum (cfs)	Maximum (cfs)	Water Year Type
2004	15	10	33	Wet
2005	16	11	53	Wet
2006	18.2	13	44	Extremely Wet
2007	12.1	9.6	23.3	Dry
2008	12.6	7.54	27.3	Dry
2009	12.6	6.38	64.8	Dry
2010	18.6	9.64	121	Wet
2011	18.1	11.4	45.2	Wet
2012	15.5	7.19	574	Normal
2013	8.77	7.49	14.4	Dry
2014	8.23	5.98	30.4	Critically Dry
2015	7.67	5.98	10.9	Dry
2016	21.4	6.72	66.9	Wet
2017	13.7	9.87	56.8	Extremely Wet
2018	11.2	6.97	664	Critically Dry
Average:	14	8.6	121.9	NA

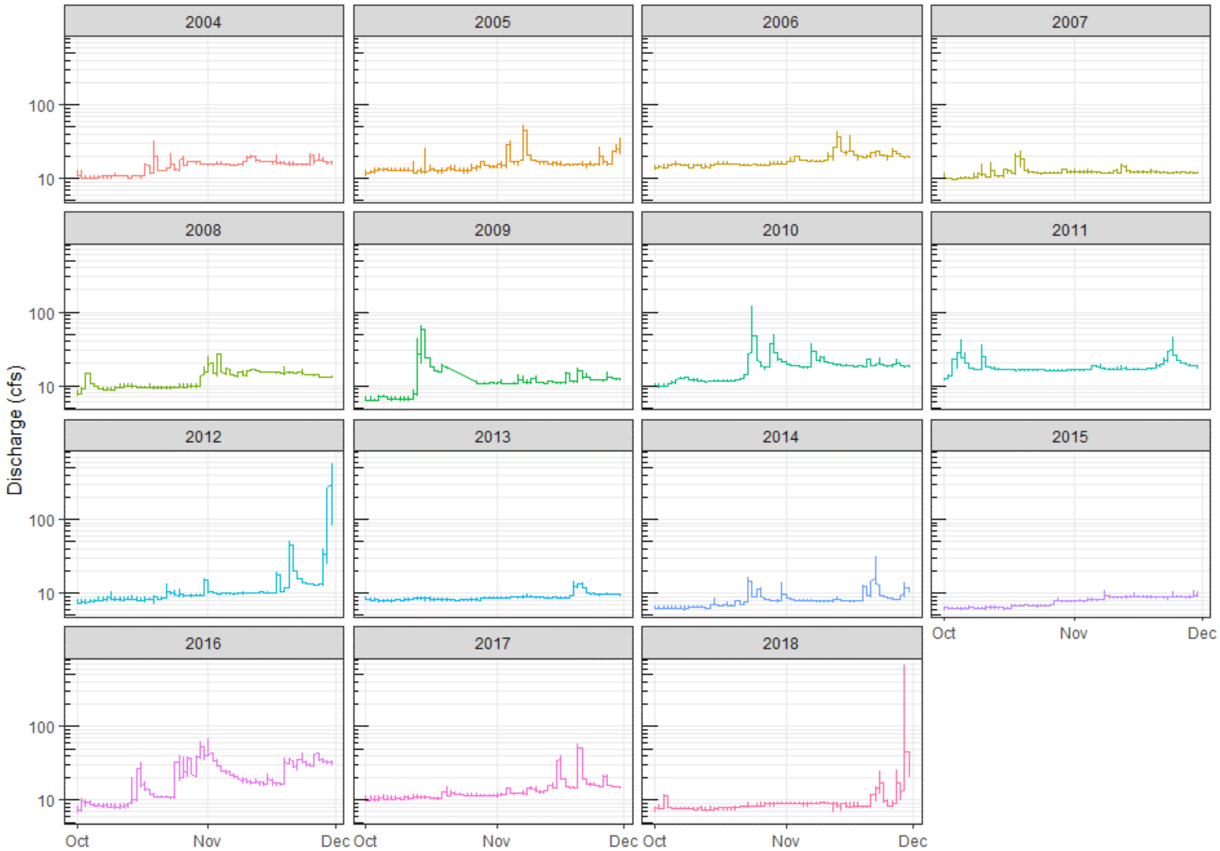


Figure 3. Discharge (cfs) in Grass Valley Creek at USGS Gage 11525630 from October through November, 2004–2018

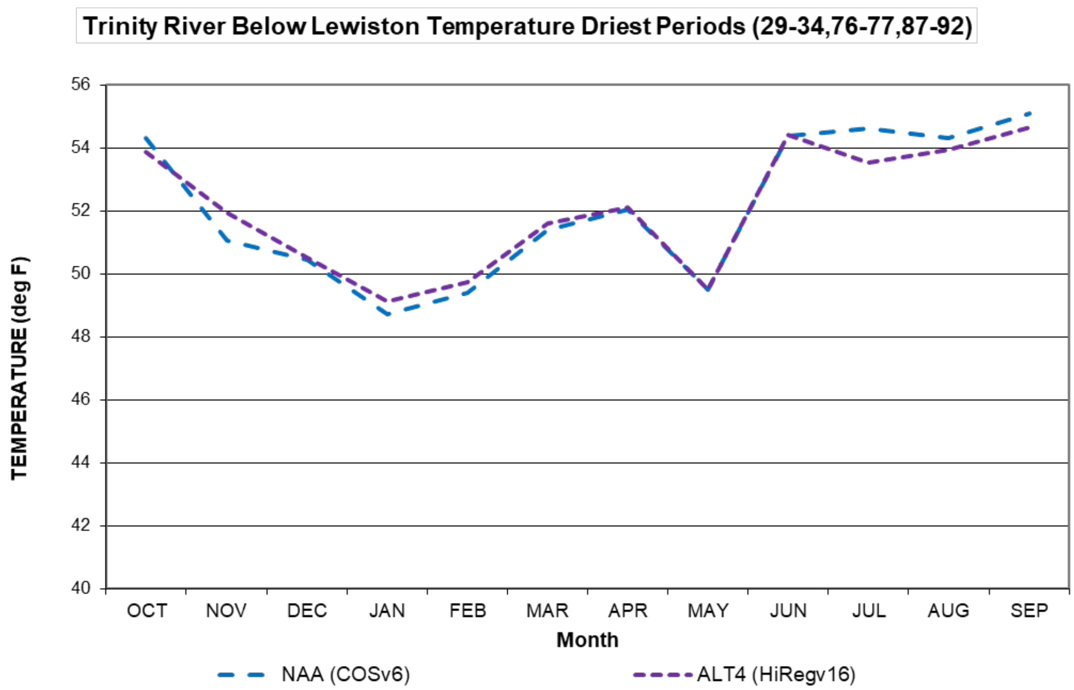


Figure O.3-137. Water Temperature in the Trinity River below Lewiston Dam during the Driest Periods of the Year under the No Action Alternative and Alternative 4.

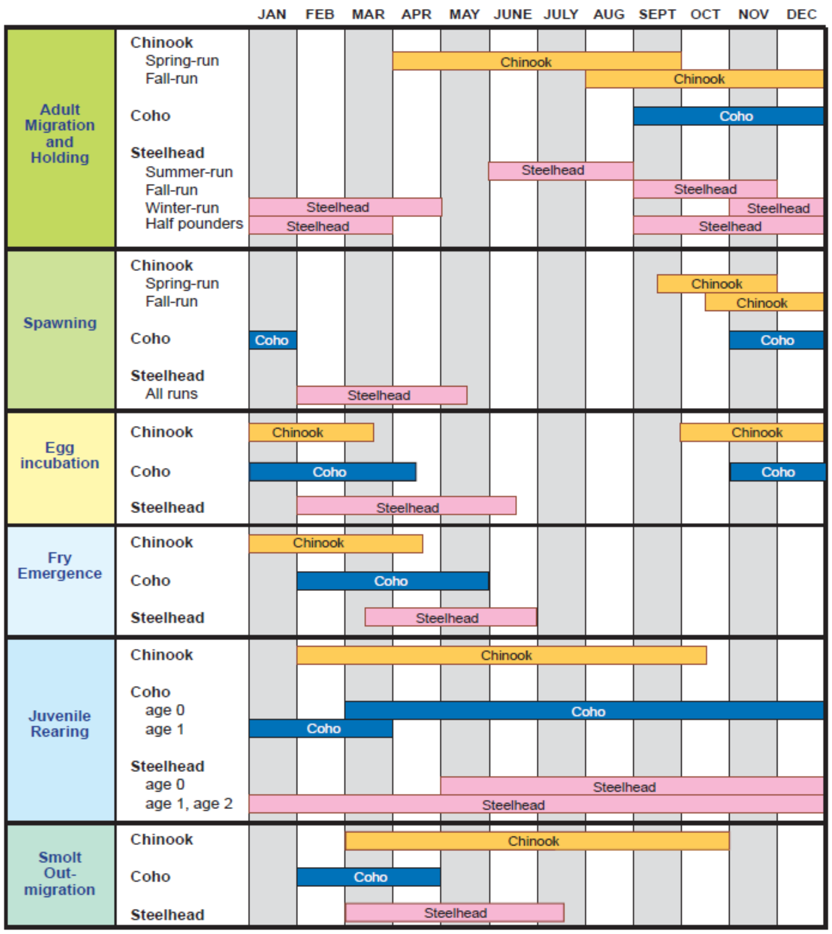
Potential changes to aquatic resources due to changes in pulse flows in Grass Valley Creek

Coho Salmon

Under Alternative 4, juvenile Coho Salmon in the GVC outlet channel would experience pulse flows from Buckhorn Dam from March 1 through April 15 when the Buckhorn Reservoir is above maximum capacity. Pulse flows are intended to incorporate a natural hydrograph element and would occur during spring runoff period, cuing juvenile Coho Salmon to begin their downstream migration to the Trinity River and eventually the ocean. Flow releases to the outlet channel under Alternative 4 would be up to 100 cfs and sufficient to mobilize gravel compared with the No Action Alternative, under which releases are kept at 6 cfs to 10 cfs year-round. In 2011, prior to restoration in the outlet channel occurring in 2012, juvenile Coho Salmon were documented below the exposed bedrock outcrop located approximately 600 ft downstream of the outlet works (Gutermuth 2011). Depending on the outlet channel complexity and the availability of high flow cover, newly emerged Coho Salmon may be subject to displacement downstream during pulse flows.

Under Alternative 4, incubating Coho Salmon eggs could be negatively affected by pulse flow releases. Coho Salmon egg incubation in the Trinity River occurs from November until mid-April (Figure O.3-138). A main goal of the spring pulse flows is to maintain the outlet channel through bed mobilization, an action that could negatively affect egg incubation. It is unlikely flows of 100 cfs will disrupt Coho Salmon redds in the outlet channel, but the potential for redd scour does exist if redds are located at constriction points.

Fall flow releases to attract and provide sufficient flows for migration of adult Coho Salmon in GVC are proposed under Alternative 4 but not the No Action Alternative. These releases are anticipated to be beneficial to adult Coho Salmon in GVC, as they would provide a depth ≥ 0.6 ft at riffle crests in the outlet channel to aid with migration and predation avoidance. Overall, Alternative 4 is anticipated to have a net beneficial effect on Coho Salmon in the GVC compared with the No Action Alternative.



* A small percentage of chinook in the Trinity River overwinter and outmigrate at age 1, similar to coho age 1 life history.

Figure O.3-138. Diagram of the Timing and Duration of Various Life-History Events for Chinook Salmon, Coho Salmon, and Steelhead in the Trinity River (USFWS and Hoopa Tribe 1999)

Chinook Salmon (Spring-Run and Fall-Run)

Fall-Run Chinook Salmon are known to occur in GVC from its confluence with the Trinity River upstream 7.5 miles (Baldwin 2002). Spring-Run Chinook Salmon are not present in GVC, and it is unknown if they existed there historically (Moyle et al. 2017). Under Alternative 4 releases into the outlet channel only occur when the reservoir is at maximum capacity, producing a very similar, if not the same, hydrograph as the No Action Alternative for fish downstream of the confluence of the outlet channel with the spillway channel. Due to the distribution of Fall-Run Chinook Salmon in GVC, no effect is predicted under Alternative 4 compared with the No Action Alternative; however, if the distribution of Chinook spreads to the outlet channel, eggs and juvenile Chinook Salmon will experience similar effects to Coho Salmon.

Fall flow releases under Alternative 4 that meet specific depth and flow criteria will provide a positive effect on adult migration of Chinook Salmon compared with the No Action Alternative. These releases are anticipated to be beneficial to adult Chinook Salmon in GVC, as they would increase discharge to ≥10 cfs at the USGS gage near Lewiston and aid with migration and predator avoidance.

Steelhead (Winter-Run and Summer-Run)

Winter-Run Steelhead are known to occur in GVC from its confluence with the Trinity River upstream to the outlet channel pool, located immediately downstream of the outlet works (Baldwin 2002). GVC is one of the most productive Winter-Run Steelhead tributaries in the upper Trinity River (Hill 2010). Summer-Run Steelhead are not present in GVC, and it is unknown if they existed there historically (Moyle et al. 2017). Pulse flows under Alternative 4 are intended to incorporate a natural hydrograph element and would occur during spring runoff peaks, cuing juvenile Winter-Run Steelhead in the outlet channel to begin their downstream migration to the Trinity River and eventually the ocean. Flow releases to the outlet channel under Alternative 4 would be up to 100 cfs and sufficient to mobilize gravel compared with the No Action Alternative, under which releases are kept at 6 cfs to 10 cfs year-round. Depending on the outlet channel complexity and the availability of high flow cover, newly emerged Winter-Run Steelhead may be subject to displacement downstream during pulse flows.

Under Alternative 4, Winter-Run Steelhead eggs could be negatively affected by pulse flow releases. Steelhead egg incubation in the Trinity River occurs from February through mid-June (Figure 4). A main goal of the spring pulse flow release is to maintain the outlet channel through bed mobilization, an action that could negatively affect egg incubation. It is unlikely flows of 100 cfs will disrupt Winter-Run Steelhead redds in the outlet channel, but the potential for redd scour does exist if redds are located at constriction points.

Fall flow releases under Alternative 4 that meet specific depth and flow criteria will provide a positive effect on adult Winter-Run Steelhead migration compared with the No Action Alternative. These flow releases are anticipated to be beneficial to adult Winter-Run Steelhead in GVC, as they would increase discharge to ≥10 cfs at the USGS gage near Lewiston and aid with migration and predator avoidance. Overall, Alternative 4 is predicted to have a net beneficial effect on Winter-Run Steelhead in GVC compared with the No Action Alternative.

Pacific Lamprey

Ammocoetes (juvenile lamprey) of potential Pacific Lamprey and Pit-Klamath Brook Lamprey have been recorded in GVC; however, without genetic testing ammocoetes of these two species cannot be differentiated. Based on habitat characteristics of GVC and species distribution, Pacific Lamprey are suspected to occur in GVC from its confluence with the Trinity River upstream to the outlet channel pool (Reid 2017). Pulse flows under Alternative 4 are intended to incorporate a natural hydrograph element and would occur during spring runoff peaks, cuing Pacific Lamprey ammocoetes in the outlet channel to begin their downstream migration to the Trinity River and eventually the ocean. A main goal of the spring pulse flows is to maintain the outlet channel through bed mobilization, an action that could negatively affect the ammocoete life stage. Because Pacific Lamprey spend the majority of the ammocoete life stage in the substrate, bed mobilizing flows have the potential to disrupt this life stage.

Under Alternative 4 Pacific Lamprey eggs could be negatively affected by bed mobilizing pulse flow releases in the outlet channel. Egg incubation in the Trinity River occurs from February through June; however, minimal Pacific Lamprey spawning habitat was recorded in the outlet channel in 2017 (Reid 2017). It is unlikely flows of 100 cfs will disrupt Pacific Lamprey redds in the outlet channel, but the potential for scouring does exist if redds are located at constriction points.

Fall flow releases under Alternative 4 that meet specific depth and flow criteria will provide no effect on Pacific Lamprey adults due to migration occurring from January through April. Overall, Alternative 4 is anticipated to have a net beneficial effect on Pacific Lamprey in the GVC compared with the No Action Alternative.

O.3.9.2 *Sacramento River*

Potential changes to aquatic resources in the Sacramento River from seasonal operations

Under all the Project alternatives, flows in the upper Sacramento River result from controlled releases from Shasta and Keswick reservoirs, as well as transfers from the Trinity River and natural accretions. Dry hydrologic conditions often lead to inadequate storage in Shasta Reservoir for operators to provide suitable conditions for salmonids and other native species in the upper Sacramento River. In most cases, water temperature rather than flow is the limiting factor creating unsuitable conditions, as discussed below. The primary differences between the No Action Alternative and Alternative 4 for the Sacramento River flow and water temperature management upstream of the Delta is that Alternative 4 would manage instream flow releases with a target of realizing 55% of unimpaired flows. Reclamation would release water from Shasta Reservoir to meet this flow target at the Sacramento River above Red Bluff and the confluence with the Feather River. However, during Shasta critically dry years (defined as year when forecasted inflow to Shasta Reservoir is less than 3.2 MAF), Reclamation would reduce instream flow releases to less than the 55% target to maintain water in storage for coldwater pool. The No Action Alternative includes NMFS's 2009 BO RPAs to operate Shasta Reservoir for management of cold water in the reservoir and river to protect anadromous salmonids, and includes requirements for Fall X2 flow releases, but Alternative 4 includes neither requirement.

CalSim II modeling indicates that average flow released at Keswick Dam under Alternative 4 would generally be higher than or similar to flow under No Action Alternative, except in wet and above normal water years during September and November, when the Alternative 4 flows would be substantially lower than the No Action Alternative flows (Table O.3-59). Moderately lower mean flows are expected for a few other months and water year types during summer (e.g., July of critically dry water years). The higher September and November flows under the No Action Alternative result from Fall X2 releases, which are not included in Alternative 4. Table O.3-59 shows that the highest mean monthly flows for both alternatives occur primarily during winter of wet and above normal water years and during summer of all water year types. Flow releases are high during summer to satisfy downstream demands of water users and Delta water quality and to meet water temperature requirements of incubating Winter-Run Chinook Salmon eggs and alevins downstream of Keswick Dam.

Table O.3-59. CalSim II Monthly Average Flow (cfs) by Water Year Type and Month below Keswick Dam for No Action Alternative, Alternative 4 and Differences between Them

Alternative[1,2,3]	Monthly Flow (cfs)											
Water Year Type[4]	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
No Action Alternative												
Wet (32%)[5]	7,908	9,796	7,444	17,876	19,288	16,127	8,458	8,662	8,940	13,440	10,474	14,063
Above Normal (16%)	7,054	10,124	6,406	7,629	16,401	8,534	5,221	7,925	10,359	15,316	10,494	9,972
Below Normal (13%)	5,842	4,960	7,558	3,285	7,149	3,925	3,803	7,867	10,930	14,421	10,624	5,493
Dry (24%)	5,660	5,111	8,652	3,697	3,564	3,961	3,719	7,014	10,368	12,658	8,608	4,995
Critical (15%)	4,829	3,755	3,251	3,392	3,580	3,509	4,065	6,895	8,984	10,947	7,793	4,729

Alternative 4												
Wet (32%)	7,691	5,944	9,310	18,843	19,046	16,035	8,971	8,392	8,982	13,465	10,556	7,890
Above Normal (16%)	6,874	6,741	7,500	8,481	17,447	9,470	5,684	7,650	10,275	16,012	10,398	5,499
Below Normal (13%)	5,718	5,127	7,669	4,892	7,936	5,125	4,468	7,834	11,667	14,401	9,930	5,092
Dry (24%)	5,712	5,111	9,225	3,729	3,678	4,408	4,002	7,170	11,631	12,475	8,626	4,862
Critical (15%)	5,005	3,905	3,263	3,372	3,497	3,554	3,926	6,794	9,324	9,569	7,373	4,829
Alternative 4 minus No Action Alternative[6]												
Wet (32%)	-218	**-3,852**	**1,866**	**968**	-242	-92	**514**	-270	42	24	82	**-6,173**
Above Normal (16%)	-180	**-3,383**	**1,093**	**851**	**1,046**	**937**	**464**	-275	-83	695	-95	**-4,474**
Below Normal (13%)	-124	166	110	**1,607**	**787**	**1,200**	**665**	-33	**737**	-20	**-693**	**-401**
Dry (24%)	51	0	**572**	31	114	**447**	**283**	156	**1,263**	-183	18	-133
Critical (15%)	176	149	12	-20	-83	45	-139	-101	340	**-1,378**	**-420**	100

1 Results based on the 82-year simulation period.

2 Results displayed with calendar year - year type sorting.

3 All scenarios are simulated at ELT (Early Long-Term) Q5 with 2025 climate change and 15 cm sea level rise.

4 Water year types as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999).

5 Percent of years of each type given in parentheses.

6 Bold green font indicates greater than 5% increase in flow; bold red font indicates greater than 5% reduction in flow.

HEC-5Q modeling was used to compare water temperature effects of the No Action Alternative and Alternative 4. Based on recent investigations of Winter-Run Chinook Salmon mortality in the upper Sacramento River (Martin et al. 2017; Anderson 2018), this effects analyses uses an upper water temperature threshold of 53.5°F for suitable salmonid egg and alevin incubation in the Sacramento River. An important caution regarding the HEC-5Q water temperature modeling results, particularly with regard to meeting water temperature criteria (e.g., 56°F water temperature at Bend Bridge criterion), relates to the time step used in the modeling. HEC-5Q, like the CalSim II model on which it relies for flow data, has a monthly time step and provides estimates of monthly mean water temperatures. However, most of the regulatory requirements to meet water temperature criteria apply to daily mean (or shorter duration) water temperatures. Daily means are almost always much more variable than monthly means and, therefore, the monthly mean water temperature estimates provided by HEC-5Q are not directly comparable to the regulatory criteria. For example, even with constant flows releases, downstream daily water temperatures would fluctuate around the mean in response to variation in solar radiation and other meteorological conditions within a given month. In view of this limitation, it is helpful to consider the comparisons of temperature effects among the alternatives as indicating the relative likelihoods of exceeding temperature criteria, rather than whether or not the criteria are actually met. These considerations apply to the CalSim II flow data as well, but are less important for flow because there are fewer regulatory criteria for flow and, except during storm events, flow tends to be less variable than water temperature.

During the summer and much of the fall, water released from Keswick Dam warms downstream, resulting in warmer water temperatures in more downstream habitats. Therefore, the effects of the alternatives on fish populations depend on the habitat distributions of the populations as well as the results of temperature management operations. Winter-Run mostly spawn from Keswick Dam to about 6 miles downstream of the Clear Creek temperature gage, Spring-Run from Keswick Dam to about Balls Ferry, fall-run from Keswick Dam to about RBDD, late fall-run spawning distribution is similar to that of Winter-Run, and Green Sturgeon spawn downstream of the Cow Creek confluence to the GCID oxbow near Hamilton City (NMFS 2018b). Steelhead spawning areas in the upper Sacramento River are poorly known.

Based on the HEC-5Q modeling, the mean monthly water temperatures at Keswick Dam are roughly equal under the No Action Alternative and Alternative 4, except for August of dry and critically dry water years and October of all except critically dry water years (Table O.3-60). For all these months and water year types, the mean monthly water temperature under Alternative 4 is between 1.0 and 1.5°F cooler under Alternative 4 than under the No Action Alternative. Summer mean monthly water temperatures are consistently below the 53.5°F temperature threshold, except in critically dry water years during July through September under the No Action Alternative and August and September under Alternative 4. The October monthly mean water temperatures are above the critical water temperature threshold for all water year types under the No Action Alternative and below the threshold under all but critically dry water years under Alternative 4 (Table O.3-60), which would be expected to benefit salmonid eggs and alevins. A more detailed examination of this difference shows that mean October water temperatures are predicted to be less than the temperature threshold in 20% of the years under the No Action Alternative, while under Alternative 4 they are predicted to be less than the threshold in 70% of the years (Figure O.3-18). Similarly, in August the mean water temperatures are predicted to be less than the temperature threshold in 75% of the years under the No Action Alternative and in 93% of the years under Alternative 4 (Figure O.3-19). By November, monthly mean water temperatures for all water year types are above the critical water temperature threshold under both alternatives (Table O.3-60). The temperature reductions for August of dry and critically dry water years under Alternative 4 would also be expected to benefit for salmonid eggs and alevins. The largest predicted increase in mean water temperature under Alternative 4 is 0.8°F for January of critically dry water years and September of Above Normal water years (Table O.3-60). Both of these increases occur over ranges well below the critical temperature threshold and are therefore unlikely to have much effect on the salmonids.

Table O.3-60. HEC-5Q Monthly Average Water Temperature (°F) by Water Year Type and Month at Keswick Dam for No Action Alternative, Alternative 4 and Differences between Them

Alternative[1,2,3] / Water Year Type[4]	Monthly Temperature (°F) Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
No Action Alternative												
Wet (32%)[5]	54.3	55.4	52.0	47.3	45.9	46.3	47.8	48.7	49.6	50.4	51.4	51.0
Above Normal (16%)	53.9	54.9	51.4	47.6	46.0	46.5	48.1	48.6	49.3	50.0	51.1	51.0
Below Normal (13%)	54.2	54.3	51.3	48.2	46.9	47.8	49.1	49.4	49.7	50.8	52.0	52.8
Dry (24%)	54.5	54.4	50.8	48.4	47.3	47.8	49.1	49.5	50.1	51.4	53.0	53.2
Critical (15%)	58.9	56.3	51.5	48.2	47.1	48.1	49.5	50.7	52.3	53.9	56.2	58.4
Alternative 4												
Wet (32%)	52.8	54.7	51.8	47.5	46.0	46.3	47.6	48.7	49.7	50.5	51.4	51.5
Above Normal (16%)	52.5	54.1	51.2	47.6	46.1	46.5	48.1	48.8	49.5	50.2	51.4	51.8
Below Normal (13%)	53.0	54.7	51.7	48.4	47.1	47.8	49.2	49.3	49.7	50.8	51.6	52.5
Dry (24%)	53.3	54.8	51.5	48.6	47.4	47.8	49.1	49.6	50.0	51.3	51.9	52.8
Critical (15%)	58.4	56.2	52.0	49.0	47.6	48.3	49.9	50.9	52.0	53.1	54.8	57.6
Alternative 4 minus No Action Alternative[6]												
Wet (32%)	**-1.5**	-0.6	-0.2	0.2	0.1	0.0	-0.3	0.0	0.1	0.1	-0.1	0.5
Above Normal (16%)	**-1.4**	-0.7	-0.2	0.0	0.1	0.0	-0.1	0.2	0.2	0.2	0.2	0.8
Below Normal (13%)	**-1.1**	0.4	0.4	0.2	0.1	0.0	0.1	-0.1	0.0	0.0	-0.4	-0.3
Dry (24%)	**-1.2**	0.4	0.7	0.2	0.2	0.0	0.0	0.1	0.0	-0.1	**-1.1**	-0.5
Critical (15%)	-0.6	0.0	0.5	0.8	0.5	0.2	0.4	0.2	-0.3	-0.8	**-1.5**	-0.8

1 Results based on the 82-year simulation period.

2 Results displayed with calendar year - year type sorting.

3 All scenarios are simulated at ELT (Early Long-Term) Q5 with 2025 climate change and 15 cm sea level rise.

4 Water year types as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999).

5 Percent of years of each type given in parentheses.

6 Bold green font indicates greater than 1°F reduction in temperature, bold red font indicates greater than 1°F increase in temperature.

The HEC-5Q results indicate that late spring through early fall water temperatures in the Sacramento River at Clear Creek are slightly warmer than those at Keswick Dam, and temperature reductions in October and August are similar but slightly smaller (Table O.3-61). The results also show increases in September water temperature between the No Action Alternative and Alternative 4 during wet and above normal water years, similar to those found for the other alternatives (e.g., Tables O.3-7 through O,3-11). The reductions in October and August result in Alternative 4 water temperatures more suitable for salmonid eggs and alevins, but the increases in September result in water temperatures approach or exceed the threshold (Table O.3-61). Summer mean monthly water temperatures are below the 53.5°F temperature threshold, except in drier water years, especially in August and September. All mean temperatures for October and November under both alternatives are above the threshold, except for October of wet and above normal water years under Alternative 4 (Table O.3-61). At Balls Ferry, the temperatures are warmer still and the October and August reductions are slightly lower, while the September increases are larger (Table O.3-62). October and November mean water temperatures are above the threshold under both alternatives. The mean September water temperatures for wet and above normal water years at Balls Ferry exceed the threshold under Alternative 4, but not under the No Action Alternative (Table O.3-62). The exceedance plot of annual mean September temperatures indicate that water temperatures are below the threshold 40% of years under the No Action Alternative and about 15%

of years under Alternative 4 (Figure O.3-31). As discussed previously, the monthly mean water temperatures provide a rough estimate of the probability of mean daily water temperatures exceeding a temperature threshold. Therefore, when the monthly mean water temperature exceeds the temperature threshold, the probability or frequency of the daily mean temperature exceeding the threshold is greater than when the monthly mean water temperature is less than the threshold.

Table O.3-61. HEC-5Q Monthly Average Water Temperature (°F) by Water Year Type and Month at Clear Creek Confluence for No Action Alternative, Alternative 4 and Differences between Them

Alternative[1,2,3] Water Year Type[4]	Monthly Temperature (°F)											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
No Action Alternative												
Wet (32%)[5]	54.7	55.3	51.6	47.3	46.2	47.0	49.2	50.3	51.4	51.9	52.9	51.9
Above Normal (16%)	54.4	54.7	51.0	47.7	46.4	47.4	49.9	50.3	51.0	51.3	52.6	52.1
Below Normal (13%)	54.7	54.2	51.0	48.1	47.4	49.0	51.1	51.0	51.3	52.1	53.5	54.5
Dry (24%)	55.2	54.3	50.6	48.3	47.9	49.1	51.0	51.2	51.7	52.8	54.6	55.0
Critical (15%)	59.4	56.1	51.2	48.2	47.8	49.5	51.4	52.4	54.0	55.5	57.8	59.8
Alternative 4												
Wet (32%)	53.3	54.6	51.4	47.4	46.2	46.9	48.7	50.3	51.5	52.0	52.9	52.9
Above Normal (16%)	53.2	53.9	50.8	47.6	46.4	47.2	49.5	50.6	51.2	51.4	52.8	53.6
Below Normal (13%)	53.8	54.5	51.3	48.2	47.4	48.7	50.9	50.8	51.3	52.1	53.1	54.3
Dry (24%)	54.0	54.6	51.2	48.4	47.9	48.9	50.9	51.3	51.5	52.8	53.6	54.6
Critical (15%)	58.9	56.1	51.5	48.8	48.2	49.6	51.8	52.6	53.7	54.9	56.5	59.1
Alternative 4 minus No Action Alternative[6]												
Wet (32%)	**-1.3**	-0.7	-0.2	0.1	0.0	-0.1	-0.5	-0.1	0.1	0.1	-0.1	**1.0**
Above Normal (16%)	**-1.3**	-0.8	-0.2	0.0	0.0	-0.2	-0.4	0.3	0.2	0.1	0.2	**1.5**
Below Normal (13%)	-1.0	0.3	0.3	0.1	0.0	-0.2	-0.2	-0.1	0.0	0.0	-0.3	-0.2
Dry (24%)	**-1.1**	0.3	0.6	0.2	0.0	-0.2	-0.2	0.0	-0.2	-0.1	**-1.0**	-0.4
Critical (15%)	-0.5	-0.1	0.3	0.7	0.4	0.1	0.4	0.2	-0.3	-0.6	**-1.3**	-0.7

1 Results based on the 82-year simulation period.

2 Results displayed with calendar year - year type sorting.

3 All scenarios are simulated at ELT (Early Long-Term) Q5 with 2025 climate change and 15 cm sea level rise.

4 Water year types as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999).

5 Percent of years of each type given in parentheses.

6 Bold green font indicates greater than 1°F reduction in temperature, bold red font indicates greater than 1°F increase in temperature.

Table O.3-62. HEC-5Q Monthly Average Water Temperature (°F) by Water Year Type and Month at Balls Ferry for No Action Alternative, Alternative 4 and Differences between Them

Alternative[1,2,3] Water Year Type[4]	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
	Monthly Temperature (°F)											
No Action Alternative												
Wet (32%)[5]	55.1	54.9	50.7	46.9	46.4	47.7	50.8	52.5	53.6	53.3	54.2	52.6
Above Normal (16%)	54.9	54.4	50.2	47.0	46.6	48.2	51.6	52.3	52.7	52.4	53.8	53.0
Below Normal (13%)	55.3	53.8	50.2	47.4	47.6	49.8	52.9	52.6	52.8	53.3	54.6	55.8
Dry (24%)	55.7	53.8	49.8	47.7	47.9	49.8	52.8	53.0	53.2	54.1	55.9	56.4
Critical (15%)	59.7	55.7	50.1	47.9	48.2	50.4	53.0	54.0	55.4	56.7	59.1	60.8
Alternative 4												
Wet (32%)	53.8	54.2	50.7	47.0	46.4	47.6	50.2	52.4	53.7	53.4	54.2	54.1
Above Normal (16%)	53.7	53.5	50.1	47.1	46.6	47.9	51.1	52.5	52.9	52.5	54.0	55.0
Below Normal (13%)	54.4	54.1	50.5	47.6	47.6	49.5	52.6	52.5	52.7	53.2	54.4	55.7
Dry (24%)	54.6	54.0	50.4	47.9	47.9	49.6	52.6	53.0	52.9	54.0	55.0	56.0
Critical (15%)	59.2	55.7	50.3	48.4	48.6	50.4	53.3	54.1	55.1	56.3	57.9	60.2
Alternative 4 minus No Action Alternative[6]												
Wet (32%)	**-1.2**	-0.7	0.0	0.1	0.0	-0.1	-0.6	-0.1	0.1	0.1	-0.1	**1.5**
Above Normal (16%)	**-1.2**	-0.9	-0.1	0.1	0.0	-0.3	-0.5	0.3	0.2	0.1	0.2	**2.0**
Below Normal (13%)	-0.9	0.3	0.3	0.2	0.0	-0.3	-0.3	-0.1	-0.1	0.0	-0.3	0.0
Dry (24%)	**-1.1**	0.2	0.6	0.1	0.0	-0.2	-0.3	-0.1	-0.3	0.0	-1.0	-0.3
Critical (15%)	-0.5	0.0	0.3	0.5	0.4	0.1	0.3	0.2	-0.3	-0.4	**-1.2**	-0.6

1 Results based on the 82-year simulation period.

2 Results displayed with calendar year - year type sorting.

3 All scenarios are simulated at ELT (Early Long-Term) Q5 with 2025 climate change and 15 cm sea level rise.

4 Water year types as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999).

5 Percent of years of each type given in parentheses.

6 Bold green font indicates greater than 1°F reduction in temperature, bold red font indicates greater than 1°F increase in temperature.

The downstream trends in water temperature conditions noted for Keswick Dam, Clear Creek and Balls Ferry continue to RBDD, with reduced differences in water temperatures between the alternatives, except for substantially warmer temperatures in September of wet and above normal water years under Alternative 4 (Table O.3-63). The growing downstream differences in wet and above normal water year temperatures for September can be seen in Figures O.3-20, O.3-30, O.3-31, and O.3-22. The temperature differences are largely limited to the cooler 50% of years. Under both the No Action Alternative and Alternative 4, the mean water temperatures at RBDD for April through October are above the 53.5°F critical water temperature threshold in all water year types, except April of wet water years under Alternative 4. The pattern of increasing water temperatures differences in September of wet and above normal water years between the No Action Alternative and Alternative 4 continues downstream to Hamilton City and Knights Landing (Table O.3-64 and O.3-65; Figures O.3-23 and O.3-24). There is less late spring to late summer water temperature reduction at these locations from the No Action Alternative to Alternative 4 than that found for the other alternatives (Tables O.3-10, O.3-11, O.3-30, O.3-31, O.3-48, O.3-49, O.3-64, O.3-65), but there are reductions of 0.9 and 1.1°F between the No Action Alternative and Alternative 4 during June of dry water years at Hamilton City and Knights Landing, respectively (Table O.3-64 and O.3-65; Figure O.3-90 and O.3-91). These reductions may result from moderate increases in flow for June of dry years under Alternative 4 relative to the No Action Alternative, but for the other months and water year types there are smaller late spring to late summer flow increases from the No Action Alternative to Alternative 4 at these locations than those found for the other alternatives (Tables O.3-13, O.3-14, O.3-33, O.3-34, O.3-51, O.3-52, O.3-66, and O.3-67).

Table O.3-63. HEC-5Q Monthly Average Water Temperature (°F) by Water Year Type and Month at Red Bluff Diversion Dam for No Action Alternative, Alternative 4 and Differences between Them

Alternative[1,2,3]	Monthly Temperature (°F)											
Water Year Type[4]	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
No Action Alternative												
Wet (32%)[5]	56.2	54.3	49.3	46.5	47.0	49.3	53.7	56.7	59.1	58.1	58.9	55.4
Above Normal (16%)	56.2	53.7	48.8	46.6	47.1	50.0	54.9	56.9	57.8	56.5	58.3	56.3
Below Normal (13%)	56.6	53.3	48.9	46.7	48.0	51.7	56.4	56.7	57.4	57.4	58.8	60.1
Dry (24%)	57.1	53.0	48.5	46.9	48.3	51.5	56.1	57.5	57.9	58.5	60.6	60.9
Critical (15%)	60.6	54.7	48.6	47.3	49.0	52.4	56.6	58.0	60.0	61.2	63.3	64.3
Alternative 4												
Wet (32%)	55.3	53.6	49.4	46.6	47.0	49.2	53.1	56.6	59.1	58.1	58.8	58.2
Above Normal (16%)	55.4	52.7	48.8	46.7	47.1	49.7	54.3	57.1	58.0	56.5	58.5	59.6
Below Normal (13%)	56.0	53.5	49.1	46.9	48.0	51.3	56.0	56.6	57.1	57.3	58.8	60.3
Dry (24%)	56.3	53.2	49.0	47.0	48.3	51.4	55.9	57.3	57.3	58.5	59.9	60.7
Critical (15%)	60.3	54.6	48.8	47.6	49.2	52.4	56.8	58.1	59.6	61.4	62.6	63.8
Alternative 4 minus No Action Alternative[6]												
Wet (32%)	-0.9	-0.7	0.1	0.1	0.0	-0.1	-0.6	-0.1	0.0	0.1	-0.1	**2.8**
Above Normal (16%)	-0.8	-0.9	0.0	0.1	0.0	-0.3	-0.6	0.2	0.2	-0.1	0.2	**3.3**
Below Normal (13%)	-0.6	0.2	0.2	0.2	0.0	-0.4	-0.4	-0.1	-0.3	0.0	0.0	0.2
Dry (24%)	-0.8	0.2	0.4	0.1	0.0	-0.1	-0.2	-0.2	-0.6	0.0	-0.8	-0.2
Critical (15%)	-0.3	0.0	0.2	0.3	0.3	0.0	0.2	0.1	-0.4	0.1	-0.7	-0.5

1 Results based on the 82-year simulation period.

2 Results displayed with calendar year - year type sorting.

3 All scenarios are simulated at ELT (Early Long-Term) Q5 with 2025 climate change and 15 cm sea level rise.

4 Water year types as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999).

5 Percent of years of each type given in parentheses.

6 Bold green font indicates greater than 1°F reduction in temperature, bold red font indicates greater than 1°F increase in temperature.

Table O.3-64. HEC-5Q Monthly Average Water Temperatures (degree Fahrenheit) by Water Year Type and Month below Hamilton City for No Action Alternative, Alternative 4 and Differences between Them

Alternative[1,2,3]	Monthly Temperature (°F)											
Water Year Type[4]	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
No Action Alternative												
Wet (32%)[5]	57.8	54.3	48.9	46.5	47.4	50.4	55.4	60.2	64.1	63.0	63.7	58.2
Above Normal (16%)	58.0	53.6	48.6	46.7	47.6	51.1	56.8	61.0	62.8	61.0	62.9	59.6
Below Normal (13%)	58.5	53.5	48.5	46.7	48.6	53.1	58.9	60.7	62.0	61.8	63.2	64.2
Dry (24%)	59.1	53.3	48.3	46.9	49.0	52.8	58.5	61.5	62.7	63.1	65.3	65.1
Critical (15%)	62.2	54.8	48.3	47.4	50.0	54.2	59.6	62.1	64.5	65.9	67.9	67.9
Alternative 4												
Wet (32%)	57.2	53.7	49.0	46.6	47.4	50.3	54.9	60.1	64.1	63.0	63.6	62.1
Above Normal (16%)	57.5	52.8	48.5	46.8	47.6	50.8	56.3	61.1	63.0	60.8	63.1	63.8
Below Normal (13%)	58.1	53.6	48.7	46.9	48.6	52.7	58.5	60.6	61.6	61.7	63.4	64.5
Dry (24%)	58.5	53.3	48.6	47.0	48.9	52.7	58.3	61.4	61.8	63.1	64.8	65.0
Critical (15%)	61.9	54.8	48.4	47.6	50.2	54.2	59.7	62.1	64.1	66.4	67.4	67.4
Alternative 4 minus No Action Alternative[6]												
Wet (32%)	-0.6	-0.6	0.1	0.1	0.0	-0.1	-0.5	-0.1	0.0	0.0	-0.1	**3.8**
Above Normal (16%)	-0.5	-0.8	-0.1	0.1	0.0	-0.3	-0.5	0.2	0.2	-0.2	0.2	**4.2**
Below Normal (13%)	-0.4	0.1	0.2	0.2	-0.1	-0.4	-0.4	-0.1	-0.4	0.0	0.2	0.4
Dry (24%)	-0.6	0.1	0.4	0.1	0.0	-0.1	-0.2	-0.1	-0.9	0.0	-0.6	-0.1
Critical (15%)	-0.3	0.0	0.1	0.2	0.2	0.0	0.1	0.1	-0.5	0.5	-0.4	-0.5

1 Results based on the 82-year simulation period.

2 Results displayed with calendar year - year type sorting.

3 All scenarios are simulated at ELT (Early Long-Term) Q5 with 2025 climate change and 15 cm sea level rise.

4 Water year types as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999).

5 Percent of years of each type given in parentheses.

6 Bold green font indicates greater than 1°F reduction in temperature, bold red font indicates greater than 1°F increase in temperature.

Table O.3-65. HEC-5Q Monthly Average Water Temperature (°F) by Water Year Type and Month at Knights Landing for No Action Alternative, Alternative 4 and Differences between Them

Alternative[1,2,3]	Monthly Temperature (°F)											
Water Year Type[4]	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
No Action Alternative												
Wet (32%)[5]	61.0	55.1	48.8	46.5	48.0	51.9	57.4	65.0	70.9	71.8	72.4	63.9
Above Normal (16%)	61.6	54.3	48.5	47.0	48.3	52.5	59.1	66.6	70.8	69.7	71.6	65.8
Below Normal (13%)	62.7	55.1	48.4	46.9	49.2	55.1	62.0	67.1	69.9	70.5	71.4	70.5
Dry (24%)	63.2	54.9	48.4	46.9	49.7	54.5	61.1	68.0	71.3	71.9	73.6	71.7
Critical (15%)	65.9	56.9	48.5	47.5	51.1	56.5	63.2	68.6	72.4	74.3	75.5	73.3
Alternative 4												
Wet (32%)	61.2	55.1	48.8	46.6	48.0	51.8	57.0	64.9	70.8	71.8	72.3	68.6
Above Normal (16%)	61.9	54.2	48.4	47.0	48.3	52.3	58.7	66.6	70.9	69.4	71.7	70.1
Below Normal (13%)	62.7	55.0	48.6	47.0	49.2	54.6	61.6	67.0	69.3	70.4	72.0	70.9
Dry (24%)	62.9	54.8	48.6	47.0	49.7	54.4	61.0	68.0	70.1	72.0	73.5	71.7
Critical (15%)	65.7	56.8	48.6	47.6	51.2	56.5	63.3	68.6	71.8	75.2	75.6	73.0
Alternative 4 minus No Action Alternative[6]												
Wet (32%)	0.2	-0.1	0.0	0.1	0.0	-0.1	-0.4	0.0	0.0	0.0	-0.1	**4.6**
Above Normal (16%)	0.4	-0.1	-0.1	0.0	0.0	-0.2	-0.4	0.1	0.1	-0.4	0.1	**4.4**
Below Normal (13%)	-0.1	0.0	0.2	0.1	-0.1	-0.4	-0.4	-0.1	-0.6	-0.1	0.6	0.4
Dry (24%)	-0.3	-0.1	0.2	0.1	0.0	-0.1	-0.1	-0.1	**-1.1**	0.0	-0.1	0.0
Critical (15%)	-0.2	-0.1	0.0	0.2	0.1	0.0	0.0	0.0	-0.6	0.9	0.1	-0.3

1 Results based on the 82-year simulation period.

2 Results displayed with calendar year - year type sorting.

3 All scenarios are simulated at ELT (Early Long-Term) Q5 with 2025 climate change and 15 cm sea level rise.

4 Water year types as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999).

5 Percent of years of each type given in parentheses.

6 Bold green font indicates greater than 1°F reduction in temperature, bold red font indicates greater than 1°F increase in temperature.

Table O.3-66. CalSim II Monthly Average Flow (cfs) by Water Year Type and Month at Hamilton City for No Action Alternative, Alternative 4 and Differences between Them

Alternative[1,2,3]	Monthly Flow (cfs)											
Water Year Type[4]	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
No Action Alternative												
Wet (32%)[5]	8,219	12,548	13,755	33,783	35,092	28,342	16,376	11,144	8,207	10,450	7,770	13,867
Above Normal (16%)	7,425	12,867	12,385	19,430	29,641	18,802	11,052	8,831	8,368	11,840	7,780	9,701
Below Normal (13%)	6,440	6,788	13,003	8,908	14,535	8,530	7,083	7,429	8,757	11,240	8,168	5,345
Dry (24%)	5,989	8,176	17,167	8,112	11,042	10,647	7,244	6,779	8,089	9,728	6,468	4,801
Critical (15%)	4,854	5,153	7,089	6,934	7,312	6,875	5,290	6,238	7,000	8,573	5,874	4,436
Alternative 4												
Wet (32%)	8,106	8,723	15,824	35,258	35,506	28,798	17,309	10,944	8,245	10,462	7,841	7,694
Above Normal (16%)	7,347	9,571	13,725	20,712	31,391	20,169	11,785	8,623	8,259	12,470	7,645	5,202
Below Normal (13%)	6,371	6,978	13,247	10,637	15,575	9,847	7,933	7,319	9,462	11,159	7,415	4,976
Dry (24%)	6,117	8,220	17,992	8,191	11,361	11,296	7,613	6,916	9,306	9,486	6,449	4,666
Critical (15%)	5,024	5,324	7,165	6,942	7,296	7,047	5,357	6,313	7,579	7,469	5,678	4,621
Alternative 4 minus No Action Alternative[6]												
Wet (32%)	-113	**-3,825**	**2,070**	1,474	414	456	**934**	-200	38	12	71	**-6,172**
Above Normal (16%)	-78	**-3,296**	**1,340**	**1,282**	**1,750**	**1,367**	**733**	-208	-109	**630**	-135	**-4,499**
Below Normal (13%)	-69	190	243	**1,729**	**1,040**	**1,317**	**851**	-110	**706**	-81	**-753**	**-369**
Dry (24%)	128	45	825	79	318	**649**	**369**	136	**1,217**	-242	-20	-134
Critical (15%)	170	171	76	8	-15	172	68	75	**579**	**-1,104**	-197	185

1 Results based on the 82-year simulation period.

2 Results displayed with calendar year - year type sorting.

3 All scenarios are simulated at ELT (Early Long-Term) Q5 with 2025 climate change and 15 cm sea level rise.

4 Water year types as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999).

5 Percent of years of each type given in parentheses.

6 Bold green font indicates greater than 5% increase in flow; bold red font indicates greater than 5% reduction in flow.

Table O.3-67. CalSim II Monthly Average Flow (cfs) by Water Year Type and Month at Wilkens Slough for No Action Alternative, Alternative 4 and Differences between Them

Alternative[1,2,3]	Monthly Flow (cfs)											
Water Year Type[4]	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
No Action Alternative												
Wet (32%)[5]	7,511	12,176	11,622	18,870	19,567	17,810	14,598	9,612	6,426	7,574	5,293	13,916
Above Normal (16%)	6,711	11,184	11,185	16,976	18,484	17,432	12,412	7,174	6,171	8,650	5,448	9,654
Below Normal (13%)	6,046	6,466	11,361	10,381	13,627	9,842	7,454	5,489	5,958	7,948	5,637	5,132
Dry (24%)	5,215	8,027	12,724	9,098	12,422	12,174	8,077	4,381	5,159	6,678	4,291	4,665
Critical (15%)	4,072	4,733	7,847	8,021	8,590	8,066	5,306	3,683	4,176	5,648	3,817	4,154
Alternative 4												
Wet (32%)	7,731	8,227	12,360	19,086	19,761	18,166	15,402	9,482	6,502	7,586	5,366	7,739
Above Normal (16%)	6,923	7,682	11,680	17,775	19,057	17,928	13,212	6,945	6,090	9,288	5,289	5,169
Below Normal (13%)	6,082	6,616	11,415	11,444	14,026	11,043	8,122	5,367	6,684	7,842	4,903	4,810
Dry (24%)	5,480	8,067	13,034	9,102	12,597	12,717	8,409	4,512	6,372	6,379	4,306	4,538
Critical (15%)	4,219	4,901	7,919	8,000	8,528	8,232	5,361	3,754	4,750	4,513	3,686	4,327
Alternative 4 minus No Action Alternative[6]												
Wet (32%)	220	**-3,950**	**738**	216	194	356	**804**	-131	75	12	73	**-6,177**
Above Normal (16%)	211	**-3,502**	496	799	573	496	**800**	-229	-81	**638**	-159	**-4,485**
Below Normal (13%)	36	150	54	**1,063**	399	**1,201**	**669**	-122	**727**	-106	**-734**	**-322**
Dry (24%)	**266**	39	310	3	175	543	332	131	**1,213**	-299	15	-126
Critical (15%)	147	168	72	-20	-62	166	56	71	**574**	**-1,134**	-130	172

1 Results based on the 82-year simulation period.

2 Results displayed with calendar year - year type sorting.

3 All scenarios are simulated at ELT (Early Long-Term) Q5 with 2025 climate change and 15 cm sea level rise.

4 Water year types as defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999).

5 Percent of years of each type given in parentheses.

6 Bold green font indicates greater than 5% increase in flow; bold red font indicates greater than 5% reduction in flow.

The reduced downstream warming of the river in September of wet and above normal under the No Action Alternative relative to the Alternative 4 is due, at least in part, to the much higher flow releases for Fall X2, as noted above (Table O.3-59). Note that November Fall X2 flow releases under the No Action Alternative do not result in higher water temperatures under Alternative 4 (e.g., Table O.3-65), presumably because November air temperatures would, on average, be similar to or lower than the water temperatures.

It is expected that, in general, water temperatures between the No Action Alternative and Alternative 4 would be largely similar, with the exception of September of wet and above normal water years, when water temperatures are warmer under the Alternative 4, because this alternative would not include the Fall X2 flows that reduce downstream warming under the No Action Alternative, and with the exception of August of dry and critically dry water years and October of all but critically dry water years at the sites upstream of RBDD, when water temperatures would be lower under Alternative 4 (Tables O.3-60, O.3-61, O.3-62).

O.3.9.2.1 Sacramento River Winter-Run Chinook Salmon

Spawning and Egg/Alevin Incubation

Winter-Run Chinook Salmon adults spawn from May through August with peak spawning during June and July (Section O.2.4.2.1, *Winter-Run Chinook Salmon*). Fry emergence occurs up to 3 months after eggs are spawned, so effects of flow and water temperature on Winter-Run eggs and alevins may occur from May through November, but primarily occur during June through October.

As previously noted, CalSim II modeling indicates that mean monthly flow released at Keswick Dam under Alternative 4 would generally be higher than or similar to flow under No Action Alternative, except in wet and above normal water years during September and November, when the Alternative 1 flows would be substantially lower than the No Action Alternative flows (Table O.3-59). By September in most years, a large proportion of Winter-Run redds still contain incubating alevins. Assuming flows are stable enough to avoid dewatering the redds, which is generally true in September, the most important effect of flows on alevins is to transport dissolved oxygen to the developing alevins and to flush potentially toxic metabolites out of the redds. Although the mean September wet and above normal water year flows are substantially lower under Alternative 1 than under the No Action Alternative, the flows under Alternative 1 flows remain moderately high (>6,000 cfs) (Figure O.3-25). Flows at this level are expected to provide sufficient flow velocity to keep the redds clean and well oxygenated. With regard to redd dewatering, reductions in fall flow releases to conserve storage would be balanced by needs to maintain suitable water temperatures, minimize dewatering redds of Winter-Run and other salmonids, and avoid stranding rearing juveniles. Therefore, differences in flow between the No Action Alternative and Alternative 1 are expected to have little effect on Winter-Run Chinook Salmon spawning and incubation habitat.

Differences between the No Action Alternative and Alternative 4 in water temperature during the Winter-Run spawning period may be important. As described in the previous section, HEC-5Q mean October water temperatures are predicted to be below the 53.5°F water temperature threshold in the majority of years under Alternative 4 and above the threshold in most years under the No Action Alternative (Figure O.3-18), and in August, the mean water temperatures are predicted to be above the threshold in about 25% of years under the No Action Alternative and 7% of years under Alternative 4 (Figure O.3-19). September water temperatures are expected to be higher under Alternative 4 than under the No Action Alternative, but the increases are expected only for the most downstream portion of the Winter-Run spawning distribution and primarily for wet and above normal water years, for which the mean temperatures for both alternatives would mostly be below the water temperature threshold (Tables O.3-60 and O.3-61; Figure O.3-20).

Recent investigations of Winter-Run Chinook Salmon mortality in the upper Sacramento River (Martin et al. 2017; Anderson 2018) yielded models for estimating mortality of Winter-Run Chinook Salmon eggs and alevins under different water temperature conditions. These models, referred to hereinafter as the Martin and Anderson models, were used to compare water-temperature-related mortality of Winter-Run Chinook Salmon eggs and alevins under Alternative 4 and the No Action Alternative. The modeling was based on the HEC-5Q water temperature estimates for the years used in the HEC-5Q modeling (1922 to 2002). <The egg mortality results for Alternative 4 are not yet available. Conclusions will be provided after egg mortality results become available.>

Juvenile Rearing and Emigration

Winter-Run Chinook Salmon juveniles rear in the Sacramento River primarily from late summer to late winter, and emigrate from the river to the Delta beginning in November (see Section O.2.4.2.1, *Winter-*

Run Chinook Salmon). The proportion of juveniles surviving to emigrate to the Delta depends largely on habitat conditions, including flow and water temperature. Inundated floodplain habitat has been shown to benefit growth and survival of juvenile salmon (Sommer et al. 2001, 2005; Katz et al. 2017), but natural flood flows largely determine the availability of this habitat, rather than operations of the CVP and SWP dams.

Sacramento River flow during the Winter-Run juvenile rearing and emigration period differs substantially between the No Action Alternative and ALT4, especially during September and November of wet and above normal water years (Tables O.3-59, O.3-66 through O.3-68). The juveniles rear primarily in the upper and middle Sacramento River until about October, when they begin to appear in the lower river (e.g., Knights Landing) (del Rosario et al. 2013). As noted previously, because the No Action Alternative includes Fall X2 releases but not Alternative 4 does not, the mean monthly flows during September and November are much lower under Alternative 4 than under the No Action Alternative, which would potentially reduce suitable rearing habitat for juveniles (Tables O.3-59 and O.3-66 through O.3-68; Figures O.3-25, O.3-28 and O.3-29).

Emigration of juvenile Winter-Run from the Sacramento River is triggered by pulse flows of about 14,000 cfs and above (at Wilkins Slough) (del Rosario et al. 2013). CalSim II September flows at Wilkins Slough exceed this threshold in about 18% of years under the No Action Alternative and never exceed it under Alternative 3, but September is too early for juvenile Winter-Run to emigrate to the Delta (del Rosario et al. 2013). For November, when Winter-Run juveniles are ready to emigrate, monthly mean flow at Wilkins Slough is much higher under the No Action Alternative than under Alternative 3, but remains below the 14,000 cfs threshold for both alternatives, except for the highest 9% of flows (Figure O.3-29). There are no differences between the alternatives at these highest flows. An important limitation with this analysis is that the CalSim II flow estimates are monthly averages and Winter-Run emigration can be triggered by flow pulses that exceed 14,000 cfs for only a few days (del Rosario et al. 2013), so the flow differences in Figure O.3-29 incompletely represent the likelihood of triggering pulse flows occurring under the two alternatives.

Results from a more recent analysis suggest that the reduction in November flows from the No Action Alternative to Alternative 3 during wet and above normal water years could adversely affect Winter-Run juveniles emigrating at that time. The NMFS Southwest Fisheries Science Center ran statistical models using 2012-2017 tagging data from Spring-Run Chinook Salmon and Fall-Run Chinook Salmon and found a significant increase in smolt survival when Sacramento River flow at Wilkins Slough was above 9,100 cfs during the smolts out-migration period (Cordoleani et al. 2019). The CalSim II results for November at Wilkins Slough indicate that, under the No Action Alternative, 50% of years would have mean monthly flows that exceed the 9,100 cfs threshold, but that under Alternative 3 only 20% of years would exceed the threshold (Figure O.3-29). If these results apply to Winter-Run juveniles emigrating in November, they indicate a potential adverse effect of Alternative 3 on emigrating Winter-Run juveniles. The applicability of the results to Winter-Run are currently unknown, so the effect on Winter-Run is uncertain.

The USEPA (2003) gives 61°F as the critical 7 day average daily maximum (7DADM) water temperature for Winter-Run Chinook Salmon juveniles rearing in the upper Sacramento River and 64°F (7DADM) for those rearing in the middle Sacramento River (Knights Landing). Under the No Action Alternative, NMFS's RPA 1.2.4 requires Reclamation to maintain water temperature from May 15 through October 31 in the Sacramento River at no more than 56°F at compliance locations between Ball's Ferry and Red Bluff Diversion Dam. Under Alternative 3, SWRCB's WRO 90-5 has similar but more flexible water temperature requirements for Reclamation. Therefore, under both alternatives, juveniles rearing in the upper Sacramento River are likely to be well protected from water temperature extremes through the end of October in all but the driest years.

Under the No Action Alternative and Alternative 3, mean monthly water temperatures at Keswick exceed the 61°F threshold in only about 5% of years in September and October, with no appreciable water temperatures differences between the alternatives for water temperatures greater than the 61°F threshold (Figures O.3-18 and O.3-20). The monthly average temperatures for these months should reasonably estimate daily mean temperatures because operations at Shasta and Keswick dams create relatively stable summer and fall flow and water temperature conditions in the upper Sacramento River. From November through March, by which months most juvenile Winter-Run have emigrated to the Delta, there are only minor differencs in mean water temperatures at all locations from Keswick Dam to Knights Landing (Tables O.3-26 through O.3-31).

The water temperature effects on juvenile Winter-Run Chinook Salmon rearing in or emigrating from the Sacramento River resulting from Alternative 4 would be less-than-significant relative to the No Action Alternative, but the flow effects are potentially significant because the reductions in September flows in wet and above normal water years could reduce rearing habitat and the reductions November flows in wet and above normal water years could reduce smolt survival.

Adult Upstream Migration and Holding

Winter-Run Chinook Salmon adults enter the Sacramento River from the Delta and make their way to the upper Sacramento River, beginning as early as December. They hold in the upper River within 10 to 15 miles of Keswick Dam until they are ready to spawn, which may extend through August (Windell et al. 2017).

There are no flow or temperature requirements for the middle Sacramento River designed to protect fish. However, releases from Shasta Reservoir during November through early May may be reduced to conserve water for the May through October Winter-Run and Spring-Run spawning and incubation periods, resulting in reduced flow in the middle river (NMFS 2011: RPA I.2.2; SWRCB 1990: WRO 90-5). Lower flow in the Sacramento River relative to flow from the lower Yolo and Sutter bypasses and agricultural drains may affect navigation cues and straying of Winter-Run adults into canals and behind weirs, increasing their stranding risk. Once the adults reach holding habitat in the upper Sacramento River, they are more directly affected by Shasta and Keswick reservoir operations designed to preserve cold water for the Winter-Run and Spring-Run spawning and incubation periods. During the December through August period of adult Winter-Run immigration and holding, the mean monthly flows under Alternative 4 at Keswick Dam, RBDD, Hamilton City and Wilkins Slough would generally be similar to or greater than flows under the No Action Alternative, except during June of critically dry water years and August of below normal water years (Tables O.3-59 and O.3-66 through O.3-68). The mean monthly CalSim II flows in July of critically dry years and August of below normal years are greater than 4,500 cfs at all four sites under Alternative 4, which is high enough to avoid obstructing upstream passage of the adults. In any case, most Winter-Run adults have migrated upstream of RBDD by late May (see Section O.2.4.2.1, *Winter-Run Chinook Salmon*) and, therefore, would not be affected by July or Augst flow reductions downstream of RBDD.

The USEPA (2003) gives 68°F as the critical 7DADM water temperature for Winter-Run Chinook Salmon adults migrating upstream in the Sacramento River and 61°F for adult Winter-Run holding in the upper river. There are no major differences in HEC-5Q water temperature estimates between the No Action Alternative and Alternative 4 during any of the months that adult Winter-Run migrate upstream in the Sacramento River or hold in the upper river (Tables O.3-60 through O.3-65). However, the monthly mean water temperatures are moderately cooler under Alternative 4 at sites upstream of RBDD during August of dry and Criticial water years (Tables O.3-60, O.3-61, and O.3-62). Under both alternatives, the mean monthly water temperatures in the middle Sacramento River (Knights Landing) would be below the 68°F threshold for immigrating adults from December through April, but would exceed the threshold in May of critically dry water years and June through August of all water year types (Table O.3-65). Most Winter-Run adults have migrated upstream of RBDD by late May (see Section O.2.4.2.1, *Winter-Run Chinook Salmon*) and would therefore not be adversely affected by the elevated downstream summer water temperatures. In the upper Sacramento River from Keswick to Balls Ferry, the mean water temperatures would be well below the 61°F threshold for holding adults from December through August under both alternatives, (Table O.3-60, O.3-61, and O.3-62).

Alternative 4 is expected to have a less-than-signficant effect on Winter-Run Chinook Salmon adult upstream migration and holding relative to the No Action Alternative.

O.3.9.2.2 Central Valley Spring-Run Chinook Salmon

Spawning and Egg/Alevin Incubation

Spring-Run Chinook Salmon adults spawn from August through October with peak spawning in September (see Section O.2.4.2.2, *Spring-Run Chinook Salmon*). Monitoring Spring-Run spawning in the mainstem Sacramento River is complicated due to lack of spatial/geographic segregation and temporal isolation from Fall-Run Chinook Salmon. Most spring-sun spawning occurs between the Keswick Dam and Ball Ferry Bridge (NMFS 2017b). Fry emergence occurs up to 3 months after eggs are spawned (Moyle 2002), so effects of flow in the upper Sacramento River on incubating Spring-Run eggs and alevins potentially occur from August through January, peaking in December.

As previously noted, CalSim II modeling indicates that mean monthly flow released at Keswick Dam under ALT4 would generally be higher than or similar to flow under No Action Alternative, except in wet and above normal water years during September and November, when the Alternative 4 flows would be substantially lower than the No Action Alternative flows (Table O.3-59). Spawning and incubating eggs and alevins could be negatively or positively affected by the flow reductions. Assuming flows are stable enough to avoid dewatering the redds, which as noted previously is an important criterion for operators of Shasta and Keswick dams, the most important effect of flows on eggs and alevins is to transport dissolved oxygen to the developing eggs and alevins and to flush potentially toxic metabolites out of the redds. Although the mean September and November wet and above normal water year flows are substantially lower under Alternative 4 than under the No Action Alternative, the flows under Alternative 4 flows remain sufficiently high (5,500 and >6,700 cfs for September and November, respectively) to provide the flow velocity needed to keep most redds clean and well oxygenated (Figures O.3-25). Therefore, differences in flow between the No Action Alternative and Alternative 4 are expected to have little effect on Spring-Run Chinook Salmon spawning and incubation habitat.

Differences in water temperature during the Spring-Run spawning period may be important. As described previously, HEC-5Q monthly mean October water temperatures at Keswick Dam under Alternative 4 are predicted to be moderately lower than those under the No Action Alternative. A consequence of these water temperature reductions is that, for all but critically dry water years, the monthly mean water temperatures under the No Action Alternative are above the 53.5°F temperature threshold and those under Alternative 4 are below the threshold (Tables O.3-60). In critically dry water years, the mean temperatures are well over the threshold for both alternatives. For the yearly mean October water temperatures (Figure O.3-18), water temperatures are above the threshold in about 90% of years under the No Action Alternative and 30% of years under Alternative 4. Summer mean monthly water temperatures at Keswick Dam are roughly equal under the No Action Alternative and Alternative 4, except for August of dry and critically dry water years, which have a 1.1 and 1.5°F lower mean water temperatures, respectively, under Alternative 4 than under the No Action Alternative (Table O.3-60). Summer mean monthly water temperatures are consistently below the 53.5°F temperature threshold, except in critically dry water years during July through September. The largest predicted increases in mean water temperature under Alternative 4 are less than 1°F. Between the Clear Creek confluence and Balls Ferry, where more of the Spring-Run spawning occurs, more of the October mean monthly water temperatures under Alternative 4 exceed the threshold, especially in drier years, but most of them continue to be below the No Action Alternative means (Tables O.3-61 and O.3-62). September water temperatures in wet and above normal water years are expected to be higher under Alternative 4 than under the No Action Alternative, especially downstream of Keswick Dam (Tables O.3-61 through O.3-65), and the increases would result in more years with mean water temperatures exceeding the 53.5°F water temperature threshold (Figures O.3-30 and O.3-31). The critical temperature threshold for spawning adult Chinook Salmon in the Sacramento River is the same as that for eggs and alevins, 53.5°F (Martin et al. 2017) or 55.4°F (USEPA 2003).

The HEC-5Q modeling results show increased exceedance of the 53.5°F water temperature threshold during September under ALT4 relative to the No Action Alternative, and reduced exceedance of the threshold in October in all but critically dry water years, especially at Keswick Dam. It is concluded that Alternative 4 would have no net effect on Spring-Run spawning and egg and alevin incubation. Therefore, Alternative 4 would have a less-than-significant impact on Spring-Run Chinook Salmon spawning and egg and alevin incubation with respect to flow and water temperature.

Juvenile Rearing and Emigration

Spring-Run Chinook Salmon juveniles rear in the Sacramento River primarily from November through early May and most emigrate to the Delta during December and again in March and April (see Section O.2.4.2.2, *Spring-Run Chinook Salmon*). Migratory cues, such as increased flow and/or turbidity from runoff, may spur emigration of juveniles from the upper Sacramento River basin when they have reached the appropriate stage of maturation (NMFS 2009).

Based on the CalSim II modeling results, during most of the Spring-Run juvenile rearing and emigration period, Sacramento River flow would be higher under Alternative 4 than under the No Action Alternative at all locations and many of the increases would be greater than 5% (Tables O.3-59 and O.3-14). However, the mean monthly flows for November of wet and above normal water years would be much lower under Alternative 4, because of the Fall X2 flows that are included in the No Action Alternative but not Alternative 4. Despite the reductions, the November flows under Alternative 4 remain relatively high (Tables O.3-59 and O.3-66 through O.3-68; Figures O.3-28 and O.3-29), so they are not expected to substantially affect rearing juveniles. Furthermore, as noted above, emigration occurs primarily in December and in the spring.

Results from a recent study suggest that for Spring-Run that do emigrate as early as November, the Alternative 4 flow reductions in November of wet and above normal water years would have a potentially adverse effect. The NMFS Southwest Fisheries Science Center ran statistical models using 2012-2017 tagging data from Spring-Run Chinook Salmon and Fall-Run Chinook Salmon and found a significant increase in smolt survival when Sacramento River flow at Wilkins Slough was above 9,100 cfs during the smolts emigration period (Cordoleani et al. 2019). The CalSim II results for November at Wilkins Slough indicate that 50% of years would have mean monthly flows that exceed the 9,100 cfs threshold under the No Action Alternative, and 20% of years would have flows that exceed the threshold under Alternative 4 (Figure (O.3-29). As shown by recent sampling at RBDD (Figure O.3-22) almost all Spring-Run juveniles emigrate from the upper Sacramento River after November, so the percentage of Spring-Run juveniles that would be affected by the expected reductions in November flows at Wilkins Slough would be small. Therefore changes in flow resulting from Alternative 4 are not expected to substantially affect rearing and emigrating juvenile Spring-Run Chinook Salmon.

The USEPA (2003) gives 61°F as the critical 7 day average daily maximum (7DADM) water temperature for Spring-Run Chinook Salmon juveniles rearing in the upper Sacramento River and 64°F (7DADM) for those rearing in the middle Sacramento River (Knights Landing). Under the No Action Alternative and Alternative 4, HEC-5Q estimates of mean monthly water temperatures from Keswick to RBDD do not exceed the 61°F threshold during any month and water year type during the November through May rearing period (Tables O.3-60 through O.3-63). The mean monthly water temperatures for Hamilton City do not exceed the 64°F threshold for the middle Sacramento River during any of the months, but the mean monthly water temperatures for May exceed the middle river threshold at Knights Landing in all water year types under both alternatives. However, there are no meaningful differences between the Alternative 4 and No Action Alternative temperatures at Knights Landing (Table O.3-64). These results indicate that water temperature conditions would be too warm for juvenile Spring-Run Chinook Salmon rearing and emigrating in the middle Sacramento River during May. It should be noted that May is the last month during spring or summer that Spring-Run Chinook Salmon juveniles are found in the middle river, and it is likely that when water temperatures are too high they emigrate to the ocean before May, However, early emigration could have other adverse effects.

The flow and water temperature effects resulting from Alternative 4 would have a less-than-significant effect relative to the No Action Alternative on juvenile Spring-Run Chinook Salmon in the Sacramento River.

Adult Upstream Migration and Holding

Spring-Run Chinook Salmon adults enter the Sacramento River from the Delta as early as January and make their way to the upper Sacramento River beginning in February, where they hold until ready to spawn in late summer and early fall (Windell et al. 2017). Adults may continue migrating upstream until August, and holding continues until October when spawning is complete. There are no flow or temperature requirements for the middle Sacramento River designed to protect fish. Once the adults reach holding habitat in the upper Sacramento River, they are more directly affected by Shasta and Keswick reservoir operations designed to preserve cold water for the Winter-Run and Spring-Run spawning and incubation periods.

During the January through August period of adult Winter-Run immigration, the mean monthly CalSim II flows under Alternative 4 at Keswick, RBDD, Hamilton City, and Wilkins Slough would generally be similar to or greater than those under the No Action Alternative, except during July of critically dry water years (Tables O.3-59 and O.3-66 through O.3-68). However, the mean July flows under both alternatives would remain high enough (>4,500 cfs) to allow upstream passage. During the holding period, September flow would be much lower under Alternative 4 than under the No Action Alternative (Tables O.3-59 and O.3-66 through O.3-68; Figure O.3-25), but the mean September Alternative 4 flows at Keswick Dam would not fall below 6,000 cfs over the range of flows for which the alternatives have major flow differences (i.e., upper 50% in Figure O.3-25). A flow of 6,000 cfs would presumably be sufficient to maintain good water quality conditions in the Spring-Run holding habitats. Note that monthly mean flows for these months should reasonably estimate daily mean flows because operations at Shasta and Keswick dams create relatively stable summer and fall flow and water temperature conditions in the upper Sacramento River.

The USEPA (2003) gives 68°F as the critical 7DADM water temperature for Spring-Run Chinook Salmon adults migrating upstream in the middle Sacramento River and 61°F for adult Spring-Run holding in the upper river. Throughout the January through August period of Spring-Run upstream migration, HEC-5Q water temperatures for Alternative 4 are similar to or slightly lower than those for the No Action Alternative at all locations, including greater than 1°F reductions in mean monthly water temperature for June of dry water years at Knights Landing (Tables O.3-60 through O.3-65). Under both alternatives, the mean monthly water temperatures in the middle Sacramento River (Knights Landing) would be below the 68°F threshold for immigrating adults from December through April, but would exceed the threshold in May of critically dry water years and in June through August of all water year types (Table O.3-65). The high May through August water temperatures would be likely to adversely affect any Spring-Run adults that were migrating upstream in those months. High water temperatures were found to cause adult Spring-Run Chinook Salmon in Butte Creek to terminate their upstream migrations, which made them more susceptible to mortality from rising water temperatures (Mosser et al. 2012). The June temperature reduction under Alternative 4 occurs in a range slightly above the 68°F threshold and, therefore, would likely have a beneficial effect on upstream migrating adults. In the upper Sacramento River at Keswick Dam to Balls Ferry, the mean water temperatures under both alternatives would be well below the 61°F threshold for holding adults from February through October (Tables O.3-60 through O.3-62). As previously noted, flow below Keswick Dam is relatively stable during the summer and fall months, so monthly mean flows and temperatures are likely to be fairly representative of daily means in those months.

With respect to flow and water temperature, Alternative 4 is expected to have a less-than-significant effect relative to the No Action Alternative on Spring-Run Chinook Salmon adult migration and holding.

O.3.9.2.3 Central Valley Steelhead

Spawning and Egg Incubation

CV steelhead adults spawn from November through April with peak spawning from January through March. Based on the general timing of hatching and fry emergence, eggs and alevins may occur from November through May. Little is known about steelhead spawning locations in the Sacramento River, but it is generally assumed that spawning occurs primarily between Keswick Dam and RBDD.

During the steelhead spawning and incubation period, CalSim II modeling indicates that Alternative 4 flows in wet and above normal years would be substantially lower in November, and generally higher during the winter and spring months (Table O.3-59). Based on PHABSIM results (flow versus weighted usable area [WUA] relationships) for steelhead in the Sacramento River between Keswick Dam and Battle Creek (see O.3.3 Alternative 1, Central Valley Steelhead Spawning and Egg Incubation), lower flows in November of wet and above normal years under Alternative 4 correspond to an average 15% increase in spawning WUA, while higher flows in subsequent months correspond to average reductions in spawning WUA of less than 10% (Figure WUA-SH-S). Therefore, changes in flows under Alternative 4 would have both positive and negative effects on the availability of steelhead spawning habitat relative to the No Action Alternative.

HEC-5Q modeling for Alternative 4 indicates that the water temperatures in the upper Sacramento River during the steelhead spawning and incubation period (November through May) would be similar to those under the No Action Alternative (Tables O.3-60 through O.3-63). Based on the steelhead spawning and incubation threshold of 53°F (see O.3.3 Alternative 1, Central Valley Steelhead Spawning and Egg Incubation), both alternatives would maintain suitable water temperatures for spawning and incubation through April or May in the reach between Keswick Dam and Clear Creek, and there would be no major differences in the frequency and magnitude of water temperatures exceeding 53°F in other months or locations with the primary spawning (Keswick Dam to RBDD). Therefore, changes in water temperatures under Alternative 4 would not likely have significant effects on spawning adults, eggs, and alevins relative to the No Action Alternative.

Juvenile Rearing and Emigration

CV steelhead rear year-round in the Sacramento River, and use the river downstream from spawning areas as both a rearing and migration corridor. The timing of downstream migration is variable but generally peaks in the upper river at RBDD in spring and summer (March through June) and in the lower river at Knights Landing in winter and spring (January through May) (NMFS 2009). The peak migration of yearling and older juveniles through the Delta occurs in March and April (NMFS 2009).

CalSim II modeling indicates that the largest differences in Sacramento River flows between Alternative 4 and the No Action Alternative would occur in the late summer and fall (September and November) of above normal and wet years, and in winter and spring of most water year types, potentially affecting fry and juvenile rearing habitat (Table O.3-59). Based on the flow-habitat relationships for Late Fall-Run Chinook Salmon fry and juvenile life stages (see O.3.3 Alternative 1, Central Valley Steelhead Juvenile Rearing and Emigration), lower flows under Alternative 4 in the fall of wet and above normal water years would increase the amount of juvenile rearing habitat (as measured by WUA), while higher flows in winter and spring of most water year types would generally reduce the amount of fry and juvenile rearing habitat (Figures O.3-39 and O.3-40). For example, in wet years, reductions in average flows of approximately 6,200 cfs in September and 3,900 cfs in November would increase juvenile WUA by approximately 40% relative to the No Action Alternative. In below normal years, increases in average winter and spring flows (averaging 700 cfs to 1,600 cfs higher than No Action Alternative flow) would reduce juvenile WUA by 10% or less relative to the No Action Alternative. During the fry rearing period (March through May, the largest effect on fry WUA would be a 15% reduction in fry WUA in March of below normal years. Therefore, changes in flows under Alternative 4 would have both positive and negative effects on the availability of steelhead rearing habitat relative to the No Action Alternative.

In the upper Sacramento River, HEC-5Q modeling for Alternative 4 and the No Action Alternative indicates that average water temperatures between Keswick Dam and RBDD would be maintained at or below the "core rearing area threshold" of 61°F (see O.3.3 Alternative 1, Central Valley Steelhead Juvenile Rearing and Emigration) throughout the year except in summer (July through September) of critical water years (Table O.3-63). During summer, water temperatures under Alternative 4 would be similar to those under the No Action Alternative except in September of wet and above normal years when water temperatures would average up 3.3°F higher at RBDD (Tables O.3-63); however, there would be no major differences in the frequency and magnitude of temperatures above 61°F (Figure O.3-22). Similarly, water temperatures during the steelhead emigration season (January through June) are expected to similar or cooler than those under the No Action Alternative (Table O.3-63 to O.3-65). For example, although water temperatures at Knights Landing would frequently exceed the 64°F "non-core rearing area" threshold in May under both alternatives (Figure O.3-41), higher spring flows under Alternative 4 would reduce average water temperature by up to 1.1°F (dry water years) (Table O.3-65). Therefore, changes in water temperature under Alternative 2 would not likely have significant effects on rearing and emigrating steelhead relative to the No Action Alternative.

Adult Upstream Migration and Holding

Adult steelhead immigration into Central Valley streams potentially occurs during all months of the year but typically begins in August and continues through March or April (McEwan 2001; NMFS 2014a). In the Sacramento River, adults migrate upstream past RBDD during all months of the year, but primarily during September and October (NMFS 2009). Adults may hold until the spawning season which generally extends from November through April.

During the steelhead immigration and holding period, lower flows in September and November of wet and above normal water years under Alternative 4 could affect immigrating and holding adults. However, mean monthly flows would be maintained at a minimum of 3,250 under both alternatives, and would not differ substantially in frequency and magnitude between the alternatives until flows exceed approximately 5,000 cfs (Figures O.3-25, O.3-27, and O.3-29). Within this flow range (>5,000 cfs), no adverse effects on migrating and holding adults would be expected; flows of this magnitude would presumably be sufficient to maintain suitable passage and holding conditions under both alternatives.

Under both Alternative 4 and the No Action Alternative, HEC-5Q modeling indicates that suitable water temperatures for steelhead immigration in the Sacramento River (based on the immigration threshold of 68°F; see O.3.3 Alternative 1, Central Valley Steelhead Adult Upstream Migration and Holding) would generally not occur until September or October (Table O.3-65). However, under Alternative 4, substantially lower flows in September of wet and above normal water years would increase the frequency of water temperatures exceeding this threshold, resulting in potential delays in migration or adverse physiological effects on migrating adults relative to the No Action Alternative. For example, at Knights Landing, mean monthly water temperatures in September exceeded 68°F approximately 82% of the time compared to 52% of the time under the No Action Alternative (Figure O.3-24). Therefore, changes in water temperatures under Alternative 4 in September would have a potentially adverse effect on immigrating adult steelhead in the Sacramento River relative to the No Action Alternative. Lower flows in September would also result in higher water temperatures in the upper Sacramento River, potentially affecting holding adults. However, no major differences would be expected to occur in the frequency and magnitude of water temperatures exceeding the threshold for holding adults (61°F; see O.3.3 Alternative 1, Central Valley Steelhead Adult Upstream Migration and Holding) (Figure O.3-22).

O.3.9.2.4 Southern DPS Green Sturgeon

Spawning and Egg Incubation

Green Sturgeon spawn in deep pools (averaging about 28 feet deep) (NMFS 2018b). Eggs from spawning Southern DPS Green Sturgeon have been found in the middle and upper Sacramento River from the GCID oxbow (RM 207) to Inks Creek (RM 265) and spawning is believed to extend upstream to the confluence with Cow Creek (RM 277) (Heublein et al. 2017b). Green Sturgeon spawn primarily from April through July, although they periodically spawn in late summer and fall (as late as October) (Heublein et al. 2009, 2017b, NMFS 2018b). Eggs hatch about a week after fertilization (at 60ºF) (Heublein et al. 2017b). Because the incubation time for Green Sturgeon is so short, the effects analysis period for incubating eggs is considered to be the same as the spawning period. Based on laboratory studies for Northern DPS Green Sturgeon, Heublein et al. 2017b) concluded that the optimal range for normal embryo development of Southern DPS Green Sturgeon is 53 to 64°F, and impaired fitness occurs below 52°F and above 71°F.

During the April through July Green Sturgeon spawning period, CalSim II estimates of mean monthly flows at RBDD (RM 244) under the No Action Alternative and Alternative 4 range from about 5,000 cfs for April of critically dry water years to about 14,900 cfs in July of Above Normal water years (Table O.3-66). Mean flows during most of this period are moderate (~8,000 cfs to ~12,000 cfs). These flow levels are likely to be suitable for Green Sturgeon spawning and egg incubation, and no adverse effects are expected to result.

Differences in flows between Alternative 4 and the No Action Alternative are small in most months, but flows are moderately higher for Alternative 4 in April during all water years except critically dry water years and June during below normal, dry and critically dry water years (Table O.3-66). During the August through October period, when Green Sturgeon spawning occurs in occasional years, the flows under both alternatives tend to be lower than those in April through July, but the mean flows would be close to or above 5,000 cfs for all water year types in all three months. Large reductions in mean flows from the No Action Alternative to Alternative 4 are predicted for September of wet and above normal water years and, although the resulting Alternative 4 mean flows are greater than 5,000 cfs, the flow reductions are so large (about 46%) that conditions for Green Sturgeon spawning and egg incubation are likely to be adversely affected (Table O.3-32). However, September spawning occurs only sporadically, so any effect on the Green Sturgeon population would be minor (NMFS 2018b). Therefore, the September flow reductions are expected to have a minor adverse impact on Green Sturgeon.

Based on the HEC-5Q modeling, mean water temperatures during the April through July primary spawning period of Green Sturgeon are below the 53 and 52°F lower temperature thresholds for Green Sturgeon egg development at Clear Creek and Balls Ferry during many of the months and water year types (Tables O.3-61 and O.3-62). As discussed previously, daily water temperatures are likely to be more variable than monthly mean temperatures, so the reductions of the mean temperatures below the 52 and 53°F thresholds probably underestimate the largest daily reductions below the thresholds.

The HEC-5Q modeling results show little difference in Clear Creek confluence and Balls Ferry mean water temperatures between Alternative 4 and the No Action Alternative during the April through July primary Green Sturgeon spawning and incubation period (Table O.3-61). Therefore, Alternative 4 is unlikely to cause a reduction in water temperatures relative to the No Action Alternative and thereby would not adversely affect Green Sturgeon spawning and egg incubation.

Larval and Juvenile Rearing and Emigration

As discussed under Alternative 1 (Section O.3.3, *Alternative 1*), the larval period for Green Sturgeon is considered to be April through September. The downstream distribution of Green Sturgeon larvae in the Sacramento River is uncertain, but is estimated to extend to the Colusa area, at RM 157 (Heublein et al. 2017b). The upstream limit is the Cow Creek confluence. Green Sturgeon juveniles rear in the Sacramento River from about May through December (NMFS 2017b). During most of this period, the juveniles are likely to be found anywhere from the upstream spawning habitat near the Cow Creek confluence to the Delta.

CalSim modeling for the Sacramento River at RBDD indicates that mean monthly flows during the April through September period of larval rearing are greater in April (wet through dry years) and June (below normal to critically dry years) under Alternative 4 than under the No Action Alternative. During the months of July (critically dry years), August (below normal years) and September (wet to below normal years) there is a decrease in flows (Table O.3-66). The September reductions in flow from the No Action Alternative to Alternative 4 during wet and above normal years are substantial and would potentially affect Green Sturgeon larvae adversely because, as discussed for Alternative 1 (Section O.3.3, *Alternative 1*), there appears to be a positive relationship between annual outflow and abundance of White Sturgeon larvae and juveniles. However, the applicability of the relationship to Green Sturgeon is uncertain.

CalSim modeling for the Sacramento River at Hamilton City indicates that mean monthly flows during the period of juvenile rearing and emigration, May through December, are higher in June (below normal to critically dry years) and December (wet and above normal years) (Table O.3-66). Reductions in flows occur in September and November (wet and above normal years). These reductions in flow could adversely affect Green Sturgeon juveniles under Alternative 4 because, as noted above, there may be a positive relationship between annual outflow and abundance of Green Sturgeon.

There are few notable differences in the HEC-5Q mean monthly water temperature estimates at RBDD or Hamilton City between the No Action Alternative and Alternative 4 during the Green Sturgeon larval and juvenile rearing and emigration period in any month, except for September (Tables O.3-63 and O.3-64). During over half of the years in September, the Alternative 4 water temperature at RBDD is greater than the No Action Alternative temperature, with a maximum difference of about 3°F (Figure O.3-22). Over the range of years for which there are temperature differences, the water temperatures of both the No Action Alternative and Alternative 4 are under the 63°F lower limit of the optimal range for larvae. However, the Alternative 4 water temperatures are closer to the optimal range and therefore would potentially provide more favorable conditions for larval growth and survival. For the juveniles at RBDD, the September water temperatures under the No Action Alternative are below the 59°F lower limit of the optimal temperature range in about half of the years, and under Alternative 4 they are below the optimal range in about a third of the years (Figure O.3-22). The September HEC-5Q temperature estimates for Hamilton City also fall within or are closer to the optimal ranges of Green Sturgeon larvae and juveniles in more years under the Alternative 4 than the No Action Alternative, however overall temperatures are slightly lower in the other months (Table O.3-64; Figure O.3-23).

The CalSim II flow results indicate that Alternative 4 would not have an adverse impact on rearing larval and juvenile southern DPS Green Sturgeon relative to the No Action Alternative, and the HEC-5Q water temperature modeling results indicate that Alternative 4 would provide a minor potential benefit to rearing larval and juvenile Green Sturgeon relative to the No Action Alternative.

Adult Upstream Migration and Holding

Green Sturgeon adults enter the Sacramento River from the Delta as early as February and ultimately make their way upstream to spawn in deep pools from the GCID oxbow (near Hamilton City) to the Cow Creek confluence (Heublein et al. 2017b). After spawning, the adults hold in the river for varying amounts of time, but typically emigrate back to the San Francisco Estuary and the ocean from about October through December (Heublein et al. 2017b).

Flows during the February through December period of Green Sturgeon immigration, spawning and holding are greater during February to April, June and December at RBDD and Hamilton City under Alternative 4 versus No Action Alternative. Wilkins Slough also shows increased flows during these months, but under fewer of the water year types (Tables O.3-66 through O.3-68). A moderate decrease in flows occurs at all of these locations during July (critically dry years), September (wet and above normal years), and November (wet and above normal years). All of the more notable flow differences occur within a range of river flows (~5,000 cfs to 14,000 cfs) that are not expected to substantially affect upstream passage of migrating Green sturgeon, but the September and November flow reductions under Alternative 4 at Hamilton City and RBDD could result in reduced habitat quality in holding pool habitats, adversely affecting holding adults.

There are few major differences in mean monthly water temperatures between the No Action Alternative and Alternative 4 in the Sacramento River at Knights Landing during the February through April period that most adult Green Sturgeon migrate upstream or during the later months (through December) when the sturgeon migrate downstream after spawning (Table O.3-65). Temperatures are lower during June of dry years, which would benefit migrating adults by bringing temperatures closer to the 66 degree threshold. However, increases of more than 4°F are expected in September of wet and above normal water years. The means exceed the 66°F threshold for migrating Green Sturgeon adults in both water year types under Alternative 4 and in neither water year type under the No Action Alternative. The mean monthly water temperatures at Knights Landing also exceed the 66°F threshold under both alternatives during June through August of all water year types and May of all but wet years (Table O.3-65). Adults migrating downstream from May through September would potentially be adversely affected by the high water temperatures. However, adults migrating upstream would be less affected because most upstream immigration occurs before late spring (Heublein et al. 2009), when water temperatures are below the 66°F threshold.

During the May through December spawning and post-spawn holding period for Green Sturgeon, the HEC-5Q mean monthly water temperatures at Hamilton City are generally similar between the No Action Alternative and Alternative 4, except for higher temperatures under Alternative 4 in September (Table O.3-64). The mean monthly water temperatures during the hottest months of this period, July through September, range from 58°F to 68°F (both in September). The temperatures frequently exceed the 63°F threshold for spawning adults and the 61°F threshold for holding adults during these months. During September, the mean water temperatures only exceed the 61°F threshold in wet and above normal years under Alternative 4 but not under the No Action Alternative. September water temperatures are cooler at RBDD and there is no difference at this location between Alternative 4 and the No Action Alternative in the frequency of the threshold exceedances (Figure O.3-22). During October through December, the mean monthly water temperatures stay below both thresholds in every water year type (Table O.3-63).

The CalSim II modeling results indicate that for adult southern DPS Green Sturgeon holding in September or November, reduced flows under Alternative 4 would have a potentially significant adverse impact on holding habitat relative to the No Action Alternative. The HEC-5Q modeling results indicate that the water temperatures for September of wet and above normal water years would more often exceed the 66, 63 and 61°F thresholds for migrating, spawning and holding adult Green Sturgeon under Alternative 4 than under the No Action Alternative, would be substantially higher under Alternative 4 than under the No Action Alternative, and would exceed the 61°F thresholds for migrating, spawning and holding adult Green Sturgeon only under Alternative 4. In conclusion, the HEC-5Q results for Alternative 4 are expected to result in substantially less favorable water temperatures for Green Sturgeon in September of wet and above normal water years. In combination, the reduced flows in September and November of wet and above normal water years and increased water temperatures in September of wet and above normal water years are expected to have a significant adverse impact on southern DPS Green Sturgeon adults.

O.3.9.2.5 Fall-Run Chinook Salmon

Spawning and Egg/Alevin Incubation

Fall-Run Chinook Salmon migrate upstream past RBDD on the Sacramento River between July and December, typically spawning in upstream reaches from October through January, with a peak in October and November. Eggs and alevins are present from October through April. The primary spawning area used by Fall-Run Chinook Salmon in the Sacramento River is the area from Keswick Dam downstream to RBDD. Spawning densities for all Chinook Salmon runs are highest in this reach, but the distribution of spawning fall-run generally extends downstream to spawning areas below RBDD (Gard 2013).

During the Fall-Run Chinook Salmon spawning and incubation period, relatively large reductions in flows in November of wet and above normal water years under Alternative 4 would increase the amount of available spawning habitat, while moderate increases in flow in subsequent months would decrease available spawning habitat. For example, in wet years, a reduction in average flow of approximately 3,800 cfs in November would increase the amount of available spawning habitat (as measured by WUA) by 81%, while an increase in average flow of approximately 1,900 cfs in December would decrease available spawning habitat by 25% (Figure O.3-35). Therefore, changes in flows under Alternative 4 would have both positive and negative effects on the availability of spawning habitat relative to the No Action Alternative.

HEC-5Q modeling indicates that Alternative 4 would not substantially affect the frequency of water temperatures exceeding the 53.5°F threshold (see O.3.3.1.2, Sacramento River, *Potential changes to aquatic resources in the Sacramento River from seasonal operations*) during the Fall-Run Chinook Salmon spawning and incubation period (October through April) (Table O.3-60). Both alternatives would maintain suitable water temperatures for spawning and incubation through April in the reach between Keswick Dam and Clear Creek, and there would be no major differences in the frequency and magnitude of water temperatures exceeding 53.5°F in other months or locations within the primary spawning area (Keswick Dam to RBDD) (e.g., Figure O.3-22). Therefore, changes in water temperatures under Alternative 4 are not likely to have significant effects on steelhead spawning and incubation relative to the No Action Alternative.

Juvenile Rearing and Emigration

Fall-Run Chinook Salmon juveniles rear in the Sacramento River primarily from December through May. Following emergence, juveniles rear for variable lengths of time in the Sacramento River before entering the Delta and estuary, and may emigrate as fry, parr, or smolts. The timing of emigration is variable but generally peaks in the upper river from January through April and in the lower river from January through May (NMFS 2009).

Under Alternative 4, higher winter and spring flows in the Sacramento River relative to the No Action Alternative could affect rearing and emigrating Fall-Run Chinook Salmon. Based on the flow-habitat relationships for Fall-Run Chinook Salmon fry and juvenile life stages (see O.3.3 Central Valley Fall-Run Chinook Salmon, Juvenile Rearing and Emigration), higher winter and spring flows under Alternative 4 would generally reduce the amount of available fry and juvenile rearing habitat in the upper Sacramento River. CALSIM II modeling indicates that the largest differences in flows between Alternative 4 and the No Action Alternative would occur in December of wet years (averaging approximately 1,900 cfs) and in January of below normal water years (averaging approximately 1,600 cfs). Based on the flow-habitat relationships, these flow increases correspond to a 7% reduction in fry WUA in December of wet years and a 15% reduction in fry WUA in January of below normal years (Figures O.3-36 and O.3-37). While these results indicate that Alternative 4 would potentially reduce the availability of suitable rearing habitat for Fall-Run Chinook Salmon relative to the No Action Alternative, uncertainty exists in the importance of this reduction relative to other factors that affect the quantity and quality of rearing habitat for juvenile Chinook Salmon in the Sacramento River.

In the upper Sacramento River, HEC-5Q modeling for Alternative 4 and the No Action Alternative indicates that both alternatives would maintain suitable water temperatures (≤ 61°F; see O.3.3 Alternative 1, Central Valley Steelhead Juvenile Rearing and Emigration) between Keswick Dam and RBDD during the Fall-Run Chinook Salmon fry and juvenile rearing period (December through May) (Tables O.3-60 through O.3-63). Farther downstream, mean monthly water temperatures in the lower river at Knights Landing would be similar or slightly cooler under Alternative 4 (Table O.3-65), but there would be no differences in the frequency and magnitude of temperatures exceeding the 64°F "non-core rearing area threshold" (Figure O.3-41). Therefore, changes in Sacramento River water temperatures under Alternative 4 would not likely have significant effects on rearing and emigrating juvenile Fall-Run Chinook Salmon relative to the No Action Alternative.

Adult Upstream Migration and Holding

Fall-Run Chinook Salmon migrate upstream past RBDD on the Sacramento River between July and December. Adults may hold until the spawning season, which occurs primarily from October through January.

CALSIM II modeling indicates that mean monthly flows in the Sacramento River under Alternative 4 would be substantially lower in September and November of wet and above normal water years relative to the No Action Alternative (Tables O.3-59, O.3-66, and O.3-67), potentially affecting immigrating and holding adults. However, flows under both alternatives would be maintained at or above 3,250 cfs throughout the immigration and holding period. Although flows would differ substantially in September and November, the differences would be limited to flows exceeding approximately 5,000 cfs (Figures O.3-25, O.3-25, and O.3-29). Within this range (>5,000 cfs), no adverse effects on migrating and holding adults would be expected; flows of this magnitude would presumably be sufficient to maintain suitable passage and holding conditions under both alternatives.

Under both Alternative 4 and the No Action Alternative, HEC-5Q modeling indicates that suitable water temperatures for Fall-Run Chinook Salmon immigration in the Sacramento River (based on the immigration threshold of 68°F; see O.3.3 Alternative 1, Central Valley Fall-Run Adult Upstream Migration and Holding) would generally not occur until September or October (Table O.3-65). However, under Alternative 4, substantially lower flows in September would increase the frequency of water temperatures exceeding this threshold, resulting in potential delays in migration or adverse physiological effects on migrating adults relative to the No Action Alternative. For example, at Knights Landing, mean monthly water temperatures in September exceeded 68°F approximately 82% of the time under Alternative 4 compared to 52% of the time under the No Action Alternative (Figure O.3-24). Therefore, changes in water temperatures under Alternative 4 in September would have a potentially adverse effect on immigrating adult Fall-Run Chinook Salmon in the Sacramento River relative to the No Action Alternative. Lower flows in September would also result in higher water temperatures in the upper Sacramento River, potentially affecting holding adults. However, no major differences would be expected to occur in the frequency and magnitude of water temperatures exceeding the threshold for holding adults (61°F; see O.3.3 Alternative 1, Central Valley Fall-Run Adult Upstream Migration and Holding) (Figure O.3-22).

O.3.9.2.6 Late Fall-Run Chinook Salmon

Spawning and Egg/Alevin Incubation

Late Fall-Run Chinook Salmon spawn primarily from December through April, and eggs and alevins are present in the gravel from December through June. In the Sacramento River, most adults spawn upstream of Red Bluff Diversion Dam, with the majority spawning between Keswick Dam and the ACID Dam.

CALSIM II modeling indicates that Sacramento River flows under Alternative 4 would generally be higher than or similar to the flows under the No Action Alternative during the Late Fall-Run Chinook Salmon spawning and incubation period (December through June) (Table O.3-59). The largest increases in flow are expected to occur in the winters of wet, above normal, and below normal years. Based on PHABSIM results (flow-habitat relationships) for the Sacramento River between Keswick Dam and Battle Creek (USFWS 2003a), higher flows under Alternative 4 would reduce the amount of available spawning habitat for Late Fall-Run Chinook Salmon (as measured by WUA) (Figure O.3-38). For example, spawning habitat WUA would be reduced by approximately 17% in December of wet years, 5% in January of below normal years, and 8% in March of below normal years. While these results indicate that Alternative 4 would potentially reduce the availability of suitable spawning habitat for Late Fall-Run Chinook Salmon relative to the No Action Alternative, uncertainty exists in the importance of this reduction relative to other factors that affect the quantity and quality of spawning and incubation habitat for Late Fall-Run Chinook Salmon in the Sacramento River.

HEC-5Q modeling for Alternative 4 indicates that the water temperatures in the upper Sacramento River during the Late Fall-Run Chinook Salmon spawning and incubation period (December through June) would be similar to those under the No Action Alternative (Tables O.3-60 through O.3-63). Based on the spawning and incubation threshold of 53.5°F (see O.3.3.1.2, Sacramento River, *Potential changes to aquatic resources in the Sacramento River from seasonal operations*, both alternatives would maintain suitable water temperatures from spawning and incubation through May or June in the primary spawning reach (Keswick Dam and Clear Creek) (Table O.3-61), and there would be no major differences in frequency and magnitude of water temperatures exceeding this threshold (Figure O.3-139). Therefore, changes in water temperatures under Alternative 2 are not likely to have significant effects on spawning adults, eggs, and alevins relative to the No Action Alternative.

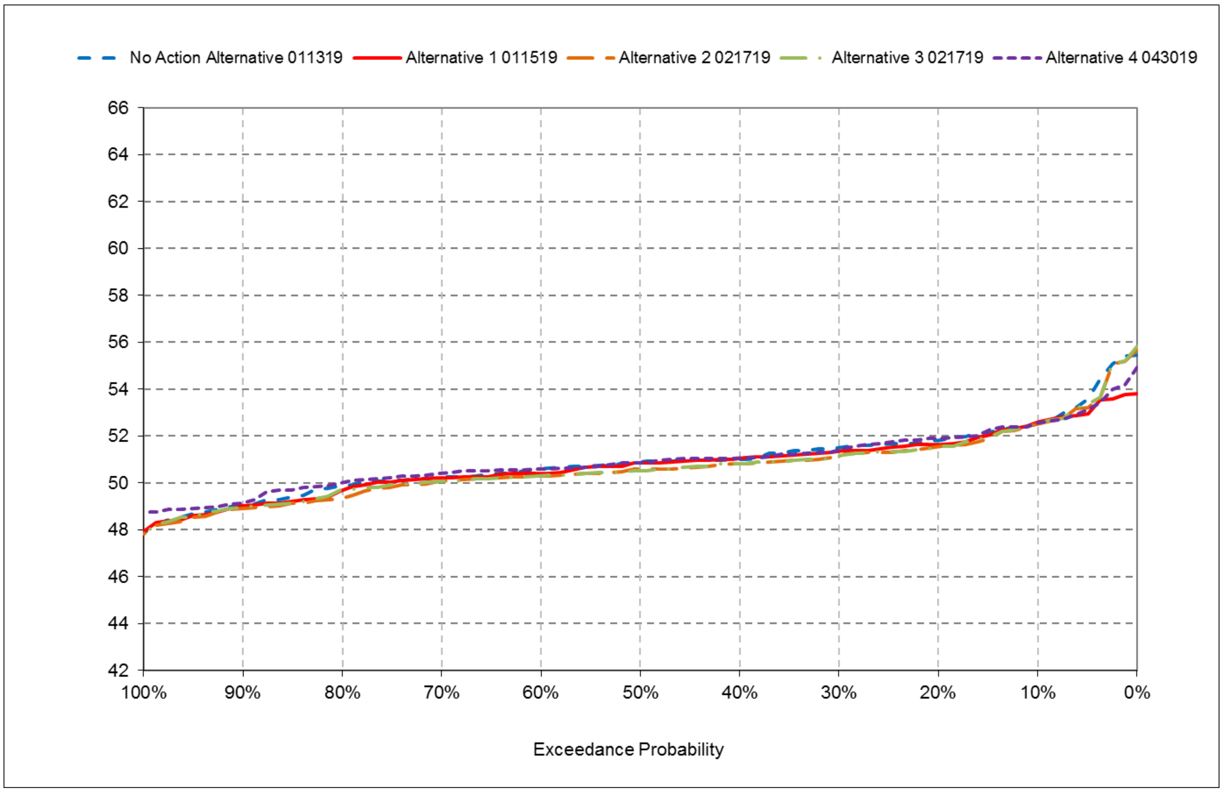


Figure O.3-139. HEC-5Q Sacramento River Water Temperatures at Clear Creek Confluence under the No Action Alternative, Alternative 1, Alternative 2, Alternative 3, and Alternative 4; May

Juvenile Rearing and Emigration

Late fall–run Chinook Salmon fry generally emerge from March through June, and juveniles rear in the Sacramento River through the summer before emigrating at a relatively large size (150- to 170-mm fork length) primarily from November through May.

CalSim II modeling indicates that Sacramento River flows under Alternative 4 would generally be higher than or similar to flows under the No Action Alternative during the Late Fall-Run Chinook Salmon rearing period except in September and November of wet and above normal water years when flows would be substantially lower (Table O.3-59). Based on PHABSIM results (flow-habitat relationships) for fry and juvenile rearing in the upper Sacramento River (USFWS 2005), generally higher spring flows in above normal, below normal, and dry water years would reduce the amount of rearing habitat, while lower fall flows in wet and above normal years would increase the amount of rearing habitat (Figures O.3-39 and O.3-40). For example, higher flows in March of below normal years (averaging 1,200 cfs lower than No Action Alternative flows) correspond to a 15% reduction in fry WUA, while lower flows in September of wet years (averaging approximately 6,200 cfs) would increase juvenile rearing habitat (as measured by WUA) by approximately 40%. Therefore, changes in flows under Alternative 4 would have both positive and negative effects on the availability of rearing habitat relative to the No Action Alternative.

In the upper Sacramento River, HEC-5Q modeling for Alternative 4 and the No Action Alternative indicates that average water temperatures between Keswick Dam and RBDD would be maintained at or below the “core rearing area threshold” of 61°F throughout the year except in the summer (July through September) of critically dry water years (Tables O.3-63). During summer, water temperatures under Alternative 4 would be similar or cooler than those under the No Action Alternative except in September of wet and above normal years when average water temperatures would be up to 3.3°F higher (Tables O.3-63); however, there would be no major differences in the frequency and magnitude of temperatures above 61°F (Figure O.3-22). Similarly, water temperatures during the Late Fall-Run Chinook Salmon emigration season (November through May) are expected to similar or cooler than those under the No Action Alternative (Table O.3-63 to O.3-65), but there would be no differences in the frequency of temperatures exceeding the 64°F “non-core rearing area threshold” (Figure O.3-41). Therefore, changes in water temperature under Alternative 4 would not likely have significant effects on rearing and emigrating Late Fall-Run Chinook Salmon relative to the No Action Alternative.

Adult Upstream Migration and Holding

In the Sacramento River, adult Late Fall-Run Chinook Salmon migrate from October through April, with a peak during January through March (NMFS 2009). Adults hold for 1 to 3 months prior to spawning, which occurs primarily from December through April.

CALSIM II modeling indicates that flows in the Sacramento River during the Late Fall-Run Chinook Salmon immigration period would be similar or higher than those under the No Action Alternative except in November of wet and above normal water years when flows would be substantially reduced relative to the No Action Alternative (Tables O.3-59, O.3-66, and O.3-67). However, flows under both alternatives would be maintained at or above 3,250 cfs throughout the immigration and holding period. Although flows would differ substantially in November, the differences would be limited to flows exceeding approximately 5,000 cfs (Figures O.3-25, O.3-27, and O.3-29). Within this flow range (>5,000 cfs), no adverse effects on migrating and holding adults would be expected; flows of this magnitude would presumably be sufficient to maintain suitable passage and holding conditions under both alternatives.

Based on the water temperature thresholds for immigration (68°F) and holding (61°F) (see O.3.3 Alternative 1, Central Valley Fall-Run Adult Upstream Migration and Holding), Alternative 4 and the No Action Alternative would maintain suitable water temperatures for Late Fall-Run Chinook Salmon throughout the immigration and holding period (October through April) (Tables O.3-63 and-O.3-65). Therefore, changes in water temperatures under Alternative 4 would not likely have significant effects on immigrating and holding Late Fall-Run Chinook Salmon in the Sacramento River relative to the No Action Alternative.

O.3.9.2.7 White Sturgeon

Spawning and Egg Incubation

White sturgeon spawn in deep water in the middle and lower Sacramento River from Verona (RM 80) to just upstream of Colusa (~RM 156) from late February to early June, but primarily during March and April, (Moyle et al. 2015; Heublein et al. 2017). The adults typically return promptly to the Delta/Estuary after spawning.

During the March and April spawning and egg incubation period of White Sturgeon, CalSim II estimates of mean monthly flows at Wilkins Slough under the No Action Alternative and Alternative 4 range from about 5,300 cfs for April of critically dry water years to about 18,000 cfs for March of wet water years (Table O.3-68). These flow levels are likely to be adequate for White Sturgeon spawning and egg incubation, so no adverse effects are expected to result. Differences in flows between Alternative 4 and the No Action Alternative are small in both months, but flows are moderately higher for Alternative 4 in April of wet to below normal water years (Table O.3-59). It is concluded that Alternative 4 would have no flow effects on White Sturgeon eggs and embryos relative to the No Action Alternative.

The HEC-5Q water temperature modeling results for March and April indicate that mean monthly water temperatures at Knights Landing are below the 63°F threshold for optimal temperatures (see Section O.3.3.1.2, *Sacramento River*), except in April of critically dry water years (Table O.3-65). There are no appreciable differences in water temperatures between Alternative 4 and No Action Alternative in March or April (Table O.3-65; Figures O.3-43). During June, the warmest month of the full spawning and egg incubation period, the mean monthly water temperatures are predicted to exceed the 68°F lethal temperature in all water year types, but the water temperatures are lower for Alternative 4 than for the No Action Alternative in drier water years (Table O.3-65). It is concluded that Alternative 4 would have no water temperature effects on White Sturgeon eggs and embryos relative to the No Action Alternative.

Larval and Juvenile Rearing and Emigration

During the March through June larval period, water temperature modeling indicates that water temperatures frequently exceed these water temperature thresholds (61°F and 68°F, see Section O.3.3.1.2, *Sacramento River*) at Knights Landing under the No Action Alternative and Alternative 4 (Table O.3-65), especially, as noted above, in June. Such high levels of temperature threshold exceedances suggest that typical water temperature conditions in the lower Sacramento River may be highly stressful for white sturgeon larvae. In any case, the water temperatures, especially in June, are slightly lower under Alternative 4 than under the No Action Alternative (Table O.3-65). It is concluded that Alternative 4 compared to the No Action Alternative will not have an adverse effect on larval and juvenile rearing.

During the White Sturgeon juvenile emigration period, approximately April to July, CalSim II results indicate that flows at Wilkins Slough during April and June would increase with Alternative 4 compared to No Action Alternative and in July would increase of Above Normal years and decrease in critically dry years (Table O.3-14).

Adult Upstream Migration and Holding

White Sturgeon adults to initiate their upstream spawning migrations during late winter and early spring, presumably in response to elevated flows (Heublein et al. 2017). CalSim II flows at Wilkins Slough for

December through February are are generally similar between Alternative 4 and No Action Alternative or moderately higher for Alternative 4. Increased flows potentially benefice White Sturgeon migration, but all flows are between 7,800 and 19,000 cfs, which are adequate for migration. There are no appreciable temperature differences from December through February for Knights Landing. Alternative 4 would have no flow or water temperature effects on White Sturgeon adults.

The CalSim II flow results for Wilkins Slough and the HEC-5Q water temperature results for Knight Landing indicate that Alternative 4 would have no adverse effect on White Sturgeon relative to the No Action Alternative.

O.3.9.2.8 Sacramento Splittail

Sacramento splittail occur in the Sacramento River upstream of the Delta from about December through May. The adults spawn in river-margin and inundated floodplain habitats in February through April (Feyrer et al. 2005, 2006; Sommer et al. 2007; Moyle et al. 2015). The larvae hatch several days after spawning then rear for about a month in habitat similar to the spawning habitat (Moyle et al. 2004). The juveniles rear upstream and then begin their downstream migration during April and May, as the river level recedes back to the channel (Moyle et al. 2004; Feyrer et al. 2005). Floodplain spawning in wet years overwhelmingly dominates production, but spawning in side channels and channel margins is important during low-flow years when floodplains are not inundated. In the Sacramento River drainage, splittail spawn from Colusa to Knights Landing, but the most important spawning areas are the inundated floodplains of the Yolo and Sutter bypasses (Feyrer et al. 2005).

High flows benefit adults migrating upstream (Feyrer et al. 2006), and greatly enhance spawning and rearing habitat for larvae and early juveniles (Crain et al. 2004). Mean monthly flows at Wilkins Slough during January through March of wet and above normal water years consistently equal or exceed 17,000 cfs under both alternatives (Table O.3-68). Figure O.3-44 shows the expected mean February flows for each year of the CalSim II record. About 15% of the years have mean February flows greater than 22,500 cfs, which is the approximate flow at which the Tisdale Weir begins to spill into the Sutter Bypass (DWR 2010b). In any case, differences between Alternative 4 and the No Action Alternative in flows at Wilkins Slough during December through May are relatively minor and generally result from higher flow under the Alternative 4, especially in April during wet, above normal and below normal water years and January and March of below normal years (Table O.3-67). It is concluded that Alternative 4 would have no flow effects on Sacramento Splittail relative to the No Action Alternative.

Preferred water temperature for Sacramento splittail ranges from about 66°F for adults to about 75°F for juveniles, and the “upper limit of safe temperatures” ranges from about 75°F for adults and 81°F for juveniles (Young and Cech 1996). Mean monthly water temperatures during December through May at Knights Landing, which is at the approximate downstream limit of splittail spawning in the Sacramento River, exceed 68°F under both alternatives in May of critically dry water years (Table O.3-65). There are no meaningful water temperature differences between the alternatives at Knights Landing during the December through May period that Sacramento Splittail occupy the river upstream of the Delta (Table O.3-65). There is evidence that some juvenile splittail remain in the Sacramento River well upstream of the Delta through the entire year (Feyrer et al. 2005), but summer water temperatures in the more upstream locations where they have been found are considerably cooler than those at Knights Landing (compare Tables O.3-64 and O.3-65). Therefore, Alternative 4 is considered to have no water temperature effects on splittail relative to the No Action Alternative.

The CalSim II flow results for Wilkins Slough and the HEC-5Q water temperature results for Knight Landing indicate that Alternative 4 would not have an adverse impact on Sacramento Splittail relative to the No Action Alternative.

O.3.9.2.9 Pacific Lamprey

Sacramento River Pacific Lamprey adults enter the Sacramento River from the Delta primarily during about March through June and hold in the river for about a year prior to spawning (Moyle et al. 2015). Spawning occurs in gravel redds in the upper river from March through July. The eggs and pro-larvae incubate for about 1 to 1.5 months. After the larvae (ammocoetes) emerge, they drift downstream and burrow into fine sediments primarily in off-channels habitats, where they rear (Schultz et al. 2014; Moyle et al. 2015). After 5 or more years, the ammocoetes metamorphose to the macropthalmia (juvenile) stage and migrate downstream to the Delta and ocean, typically migrating from March through June during pulse flow events (Moyle et al. 2015).

River flow potentially affects survival of Pacific Lamprey eggs and larvae, and migratory habitat of the juveniles and adults. Pacific lamprey build their spawning redds in shallow water (about 0.5 to 3.5 feet) (Gunckel et al. 2009; Schultz et al. 2014; Moyle et al. 2015), so reductions in water level can dewater the redds. The larvae select habitats, often off-channel, with fine sediments, low flow velocity, and shallow depths (~1 ft), so they are vulnerable to stranding by reductions in water level. Migrations of the juveniles and adults may be triggered by surges in flow (Moyle et al. 2015).

The types of variations in flow that potentially affect Pacific Lamprey, as described above, often occur on a time scale of hours or days, and therefore may not be detectable using the CalSim II monthly time-step modeling results. However, the CalSim II results mostly show no large differences in Sacramento River flow between the No Action Alternative and Alternative 4, so there is no reason to expect much difference in short period flow fluctuations between the alternatives. The biggest differences in monthly mean flows occur in September and November of wet and above normal water years, when flows are much lower under Alternative 4 than the No Action Alternative because Alternative 4 operations do not include releases for Fall X2 flows (Table O.3-66; Figures O.3-25 and O.3-28). Pacific lamprey are generally done spawning by late July and the prelarvae have finished emerging from their redds by early September. In contrast, the larvae are present in the river yearround and so could be vulnerable to flow reductions during September and November. However, water levels during these months are generally relatively stable because they are largely determined by Shasta and Keswick dam releases rather than runoff. The adults and juveniles carry out their migrations primarily during March through June. CalSim II modeling flow results for these months are generally higher under Alternative 4 than under the No Action Alternative (Table O.3-67 and O.3-68). Therefore, Alternative 4 and the No Action Alternative are expected to similarly affect Pacific Lamprey with respect to flow in the Sacramento River.

As described for Alternative 1, laboratory studies conducted on Columbia River Pacific Lamprey indicated that survival of incubating eggs and pre-larvae and of young larvae was greatest at a water temperature of 64°F and lowest at the highest water temperature included in the study, 72°F (Meeuwig et al. 2005). HEC-5Q modeling results indicate that mean monthly water temperatures in the Sacramento River between Keswick and RDBB during the March through August spawning and egg/prelarvae incubation period would be consistently below 64°F, with minor differences between the alternatives (Tables O.3-60 through O.3-63). During September, when Pacific Lamprey larvae would be present in the river, mean water temperatures would exceed the 64°F optimal temperature at RBDD in critically dry water years under the No Action Alternative. September has the highest water temperatures of the year upstream of RBDD. Mean September water temperatures at RBDD for individual years exceed 64°F in about 7% of years for the No Action Alternative and about 5% of years for Alternative 4, but both alternatives are below 72°F for all years (Figure O.3-22). The downstream distribution of Pacific Lamprey larvae is uncertain, but if the larvae drift well downstream of RBDD or enter the Sacramento River from downstream tributaries, they would be subject to higher water temperatures, especially during July and August. However, there is little difference between July and August water temperatures at the downstream temperature modeling sites (Table O.3-64 and O.3-65; Figure O.3-45). There are no biologically meaningful differences in water temperature conditions for Pacific Lamprey between the No Action Alternative and Alternative 4.

The CalSim II flow results and the HEC-5Q water temperature results indicate that Alternative 4 would have a less-than-significant impact on Pacific Lamprey relative to the No Action Alternative.

O.3.9.2.10 River Lamprey

River Lamprey adults migrate from the ocean to spawning areas during the fall and late winter (Beamish 1980). Spawning is believed to occur from February through May in small tributary streams (Moyle 2002). The redds are built at the upstream end of small riffles (Moyle 2002). After the larvae (ammocoetes) emerge, they drift downstream and burrow into sediments in pools or side channels where they rear. After several years, the larvae metamorphose in late July and the juvenile (macrothalmia) migrate downstream in the following year from May to July (Moyle 2002).

River flow potentially affects survival of River Lamprey eggs and larvae, and migratory habitat of the juveniles and adults. River lamprey build their spawning redds in shallow water (Moyle et al. 2015), so reductions in water level can dewater the redds. Assuming River Lamprey larvae habitat requirements are similar to those of Pacific Lamprey, the larvae select habitats, often off-channel, with low flow velocity and shallow depths, so they are vulnerable to stranding by reductions in water level.

The types of variations in flow likely to cause redd dewatering and stranding of larvae often occur on a time scale of hours or days and, therefore, may not be detectable using the CalSim II monthly time-step modeling results. However, the CalSim II results mostly show little difference in Sacramento River flow between the No Action Alternative and Alternative 4, so there is no reason to expect much difference in short period flow fluctuations between the alternatives. The biggest differences in monthly mean flows occur in September and November of wet and above normal water years, when flows are lower under Alternative 4 than the No Action Alternative because Alternative 4 operations do not include releases for Fall X2 flows (Table O.3-66; Figures O.3-25 and O.3-28). River lamprey are generally done spawning by May and, assuming their incubation times are similar to those of Pacific Lamprey, the prelarvae complete their emergence from redds by June or July. In contrast, the larvae are present in the river yearround and so could be vulnerable to flow reductions during September and November. However, water levels during these months are generally relatively stable because they are largely determined by Shasta and Keswick dam releases rather than runoff.

The juveniles carry out their migrations during May through July. CalSim II modeling flow results for Hamilton City and Wilkins Slough show similar to slightly lower flows during May under Alternative 4, moderately higher flows during June of drier water year types, and moderately higher flow in July of Above Normal water years but moderately lower flow in July of critically dry years (Table O.3-67 and O.3-68). The adults migrate upstream primarily in the fall and winter and could be adversely affected by the reductions in flow under Alternative 4 relative to the No Action Alternative during September and November (Tables O.3-67 and O.3-68), but little is known about flow needs of migrating adult River Lamprey. Overall, Alternative 4 and the No Action Alternative are expected to similarly affect River Lamprey with respect to flow in the Sacramento River.

The water temperature requirements of River Lamprey have not been studied, but they are assumed to be similar to those of Columbia River Pacific Lamprey with 64°F for maximum survival of eggs and prelavae and 72°F and above for minimum survival (Meeuwig et al. 2005). HEC-5Q modeling results indicate that mean monthly water temperatures in the Sacramento River between Keswick and RDBB during the February through May spawning and egg/prelarvae incubation period would be consistently below 64°F, with minor differences between the alternatives (Tables O.3-60 through O.3-63). It should be noted that River Lamprey are believed to spawn in tributary streams rather than the mainstem, but this is uncertain (Moyle et al. 2015). During September, when River Lamprey larvae would be present in the river, mean water temperatures would exceed the 64°F optimal temperature at RBDD in critically dry water years under the No Action Alternative. September has the highest water temperatures of the year upstream of RBDD. Mean September water temperatures at RBDD for individual years exceed 64°F in about 7% of years for the No Action Alternative and about 5% of years for Alternative 4, but both alternatives are below 72°F for all years (Figure O.3-22). The downstream distribution of River Lamprey larvae is uncertain, but if the larvae drift well downstream of RBDD or enter the Sacramento River from downstream tributaries, they would subject to higher water temperatures, especially during July and August. However, there is little difference between July and August water temperatures at the downstream temperature modeling sites (Table O.3-64 and O.3-65; Figure O.3-45). There are no biologically meaningful differences in water temperature conditions for River Lamprey between the No Action Alternative and Alternative 4.

The CalSim II flow results and the HEC-5Q water temperature results indicate that Alternative 4 would have a less-than-signficant impact on River Lamprey relative to the No Action Alternative.

O.3.9.2.11 Hardhead

Hardhead are believed to spawn in riffles, runs, and heads of pools, primarily during April and May (Moyle et al. 2015). Most spawning probably occurs in tributaries rather than in the Sacramento River mainstem (Moyle et al. 2015). Larvae and juveniles likely inhabit stream margins with abundant cover, and move into deeper habitats as they grow larger. Adults occupy the deepest part of pools. Juvenile and adult Hardhead are present in the Sacramento River year-round. They tend to prefer water temperatures near 67°F (Thompson et al. 2012), but have been captured at RBDD, where water temperatures are generally much cooler (USFWS 2002) (Table O.3-9).

Spawning success of Hardhead in the lower Tuolumne River is highest when there are higher flows during in April and May (Brown and Ford 2002), which is likely true for the Sacramento River Hardhead as well. The CalSim II results for Keswick, Red Bluff, Hamilton and Wilkiuns Slough indicate that monthly mean flow would be moderately higher under Alternative 4 than under the No Action Alternative during the April of all but critically dry water years (Tables O.3-59, O.3-66 through O.3-68). During most of the other months, flows would generally be similar between Alternative 4 and the No Action Alternative, but from Keswick Dam to Wilkins Slough they would be up to 20% lower under Alternative 4 in July during critically dry water years and 26 to 46% lower in September and November of wet and above normal water years. The large flow reductions in all three months would likely have little effect on Hardhead because they are predicted for months and water year types when flows are generally moderate to high, and because by September and November, hardhead hatched in the spring would be well developed and have gravitated to deeper water. On balance, the flow effects of Alternative 4 are not expected to substantially affect Hardhead.

Hardhead juveniles and adults performed well in laboratory tests at water temperatures from about 61 to 70°F (Thompson et al. 2012). They consistently preferred a mean water temperature of 67°F and avoided temperatures above about 79°F. HEC-5Q modeling results indicate that mean monthly water temperatures in the Sacramento River would be below 79°F at all locations under both alternatives (Tables O.3-60 through O.3-65). There would be only minor differences in mean water temperatures between the alternatives, except for large increases under Alternative 4 during September of wet and above normal water years. However, these Alternative 4 mean water temperatures would be only slightly warmer than the Hardhead preferred temperature, and only at Knights Landing (Table O.3-64). There are no biologically meaningful differences in water temperature conditions for Hardhead between the No Action Alternative and Alternative 4.

The CalSim II flow results and the HEC-5Q water temperature results indicate that Alternative 4 would have no impact on Hardhead relative to the No Action Alternative.

O.3.9.2.12 Central California Roach

As discussed for Alternatives 1 through 3, due to the adaptability of California Roach to different habitat types and its water temperature tolerances, Alternative 4 is expected to have no impact on Central California Roach relative to the No Action Alternative.

O.3.9.2.13 Striped Bass

Striped Bass spawn in the Sacramento River primarily between about Verona (RM 78) and Wilkins Slough (RM 121) during April through June (Moyle 2002). No spawning occurs until water temperature reaches 57°F (Moyle 2002). The eggs are free-floating and negatively buoyant and hatch in about two days after spawning (at 66°F) as they drift downstream. Low flows can result in eggs settling on the bottom, which they cannot survive for long. The larvae may inhabit shallow, open water of the lower river from April to mid-June and then are carried by flows to the Delta and Suisun Bay (Stevens 1966; Moyle 2002). Adult striped bass are found in the upper Sacramento River at RBDD and upstream, primarily from late spring through early fall, where they forage heavily on juvenile salmon and other fish (Tucker et al. 1998).

High flows in April through June benefit striped bass eggs because they help prevent them from settling to the river bottom. High flows likely also accelerate transport of Striped Bass larvae to their nursery habitats in the Delta and Suisun Bay (Moyle 2002). CalSim II flow results for Wilkins Slough indicate that mean monthly flow during April and June under Alternative 4 would be similar to or higher than flow under the No Action Alternative, but would be generally similar during May (Table O.3-68). The greatest reductions in flow resulting from Alternative 4 would occur in September and November of wet and above normal water years. Adult Striped Bass may reside throughout the Sacramento River in September (Tucker et al. 1998). However, although the Alternative 4 mean monthly flows are reduced from the No Action Alternative flows in wet and above normal years, they remain close to or well above 5,000 cfs (Table O.3-66 through O.3-68), which is likely adequate for foraging Striped Bass.

Optimal spawning temperature range for Striped Bass is 59 to 68°F and spawning ceases at about 70°F (Moyle 2002). The eggs can withstand temperatures of about 54 to 75°F, with the optimum being about 64°F (Emmett et al. 1991). Larvae tolerate temperatures of 50 to 77°F, but optimal temperatures for survival are 59 to 72°F (Emmett et al. 1991). The adults appear to prefer water temperatures ranging from about 68 to 75°F (Emmett et al., 1991) and juveniles prefer rearing temperatures of 61 to 66°F (Hasler 1988). Adults are under stress at temperatures over 77°F, and temperatures over 86°F are lethal (Moyle 2002).

HEC-5Q modeling results indicate that mean monthly water temperatures in the Sacramento River at Knights Landing during the April through June spawning period would be within the optimal range for spawning in April of all but wet years and in May of all but critically dry years, but would be above the optimal range in June during all water year types (Table O.3-65). The mean monthly temperatures would be below the optimal range for adults during April and May of all water year types except critically dry years in May, but would be within this range in all water year types in June. The temperatures would be acceptable for eggs and optimal for larvae throughout the spawning period (Table O.3-65). Juvenile striped bass generally do not occur in the Sacramento River upstream of the Delta. The adults, as noted earlier, may forage in the river upstream to and above RBDD from about May through early October. Mean monthly water temperatures at RBDD throughout this period would be well below the optimal range for adults (Table O.3-63).

The largest difference in monthly mean water temperatures between the No Action Alternative and Alternative 4 at Knights Landing during the Striped Bass spawning season is a moderate reduction in June of dry water years (Table O.3-65). This reduction would move the mean water temperatures under Alternative 4 closer to the optimal range for spawning, providing a minor benefit. The largest temperature differences at any time of year are substantial increases under Alternative 4 for September of wet and above normal water years. These increases would be potentially beneficial for foraging Striped Bass adults because the No Action Alternative water temperatures for these months and water year types would be well below the optimal range for adults throughout the river (Tables O.3-63 through O.3-65).

The CalSim II flow results and the HEC-5Q water temperature results indicate that Alternative 4, with regard to flow and water temperature, would have a less-than-significant impact on Striped Bass relative to the No Action Alternative.

O.3.9.2.14 American Shad

American shad migrate upstream in the Sacramento River starting in March, and typically spawn from April to June. Water temperature influences the timing of runs, with peak runs and spawning usually occurring at water temperatures of 62 to 75°F (Moyle 2002). Shad eggs drift downstream from spawning areas and hatch in 3 to 12 days, depending on water temperature (MacKenzie et al. 1985). Larval shad are planktonic for about 4 weeks, after which they metamorphose to actively swimming juveniles. Juveniles spend the next several months in freshwater, and seem to prefer temperatures of 63 to 77°F. In the Sacramento River, summer rearing habitat occurs in the main river from Colusa to the north Delta (Stevens et al. 1987). As the season progresses, juvenile shad move downstream and enter salt water primarily during September through November (Moyle 2002). In general, variations in river discharge and temperature during early larval development are considered important regulators of year-class strength and recruitment of American shad (Hinrichsen et al. 2013). Although the importance of various potential mechanisms is unknown, the abundance of juvenile American shad in the Sacramento-San Joaquin Delta has been shown to be positively correlated with freshwater inflow during the April through June spawning and nursery periods (Stevens et al. 1987, Kimmerer 2002, Kimmerer et al. 2009).

During the spawning and larval rearing period (April through June), CalSim II modeling results at Wilkins Slough indicates that average monthly flows in April and June under Alternative 4 would be higher than those under the No Action Alternative, which may have a minor positive effect on spawning and early rearing success of American shad (Table O.3-52). Flows would be largely similar in May HEC-5Q modeling results indicate that there are few meaningful differences in mean monthly temperatures in the lower Sacramento River (Knights Landing) during May through June (Table O.3-49 in this appendix and the ROC LTO BA). The largest differences in flows and water temperatures in the Sacramento River between Alternative 4 and the No Action Alternative would occur in September and November of wet and above normal water years (Table O.3-65 and O.3-68). However, the importance of river inflows and river temperatures for juvenile shad in September and November is unknown. Correlations between Delta inflows and abundance of juvenile shad have been demonstrated for the months of April through August, with the highest correlations in April through June, suggesting that the principal factors influencing abundance occur during periods of larval dispersal and transport. Alternative 4 is considered to have a less-than-significant effect on American Shad.

O.3.9.2.15 Largemouth Bass

The Sacramento River above the Delta generally provides poor habitat conditions for Largemouth Bass because of large seasonal flow fluctuations, relatively cold water, and lack of suitable nesting and rearing habitat. Consequently, Largemouth Bass populations in the Sacramento River above the Delta are largely dependent on upstream sources, including reservoirs, floodplain ponds and sloughs, and irrigation canals that provide suitable conditions for spawning and rearing during the late spring and summer months.

Largemouth bass spawning activity typically starts in April when water temperatures reach 59 to 61°F, and continues through June (Moyle 2002). Nests are typically constructed at a depth of about 3 feet (Brown et al. 2009a). Optimal temperatures for successful spawning and incubation are 68 to 70°F, although spawning is generally observed over a range of 55 to 79°F (Stuber et al. 1982). Eggs hatch in 2 to 7 days after spawning and the sac fry usually spend 5 to 8 days in the nest until they begin actively feeding (Moyle 2002). Optimal temperatures for growth of juvenile and adult bass range from 77 to 86°F, although growth will occur over a much wider range (50 to 95°F) (Moyle 2002).

The CALSIM II and HEC-5Q modeling results for Alternative 4 indicate that Sacramento River mean flows are higher and water temperatures are slightly lower in June relative to the No Action Alternative, potentially affecting largemouth bass spawning and incubation, while differences in May are too small to be meaningful (Tables O.3-65 and O.3-68). However, based on modeled mean monthly water temperatures in the lower Sacramento River at Knights Landing, no substantial changes would be expected to occur in the frequency of suitable water temperatures for spawning and incubation (Figures O.3-41 and O.3-91). The relatively large changes in flows and water temperatures in September and November of wet and above normal years under Alternative 4 (Tables O.3-65 and O.3-68) could affect habitat conditions for juvenile and adult bass, but water temperatures would remain below optimum levels for growth under both alternatives. Consequently, the generally poor habitat conditions for largemouth bass in the Sacramento River under the No Action Alternative would persist under Alternative 4. Therefore, changes in Sacramento River flows and water temperatures associated with Alternative 4 would have a less-than-significant effect on largemouth bass in the Sacramento River relative to the No Action Alternative.

O.3.9.2.16 Smallmouth Bass

The optimal temperature range for Smallmouth Bass spawning is 55 to 70°F (Brown et al. 2009b) and the optimal for adult growth is approximately 77 to 80°F, but rapid growth of has been seen in the wild at temperatures as high as 84°F, providing prey is abundant (Moyle 2002). Populations are rarely established in water temperatures that do not exceed 66°F in summer for extended periods, and most smallmouth populations in California are present where summer temperatures are typically 69°F to 71°F. In northern California reservoirs most spawning takes place in May and June, but spawning in streams may occur into July, depending on flows and temperatures. Males start making nest depressions when water temperatures reach 55°F to 61°F. The nests are typically built at depths of about 3 to 8 feet (Brown et al. 2009). In streams, nesting and reproduction can be disrupted by flow reductions that lead to nest dewatering or elevated flows that wash embryos and fry out of nests or lower water temperatures excessively (Graham and Orth 1986; Lukas and Orth 1995).

CalSim II results for Wilkins Slough flow for Alternative 4 compared to No Action Alternative during the May through July spawning season indicate moderately increased flow during June of the drier water year types and slightly reduced flow in July, except for moderately increased flow in above normal years and moderately reduced flow in critically dry water years (Table O.3-68). Higher flows could adversely affect embryos and fry by dewatering nests or washing them out of the nests, but it is unknown what magnitude of flows would have these effects.

HEC-5Q monthly mean water temperatures at Hamilton City consistently fall within the 55°F to 70°F optimal spawning range during the spawning season of May through July under both Alternative 3 and the No Action Alternative (Table O.3-64). At Knights Landing, however, the temperatures fall within the optimal range during May of all water year types, but lie above the range during June and July of most water year types (Table O.3-65). The mean water temperatures under Alternative 4 are generally similar to those under the No Action Alternative, except for moderately lower flow in June of dry years. The monthly mean summer water temperatures at Hamilton City consistently fall below the 66°F threshold that has been found to be a minimum for Smallmouth Bass to establish populations in California (Moyle 2002), except for critically dry water years in August and September (Table O.3-64). At Knights Landing, however, the 66°F threshold is exceeded in all summer months and water year types except September of wet and above normal years under the No Action Alternative (Table O.3-65). Note that the large wet-and-above-normal-year September water temperature increases under Alternative 4 result in water temperatures exceeding the threshold, which may benefit Smallmouth Bass. The mean water temperatures are consistently well below the optimal range for adult growth, 77°F to 80°F, at both locations.

The CalSim II flow and HEC-5Q water temperature results indicate that Alternative 3 would have a less-than-significant impact on Smallmouth Bass relative to the No Action Alternative with regard to flow and water temperature.

O.3.9.2.17 <u>Spotted Bass</u>

Spotted Bass inhabit streams and reservoirs and prefer moderate-size, clear, low-gradient sections of rivers and reservoirs (McKechnie 1966). They prefer pool habitat and slower, more turbid water than Smallmouth Bass, but faster water than Largemouth Bass (Moyle 2002). Their summer water temperature preference is 75°F to 87°F (Moyle 2002). In streams, nests are constructed in low-current areas on bottoms ranging from debris to gravel (Moyle 2002). Spawning depths are deeper than those of largemouth bass (Aasen and Henry 1981). They spawn in the spring when water temperatures rise to 59°F to 64°F (Aasen and Henry 1981; Howland 1931). Spawning continues through late May and early June, until temperatures reach 71°F to 73°F.

During the spring (April through June) spawning season, CalSim II results for Wilkins Slough monthly mean flows under Alternative 4 are mostly higher than the No Action Alternative flows in April and June, but little different in May (Table O.3-68). Higher flows could adversely affect embryos and fry by dewatering nests or washing them out of the nests, but it is unknown what magnitude of flows would have these effects.

HEC-5Q monthly mean water temperatures at Knights Landing during the spawning season of April through June would largely be within the 59°F to 64°F spawning range in April under Alternative 4 and the No Action Alternative, but would exceed the range in May and June under both alternatives. The preferred summer water temperatures range of 75°F to 87°F would be available only in critically dry water years, especially in August, under both Alternative 4 and the No Action Alternative (Table O.3-65).

The CalSim II flow results and the HEC-5Q water temperature results indicate that Alternative 4, with regard to flow and water temperature, would have a less-than-significant impact on Spotted Bass relative to the No Action Alternative.

Potential changes to aquatic resources in the Sacramento River from Shasta cold water pool management

Shasta Cold Water Pool Management will not occur under either Alternative 4 or the No Action Alternative. Therefore, Alternative 4 and the No Action Alternative are likely to have similar effects on aquatic resources with respect to the effects of this action. However, Alternative 4 and the No Action Alternative have very different management guidelines, which results in differences in their effects on flow and water temperature and, ultimately, on the focal fish species. Operations of all the alternatives are regulated by SWRCB's D-1641 decision, which requires flow releases to meet Delta standards, and their WRO 90-5 decision, which requires cold water releases to meet temperature targets at compliance points in the upper Sacramento River. However, the No Action Alternative also includes NMFS's 2009 BO RPAs to operate Shasta Reservoir for management of cold water in the river for protection of salmon and steelhead, and includes requirements for Fall X2 flow releases, but Alternative 4 includes neither requirement. And Alternative 4 includes new operations criteria not included in the No Action Alternative. These criteria would manage Shasta Reservoir to increase instream flow releases with a target of 55% of unimpaired flows in the Sacramento River above Red Bluff and at the Feather River confluence. However, balancing instream flow releases with storage needed to maintain the coldwater pool for fish would continue to be critical to operations. Other rivers in the basin with major reservoirs would have similar flow targets. The effects of the differences in operations between Alternative 4 and the No Action Alternative on water temperatures and flows in the Sacramento River and the potential effects of resulting water temperature and flow differences on the focal fish species in the river are discussed above in the assessments for the individual fish species in the *Potential changes to aquatic resources in the Sacramento River from seasonal operations* section for the Sacramento River under Alternative 4.

Potential changes to aquatic resources in the Sacramento River from spring pulse flows

Spring Pulse Flows for fish will not occur under either Alternative 4 or the No Action Alternative. Therefore, Alternative 4 and the No Action Alternative are likely to have similar effects on aquatic resources with respect to potential effects of this action.

Potential changes to aquatic resources in the Sacramento River from fall and winter refill and redd maintenance

Fall and winter refill and redd maintenance will not occur under either Alternative 4 or the No Action Alternative. Therefore, Alternative 4 and the No Action Alternative are likely to have similar effects on aquatic resources with respect to potential effects of this action.

Potential changes to aquatic resources in the Sacramento River from rice decomposition smoothing

Rice decomposition smoothing will not occur under either Alternative 4 or the No Action Alternative. Therefore, Alternative 4 and the No Action Alternative are likely to have similar effects on aquatic resources with respect to potential effects of this action.

Potential changes to aquatic resources in the Sacramento River from spring management of spawning locations

Rice decomposition smoothing will not occur under either Alternative 4 or the No Action Alternative. Therefore, Alternative 4 and the No Action Alternative are likely to have similar effects on aquatic resources with respect to potential effects of this action.

O.3.9.3 *Clear Creek*

O.3.9.3.1 Whiskeytown Reservoir Operations

Alternative 4 would incorporate the same assumptions of Alternative 1 but would also include flow objectives based on unimpaired instream flow.

Under current operations and the No Action Alternative, Whiskeytown Lake is annually drawn down 13 feet (approximately 35 TAF) between November and April for flood control purposes, although it can be lowered as much as 30 feet as needed for maintenance. Model output for Whiskeytown Lake predicts that compared to the No Action Alternative, minimum reservoir volumes would be lower under Alternative 4 during the months of May and July (2.0 TAF and 59.8 TAF lower, respectively), although this is only anticipated to occur in approximately 2% to 3% of years (Figure O.3-140, Table O.3-69). During those two months, water surface elevations would also be lower under Alternative 4 compared to the No Action Alternative. In April, water surface elevations would be 2.8 TAF higher under Alternative 4 compared to the No Action Alternative. In all other months, Whiskeytown Lake storage volumes under Alternative 4 would be either identical to, or 0.1 TAF higher that those predicted under the No Action Alternative.

Whiskeytown Storage / monthly statistics (5-2-16-1b):

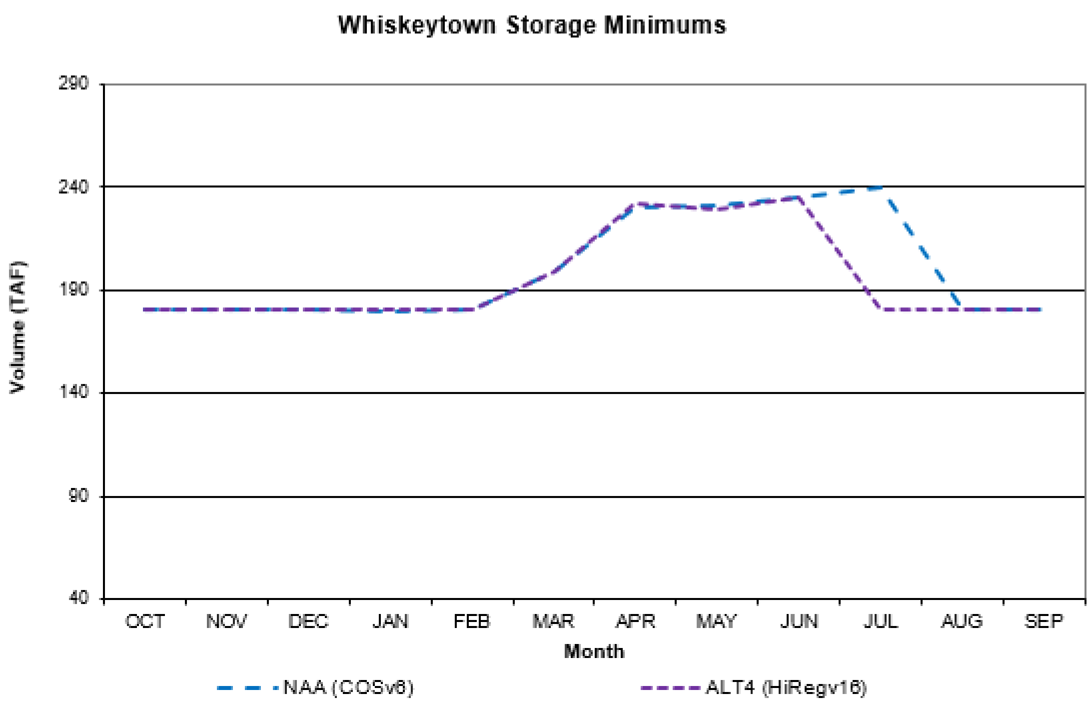


Figure O.3-140. Modeled Whiskeytown Lake Monthly Minimum Storage Volume under the No Action Alternative and Alternative 4 during all Water Year Types

Table O.3-69. Modeled Differences in Whiskeytown Lake Monthly Minimum Storage Volumes from March to July under Alternative 4 Relative to the No Action Alternative

Month	Change in Volume from No Action Alternative (TAF)
October	0.0
November	0.1
December	0.1
January	0.1
February	0.0
March	0.1
April	2.8
May	-2.0
June	0.1
July	-59.8
August	0.0
September	0.0

The seasonal draw-down in July under Alternative 4 could cause an increase in bank and bed erosion in newly exposed areas of tributary stream mouths where they are devoid of stabilizing riparian vegetation. This scour could cause channel incision (i.e., down-cutting) and result in increased lake water turbidity. Channel incision can create erosional nick points that propagate upstream until they encounter scour-resistant grade-controlling materials such as bedrock, at which point a cascade can form. A draw-down of this magnitude would also occur under the No Action Alternative, but approximately one month later. The earlier draw-down therefore represents a change in timing and duration of lower water surface elevation but not a new type or mechanism of disturbance, and channel incision may have already occurred and stabilized as a result of past operations.

Potential changes to aquatic resources in Clear Creek from seasonal variation in water surface elevation

Hardhead

Hardhead migrate from the reservoir into tributaries in April and May to spawn upstream of Whiskeytown Lake. The timing of proposed increased draw-downs in May and July under Alternative 4 could affect Hardhead if the lower water surface elevations in May expose any previously submerged cascades at tributary mouths or create new ones. No such cascades have been documented, but if they are present or created by tributary incision at low water, they could present barriers to migration that would prevent reservoir-dwelling adult Hardhead from spawning in tributary streams. Alternately, higher water surface elevation in April may benefit migrating Hardhead at the start of their upstream migration season. The larger June-August drawdown (Figure 4) would occur after upstream migration has concluded and would therefore not be expected to affect Hardhead access to tributary spawning areas.

Hardhead are not a cold-water species, so drawing additional cold water from the bottom layers of the reservoir would not be expected to affect them directly. Hardhead have shown sensitivity to high sediment loads (Gard 2002), so increased reservoir turbidity due to varial zone erosion during draw-down periods could reduce suitability of reservoir and downstream waters for Hardhead persistence.

Annual variations in reservoir water surface elevation under Alternative 4 could cause Hardhead to be affected by reducing habitat connectivity and increasing water turbidity. However, changes to storage volume and seasonal timing of water surface elevation in Whiskeytown Lake are likely to be negligible due to low frequency of occurrence under Alternative 4 compared to the No Action Alternative, and higher water surface elevation in April could benefit migrating Hardhead at the start of their upstream migration season.

Other Fish Species

Central California Roach are not likely to be affected by changes in reservoir operations because, although they are found in upstream tributaries, they do not reside in Whiskeytown Lake, having likely been extirpated from the reach after the reservoir was originally filled in 1963. Future operations of Whiskeytown Dam under Alternative 4 are therefore unlikely to affect either individuals or populations.

Annual variations in reservoir water surface elevation under Alternative 4 compared to the No Action Alternative could cause varying effects to stocked and introduced nonnative game species in Whiskeytown Lake. Stocked species would not be expected to be affected by changes in reservoir operations. Rainbow Trout, Brown Trout, Kokanee Salmon, and Brook Trout typically spawn in tributary streams, but they are capable of spawning in lakes if they are unable to access moving water. Whiskeytown Lake Kokanee spawn in the fall, a period when no differences in water levels are expected under Alternative 4 compared to the No Action Alternative. Pond species such as Largemouth Bass, Smallmouth Bass, Spotted Bass, Bluegill, Black Crappie, Channel Catfish, and Brown Bullhead are able to tolerate a wide range of conditions, but the basses and panfish spawn in relatively shallow lake areas when water warms to at least 50°F in late spring or summer. Reducing reservoir volume in May and July could put some of their nests at risk of being dewatered in years when springtime and early summer conditions are warm. However, these species have rapid reproductive rates which can enable them to recover from episodic recruitment failures which could occur with very low frequency (2% to 3% of years).

O.3.9.3.2 Clear Creek Flows

Under Alternative 4 Reclamation proposes to operate flows in Clear Creek based on downstream water rights, the 1963 Reclamation proposal to USFWS and NPS, and predetermined CVPIA 3406(b)(2) flows, as done under the No Action Alternative. Under Alternative 4, however, the minimum instream flow requirements are based on 55% of unimpaired flow rather than a requirement of 50 cfs to 100 cfs as under the No Action Alternative. Channel maintenance and pulse flows would also be based on the unimpaired inflow, whereas under the No Action Alternative channel maintenance flows would occur in congruence with flood operations, and two pulse flows would be released in May and June of at least 600 cfs for at least 3 days per pulse per year.

Modeling results indicate that Clear Creek average flow below Whiskeytown Dam under Alternative 4 would generally exceed flow under the No Action Alternative from late fall through spring in all water year types (Figure O.3-141). On average, the peak difference in flow between Alternative 4 and No Action Alternative scenarios occurs in February, with Alternative 4 flow surpassing 600 cfs and No Action Alternative flow at approximately 200 cfs (Figure O.3-141).

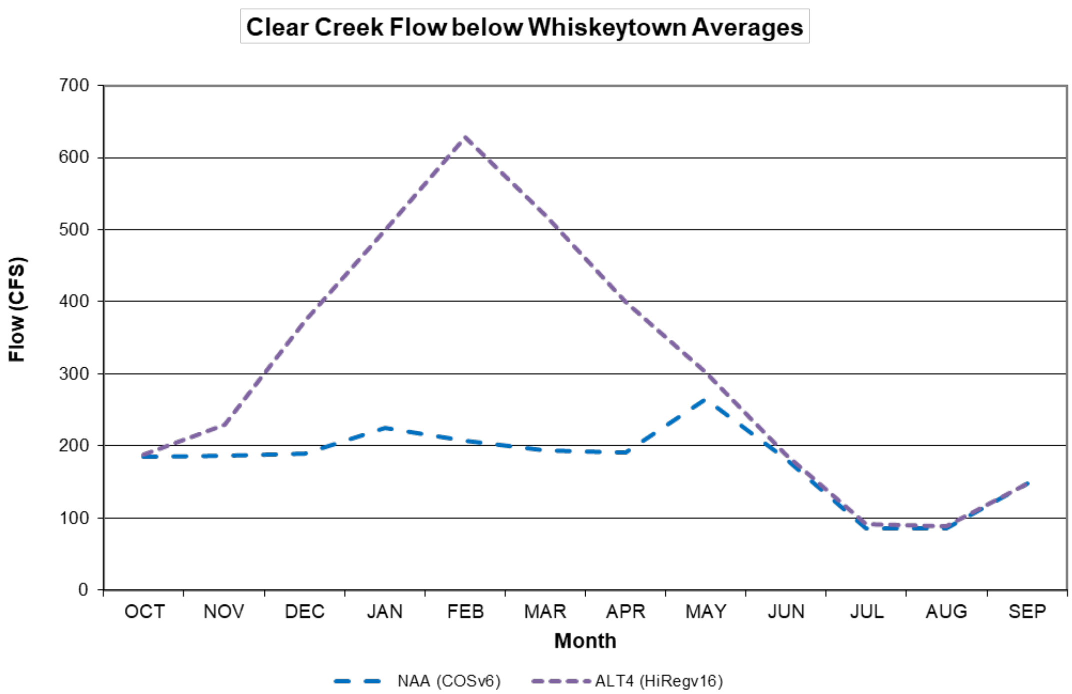


Figure O.3-141. CalSim II Estimates of Average Flow below Whiskeytown under the No Action Alternative and Alternative 4.

Potential changes to aquatic resources in Clear Creek from variation in flow

Spring-Run Chinook Salmon

Under Alternative 4, Clear Creek flow would increase compared to flow under the No Action Alternative from October through May of all water years, with the peak difference occurring in February (Figure O.3-141); flow is otherwise similar from June through September. These changes in flow would coincide with the seasonal occurrence of various life stages of Spring-Run Chinook Salmon in Clear Creek, including migrating adults (March to June), eggs and fry (September to October), and rearing and outmigrating juveniles (November to May). Increased flow would benefit adults by increasing attraction flow, pool connectivity, and available habitat; juveniles by increasing foraging habitat and shelter and increasing DO; and eggs and fry by lowering temperatures and increasing DO.

Alternative 4 also allows for greater flexibility in the timing of channel maintenance and pulse flows, so releases could be scheduled in a manner beneficial to various life stages of Spring-Run Chinook Salmon based on their seasonal occurrence in Clear Creek. Relative to the No Action Alternative, Alternative 4 would potentially benefit Spring-Run Chinook Salmon in Clear Creek.

Fall-Run Chinook Salmon

Under Alternative 4, Clear Creek flow would increase compared to flow under the No Action Alternative from October through May of all water years, with the peak difference occurring in February (Figure O.3-141); flow is otherwise similar from June through September. These changes in flow would coincide with the seasonal occurrence of various life stages of Fall-Run Chinook Salmon in Clear Creek including migrating adults (June to April), eggs and fry (October to April), and rearing and outmigrating juveniles (April to June). Increased flow would benefit adults and juveniles by pool connectivity and available habitat. Increased flow would also lower temperatures and increase DO, benefiting eggs, fry, and juveniles.

Alternative 4 also allows for greater flexibility in the timing of channel maintenance and pulse flows, so releases could be scheduled in a manner beneficial to various life stages of Fall-Run Chinook Salmon based on their seasonal occurrence in Clear Creek. Relative to the No Action Alternative, Alternative 4 would potentially benefit Fall-Run Chinook Salmon in Clear Creek.

Central Valley Steelhead

Under Alternative 4, Clear Creek flow would increase compared to flow under the No Action Alternative from October through May of all water years, with the peak difference occurring in February (Figure O.3-141); flow is otherwise similar from June through September. These changes in flow would coincide with the seasonal occurrence of California Central Valley DPS Steelhead holding adults (December to March), migrating adults (September to October), rearing to outmigrating juveniles (January to May), and eggs and fry (January). Increased flow would benefit adults and juveniles by increasing pool connectivity and available habitat. Increased flow would also lower temperatures and increase DO, benefiting eggs, fry, and juveniles.

Alternative 4 also allows for greater flexibility in the timing of channel maintenance and pulse flows, so releases could be scheduled in a manner beneficial to various life stages of Central Valley Steelhead based on their seasonal occurrence in Clear Creek. Relative to the No Action Alternative, Alternative 4 would potentially benefit Central Valley Steelhead in Clear Creek.

Pacific Lamprey

Under Alternative 4, Clear Creek flow would increase compared to flow under the No Action Alternative from October through May of all water years, with the peak difference occurring in February (Figure O.3-141); flow is otherwise similar from June through September. These changes in flow would coincide with the seasonal occurrence of various life stages of Pacific Lamprey in Clear Creek, including spawning adults (January to May), ammocoetes (year-round), and outmigrating adults (early winter to spring). Increased flow would benefit adults by increasing pool connectivity and available habitat. Increased flow would also lower temperatures and increase DO, benefiting ammocoetes.

Alternative 4 also allows for greater flexibility in the timing of channel maintenance and pulse flows, so releases could be scheduled in a manner beneficial to various life stages of Pacific Lamprey based on their seasonal occurrence in Clear Creek. Relative to the No Action Alternative, Alternative 4 would potentially benefit Pacific Lamprey in Clear Creek.

Potential changes to aquatic resources in Clear Creek from variation in water temperature due to flow objectives

Water temperatures under Alternative 4 would be controlled by flow objectives, rather than specific water temperature objectives as under the No Action Alternative. Under the No Action Alternative, these objectives are a daily water temperature of 60°F at the Igo gage from June 1 through September 15 and 56°F from September 15 through October 31.

Modeling results indicate that average water temperatures in Clear Creek above the Sacramento River would be nearly identical under the No Action Alternative and Alternative 4 (Figure O.3-142); however, maximum temperatures do differ between the two scenarios (Figure O.3-143). Under the No Action

Alternative, modeled maximum water temperatures exceed those under Alternative 4 in September and October by up to 7°F (Figure O.3-143).

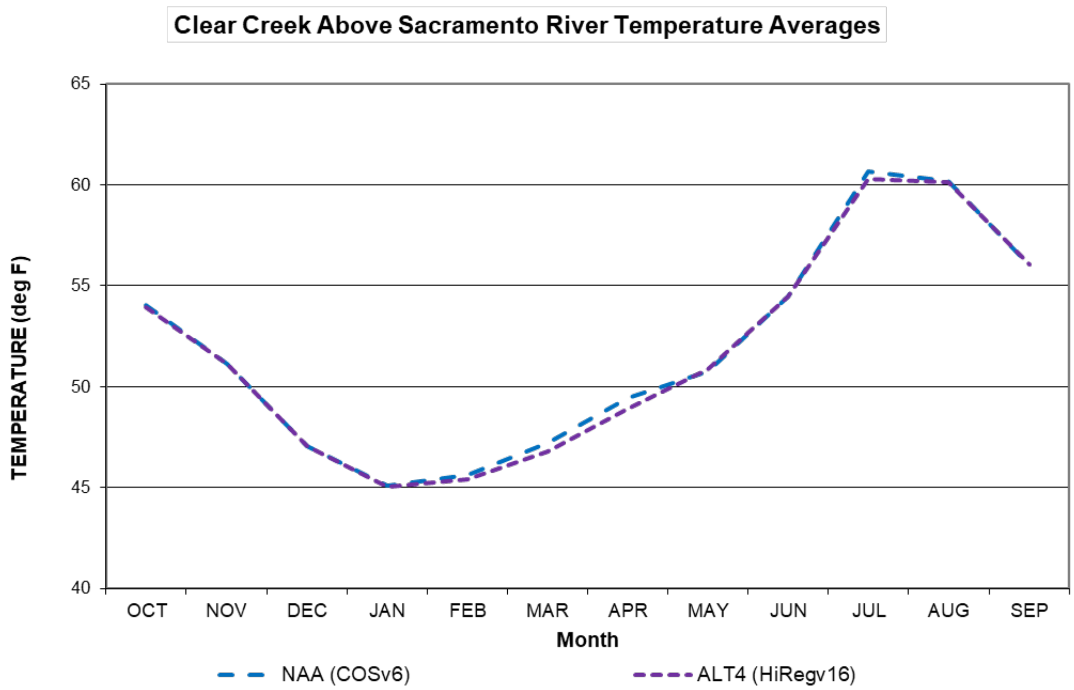


Figure O.3-142. Average Modeled Water Temperatures in Clear Creek above the Sacramento River under the No Action Alternative and Alternative 4.

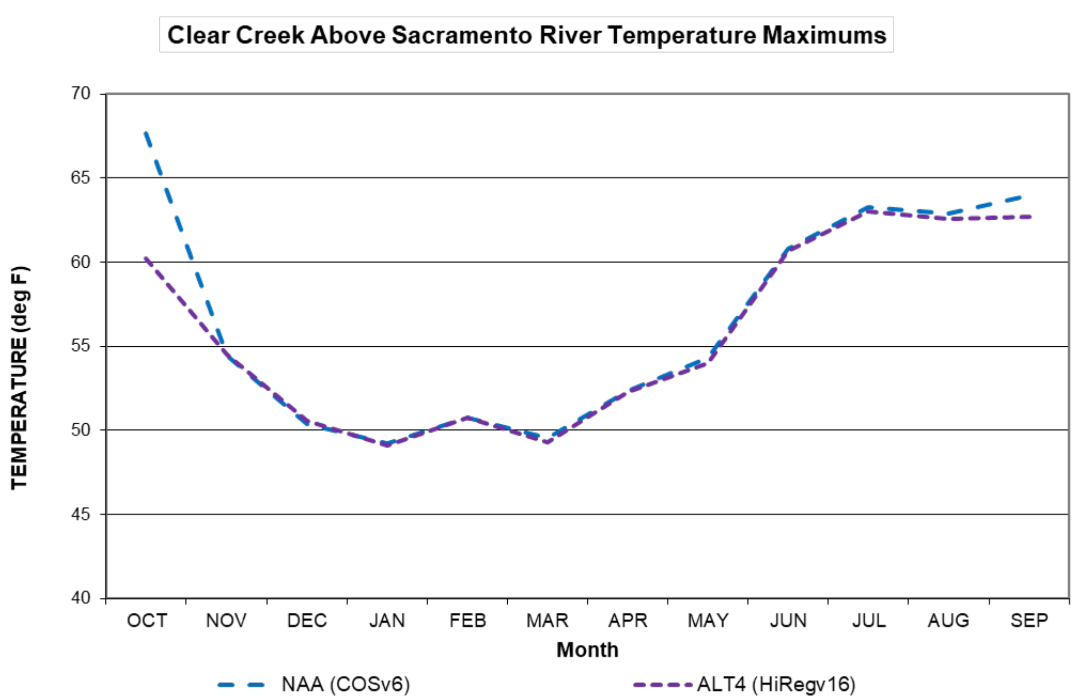


Figure O.3-143. Maximum Modeled Water Temperatures in Clear Creek above the Sacramento River under the No Action Alternative and Alternative 4.

Table O.3-70. Water Temperatures Suitable for Spring-Run and Fall-Run Chinook Salmon, and Central Valley Steelhead by Life Stage

Life Stage	Peak Occurrence	Optimal	Suboptimal	Stress-inducing
Spring-Run Chinook Salmon				
Eggs to fry	September to October	< 54°F	54°F to 58°F	> 58°F
Rearing to out-migrating	November to May	< 60°F	60°F to 65°F	> 65°F
Migrating adults	March to June	< 56°F	56°F to 65°F	> 65°F
Adult holding	May to August	< 60.8°F	60.8°F to 66.2°F	> 66.2°F
Fall-Run Chinook Salmon				
Eggs to fry	October to April	48.2°F to 55.4°F	55.4°F to 62.6°F	> 62.6°F
Rearing to out-migrating	April to June	55.4°F to 68°F	68°F to 75.2°F	> 75.2°F
Migrating adults	June to April	50°F to 68°F	68°F to 69.8°F	> 69.8°F
Central Valley Steelhead				
Eggs to fry	January	46°F to 52°F	52°F to 55°F	> 55°F
Rearing to out-migrating	January to May	< 65°F	65°F to 68°F	> 68°F
Migrating adults	September to October	< 52°F	52°F to 70°F	> 70°F
Adult holding	December to March	< 60.8°F	60.8°F to 66.2°F	> 66.2°F

Sources: NMFS 2016a; Stillwater Sciences 2006; CDFG 2012a, 2012b.

Spring-Run Chinook Salmon

Effects of water temperature on Spring-Run Chinook Salmon have been heavily studied, resulting in an understanding of the optimal (beneficial), suboptimal, and stress-inducing (adverse) temperature ranges for each life stage during its period of peak abundance in Clear Creek (Table O.3-70).

On average, modeled Alternative 4 and No Action Alternative water temperatures are essentially identical, so no difference in effects of water temperature on Spring-Run Chinook Salmon is generally expected. Maximum temperatures under the No Action Alternative, however, reach higher levels in September and October than they do under Alternative 4 (Figure O.3-143). Spring-Run Chinook eggs and fry are present during this period (Table O.3-70) and would be exposed to the possible adverse effects of elevated water temperature, including effects of physiologic stress such as slower growth rates and an inability to satisfy metabolic demand (Stillwater Sciences 2006; Martin et al. 2017). Maximum water temperatures under both scenarios exceed stress-inducing levels for Spring-Run Chinook eggs and fry in September and October, but maximum water temperatures under the No Action Alternative remain stress-inducing for a longer period (Figure O.3-143). Under Alternative 4, therefore, minimal difference in effects of water temperature on Spring-Run Chinook Salmon is expected, but there is potential for beneficial effects on eggs and fry when temperatures reach their maximum levels.

Fall-Run Chinook Salmon

Effects of water temperature on Fall-Run Chinook Salmon have been heavily studied, resulting in an understanding of the optimal (beneficial), suboptimal, and stress-inducing (adverse) temperature ranges for each life stage during its period of peak abundance in Clear Creek (Table O.3-70).

On average, modeled Alternative 4 and No Action Alternative water temperatures are essentially identical, so no difference in effects of water temperature on Fall-Run Chinook Salmon is generally expected. Maximum temperatures under the No Action Alternative, however, reach higher levels in September and October than they do under Alternative 4 (Figure O.3-143). Fall-Run Chinook eggs and fry are present during October (Table O.3-70) and would be exposed to the possible adverse effects of elevated water temperature, including effects of physiologic stress such as slower growth rates and an inability to satisfy metabolic demand (Stillwater Sciences 2006; Martin et al. 2017). Maximum water temperatures under Alternative 4 do not exceed stress-inducing levels for Fall-Run Chinook eggs and fry, but maximum water temperatures under the No Action Alternative do reach stress-inducing levels in October (Figure O.3-143). Under Alternative 4, therefore, minimal difference in effects of water temperature on Fall-Run Chinook Salmon is expected, but there is potential for beneficial effects on eggs and fry when temperatures reach their maximum levels.

Central Valley Steelhead

Effects of water temperature on Central Valley Steelhead have been heavily studied, resulting in an understanding of the optimal (beneficial), suboptimal, and stress-inducing (adverse) temperature ranges for each life stage during its period of peak abundance in Clear Creek (Table O.3-70).

On average, modeled Alternative 4 and No Action Alternative water temperatures are essentially identical, so no difference in effects of water temperature on Central Valley Steelhead is generally expected. Maximum temperatures under the No Action Alternative, however, reach higher levels in September and October than they do under Alternative 4 (Figure O.3-143). Migrating adult Steelhead are present during this period (Table O.3-70) and would be exposed to the possible adverse effects of elevated water temperature, including effects of physiologic stress such as an inability to satisfy metabolic demand (Stillwater Sciences 2006; Martin et al. 2017). Maximum water temperatures under both scenarios remain at suboptimal levels for migrating adult Steelhead throughout their September to October period of peak occurrence (Figure O.3-143). Under Alternative 4, therefore, minimal difference in effects of water temperature on Central Valley Steelhead is expected, but there is potential for beneficial effects on migrating adults when temperatures reach their maximum levels.

Pacific Lamprey

Pacific Lamprey temperature tolerance have been less studied than those of salmonids. Periods of life stage occurrence and associated temperatures for Pacific Lamprey are provided in Table O.3-71.

Table O.3-71. Summary Table of Water Temperatures Suitable for Pacific Lamprey by Life Stage

Life Stage	Peak Occurrence	Temperature Range
Ammocoetes	Year-round	< 82°F [1]
Spawning	January to May	50°F to 64°F, peak 57°F to 59°F
Adult out-migration	Early winter to spring	<68°F

Source: Stillwater Sciences 2014.
[1] Temperature of 82°F is lethal to ammocoetes of four North American species of lamprey; however, it is uncertain if Pacific Lampreys have similar tolerances.

On average, modeled Alternative 4 and No Action Alternative water temperatures are essentially identical, so no difference in effects of water temperature on Pacific Lamprey is generally expected. Maximum temperatures under the No Action Alternative, however, reach higher levels in September and October than they do under Alternative 4 (Figure O.3-143). Pacific Lamprey ammocoetes are present during this period (Table O.3-71) and would be exposed to the possible adverse effects of elevated water temperature, including effects of physiologic stress such as slower growth rates and an inability to satisfy metabolic demand (Stillwater Sciences 2006; Martin et al. 2017). Maximum water temperatures under both scenarios remain at suitable levels for Pacific Lamprey ammocoetes year-round (Figure O.3-143). Under Alternative 4, therefore, minimal difference in effects of water temperature on Central Valley Steelhead is expected, but there is slight potential for beneficial effects on ammocoetes when temperatures reach their maximum levels.

O.3.9.3.3 Spring Creek Debris Dam

Existing operations of the SCDD will continue under both Alternative 4 and the No Action Alternative. Therefore, Alternative 4 and the No Action Alternative are likely to have similar effects on aquatic resources.

O.3.9.3.4 Clear Creek Restoration Program

The Clear Creek Restoration Program is being implemented under both Alternative 4 and the No Action Alternative. Therefore, Alternative 4 and the No Action Alternative are likely to have similar effects on aquatic resources.

O.3.9.4 *Feather River*

O.3.9.4.1 FERC Project #2100-134

DWR, under Alternative 4, would operate Oroville Dam consistent with the NMFS, USFWS, and CDFW environmental requirements applicable for the current Oroville Complex FERC License (FERC Project #2100-134). Reclamation would operate Oroville Dam with minimum flows of 700 cfs to 800 cfs below the Thermalito Diversion Dam in the low flow channel (2006 Settlement Agreement), 750 cfs to 1,700 cfs below the Thermalito Afterbay outlet (1983 DWR-CDFG Agreement), and the DFG/DWR operation objective of 2,800 cfs at the mouth of the Feather River from April through September, with options to vary flow depending on year types. In addition, Alternative 4 includes a minimum instream flow requirement of a minimum of 55% of unimpaired flow and the inflow at Feather River above Yuba Conference.

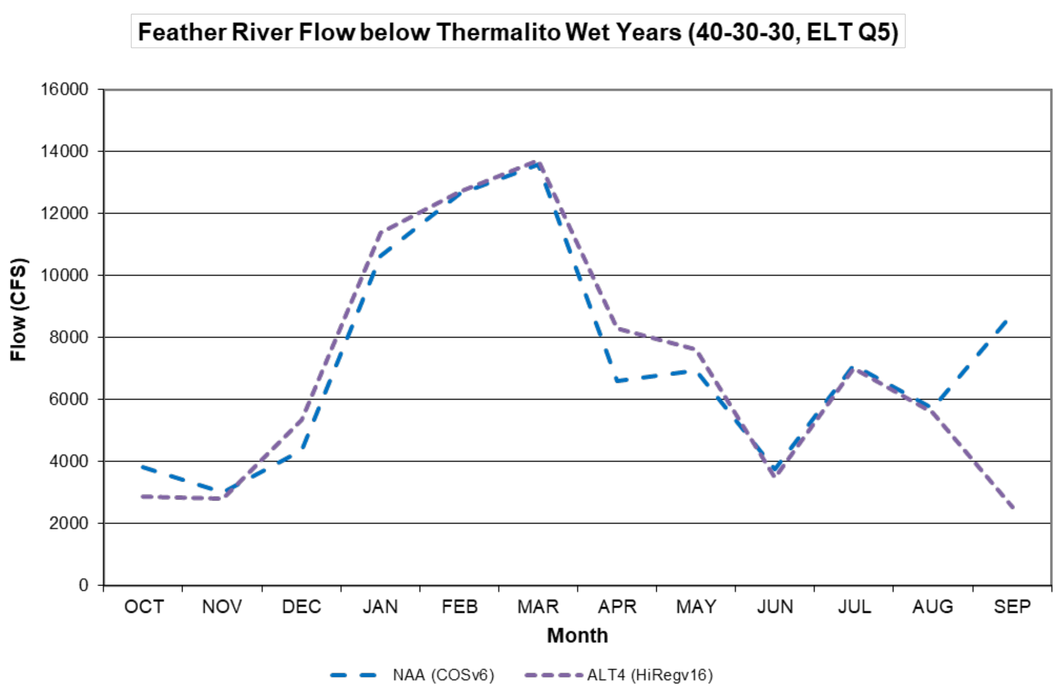
Under the No Action Alternative, DWR would operate Oroville Dam in accordance with ongoing management policies, criteria, and regulations, including water right permits and licenses issued by the SWRCB and operational requirements of the 2008 USFWS BO and the 2009 NMFS BO. Under the No Action Alternative, DWR typically releases water from Lake Oroville to meet the requirements of instream flows and D-1641.

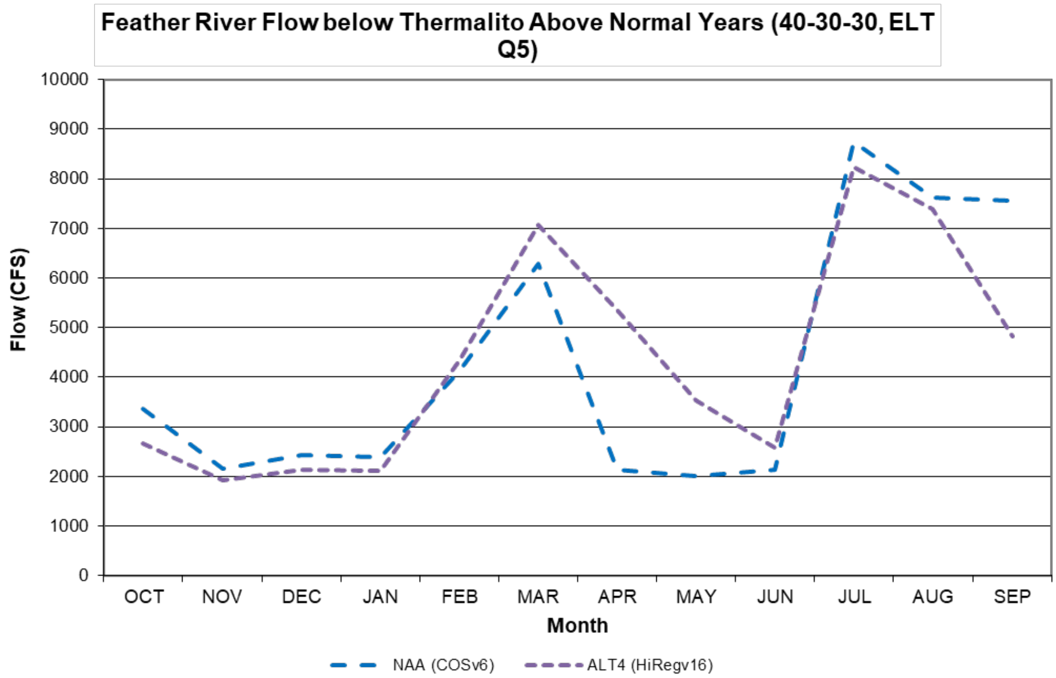
Table O.3-72. Feather River HFC Minimum Instream Flow Requirements

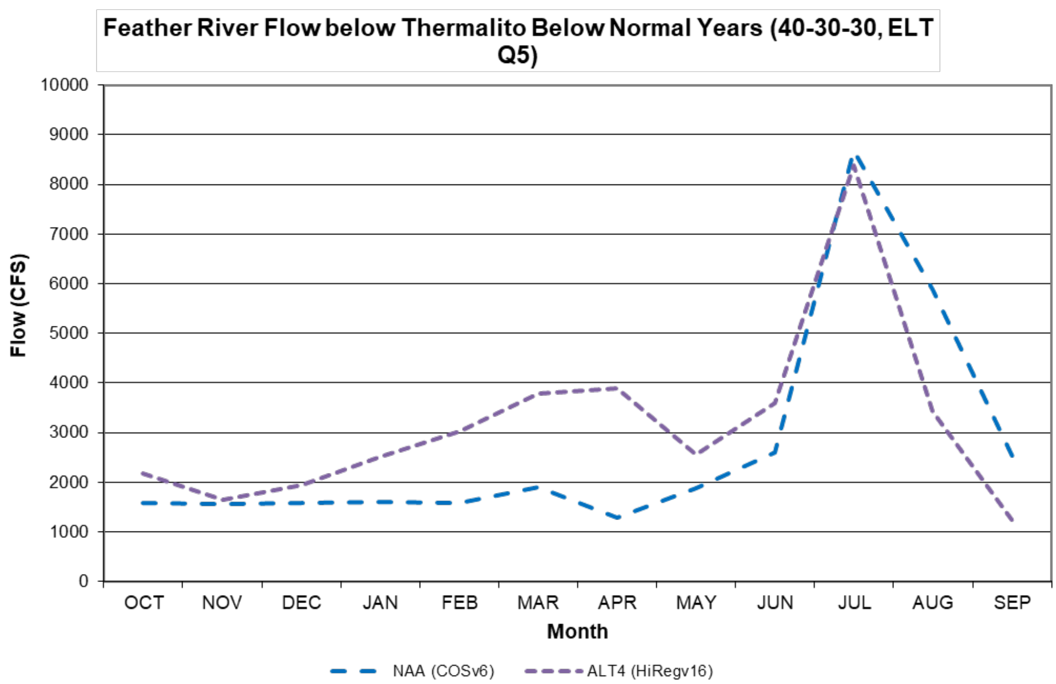
Preceding April to July Unimpaired Runoff (Percent of Normal)	Oct to Feb Minimum Instream Flow (cfs)	March Minimum Instream Flow (cfs)	April to Sept Minimum Instream Flow (cfs)
55% or greater	1,700	1,700	1,000
Less than 55%	1,200	1,000	1,000

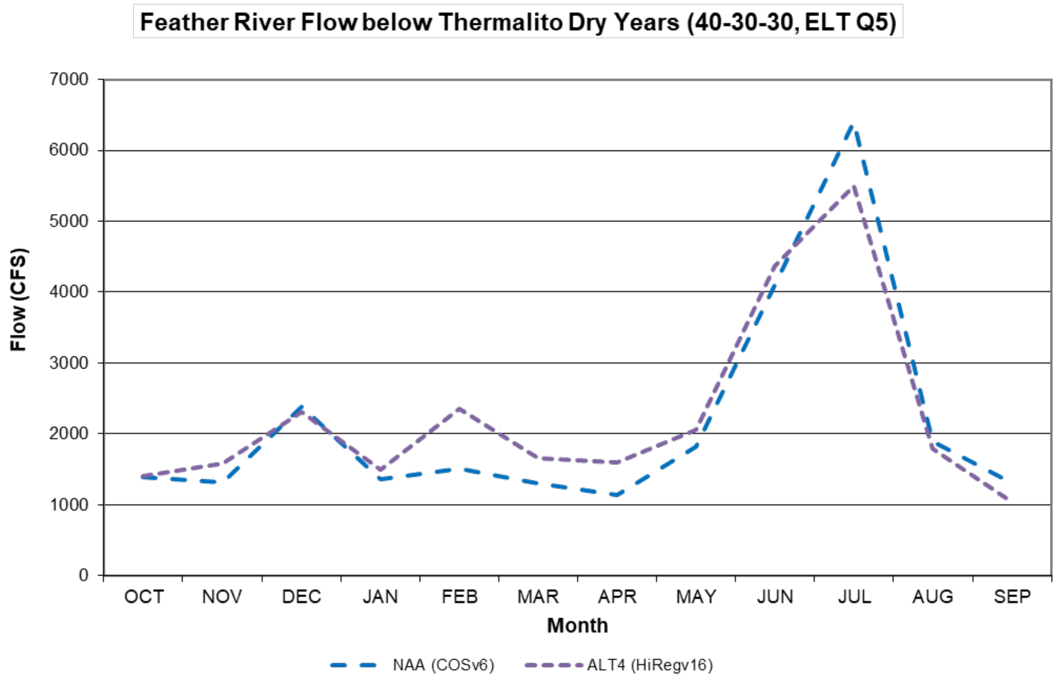
Potential changes to aquatic resources in the Feather River due to seasonal variation in flow

CalSim II model output shows that Feather River flows under Alternative 4 and the No Action Alternative would comply with Feather River HFC minimum instream flow requirements during all months in wet, above normal, and below normal water years. In dry years where the preceding April to July unimpaired runoff is less than 55% of normal, Alternative 4 and the No Action Alternative would comply with minimum instream flow requirements in the HFC (Table O.3-72 and Figure O.3-144). In critically dry years where the preceding April to July runoff is less than 55% of normal, Alternative 4 would not comply with minimum instream flow requirements in the HFC in October and November (Table O.3-72 and Figure O.3-144).




Feather River Flow below Thermalito Above Normal Years (40-30-30, ELT Q5)
Flow (CFS)
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
Month
NAA (COSv6)
ALT4 (HiRegv16)


Feather River Flow below Thermalito Below Normal Years (40-30-30, ELT Q5)
Flow (CFS)
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
Month
NAA (COSv6)
ALT4 (HiRegv16)



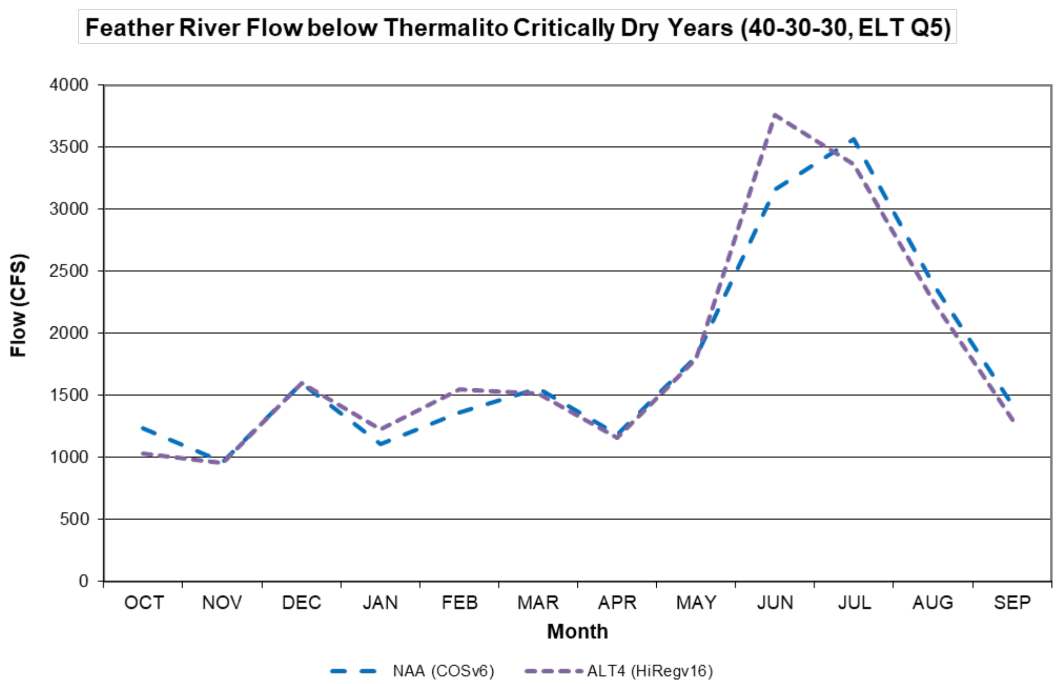


Figure O.3-144. CalSim II Estimates of Feather River Long-Term Average Flow below Thermalito, All Scenarios in Wet, Above Normal, Below Normal, Dry, and Critically Dry Water Years.

Overall, simulated flows under the Alternative 4 and No Action Alternative scenarios are similar, but flows under the No Action Alternative are higher in September of wet and above normal years, and flows under Alternative 4 are higher in April and May of wet water years, from March through June of above normal water years, from January through May of below normal and dry water years, and in June of critically dry water years (Figure O.3-144).

Winter-Run Chinook Salmon

Winter-Run Chinook are not likely to be affected by changes in flow under Alternative 4 compared to the No Action Alternative due to their limited distribution in the Feather River.

Spring-Run Chinook Salmon

Spring-Run Chinook Salmon would be exposed to the effects of Alternative 4 based on their seasonal occurrence in the Feather River, minimum instream flow requirements in the HFC, and compliance with D-1641. Eggs and emerging fry of Spring-Run Chinook Salmon may occur in the Feather River from September through February (NMFS 2016a); juvenile Spring-Run Chinook Salmon occur in the Feather River year-round, with peak abundance from November through May; and adult Spring-Run Chinook Salmon peak in abundance in the Feather River from March through June. All life stages would thus be exposed to the effects of Alternative 4.

Spring-Run Chinook Salmon eggs and emerging fry would benefit from increased Alternative 4 flows, leading to increased dissolved oxygen in January and February of below normal and dry years when Alternative 4 flows are higher than No Action Alternative flows (Figure O.3-144). Juvenile Spring-Run Chinook Salmon would also benefit from increased Alternative 4 flows relative to No Action Alternative flows in April and May of wet years, March through May of above normal years, and January through May of below normal and dry years when the increased flows result in increased rearing and foraging habitat and higher dissolved oxygen content (Figure O.3-144). Adult Spring-Run Chinook Salmon would benefit from increased Alternative 4 flows relative to No Action Alternative flows in April and May of wet years, March through June of above normal years, March through May of below normal and dry years, and June of critically dry years due to the resulting increased attraction flows and holding habitat (Figure O.3-144). Because Spring-Run Chinook Salmon benefit from increased Alternative 4 flows relative to No Action Alternative flows during key months of all life stages and because Alternative 4 flows do not comply with minimum instream flow requirements only in dry and critically dry years (Table Table O.3-72, Figure O.3-144), flow-related actions under Alternative 4 would have beneficial effects on Spring-Run Chinook Salmon.

Fall-Run Chinook Salmon

Fall-Run Chinook Salmon would be exposed to the effects of Alternative 4 based on their seasonal occurrence in the Feather River, minimum instream flow requirements in the HFC, and compliance with D-1641. Fall-Run Chinook Salmon occur in the Feather River year-round, with eggs and emerging fry occurring between January and April; juveniles out-migrating year-round with peaks from January to April and August to November; and holding and migrating adults occurring between April and July (NMFS 2016a). All life stages would thus be exposed to the effects of Alternative 4.

Fall-Run Chinook Salmon eggs and emerging fry would benefit from increased dissolved oxygen due to higher Alternative 4 flows in April and May of wet years, from March through April of above normal years, and from January through May of below normal and dry years (Figure O.3-144). Juvenile Fall-Run Chinook Salmon would benefit from increased Alternative 4 flows relative to No Action Alternative flows during the same periods when increased flows result in increased rearing and foraging habitat and higher dissolved oxygen content (Figure O.3-144). Migrating adult Fall-Run Chinook Salmon would benefit from increased Alternative 4 flows relative to No Action Alternative flows in April and May of wet, below normal, and dry years, from April through June of above normal years, and in June of critically dry years due to increased attraction flows and holding habitat (Figure O.3-144). Because Fall-Run Chinook Salmon benefit from increased Alternative 4 flows relative to No Action Alternative flows during key months of all life stages and because Alternative 4 flows do not comply with minimum instream flow requirements only in dry and critically dry years (Table O.3-72, Figure O.3-144), flow-related actions under Alternative 4 would have beneficial effects on Fall-Run Chinook Salmon.

Central Valley Steelhead

Central Valley Steelhead would be exposed to the effects of Alternative 4 based on their seasonal occurrence in the Feather River, minimum instream flow requirements in the HFC, and compliance with D-1641. Central Valley Steelhead eggs and fry occur in the Feather River from December to May; rearing juveniles occur year-round and out-migrate from January to May; peak adult migration occurs in September and October; and adult holding occurs from December to March (NMFS 2016a).

Alternative 4 flows can affect Central Valley Steelhead by influencing water temperature, DO, sedimentation, substrate composition, habitat, food availability, predation, entrainment and stranding risk, habitat availability, and migration cues. During the January to May period in which Central Valley Steelhead juveniles are out-migrating, Alternative 4 flows are higher than No Action Alternative flows in April and May of wet years, March through May of above normal years, and January through May of below normal and dry years (Figure O.3-144). The increased flow under Alternative 4 during these periods can benefit juveniles via increased rearing and foraging habitat and higher DO content. The same is true for the December to May period in which Central Valley Steelhead eggs and fry are present in the Feather River. During the September and October adult peak migration period, No Action Alternative flows are higher than Alternative 4 flows in September of wet and above normal water years, which could create higher levels of flow attraction (Figure O.3-144); there are minimal differences during all other water years. During adult holding from December to March, differences between Alternative 4 and No Action Alternative flows are minimal except in below normal and dry water years when increased flows could increase available habitat (Figure O.3-144). Because Central Valley Steelhead benefit from increased Alternative 4 flows relative to No Action Alternative flows during key months of all life stages and because Alternative 4 flows do not comply with minimum instream flow requirements only in dry and critically dry years (Table O.3-72, Figure O.3-144), flow-related actions under Alternative 4 may have beneficial effects on Central Valley Steelhead.

North American Green Sturgeon

North American Green Sturgeon would be exposed to the effects of Alternative 4 based on their seasonal occurrence in the Feather River, minimum instream flow requirements in the HFC, and compliance with D-1641. Green Sturgeon eggs and larvae occur in the Feather River from March to July; larvae and juveniles occur from April to August; subadults occur year-round; and adults occur from March to August (NMFS 2016a).

For all water year types, modeled flow under Alternative 4 is higher than under the No Action Alternative at various points in the March to August period in which Green Sturgeon eggs, larvae, juveniles, and adults occur in the Feather River, thereby potentially benefiting these life stages with increased DO content, cooler water temperatures, and increased rearing and foraging habitat. Because subadults occur year-round, they would be exposed to the same potential benefits of increased Alternative 4 flow but also to the lower flow under Alternative 4 compared to the no action alternative in September of wet and above normal water years (Figure O.3-144). Because the majority of flow differences between Alternative 4 and the No Action Alternative during key periods of Green Sturgeon presence in the Feather River are indicate increased flow under Alternative 4 and flows below the minimum instream flow requirements occur only in dry and critically dry years (Table O.3-72, Figure O.3-144), flow-related actions under Alternative 4 may have beneficial effects on North American Green Sturgeon.

Potential changes to aquatic resources in the Feather River due to changes in water temperature

Water flow, combined with other environmental drivers, has the potential to affect aspects of water quality such as temperature. Water temperature has the potential to influence the condition and survival of fish species during all stages of their life cycle. Optimal water temperatures can facilitate physiological responses that range from faster growth rates to a heightened immune system, leading to a higher likelihood of survival. In contrast, effects of elevated water temperatures include an inability to satisfy metabolic demand and acute to chronic physiological stress, eventually leading to mortality (Stillwater Sciences 2006; Martin et al. 2017).

HEC-5Q/RecTemp modeling results provide predictions of water temperature at multiple locations in the Feather River HFC from below the Thermalito Afterbay to the mouth of the Feather River. Average water temperatures in the Feather River HFC at Gridley Bridge follow a seasonal pattern where they increase to a high point around 72°F in July or August and decrease to a low point around 47°F in January (Figure O.3-145). Flow releases from Oroville facilities influence Feather River water temperature primarily in summer and fall when these releases can help to lessen water temperatures when air temperatures and solar radiation levels are at their highest. Average water temperatures in the Feather River do not change substantially between water year type in winter, but water temperatures can reach levels up to 4°F warmer (approximately 75°F) in critically dry years than in wet years (approximately 71°F).

Alternative 4 was designed to follow flow regulation procedures similar to procedures under the No Action Alternative as a way to minimize potential adverse temperature-related effects on various fish species in the Feather River.

Table O.3-73. Maximum Daily Mean Water Temperature Objectives for the Feather River HFC

Period	Temperature (°F)
January 1 to March 31	56
April 1 to 30	61
May 1 to 15	64
May 16 to 31	64
June 1 to August 31	64
September 1 to 8	61
September 9 to 30	61
October 1 to 31	60
November 1 to December 31	56

Source: NMFS 2016a.

Modeled average water temperatures under both Alternative 4 and the No Action Alternative (Figure O.3-73) exceed the daily average water temperature objectives of 64°F from June 1 to August 31 and 61°F from September 1 to 30 (Table O.3-73). There is, therefore, potential for adverse temperature-related effects on Feather River anadromous fish species, although the presence and magnitude of these effects would vary between the different species and life stages. In particular, these modeled average temperatures would reach suboptimal or stress-inducing levels for Spring-Run Chinook eggs, fry, and adults, migrating Central Valley Steelhead, and Green Sturgeon eggs, fry, and post-spawn adults.

Modeling results indicate that water temperatures under Alternative 4 operations would be similar to temperatures under the No Action Alternative for much of the year (Figures O.3-145 and O.3-146). In August and September, though, the water in the Feather River HFC at Gridley Bridge would reach temperatures, on average, up to 1°F warmer than under the No Action Alternative (Figure O.3-145). The most pronounced difference in August and September water temperatures between Alternative 4 and No Action Alternative scenarios would occur in wet years when this temperature difference could reach as much as 4°F, whereas no difference is projected in drier water years (Figure O.3-146). In below normal water years, a difference in water temperature between Alternative 4 and No Action Alternative scenarios would also occur in August, when Alternative 4 water temperatures would surpass No Action Alternative temperatures by approximately 2°F (Figure O.3-146). These differences in water temperature between Alternative 4 and the No Action Alternative would therefore occur in summer months when water temperatures are higher (> 60°F) and more likely to lead to physiological stress and mortality. The effects of water temperature on fish in the Feather River vary among species and life stages; however, water temperatures under the No Action Alternative and Alternative 4 scenarios would surpass suboptimal levels for Chinook Salmon between 58°F and 75.2°F, for Steelhead between 55°F and 70°F, and for Green Sturgeon between 66°F and 70°F (Table O.3-74).

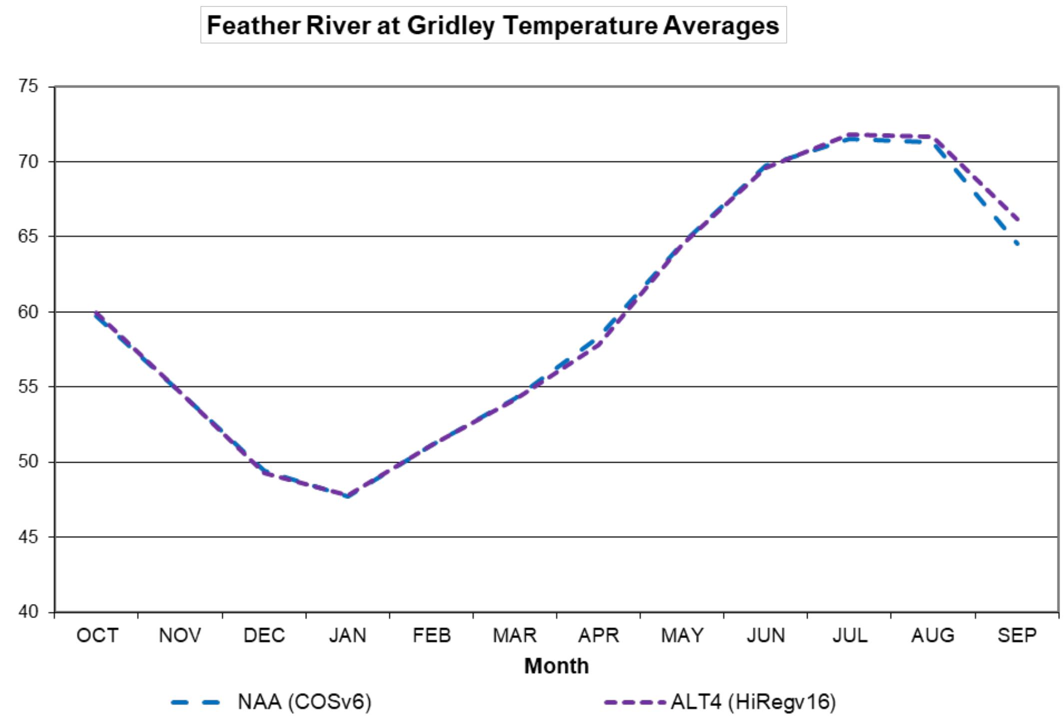


Figure O.3-145. RecTemp Average Feather River Water Temperatures at Gridley Bridge under the No Action Alternative and Alternative 4 Scenarios

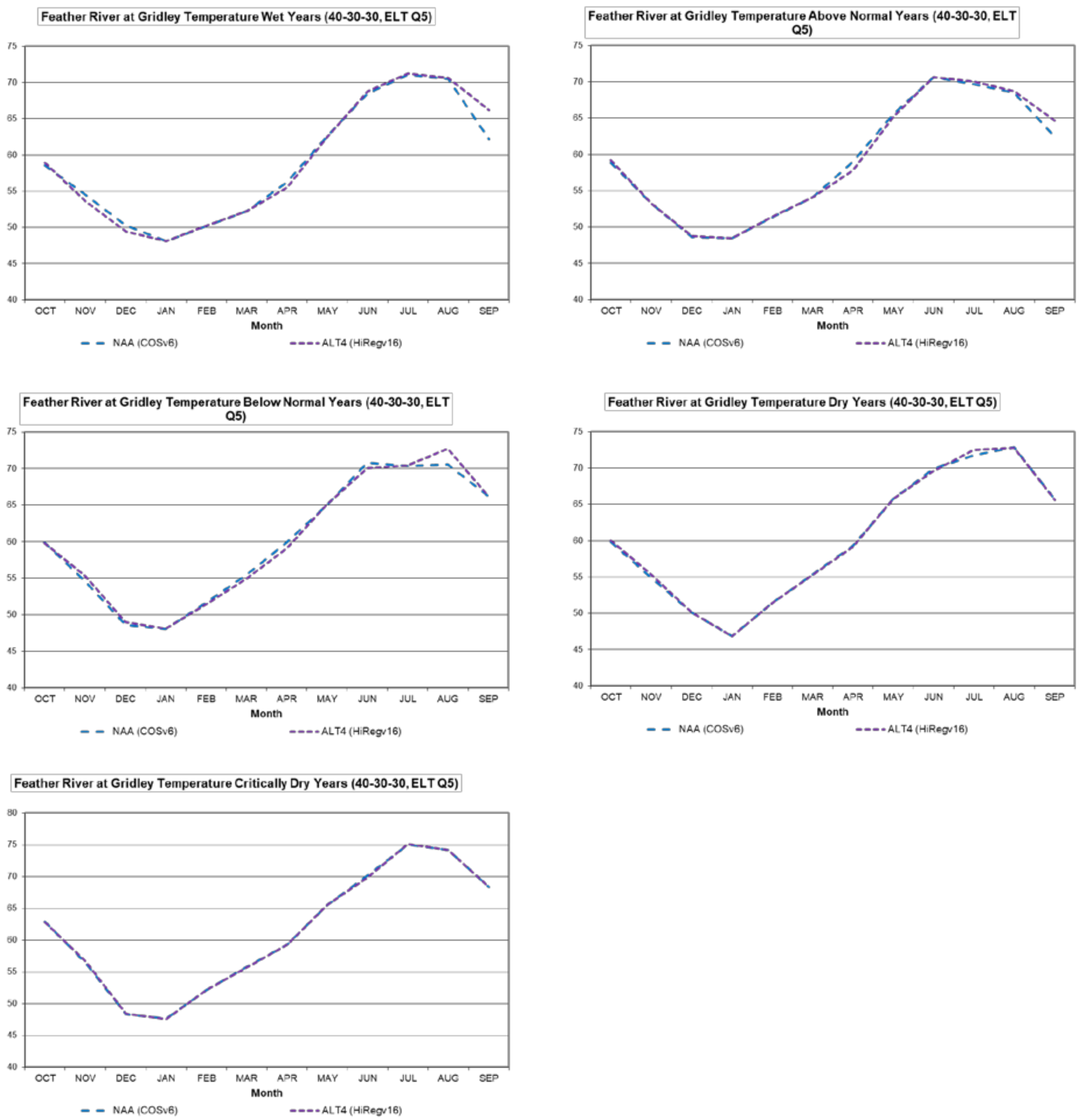


Figure O.3-146. RecTemp Average Estimated Feather River Water Temperatures at Gridley Bridge in Wet and Below Normal Water Year Types under the No Action Alternative and Alternative 4 Scenarios

Table O.3-74. Water Temperatures Suitable for Spring-Run and Fall-Run Chinook Salmon, Central Valley Steelhead, and Green Sturgeon by Life Stage

Life Stage	Peak Occurrence	Optimal	Suboptimal	Stress-inducing
Spring-Run Chinook Salmon				
Eggs to fry	September to October	< 54°F	54°F to 58°F	> 58°F
Rearing to out-migrating	November to May	< 60°F	60°F to 65°F	> 65°F
Migrating adults	March to June	< 56°F	56°F to 65°F	> 65°F
Adult holding	May to August	< 60.8°F	60.8°F to 66.2°F	> 66.2°F
Fall-Run Chinook Salmon				
Eggs to fry	October to April	48.2°F to 55.4°F	55.4°F to 62.6°F	> 62.6°F
Rearing to out-migrating	April to June	55.4°F to 68°F	68°F to 75.2°F	> 75.2°F
Migrating adults	June to April	50°F to 68°F	68°F to 69.8°F	> 69.8°F
Central Valley Steelhead				
Eggs to fry	January	46°F to 52°F	52°F to 55°F	> 55°F
Rearing to out-migrating	January to May	< 65°F	65°F to 68°F	> 68°F
Migrating adults	September to October	< 52°F	52°F to 70°F	> 70°F
Adult holding	December to March	< 60.8°F	60.8°F to 66.2°F	> 66.2°F
Green Sturgeon				
Eggs to fry	May to July	53°F to 65°F	65°F to 66°F	> 66°F
Rearing to out-migrating	May to October	58°F to 66°F	66°F to 69°F	> 69°F
Migrating adults	March to May	53°F to 64°F	64°F to 66°F	> 66°F
Post-spawn adults	March to August	46°F to 68°F	68°F to 70°F	>70°F

Sources: NMFS 2016a; Stillwater Sciences 2006; CDFG 2012a, 2012b.

Winter-Run Chinook Salmon

Winter-Run Chinook are not likely to be affected by changes in water temperature due to differences in flow under Alternative 4 compared to the No Action Alternative due to their limited distribution in the Feather River.

Spring-Run Chinook Salmon

Effects of water temperature on Spring-Run Chinook have been heavily studied in the Feather River, resulting in an understanding of the optimal (beneficial), suboptimal, and stress-inducing (adverse) temperature ranges for each life stage during its period of peak abundance (Table O.3-74).

A difference in water temperature between Alternative 4 and No Action Alternative scenarios during the peak occurrence period for Spring-Run Chinook eggs and emerging fry would occur in in September of wet water years when temperatures under Alternative 1 flows could be up to 3°F higher than temperatures under No Action Alternative flows (Figure O.3-54 and Table O.3-21). This would result in potentially adverse effects from the slightly higher water temperatures under Alternative 4 than under the No Action Alternative, yet water temperatures under both scenarios would fall in the stress-inducing range for this life stage (Table O.3-74). During the peak abundance periods of juveniles (November to May) and migrating adults (March to June), there is no projected difference between water temperatures under Alternative 4 and the No Action Alternative (Figure O.3-145 and Table O.3-74). For the majority of the peak occurrence range for holding adults, there is no difference in water temperature between Alternative 4 and the No Action Alternative (Figure O.3-145 and Table O.3-74); in August of below normal water years, however, water temperatures under Alternative 4 could be up to 2°F higher than under the No Action Alternative (Figure O.3-146). The effect on adult Spring-Run Chinook would likely be negligible because modeled water temperatures would cross the threshold for stress-inducing temperatures under both Alternative 4 and the No Action Alternative for this life stage (Figure O.3-146 and Table O.3-74).

Alternative 4 therefore has the potential for slightly adverse water temperature-related effects on eggs, fry, and holding adults relative to the No Action Alternative yet no difference in temperature-related effects on juveniles or migrating adults.

Fall-Run Chinook Salmon

Effects of water temperature on Fall-Run Chinook have been heavily studied in the Feather River, resulting in an understanding of the optimal (beneficial), suboptimal, and stress-inducing (adverse) temperature ranges for each life stage (Table O.3-74).

Modeling results indicate temperature differences between Alternative 4 and the No Action Alternative only in August and September (Figure O.3-146), and these months do not fall within the peak occurrence periods for Fall-Run Chinook eggs and fry, juveniles, or migrating adults in the Feather River (Table O.3-74). Therefore, no effects on Fall-Run Chinook Salmon due to differences in water temperature between the Alternative 4 and No Action Alternative scenarios are expected.

Central Valley Steelhead

Effects of water temperature on Central Valley Steelhead have been heavily studied, resulting in an understanding of the optimal (beneficial), suboptimal, and stress-inducing (adverse) temperature ranges for each life stage during its period of peak abundance (Table O.3-74).

Central Valley Steelhead eggs, fry, juveniles, and holding adults are present in the Feather River in winter and spring months when there is no projected difference between water temperatures under Alternative 4 and the No Action Alternative (Figure O.3-145 and Table O.3-74). Migrating (ocean to river) adult Steelhead peak in abundance in the Feather River between September and October (Table O.3-74). Modeled water temperatures for Alternative 4 and the No Action Alternative differ in September of wetter water years when temperatures under Alternative 4 could be up to 4°F higher than temperatures under No Action Alternative flows (Figure O.3-146), yet water temperatures would remain in the suboptimal range for migrating adults under both Alternative 4 and the No Action Alternative (Table O.3-74). Adverse effects of water temperature on this life stage are therefore anticipated to be slightly less severe under the No Action Alternative than under Alternative 4, yet Alternative 4 does have the potential for adverse water temperature-related effects on migrating adults relative to the No Action Alternative.

North American Green Sturgeon

Effects of water temperature on Green Sturgeon have been heavily studied in the Feather River, resulting in an understanding of the optimal (beneficial), suboptimal, and stress-inducing (adverse) temperature ranges for each life stage (Table O.3-74).

Green Sturgeon eggs and emerging fry occur in the Feather River from May to July and migrating adults from March to May (Table O.3-74), so neither life stage will be exposed to the modeled differences in water temperature between Alternative 4 and the No Action Alternative (Figure O.3-146). The peak occurrence period for juveniles and post-spawn adults includes August, when modeled Alternative 4 water temperatures can exceed No Action Alternative temperatures by up to 2°F in wet and below normal water years (Figure O.3-146), yet water temperatures remain at stress-inducing levels for both life stages under both flow scenarios (Table O.3-74). Juvenile Green Sturgeon are also present in the Feather River during September when, in wet water years, water temperatures under Alternative 4 flows could be up to 3°F higher than temperatures under No Action Alternative flows (Figure O.3-146 and Table O.3-74). Water temperatures in wet water years would drop from stress-inducing levels for juveniles to suboptimal levels and again to optimal levels later in the month under Alternative 4 than under the No Action Alternative (Figure O.3-146, Table O.3-74). Modeled water temperature differences between Alternative 4 and the No Action Alternative therefore indicate the potential for slightly adverse effects on juveniles and post-spawn adults in summer of wet and below normal water years.

O.3.9.5 *American River*

Potential changes to aquatic resources in the American River from flood control

Flood control would be similar under Alternative 4, compared to the No Action Alternative and would include following the USACE Water Control Manual, with the addition of working with the American River Stakeholders to define the “planning minimum”, an appropriate amount of storage in Folsom Reservoir that represents the lower bound for typical forecasting processes at the end of calendar year. The objective of the planning minimum is to preserve storage to protect against future drought conditions and to facilitate the development of the coldwater pool when possible. The objective of incorporating the planning minimum into the forecasting process is to provide releases of salmonid-suitable temperatures to the lower American River and reliable deliveries to American River water agencies. Analysis of Folsom Storage indicates that under average conditions, there would be little difference in flood control storage under Alternative 4 in comparison to the No Action Alternative for average, dry, and wet years (Figures O.3-55 through O.3-57).

Potential changes to Folsom Reservoir operations in the American River to meet Delta salinity requirements

Folsom Reservoir operations to address Delta water quality requirements under D-1641 would not change under Alternative 4, compared to the No Action Alternative. Folsom Reservoir flow requirements includes releases to meet Delta standards under D-1641, as needed. Since Folsom Reservoir is the closest reservoir to the Delta, releases from Folsom can more quickly address Delta water quality requirements. Releases to address Delta water quality objectives would be conducted, as needed, in coordination with the American River stakeholders. Releases to address Delta water quality objectives would improve water quality conditions, and thus habitat conditions for fish and other aquatic species in the Delta when hydrologic conditions are negatively affecting salinity levels.

Potential changes to aquatic resources from flows in the American River

Flow objectives for Alternative 4 are similar to the objectives for the No Action Alternative with the intent of providing suitable conditions for Fall Chinook and Steelhead. Flows under Alternative 4 are according to the 2017 Flow Management Standard, where additional flow measures include minimizing releases above 4,000 cfs during sensitive life stages, redd dewatering protective measures in January through May (holding releases relatively constant), providing spring pulse flows, and continued summer releases for instream temperature control. Although these objectives result additional flow measures, the modeling indicates that overall change to flows in the American River below Nimbus Dam are minor, and that instream flows during critical periods for Fall Chinook Salmon and Steelhead are driven more by hydrologic conditions (wet versus dry years) than the operations to meet objectives.

Flows in the American River below Nimbus Dam would be similar throughout the year under Alternative 4 with relatively minor differences in average flows (Figure O.3-58) and in wet years (Figure O.3-59), under Alternative 4 compared to the No Action Alternative. In dry and critically dry years, flows would be similar compared with the No Action Alternative with some differences in the late winter/early spring months and in the summer months, compared to the No Action Alternative (Figure O.3-60). Flows would be higher in February through March, slightly lower in July, and higher in August and September.

Changes to minimum flows in the American River below Nimbus Dam would be more evident in low water years, with lower minimum flows in October through January, higher minimum flows in February and March, and higher flows in July through September compared to the No Action Alternative (Figure O.3-60).

Potential changes to aquatic resources in the American River due to changes in water temperature

The water temperature objectives for Alternative 4 are similar the objectives for the No Action Alternative. The objectives address the needs for Steelhead incubation and rearing during the late spring and summer, and for fall–run Chinook Salmon spawning and incubation starting in late October or early November. Specific additional objectives for Alternative 1 are to maintain a daily average water temperature of 65°F (or other temperature as determined by the temperature modeling) or lower at Watt Avenue Bridge from May 15 through October 31, to provide suitable conditions for juvenile Steelhead rearing in the lower American River, and to provide cold water for Fall-Run Chinook Salmon spawning. In addition, the proposed alternative shutter configurations at Folsom Dam to allow temperature flexibility as part of adaptive management may provide for additional improved water temperatures.

Average water temperatures are similar throughout the year in the lower American River under Alternative 4, compared to the No Action Alternative (Figure O.3-62). Differences in water temperatures are more a function of hydrologic conditions than operations to meet objectives, wither lower summer high temperatures wet years (Figure O.3-63) than in dry years (Figure O.3-64). Maximum water temperatures are lower for Alternative 1 in summer months in comparison to the No Action Alternative and the other action alternatives, which would beneficially affect fishery resources (Figure O.3-65).

Potential changes to aquatic resources in the American River from habitat restoration

No additional habitat restoration is proposed under the No Action Alternative, therefore, there would be no changes to habitat in the lower American River under Alternative 4.

O.3.9.6 *Stanislaus River*

Effects would be expected to be similar under Alternative 4 to the potential effects as previously described for Alternative 1. A full description of potential effects for Alternative 1 are described in Section O.3.3.1.6.

O.3.9.7 *San Joaquin River*

Effects would be expected to be similar under Alternative 4 to the potential effects as previously described for the No Action Alternative. A full description of potential effects are described in Section O.3.2.7.

O.3.9.8 *Bay-Delta*

O.3.9.8.1 Delta Smelt

Potential changes to Delta Smelt due to seasonal operations

Relative to the No Action Alternative, potential effects on Delta Smelt from seasonal operations would vary under Alternative 2. The potential south Delta entrainment risk of Delta Smelt under Alternative 4 could be similar to the effects described under the No Action Alternative and Alternative 1 in winter (December–February) for adult Delta Smelt because of generally similar OMR flows (Appendix F, Attachment 3-2, Figures 40-9 through 40-11). For larval/juvenile Delta Smelt in spring (March–June), effects may generally be similar or slightly lesser or greater effects compared to the No Action Alternative, reflecting OMR flows (Appendix F, Attachment 3-2, Figures 40-12 through 40-15). Given the protective nature of the seasonal operations for entrainment risk, effects would be expected to be limited, consistent with the No Action Alternative.

With respect to other habitat attributes discussed previously under analysis of *Potential changes to Delta Smelt due to seasonal operations* for other alternatives, delivery of sediment to the Delta and resulting turbidity-related predation risk would be expected to be similar to the No Action Alternative, as indicated by general similarity of CalSim-modeled flows in the Sacramento River at Rio Vista during the higher flow winter/spring months (Appendix F, Attachment 3-2, Figures 32-9 through 32-15). Related to predation risk from Silversides, March to May south Delta exports would be less under Alternative 4 than the No Action Alternative (Appendix F, Attachment 3-3, Table 53-4), as generally would be June–September Delta inflow (as represented largely by Freeport flow; Appendix F, Attachment 3-2, Table 29-4) which could give greater predation risk under Alternative 4, based on the correlative analysis described in the ROC LTOBA). As discussed for other alternatives, there is uncertainty in this conclusion given that the relationships are correlations and do not necessarily imply causality and require further investigation (Reclamation 2019). Similar to Alternative 1, the inclusion of the USFWS (2008) fall X2 criteria under the No Action Alternative but not in Alternative 4 has the potential to affect Delta Smelt predation risk by resulting in less overlap of the low salinity zone with turbid habitat.

As described for other alternatives, various aspects of seasonal operations under Alternative 4 have the potential to affect Delta Smelt food availability relative to the No Action Alternative. There would be little difference in Yolo Bypass flooding and therefore little difference between Alternative 4 and the No Action Alternative in potential food effects for adult Delta Smelt in winter/spring (e.g., Appendix F, Attachment 3-2, Figures 25-2 through 25-6). In spring (March–May), Delta outflow would be greater and therefore X2 would be lower under Alternative 4 than the No Action Alternative, potentially producing positive effects on Delta Smelt prey (*E. affinis*), in contrast to the potential negative effects suggested for other alternatives (e.g., Alternative 1). Summer/fall subsidy of *P. forbesi* to the low salinity zone, as discussed for Alternative 1 for example, has the potential to be increased relative to the No Action Alternative, given the generally lower frequency of negative San Joaquin River at Jersey Point flows under Alternative 4 (Figures).3-70 through O.3-72).

Relative to the No Action Alternative and similar to Alternatives 2 and 3, under Alternative 4 the size of the low salinity zone in wet and above normal years would be expected to be considerably reduced (Figures O.3073 through O.3-75). Similar to other alternatives, the percentage of time that the low salinity zone is outside of Suisun Bay would also be expected to be considerably less under Alternative 4 than the No Action Alternative (Figure O.3-76), thereby potentially negatively affecting Delta Smelt under Alternative 4 relative to the No Action Alternative.

Based on the general similarity between Alternative 1 and Alternative 4 in operations during the summer/fall (June–October/November) period of potential harmful algal bloom occurrence (as reflected by OMR flows, for example: Appendix F, Attachment 3-2, Figures 40-7 and 40-8, 40-15 through 40-18), there would be expected to be little difference in modeled velocity (a potential indicator of harmful algal bloom disruption) between Alternative 4 and the No Action Alternative, given the similarity in velocity between the No Action Alternative and Alternative 1 (Reclamation 2019). This suggests that there would be little difference in harmful algal bloom potential between Alternative 4 and the No Action Alternative.

Potential changes to Delta Smelt from Delta Cross Channel operations.

The potential effects of DCC operations on Delta Smelt under Alternative 4 may be generally similar to those occurring under the No Action Alternative, given that both are based on D-1641 and NMFS (2009) BO RPA requiring consultation to avoid exceeding water quality standards. There is uncertainty in the effects that the DCC has on Delta Smelt, as described for Alternative 1.

Potential changes in Delta Smelt survival related to the Temporary Barriers Project

Under Alternative 4, potential effects of the three south Delta agricultural barriers on Delta Smelt generally would be expected to be similar to the effects under Alternative 1 (i.e., near-field predation and potential effects on transport of *P. forbesi* to the low salinity zone; see also ROC LTO BA p. 5-408), although the effects may be less because of greater OMR restrictions and therefore less risk of Delta Smelt being present in the south Delta under Alternative 4. As with Alternative 1, there may be less potential effect relative to the No Action Alternative because of no HOR barrier, although Delta Smelt would rarely be found near the HOR barrier based on historical observations.

Potential changes to Delta Smelt due to changes from Tracy and Skinner fish facilities improvements

The potential effects to Delta Smelt from the Tracy and Skinner fish facilities under Alternative 4 (i.e., mortality from pre-screen loss, collection, handling, transport, and release, with only a very small fraction potentially surviving the salvage process) could be similar to the effects described under the No Action Alternative and Alternative 1 in winter (December–February) for adult Delta Smelt because of generally similar OMR flows (see above discussion in *Potential changes to Delta Smelt due to seasonal operations*) and therefore potentially similar proportion of Delta Smelt entering the south Delta and being exposed to the south Delta fish facilities. Generally similar or slightly lesser or greater effects may occur under Alternative 4 compared to the No Action Alternative in spring (March–June).

The following project-level effects would be expected to be similar under Alternative 4 to the potential effects as previously described for Alternatives 2 and 3 because of limited potential for effect or because the operations are similar:

Potential changes to Delta Smelt from Contra Costa Water District operations

Potential changes to Delta Smelt from North Bay Aqueduct operations

Potential changes to Delta Smelt from water transfers

Potential changes to Delta Smelt from Clifton Court aquatic weed and algal bloom management

Potential changes to Delta Smelt due to changes from Suisun Marsh facilities

O.3.9.8.2 Longfin Smelt

Potential changes to Longfin Smelt due to seasonal operations

As described for the other alternatives, the principal potential effect of seasonal operations on Longfin Smelt would be changes in population abundance as a result of changes in Delta outflow. During the December–May period identified as important for Delta outflow by Nobriga and Rosenfield (2016), CalSim modeling suggests that under Alternative 4 Delta outflow generally would be greater than the No Action Alternative (Appendix F, Attachment 3.2, Table 41-2), thereby potentially positively affecting Longfin Smelt through increases in population abundance. As described for Alternative 1, however, the magnitude of the difference may be limited because of density-dependent effects, and there is appreciable variability in the estimates generated by the Nobriga and Rosenfield (2016) model, with other analyses finding stronger correlations with general hydrological conditions rather than Delta outflow specifically (Maunder et al. 2015).

Relative to the No Action Alternative, there is the potential for Longfin Smelt entrainment risk to vary under Alternative 4, as reflected by sometimes higher and sometimes lower OMR flow in December to May (Appendix F, Attachment 3.2, Figures 40-8 through 40-14) and generally similar or greater San Joaquin River flow at Jersey Point in January to March (Figures SJR_jan, SJR_feb, SJR_mar). However, as noted previously for other alternatives, it should be borne in mind that the modeling for Alternative 4 does not reflect continued adherence to the criteria of the CDFG (2009) SWP ITP, nor to any subsequent ITP that may govern Longfin Smelt south Delta entrainment protection. As previously noted for other alternatives, estimates of Longfin Smelt population-level entrainment loss during the D-1641-based regulatory period (i.e., prior to 2007, and what is included under Alternatives 2 and 3) suggest that low percentages (0–3.6%) of Longfin Smelt were lost to entrainment (ICF International 2016, Table 4.2-10 [p. 4-286] and Table 4.2-11 [p. 4-288]). This suggests that Longfin Smelt proportional entrainment loss under Alternative 4 would also be limited.

The following project-level effects under Alternative 4 would be expected to be somewhat less than Alternatives 1 through 3 because of greater OMR flow, therefore giving lower potential for Longfin Smelt to be in the south Delta; however, effects would be expected to be limited given low occurrence of the species in the south Delta:

Potential changes in Longfin Smelt survival related to the Temporary Barriers Project

Potential changes to Longfin Smelt due to changes from Tracy and Skinner fish facilities improvements

The following project-level effects would be expected to be similar under Alternative 4 to the potential effects as previously described for Alternatives 2 and 3 because of limited potential for effect or because the operations are similar:

Potential changes to Longfin Smelt from Contra Costa Water District operations

Potential changes to Longfin Smelt from North Bay Aqueduct operations

Potential changes to Longfin Smelt from water transfers

Potential changes to Longfin Smelt from Clifton Court aquatic weed and algal bloom management

Potential changes to Longfin Smelt from changes to Suisun Marsh facilities

O.3.9.8.3 Sacramento Winter-Run Chinook Salmon

Potential changes to aquatic resources due to seasonal operations

Rearing Winter-Run Chinook Salmon are present in the Delta between October and May. Key habitat attributes relevant to seasonal operations in the Delta include out-migration cues and entrainment risk. Hydrodynamic changes associated with river inflows and South Delta exports have been suggested to adversely affect juvenile Chinook Salmon in two distinct ways: 1) "near-field" mortality associated with entrainment to the export facilities, and 2) "far-field" mortality resulting from altered hydrodynamics. Near-field or entrainment effects of proposed seasonal operations can be assessed by examining patterns of proportional population entrainment available from decades of coded wire tag studies (e.g., Zeug and Cavallo 2014). A foundation for assessing far-field effects has been provided by work of the Collaborative Adaptive Management Team's (CAMT) Salmonid Scoping Team (SST). The SST completed a thorough review of this subject and defined a driver-linkage-outcome (DLO) framework for specifying how water project operations (the "driver") can influence juvenile salmonid behavior (the "linkage") and potentially cause changes in survival or routing (the "outcome"). The SST concluded altered "Channel Velocity" and altered "Flow Direction" were the only two hydrodynamic mechanisms by which exports and river inflows could affect juvenile salmonids in the Delta. Figure O.3-147 provides a simplified conceptual model of the DLO defined by the CAMT SST.

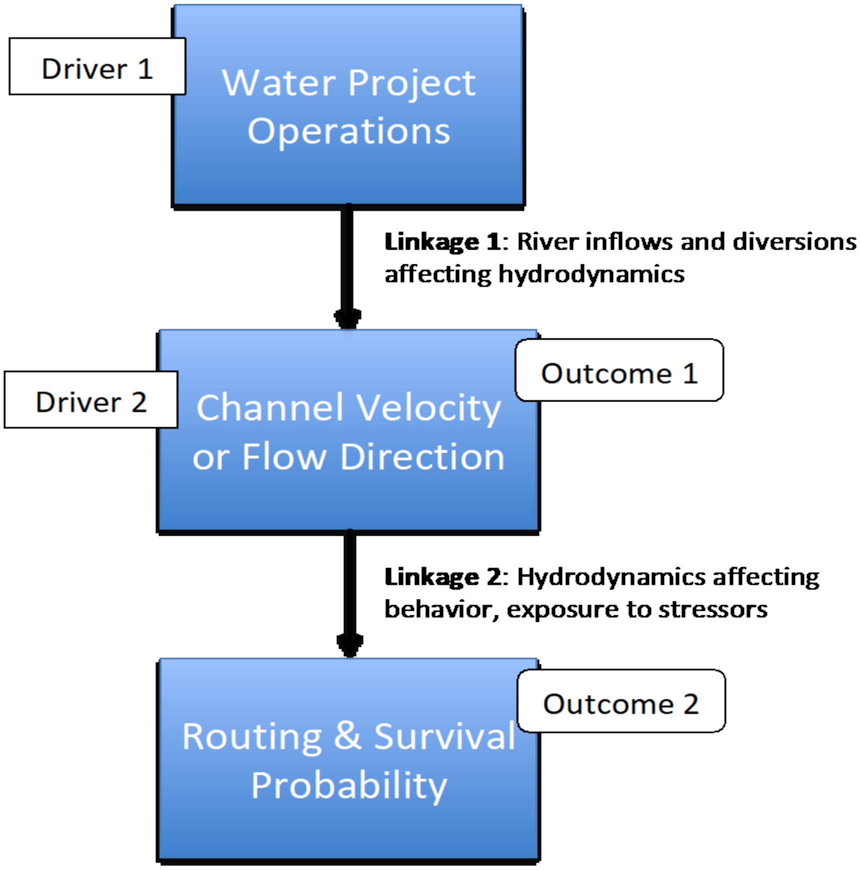


Figure O.3-147. Conceptual Model for Far-field Effects of Water Project Operations on Juvenile Salmonids in the Delta. This CM is a Simplified Version of the Information Provided by the CAMT SST.

To assess the potential for water project operations to influence survival and routing, Reclamation and DWR analyzed Delta hydrodynamic conditions by creating maps from DSM2 Hydro modeling. The maps are based on a comparative metric, proportion overlap (more below), to capture channel-level hydrodynamic details as a single number for color-scale mapping of Delta channels.

The objective of the comparative metric is to summarize the water velocity time series for each channel and scenario such the channel-level comparison is captured in a single number. For the proportion overlap metric, kernel density estimates are calculated on each time series. The kernel density estimates represent a non-parametric smoothing of the empirical distribution of time series values. The proportion overlap of two kernel density estimates is calculated with the following steps: 1) calculate the total area under the curve (AUC_t) as the sum of the AUC for each density estimate, 2) calculate the AUC of the overlapping portions (AUC_o) of the two density distributions being compared, and 3) calculate the overlapping proportion of the density distributions as AUC_o/AUC_t. Proportion overlap is naturally bound by zero and one; a value of zero indicates no overlap and a value of one indicates complete overlap. Lower values of proportion overlap identify channels demonstrating larger differences in a scenario comparison.

The proportion overlap metric is best applied over relatively short time periods because seasonal and annual variation in water velocity can overwhelm differences between scenarios. Thus, Reclamation calculated proportion overlap for every DSM2 channel for two seasons (Dec-Feb, Mar-May) in each water year (1922–2003). DSM2 output was excluded from water year 1921 to allow for an extensive burn-in period. The proportion overlap was calculated based on hourly DSM2 output. Because each season was roughly 90 days, each comparison involved roughly 4,300 DSM2 values (2 scenarios * 24 hours * 90 days) for each channel.

Because the proportion overlap was calculated for each channel in each water year, the proportion overlap values were summarized prior to mapping (i.e., not feasible to map proportion overlap for every comparison in every water year). To summarize, the minimum proportion overlap for each channel for each water year type for each comparison were found. The minimum values represent the maximum expected effect. Note that the year with the minimum proportion overlap for one channel might not be the same year as for another channel.

Entrainment

In the December through June period, the average total export rate, under Alternative 4, is similar to the export rate under No Action Alternative. Therefore, similar entrainment is expected compared to the No Action Alternative.

Zeug and Cavallo (2014) analyzed more than 1,000 release groups representing more than 28 million coded wire tagged juvenile fish including winter, late fall and Fall-Run Chinook Salmon. This data represents large release groups of tagged smolts where the number of fish representing each release group lost to entrainment at the export facilities has been estimated. Cavallo (2016) provided a supplemental assessment of Winter-Run Chinook Salmon entrainment risk (building upon Zeug and Cavallo 2014) that showed total CVP and SWP exports described entrainment risk better than OMR or other flow metrics. Entrainment loss results as reported below represents the proportion of coded wire tagged Winter-Run Chinook Salmon released upstream of the Delta which were entrained at South Delta export facilities. This proportion accounts for and includes expansion for sampling effort at the salvage facilities and also prescreen mortality. For December through February, Alternative 4 has an average total export rate greater than No Action Alternative (7,736 and 7,617 cfs respectively; Figure O1-1 in Appendix O, Attachment 1) and will therefore have similar entrainment risk. Entrainment losses should average 0.4% and not exceed 2.2%. In the March through June period, total exports for Alternative 4 will result in similar entrainment risk relative to No Action Alternative (3,610 vs. 4,164 cfs, respectively; Figure O1-2 in Appendix O, Attachment 1), and entrainment losses should average 0.09% and not exceed 1.5%.

Routing

Routing of juvenile Chinook Salmon into alternative migration routes is closely related to hydrodynamics (Perry et al. 2015; Cavallo et al. 2015; Steel et al. 2012). Changes to hydrodynamics in Delta channels resulting from Alternative 4 were evaluated using DSM2. Juvenile Winter-Run Chinook Salmon are present in the Sacramento River at Sherwood Harbor upstream of the first distributary junctions between November and March with peak abundance in February and March (Reclamation 2019).

In the December to February period, velocity overlap between Alternative 4 and No Action Alternative in the Sacramento River mainstem between the Sutter-Steamboat and DCC/Georgiana Slough Junctions, was more than 92%, 76%, 63%, 71%, and 8% in critically dry, dry, below normal, above normal, and wet years, respectively (Figure O1-53 in Appendix O, Attachment 1). During the December through February period, velocities were higher under Alternative 4 in all water year types indicating routing into the interior Delta would be lower relative to No Action Alternative (Perry et al. 2015; Figure O1-57 in Appendix O, Attachment 1). During the March to May period, velocity overlap between No Action Alternative and Alternative 4 was more than 91%, 69%, 48%, 46%, and 62% in critically dry, dry, below normal, above normal, and wet years, respectively (Figure O1-54 in Appendix O, Attachment 1).

Abundance of juvenile Winter-Run Chinook Salmon at Chipps Island peaks in March and April but fish are collected between December and May (Reclamation 2019). During this time period, Winter-Run Chinook Salmon originating from the Sacramento River that enter the interior Delta via Georgiana Slough and the Delta Cross Channel can potentially be exposed to hydrodynamic effects associated with the CVP and SWP that could affect routing. Once these fish arrive at the junction of the Mokelumne River and the San Joaquin River, they can move south toward the export facilities or west toward the ocean. In the December through February period analysis of DSM2 data indicates that there is little change to velocities in the region of the junction of the Mokelumne and San Joaquin Rivers between Alternative 4 and the No Action Alternative (Figure O1-55 in Appendix O, Attachment 1). Similar results were obtained when comparing Alternative 4 to the No Action Alternative in the March to May period (Figure O1-56 in Appendix O, Attachment 1).

Through-Delta Survival

Perry et al. (2018) found that the effect of flow on survival is not uniform throughout the Delta. Relationships between flow and survival were significant only in reaches where flow changes from bi-directional to unidirectional when discharge increases.

To examine potential effects of Alternative 4, changes in velocity distributions were examined for the Sacramento River at Walnut Grove and Steamboat Slough which are both in this “transitional” region. During the December to February period at Walnut Grove, there are higher velocities under Alternative 4 than the No Action Alternative in all water year types (Figure O1-57 in Appendix O, Attachment 1). At Steamboat Slough in the December through February period, there are higher velocities under Alternative 4 than the No Action Alternative in all water year types (Figure O1-58). In the March through May period at Walnut Grove, when Alternative 4 was compared to the No Action Alternative, velocity overlap ranged from 61.5-94.6% (Figure O1-59 in Appendix O, Attachment 1). Velocity overlap at Steamboat Slough in the March through May period ranged from 68.4% to 95.7% (Figure O1-60 in Appendix O, Attachment 1).

Overall, Alternative 4 results in similar or higher velocities in the Delta in the spring than under No Action Alternative, during the outmigrating juvenile time period. Survival probabilities are non-linear; however, the similar or higher discharge at Freeport in the spring under Alternative 4 results in similar or higher survival in the transition reaches. Higher flows also lead to lower probability of routing into the interior Delta, which has the lowest survival probability regardless of flow.

Potential changes to aquatic resources OMR Management

See section on seasonal operations above which integrate OMR management.

Potential changes to aquatic resources due to Delta Cross Channel operations

Under Alternative 4, the DCC may be closed for up to 45 days from November through January for fishery protection purposes. From February 1 through May 20, the gates are closed for fishery protection purposes. The gates may also be closed for 14 days from May 21 through June 15 for fishery protection purposes. The peak migration of juvenile Winter-Run Chinook Salmon in the Sacramento River at Sherwood Harbor, which is near the DCC, occurs from February through March (Reclamation 2019). Therefore, the DCC is closed for the majority of the juvenile Winter-Run Chinook Salmon migration period in the Sacramento River and as such the proportion of juvenile Winter-Run Chinook Salmon exposed to an open DCC would be negligible. Juvenile Chinook Salmon entrained into an open DCC and transported to the interior Delta have reduced survival (Perry et al. 2010; Perry et al. 2018).

Potential changes to aquatic resources due to the Temporary Barriers Project

Juvenile Winter-Run Chinook Salmon are not expected to co-occur in space or time with the agricultural barriers indicating no potential impacts.

Potential changes to aquatic resources due to Contra Costa Water District operations

CCWD's operations in Alternative 4 are consistent with the operational criteria specified in separate biological opinions and permits that govern operations at CCWD's intakes and Los Vaqueros Reservoir (NMFS 1993, 2007, 2010, 2017; USFWS 1993a, 1993b, 2000, 2007, 2010, 2017; CDFG 1994, 2009a) and remain unchanged from the No Action Alternative.

The Contra Costa Canal Rock Slough Intake is located on a dead-end slough, far from the main migratory route for Winter-Run Chinook Salmon (NMFS 2017c), approximately 18 miles from the Sacramento River via the shortest route. Designated critical habitat for Winter-Run Chinook Salmon does not occur within Rock Slough, but is present further to the north in the Delta (NMFS 2017c, 2014). Salmonids are expected to avoid the area of the Rock Slough Intake during certain times of the year based on historical water temperatures.

Fish monitoring prior to the construction of the Rock Slough Fish Screen (RSFS) indicates the timing and magnitude of Winter-Run Chinook Salmon presence near the Rock Slough Intake. Since 1994, fish monitoring has been conducted by CDFW and CCWD consistent with the separate biological opinions and permits that govern CCWD's operations. From 1994 through 1999, CDFW conducted fish monitoring at the Rock Slough Intake and in the Contra Costa Canal up to the first pumping plant. Over this 6-year period, CDFW captured a total of 13 juvenile Winter-Run Chinook Salmon from January through May (CDFG 2002c; NMFS 2017c). From 1999 to 2009, the 11 years prior to construction of the RSFS, CCWD's Fish Monitoring Program collected no juvenile or adult Winter-Run Chinook Salmon at the Rock Slough Headworks (Reclamation 2016; NMFS 2017c).

Since construction of the RSFS, operation of the hydraulic rake cleaning system has been shown to trap and kill adult Chinook Salmon and other non-listed fish (Reclamation 2016). From 2011-2018, 47 Salmon were recovered at the RSFS (Reclamation 2016, Appendix A; Tenera Environmental 2018a), but none of the captured fish were identified as Winter-Run Chinook Salmon (NMFS 2017c).

NMFS issued a biological opinion in 2017 (NMFS 2017c) that considered improvements to the RSFS facility including the hydraulic rake cleaning system, operations and maintenance (O&M) of the RSFS and associated appurtenances, and administrative actions such as the transfer of O&M activities from Reclamation to CCWD. NMFS determined that the O&M of RSFS may result in the incidental take of juvenile Winter-Run Chinook Salmon and provided an incidental take limit based upon the number of listed fish collected in the pre and post-construction RSFS monitoring (NMFS 2017c). The incidental take provided in NMFS 2017c is five juvenile Winter-Run Chinook Salmon per year.

CCWD's Fish Monitoring Program also samples behind the fish screens at CCWD's other south Delta intakes. Since the intakes have been in operation, CCWD's Fish Monitoring Program has never collected Winter-Run Chinook Salmon at CCWD's Old River Intake or Middle River Intake (CCWD 2019).

CCWD's operations, including operation of the Rock Slough, Old River, and Middle River intakes and Los Vaqueros Reservoir, are simulated in the CalSim model. Thus, CalSim results discussed throughout this appendix include the effects of CCWD's operations in combination with all other water diversions and reservoir operations. A further analysis was undertaken to isolate the maximum possible effects of CCWD's operations on Delta hydrodynamics by determining the effect that CCWD pumping at

maximum capacity would have on Delta channel water velocity. Results of this analysis are shown below; in all cases the maximum possible effect of CCWD's operations is de minimis.

Due to the location of the Rock Slough Intake near the end of a dead-end slough, far from the main migratory routes, juvenile Winter-Run Chinook Salmon are not likely to be in the vicinity of the Rock Slough Intake. However, according to NMFS (2017), juvenile Salmon can be “drawn” into the south Delta under reverse flows and high CVP and SWP pumping rates. One indicator of reverse flows is the net flow in Old and Middle Rivers (OMR). Rock Slough Intake is located on Rock Slough, approximately 3.5 miles west of the junction of Rock Slough and Old River, which is over 12 river miles north of the gates to the SWP Clifton Court Forebay. Given its location, the Rock Slough Intake does not affect OMR, and any effect that diversions at Rock Slough Intake would have in the Old and Middle River corridor would be to increase the northerly (positive) flow away from the Banks and Jones Pumping Plants.

However, diversions at the Rock Slough Intake could affect flows in the San Joaquin River at Jersey Point, which is approximately 14 river miles from the Rock Slough Intake (via the shortest route through Franks Tract). Mean velocity in a river channel can be calculated by dividing the flow rate by the cross-sectional area of the channel. The maximum effect of Rock Slough diversions on the channel velocity would be the maximum diversion rate (350 cfs) divided by the minimum cross-sectional area of the channel. This calculation assumes that all water diverted at Rock Slough comes from the San Joaquin River at Jersey Point, which is a conservative assumption (i.e., overestimates the effect on velocity). The cross-sectional area of the San Joaquin River at Jersey Point is approximately 60,500 square feet (sf), but varies depending on the tidal stage from approximately 56,000 sf (at low tide and low San Joaquin River flow) to 68,000 sf (at high tide and high San Joaquin River flow) as shown in Figure O.3-148.

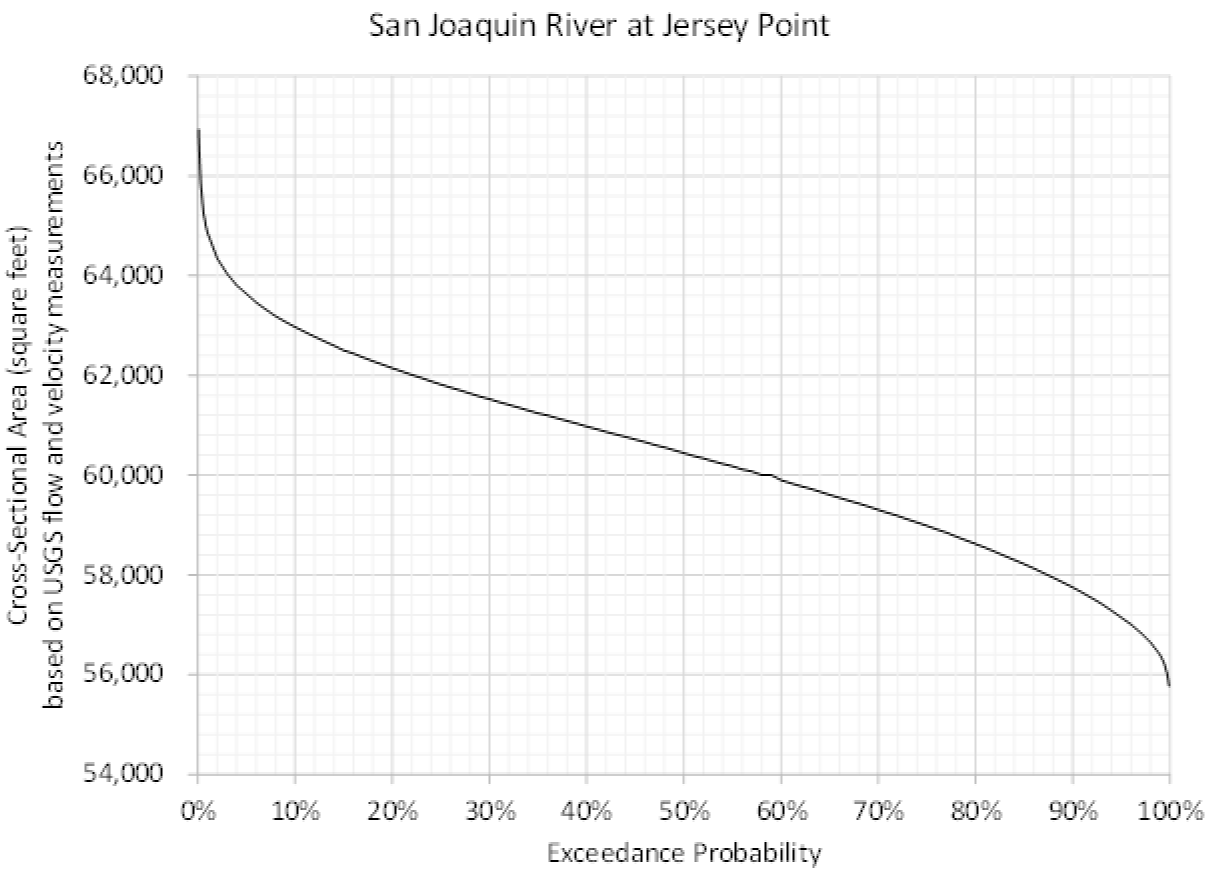


Figure O.3-148. Cross-sectional area of the San Joaquin River at Jersey Point (Station: 11337190) Calculated from USGS Measurements of Flow and Velocity every 15 Minutes for Water Years 2014 through 2018.

The maximum effect of water diversions at Rock Slough Intake on velocity in the San Joaquin River at Jersey Point is calculated as 350 cfs divided by 56,000 square feet; resulting in 0.00625 feet per second (ft/sec). For comparison, the velocity threshold for design of fish screens to prevent impingement of salmonids is 0.33 ft/sec, which is 50 times the maximum possible contribution from Rock Slough diversions. Furthermore, the actual effect is likely to be much lower than 0.00625 ft/sec because the water diverted at the Rock Slough Intake does not all come from the San Joaquin River west of Jersey Point.

Recognizing that CCWD owns and operates two additional intakes in the south Delta, the combined effect of all three intakes is examined. CCWD's Old River Intake and Middle River Intake have a physical capacity of 250 cfs at each intake. If CCWD were to divert at all three intakes at the maximum capacity at the same time, total CCWD diversions would be 850 cfs. The corresponding effect on velocity in the San Joaquin River at Jersey Point would be 0.015 ft/sec. The velocity threshold used to protect salmonids from diversions in the vicinity of fish screens (0.33 ft/sec) is over 21 times greater than the maximum possible contribution from CCWD's combined physical capacity. The water diversions at the Rock Slough Intake when combined with diversions at CCWD's Old River Intake and Middle River Intake have a negligible effect on velocity along the migratory path for juvenile Winter-Run Chinook Salmon and are not likely to affect the movement of juvenile salmonids.

Nonetheless, even extremely small changes in velocity can affect the movement of neutrally buoyant

particles such as phytoplankton. To examine the effect on neutrally buoyant particles, the distance that a particle would travel due to the maximum permitted Rock Slough diversions over the course of a day is calculated. A change in velocity of 0.00625 ft/sec could move a neutrally buoyant particle approximately 540 ft over the course of the day (0.00625 ft/sec * 86,400 sec/day). For comparison, the tidal excursion on the San Joaquin River at Jersey Point during a flood tide (i.e., the distance a particle will travel tidally upstream during a flood tide) is about 34,000 ft on average (or 6.4 miles), which is about 63 times the distance that diversions at Rock Slough could move a particle at the same location over the course of a full day. Therefore, the maximum possible contribution of diversions at Rock Slough on movement of neutrally buoyant particles such as phytoplankton is not significant in comparison to the tidal excursion and mixing at this location.

In summary, CCWD's operations under Alternative 4 would remain consistent with the operational criteria specified in separate biological opinions and permits that govern operations at CCWD's intakes and Los Vaqueros Reservoir, and as shown above, the effect of CCWD's operations on Delta hydrodynamics is negligible.

Potential changes to aquatic resources due to North Bay Aqueduct operations

Alternative 4 includes the North Bay Aqueduct (NBA) intake in the North Delta and operation of the Barker Slough Pumping Plant. Listed salmonids may be present in the waterways adjacent to the Barker Slough Pumping Plant (monitoring data is available at https://www.wildlife.ca.gov/Regions/3)). There should be no discernable effect to the Winter-Run Chinook Salmon due to the operations of the Barker Slough Pumping Facility. This is due to the infrequent presence of Winter-Run Chinook Salmon in the monitoring surveys indicating a low risk of entrainment. Further, Barker Slough Pumping Facility fish screens are designed to protect juvenile salmonids per NMFS criteria and should prevent entrainment while greatly minimizing any impingement of fish against the screen.

Potential changes to aquatic resources due to water transfers

Under Alternative 4, Reclamation is extending the water transfer window until November, from the current July through September window. This extension could result in increased flows entering the Delta and increased pumping at Jones and Banks Pumping Plants.

Egg, alevin, and fry life stages of Winter-Run Chinook Salmon do not occur in the Delta, and therefore would not be affected by this action. Winter-Run Chinook Salmon juveniles enter the Delta starting in December, and therefore would be unlikely to be exposed to increased pumping of water transfers through November. Adults returning from the ocean could possibly be in the Delta in July; however, they are strong swimmers, large fish that can avoid predators, and are unlikely to have impacts associated with direct entrainment of the pumping plants.

Potential changes to aquatic resources from Clifton Court aquatic weed removal

Few if any juvenile Winter-Run Chinook Salmon would be expected to be exposed to the Clifton Court Forebay Aquatic Weed Control Program. Juvenile Winter-Run Chinook Salmon are present in the Delta between December and May with a peak in March and April (Reclamation 2019). The application of aquatic herbicide to the waters of CCF will occur during the summer months of July and August. Thus, the probability of exposing Winter-Run Chinook Salmon to the herbicide is very low. Based on typical water temperatures in the vicinity of the salvage facilities during this period, the water temperatures would be incompatible with salmonid life history preferences, generally exceeding 70°F by mid-June.

Mechanical harvesting would occur on an as-needed basis and, therefore, Winter-Run Chinook Salmon could be exposed to this action, if entrained into the CCF.

As discussed in Appendix D, treatment of harmful algal blooms with peroxide-based algaecide is proposed to occur as needed, year-round, but there are no anticipated impacts to fish because the oxidation reaction occurs immediately upon contact with the water, destroying algal cell membranes and chlorophyll, with hydrogen peroxide and oxygen as byproducts.

Potential changes to aquatic resources due to changes from Tracy and Skinner Fish Facility improvements

A small proportion of juvenile Winter-Run Chinook Salmon are expected to be exposed to the Tracy Fish Facility (Zeug and Cavallo 2014). However, for fish that arrive at the facility, the proposed improvements are likely to increase survival through the facility. Winter-Run Chinook Salmon adults would not be expected to be exposed to the effects of construction of the carbon dioxide injection device proposed for the Tracy Fish Facility, based on the timing of in-water construction (August to October) and the typical seasonal occurrence of this life stage in the Delta (Reclamation 2019).

Few if any juvenile Winter-Run Chinook Salmon would be expected to be exposed to construction of the carbon dioxide injection device proposed for the Tracy Fish Facility Improvements based on lack of observed salvage during the August to October in-water work window (see Figures F.2.7, F.2.8, and F.2.9 in Appendix F of the ROC LTO BA). However, a few early migrants could occur during the in-water work window based on occurrence in the north Delta (see Figures WR_Seines and WR_Sherwood in Appendix F of the ROC LTO BA).

To the extent that the construction affects the ability of juvenile Winter-Run Chinook Salmon to be efficiently salvaged (as part of the entrainment risk habitat attribute in the SAIL conceptual model; Figure 5.6-44), there could be a minor effect to a small number of individuals, although risk would be minimized through appropriate mitigation measures for aquatic resources (Appendix E, *Mitigation Measures*). There is low potential exposure because of the in-water work window, the application of mitigation measures, and the small scale of the in-water construction.

Skinner Fish Facility improvements from predator control efforts to reduce predation on listed fishes following entrainment into CCF could reduce pre-screen loss of juvenile Chinook Salmon entrained into CCF. It is important to note that only small proportions of Winter-Run Chinook Salmon are lost at the SWP (Zeug and Cavallo 2014).

Potential changes to aquatic resources due to changes from Suisun Marsh facilities

Operation of the SMSCG from October through May to meet salinity standards set by the State Water Resources Control Board and Suisun Marsh Preservation Agreement provides water quality benefits to Winter-Run Chinook Salmon habitat. This beneficial operation coincides with downstream migration of juvenile Winter-Run Chinook Salmon (Reclamation 2019). Montezuma Slough provides an alternative route to their primary migration corridor through Suisun Bay. No data are available to estimate the abundance of juvenile Winter-Run Chinook Salmon in Montezuma Slough thus, the proportion of the total run utilizing this route is unknown. Winter-Run Chinook Salmon typically migrate through the estuary several months before spawning, but an extended delay in the estuary may affect their ability to access their natal spawning streams. Winter-Run generally utilize high stream flow conditions to assist their upstream migration. Rapid upstream movement may be needed to take advantage of a short duration high stream flow event, particular in dry years when high flow events may be uncommon. NMFS (2009) determined that operation of the SWSCG is unlikely to impede migration of juvenile salmonids or produce conditions that support unusually high numbers of predators.

As described by NMFS (2009: 437-438), the Roaring River Distribution System (RRDS)'s water intake (eight 60-inch-diameter culverts) is equipped with fish screens (3/32-inch opening, or 2.4 mm) operated to maintain screen approach velocity of 0.7 ft/s, so that juvenile Winter-Run Chinook Salmon would be excluded from entrainment.

The Morrow Island Distribution System (MIDS) diverts water from Goodyear Slough through three 48-inch diameter culverts during high tide. Although the MIDS intakes do not currently have fish screens, its unlikely juvenile Winter-Run Chinook Salmon will be entrained into the water distribution system, since Winter-Run Chinook have not be caught in past surveys. Also, the large size and better swimming ability of juvenile listed salmonids in the Delta allow these fish to avoid entrainment at MIDS. In addition, the location of the MIDS intake on Goodyear Slough further reduces the risk of entrainment. Goodyear Slough is not a migratory corridor Winter-Run Chinook Salmon.

Goodyear Slough Outfall improves water circulation in the marsh. This structure consists of four 48-inch diameter culverts with flap gates designed to drain water from the southern end of Goodyear Slough into Suisun Bay. On flood tides, the gates reduce the amount of tidal inflow into Goodyear Slough. Due to its location and design, Winter-Run Chinook Salmon are not likely to encounter this structure or be negatively affected by its operation. Improved water circulation by the operation of the Goodyear Slough Outfall likely benefits juvenile Winter-Run Chinook Salmon in Suisun Marsh by improving water quality and increasing foraging opportunities.

Potential changes to aquatic resources from actions for Delta Smelt summer-fall habitat No Winter-Run Chinook Salmon are detected in the Delta between June and September. Therefore, no effects would occur as a result of the Suisun Marsh Salinity Control Gate operation.

Potential changes to aquatic resources due to changes from Clifton Court predator management

Clifton Court predator management efforts could reduce predation on listed fishes following entrainment into CCF, reducing pre-screen loss.

Potential changes to aquatic resources due to the San Joaquin Basin Steelhead Telemetry Study

Potential changes to aquatic resources due to reintroduction changes from the fish conservation and culture laboratory

Potential changes to aquatic resources from monitoring

A number of monitoring activities described in Appendix C - Real Time Water Operations Charter, in section Routine Operations and Maintenance on CVP Activities would have the potential to capture Winter-Run Chinook Salmon. Not all the existing IEP monitoring programs that target pelagic fish identify Chinook Salmon race. Of the programs that target and identify Winter-Run Chinook Salmon, collective catches are less than 1% of the Winter-Run JPE (Reclamation 2019). Because such a small percentage of the total JPE is captured in the monitoring programs, the effects of the monitoring programs are not likely to have effects to the Winter-Run population. These monitoring programs are important for understanding entry and residence time of Winter-Run Chinook Salmon into the Delta and San Francisco Estuary.

O.3.9.8.4 Central Valley Spring-Run Chinook Salmon

Potential changes to aquatic resources due to seasonal operations

Reclamation and DWR propose to operate the C.W. Bill Jones Pumping Plant and the Harvey O. Banks Pumping Plant. These pumping plants affect the hydrodynamics of the south and central Delta resulting in effects to Spring-Run Chinook Salmon entrainment, routing and through Delta survival. Hydrodynamic changes associated with river inflows and South Delta exports have been suggested to negatively impact juvenile Chinook Salmon in two distinct ways: 1) “near-field” mortality associated with entrainment to the export facilities, 2) “far-field” mortality resulting from altered hydrodynamics. See Winter-Run Chinook Salmon effects section for more detail concerning “far-field” and “near-field.”

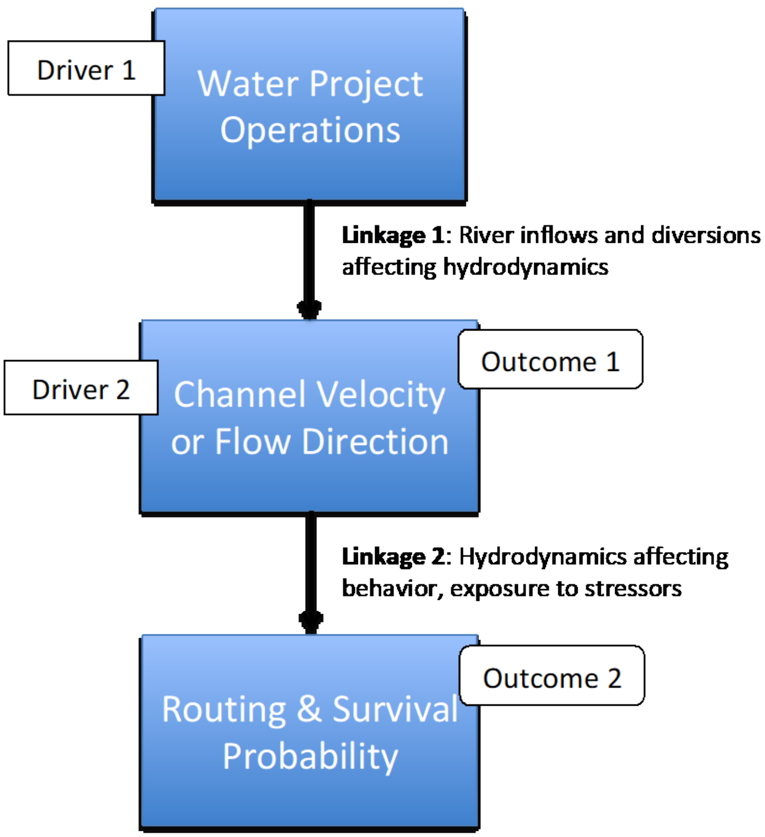


Figure O.3-149. Conceptual model for far-field effects of water project operations on juvenile salmonids in the Delta. This CM is a simplified version of the information provided by the CAMT SST.

Entrainment

Among 6.8 million tagged natural origin and 2.8 million tagged hatchery origin Spring-Run Chinook Salmon juveniles, entrainment loss averaged less than 0.0005% (Zeug and Cavallo 2014). Although data for juvenile Spring-Run Chinook Salmon originating from the San Joaquin River are limited, Zeug and Cavallo (2014) analyzed salvage of San Joaquin River-origin Fall-Run juvenile Chinook Salmon that are found in the Delta at a similar time as Spring-Run Chinook Salmon. Salvage of Fall-Run Chinook Salmon originating from the San Joaquin River averaged 1.4% and increased with export rate at the CVP and

SWP (Zeug and Cavallo 2014). However, there were few observations at export rates greater than 3,000 cfs. Average mortality at the facilities represents < 5% total juvenile mortality for San Joaquin River-origin populations but can range as high as 17.5% (Zeug and Cavallo 2014).

In the December through February period, Alternative 4 proposes an average total export rate slightly higher than No Action Alternative (119 cfs; Figure O1-1 in Appendix O, Attachment 1) and will, therefore, have a slightly higher entrainment risk. Total exports proposed for Alternative 4 in March-June (1,004 cfs lower than No Action Alternative; Figure O1-2), when juvenile Spring-Run Chinook Salmon are most abundant in the Delta, will decrease entrainment risk relative to No Action Alternative. Recent acoustic studies of juvenile Fall-Run Chinook Salmon in the San Joaquin River revealed that when the Head of Old River Barrier is out, >60% of fish detected at Chipps Island came through CVP, indicating that salvage is a higher survival route than volitional migration.

Routing

As stated in the Sacramento Winter-Run Chinook effects section, routing of juvenile Chinook Salmon into alternative migration routes is closely related to hydrodynamics (Perry et al. 2015; Cavallo et al. 2015; Steel et al. 2012). Juvenile Spring-Run Chinook Salmon are present in the Delta between November and early June with a peak in April (Reclamation 2019). In the December to February period, velocity overlap between Alternative 4 and No Action Alternative in the Sacramento River mainstem between the Sutter-Steamboat and DCC/Georgiana Slough Junctions, was more than 92%, 76%, 63%, 71%, and 58% in critically dry, dry, below normal, above normal, and wet years, respectively (Figure O1-53 in Appendix O, Attachment 1). During the December through February period, velocities were higher under Alternative 4 in all water year types indicating routing into the interior Delta would be lower relative to No Action Alternative (Perry et al. 2015; Figure O1-57 in Appendix O, Attachment 1). During the March to May period, velocity overlap between No Action Alternative and Alternative 4 was more than 91%, 69%, 48%, 46%, and 62% % in critical, dry, below normal, above normal, and wet years, respectively (Figure O1-54).

Spring-Run Chinook Salmon originating from the Sacramento River that enter the interior Delta via Georgiana Slough and the Delta Cross Channel can be exposed to hydrodynamic project effects that could affect routing. Once these fish arrive at the junction of the Mokelumne River and the San Joaquin River, they can move south toward the export facilities or west toward the ocean. In the December through February period analysis of DSM2 data indicates that there is little change to velocities in the region of the junction of the Mokelumne and San Joaquin Rivers between Alternative 4 and the No Action Alternative (Figure O1-55 in Appendix O, Attachment 1). Similar results were obtained when comparing Alternative 4 to the No Action Alternative in the March to May period (Figure O1-56 in Appendix O, Attachment 1).

Juvenile Spring-Run Chinook Salmon are present in the Delta between November and early June with a peak in April (Reclamation 2019). Early studies using coded wire tags indicated that survival of San Joaquin River-origin juvenile Chinook Salmon was lower in the Old River Route relative to the San Joaquin main stem (Newman 2008). This finding led to strategies designed to keep larger proportions of fish in the San Joaquin River main stem including the Head of Old River rock barrier and non-physical barriers. Recent studies using acoustic technology have indicated that differences in survival among the two routes are not significant (Buchanan et al. 2013; Buchanan et al. 2018). Thus, fish that enter Old River are unlikely to experience reduced survival.

Spring–run Chinook Salmon originating from the San Joaquin River that remain in the San Joaquin River main stem at the Head of Old River are exposed to additional junctions that lead into the interior Delta including; Turner Cut, Columbia Cut, Middle River, Old River, Fisherman's Cut and False River. In the December through February period analysis of DSM2 data indicates that there is little change to velocities in the region of the junctions with San Joaquin Rivers between Alternative 4 and the No Action Alternative (Figures O1-55 in Appendix O, Attachment 1). Similar results were obtained when comparing Alternative 4 to No Action Alternative in the March to May period (Figures O1-56 in Appendix O, Attachment 1).

In the December through February period, velocity overlap between Alternative 4 and No Action Alternative in the channel upstream of the Head of Old River was 95.4%, 91.9%, 90.2%, 53.4%, and 72.9% in critically dry, dry, below normal, above normal, and wet years, respectively (Figure O1-55 in Appendix O, Attachment 1). In the March to May period, velocity overlap was 88.4%, 70.5%, 65.6%, 52.5%, and 67.5% in critical, dry, below normal, above normal, and wet years, respectively (Figures O1-56 in Appendix O, Attachment 1).

Through-Delta Survival

To examine potential effects of Alternative 4, changes in velocity distributions were examined for the Sacramento River at Walnut Grove and Steamboat Slough which are both in this "transitional" region. During the December to February period at Walnut Grove, velocity distributions for Alternative 4 relative to No Action Alternative were most different in wet years (70.5%) with higher velocities in Alternative 4. Velocities were also greater for Alternative 4 relative to No Action Alternative in below normal and above normal years although overlap was greater (>80%; Figure O1-57 in Appendix O, Attachment 1). In critically dry and dry years, velocity distributions were more similar (>84%; Figure O1-57 in Appendix O, Attachment 1). At Steamboat Slough in the December to February period, velocities under Alternative 4 were higher than No Action Alternative in wet, above normal, below normal, and dry years and similar in critically dry years (Figure O1-58 in Appendix O, Attachment 1).

In the March through May period at Walnut Grove, velocity overlap between Alternative 4 and No Action Alternative was most different in below normal (61.5%) and above normal water years (65.4%) with higher mean velocities in Alternative 4 (Figure O1-59 in Appendix O, Attachment 1). Velocity overlap was higher (>78%) in critically dry, dry, and wet water years with similar velocities under Alternative 4 (Figure O1-59 in Appendix O, Attachment 1). At Steamboat Slough in the March through May period, overlap between Alternative 4 and No Action Alternative scenarios was most different in below normal (68.4%) and above normal water years (70.7%) with higher mean velocities in Alternative 4 (Figure O1-60 in Appendix O, Attachment 1). Velocity overlap was higher (>81%) in critically dry, dry, and wet water years with similar velocities under Alternative 4 (Figure O1-60 in Appendix O, Attachment 1).

A recent study by Perry et al. (2018) found that the effect of flow on survival is not uniform throughout the Delta. Relationships between flow and survival were significant only in reaches where flow changes from bi-directional to unidirectional when discharge increases. To examine potential effects of Alternative 4, changes in velocity distributions were examined for the San Joaquin River at Highway 4 and the Head of Middle River which are both in the "transitional" region of the San Joaquin River. During the December to February period at the San Joaquin River at Highway 4, velocity distributions for Alternative 4 relative to No Action Alternative exhibited high overlap in all water year types (≥84.2%; Figure O1-61 in Appendix O, Attachment 1). At the Head of Middle River during the December through February period, overlap was high between Alternative 4 and No Action Alternative in critically dry, dry, and below normal water years (≥77%) and moderate in above normal and wet years (>53%; Figure O1-62 in Appendix O, Attachment 1).

In the March to May period in the San Joaquin River at Highway 4, velocity overlap was high between Alternative 4 and No Action Alternative (≥83%; Figure O1-63 in Appendix O, Attachment 1). Velocities were similar in all water year types (Figure O1-63). At the Head of Middle River in the March –May period, overlap between Alternative 4 and No Action Alternative was moderate in most water year types (54-75%) and high in critically dry years 93.5% (Figure O1-64 in Appendix O, Attachment 1). Velocities were similar or slightly higher under Alternative 4 than No Action Alternative (Figure O1-64).

Potential changes to aquatic resources OMR Management

See section on seasonal operation above which integrates OMR management

Potential changes to aquatic resources due to Delta Cross Channel operations

The Delta Cross Channel may be closed for up to 45 days from November through January for fishery protection purposes. From February 1 through May 20, the gates are closed for fishery protection purposes. Significant amounts of flow and many juvenile Spring-Run Chinook Salmon enter the DCC (when the gates are open) and Georgiana Slough, especially during increased Delta pumping. Mortality of juvenile Salmon entering the central Delta is higher than for those continuing downstream in the Sacramento River. Juvenile Chinook Salmon which that entrained into an open DCC and transported to the interior Delta have reduced survival (Perry et al. 2010) The gates may also be closed for 14 days from May 21 through June 15 for fishery protection purposes. The peak migration of juvenile Spring-Run Chinook Salmon in the Sacramento River past Knights Landing, which is upstream of the DCC, occurs from March-April (Reclamation 2019). Therefore, the DCC is closed to protect the majority of the juvenile Spring-Run migration period in the Sacramento River and reduce the proportion of fish exposed to an open DCC.

Potential changes to aquatic resources due to the Temporary Barriers Project

The agricultural barriers at Middle River and Old River near Tracy can begin operating as early as April 15 but the tide gates are tied open from May 16 to May 31. After May 31, the barriers in Middle River, Old River near Tracy, and Grant Line Canal are permitted to be operational until they are completely removed by November 30.

The proportion of juvenile Spring-Run Chinook Salmon exposed to the agricultural barriers (Temporary Barrier Program, TBP) depends on their annual timing of installation and removal. Due to their location, primarily migrants originating from the San Joaquin River would be exposed to the TBP. The peak relative abundance of juvenile Spring-Run Chinook Salmon in the Delta is March and April (Reclamation 2019). If the agricultural barriers are operating as early as April 15 then they have the potential to expose a large proportion of the juvenile Spring-Run Chinook Salmon migrating down the San Joaquin River. When the Head of Old River barrier is not in place, acoustically tagged juvenile Chinook Salmon have demonstrated a high probability of selecting the Old River route (Buchanan 2018), which would expose them to the agricultural barriers. When the agricultural barriers are operating with tidal flap gates down, a significant decline in passage and reach survival of acoustically tagged juvenile Chinook Salmon migrating past the barrier has been observed compared to when the barrier is not present (DWR 2018). When flap gates are tied up, Chinook Salmon passage past the agricultural barrier was improved (DWR 2018). Flap gates tied up on agricultural barriers from May 16 to May 31 would help to reduce the negative effect of the barriers during this period. However, juveniles migrating before or after this period could be exposed to the agricultural barriers with flaps down which apparently decreases passage success and survival (DWR 2018).

Potential changes to aquatic resources due to Contra Costa Water District operations

CCWD's operations in Alternative 4 are consistent with the operational criteria specified in separate biological opinions and permits that govern operations at CCWD's intakes and Los Vaqueros Reservoir (NMFS 1993, 2007, 2010, 2017; USFWS 1993a, 1993b, 2000, 2007, 2010, 2017; CDFG 1994, 2009a). Therefore, CCWD's operation, including operation of the Rock Slough Intake, for Alternative 3 remain unchanged from the current operations.

The Contra Costa Canal Rock Slough Intake is located on a dead-end slough, far from the main migratory route for Central Valley Spring-Run Chinook Salmon (NMFS 2017c), approximately 18 miles from the Sacramento River and 10 miles from the San Joaquin River via the shortest routes. Designated critical habitat for Spring-Run Chinook Salmon does not occur within Rock Slough, but is present further to the north in the Delta (NMFS 2017c, 2014). Salmonids are expected to avoid the area of the Rock Slough Intake during certain times of the year based on historical water temperatures, which range from lows of about 45°F in winter (December and January) to over 70°F beginning in May and continuing to October (Reclamation 2016).

Fish monitoring prior to the construction of the Rock Slough Fish Screen (RSFS) indicates the timing and magnitude of Central Valley Spring-Run Chinook Salmon presence near the Rock Slough Intake. Since 1994, fish monitoring has been conducted by CDFW and CCWD consistent with the separate biological opinions and permits that govern CCWD's operations. From 1994 through 1999, CDFW conducted fish monitoring at the Rock Slough Intake and in the Contra Costa Canal up to the first pumping plant. Over this 6-year period, CDFW captured a total of 108 juvenile Central Valley Spring-Run from March through May (CDFG 2002c; NMFS 2017c). From 1999 to 2009, the 11 years prior to construction of the RSFS, CCWD's Fish Monitoring Program collected a total of 11 juvenile Central Valley Spring-Run from March through May at the Rock Slough Headworks (Reclamation 2016; NMFS 2017c) and 4 juvenile Central Valley Spring-Run at Pumping Plant #1 (CCWD 2019). No adult Spring-Run were collected in the vicinity of the Rock Slough Intake from 1994 through 2009 (CDFG 2002c; Reclamation 2016; NMFS 2017c). No juvenile or adult Central Valley Spring-Run have been collected in CCWD's Fish Monitoring Program at the Rock Slough Intake since 2008.

Since construction of the RSFS, operation of the hydraulic rake cleaning system has been shown to trap and kill adult Chinook Salmon and other non-listed fish (Reclamation 2016). From 2011-2018, 47 Salmon were recovered at the RSFS (Reclamation 2016, Appendix A; Tenera Environmental 2018a), but none of the captured fish were identified as Spring-Run Chinook Salmon (NMFS 2017c).

CCWD's Fish Monitoring Program also samples behind the fish screens at CCWD's other south Delta intakes. Since the intakes have been in operation, CCWD's Fish Monitoring Program has never collected Spring-Run Chinook Salmon at CCWD's Old River Intake or Middle River Intake (CCWD 2019).

CCWD's operations, including operation of the Rock Slough, Old River, and Middle River intakes and Los Vaqueros Reservoir, are simulated in the CalSim model. Thus, CalSim results discussed throughout this appendix include the effects of CCWD's operations in combination with all other water diversions and reservoir operations. A further analysis was undertaken to isolate the maximum possible effects of CCWD's operations on Delta hydrodynamics by determining the effect that CCWD pumping at maximum capacity would have on Delta channel water velocity. Results of this analysis are shown below; in all cases the maximum possible effect of CCWD's operations is de minimis.

Due to the location of the Rock Slough Intake near the end of a dead-end slough, far from the main migratory routes (i.e., 10 miles from the San Joaquin River and 18 miles from the Sacramento River), juvenile Spring-Run Chinook Salmon are not likely to be in the vicinity of the Rock Slough Intake. However, according to NMFS (2017), juvenile Spring-Run can be "drawn" into the south Delta under reverse flows and high CVP and SWP pumping rates.

One indicator of reverse flows is the net flow in OMR. Rock Slough Intake is located on Rock Slough, approximately 3.5 miles west of the junction of Rock Slough and Old River, which is over 12 river miles north of the gates to the SWP Clifton Court Forebay. Given its location, the Rock Slough Intake does not affect net reverse flow in OMR, and any effect that diversions at Rock Slough Intake would have in the OMR corridor would be to increase the northerly (positive) flow away from the Banks and Jones Pumping Plants. For juveniles that migrate down the OMR corridor that are not salvaged at TFCF or Skinner Fish Facility, any effect of Rock Slough Intake diversions would be a positive effect on OMR.

For juveniles that migrate down the mainstem of the Sacramento River or the San Joaquin River and for juveniles that were salvaged, trucked, and released in the western Delta, the potential effect of Rock Slough diversions on the net reverse flow in San Joaquin River may be relevant. The effect of water diversions at Rock Slough Intake on the velocity in the San Joaquin River at Jersey Point is presented in the effects analysis for juvenile Winter-Run Chinook Salmon. As detailed in that section, the maximum potential effect of water diversions at Rock Slough Intake (assuming diversions at the maximum permitted capacity of 350 cfs and all water diverted by the Rock Slough Intake comes from the San Joaquin River at Jersey Point) is 0.00625 ft/sec in the San Joaquin River at Jersey Point. For comparison, the velocity threshold for design of fish screens to prevent impingement of salmonids is 0.33 ft/sec, which is 50 times the maximum possible contribution from the Rock Slough diversions.

Recognizing that CCWD owns and operates two additional intakes in the south Delta, we examine the combined effect of all three intakes. CCWD's Old River Intake and Middle River Intake have a physical capacity of 250 cfs at each intake. If CCWD were to divert at all three intakes at the maximum capacity at the same time, total CCWD diversions would be 850 cfs. The corresponding effect on velocity in the San Joaquin River at Jersey Point would be 0.015 ft/sec. The velocity threshold used to protect salmonids from diversions in the vicinity of fish screens (0.33 ft/sec) is over 21 times greater than the maximum possible contribution from CCWD's combined physical capacity. The water diversions at the Rock Slough Intake when combined with diversions at CCWD's Old River Intake and Middle River Intake have a negligible effect on velocity along the migratory path for juvenile Spring-Run Chinook Salmon and are not likely to affect the movement of juvenile salmonids.

Nonetheless, even extremely small changes in velocity can affect the movement of neutrally buoyant particles such as phytoplankton. As shown in the Winter-Run Chinook Salmon section, the diversions at the Rock Slough Intake could move a neutrally buoyant particle in the San Joaquin River at Jersey Point approximately 540 ft over the course of the day. For comparison, the tidal excursion on the San Joaquin River at Jersey Point during a flood tide (i.e., the distance a particle will travel tidally upstream during a flood tide) is about 34,000 ft on average (or 6.4 miles), which is about 63 times the distance that diversions at Rock Slough could move a particle at the same location over the course of a full day. Therefore, the maximum possible contribution of diversions at Rock Slough on movement of neutrally buoyant particles such as phytoplankton is insignificant in comparison to the tidal excursion and mixing at this location.

In summary, CCWD's operations under Alternative 4 would remain consistent with the operational criteria specified in separate biological opinions and permits that govern operations at CCWD's intakes and Los Vaqueros Reservoir, and as shown above, the effect of CCWD's operations on Delta hydrodynamics is negligible.

Potential changes to aquatic resources due to North Bay Aqueduct operations

Alternative 4 includes the North Bay Aqueduct (NBA) intake in the North Delta and operation of the Barker Slough Pumping Plant. Listed salmonids may be present in the waterways adjacent to the Barker Slough Pumping Plant (monitoring data is available at https://www.wildlife.ca.gov/Regions/3). The NBA is located within designated critical habitat for Spring-Run Chinook Salmon. There should be no discernable effect to the Spring-Run Chinook Salmon due to the operations of the Barker Slough Pumping Facility. This is due to the infrequent presence of Spring-Run Chinook Salmon in the monitoring surveys indicating a low risk of entrainment. Further, Barker Slough Pumping Facility fish screens are designed to protect juvenile salmonids per NMFS criteria and should prevent entrainment while greatly minimizing any impingement of fish against the screen.

Potential changes to aquatic resources due to water transfers

Under Alternative 4, Reclamation is expanding the transfer window to November from the current July to September. Expanding the transfer window could lead to increased pumping at Jones and Banks Pumping Plants, when capacity is available. The Figures below show when capacity is available under Alternative 1 and the No Action Alternative, in terms of exceedances, years in the model period of record, and average by water year types. These values are total available and are not filtered for the pattern on which water might be acquired for transfer. The pattern of acquisition could decrease these values, as well as reoperation of storage that might be required, or the water cost of meeting D-1641. Prior estimates indicate that approximately 50% of the capacity in the figures below would be useful for water transfers given these timing and upstream considerations. In addition, a 20-30% surcharge on acquisition might be necessary to accommodate the salinity related inefficiencies that arise in operations. Based on the figures below and these additional estimates, expanding the water transfer window could result in an additional approximately 50 TAF of pumping in most year types. As more stored water is available from CVP and SWP reservoirs to pump in wetter year types, most of the available capacity for transfers is in drier year types (Figures O.3-150 through O.3-151).

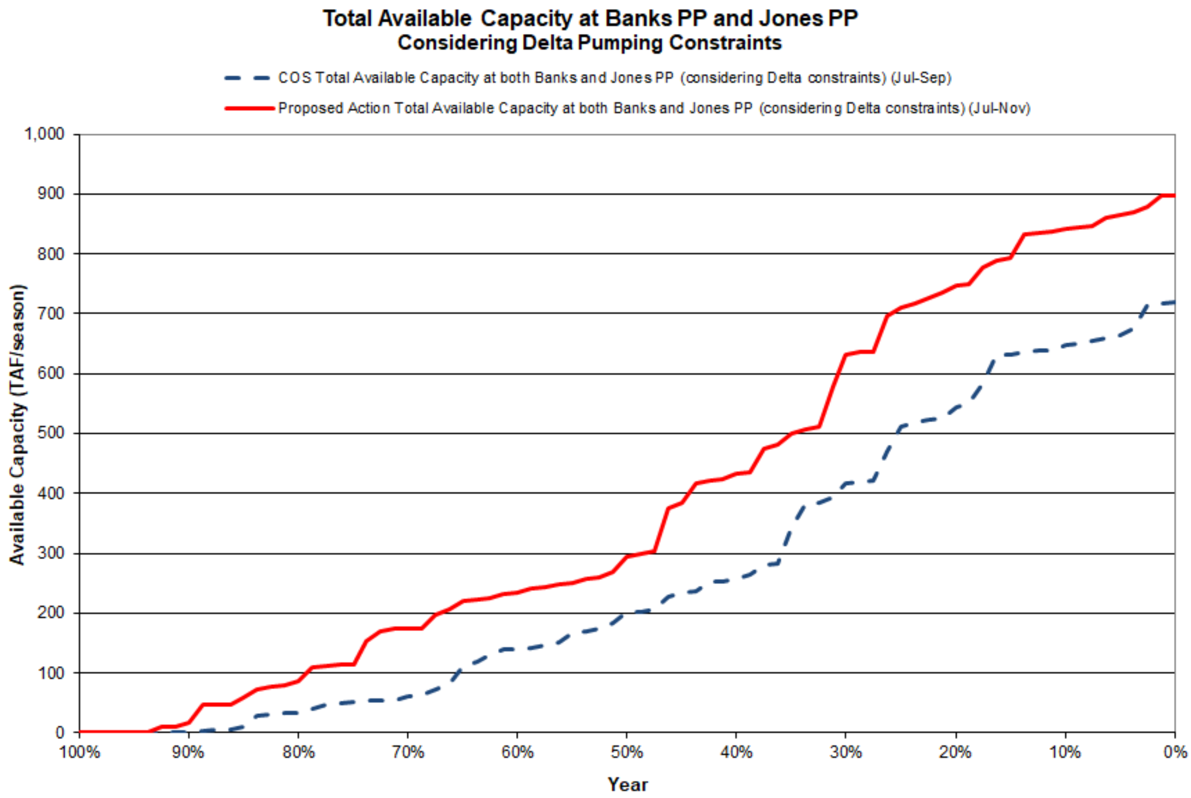


Figure O.3-150. Exceedance of Available Capacity for Transfers at Jones and Banks under the Alternative 1 and No Action Alternative

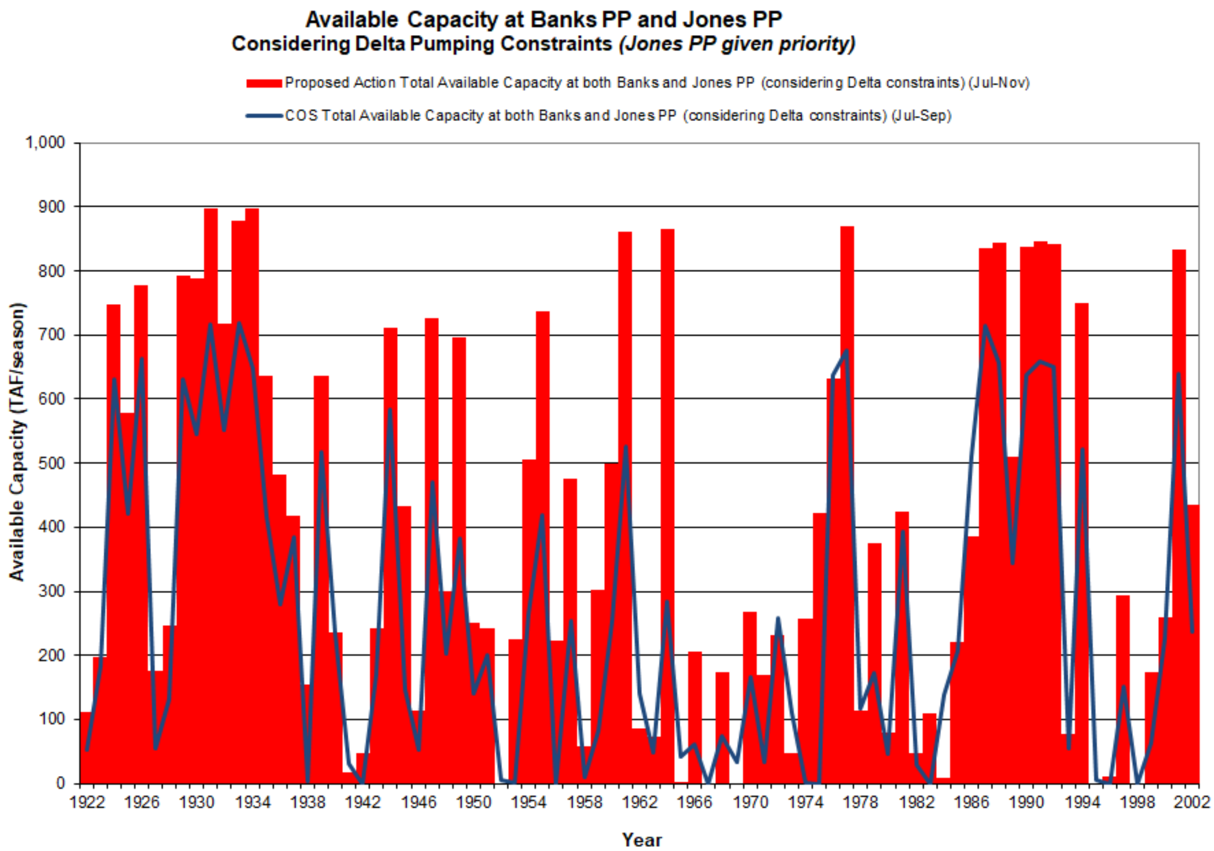


Figure O.3-151. Modeled Annual Maximum Available Capacity for Transfers under Alternative 1 and No Action Alternative, CalSim Period of Record (1922–2003)

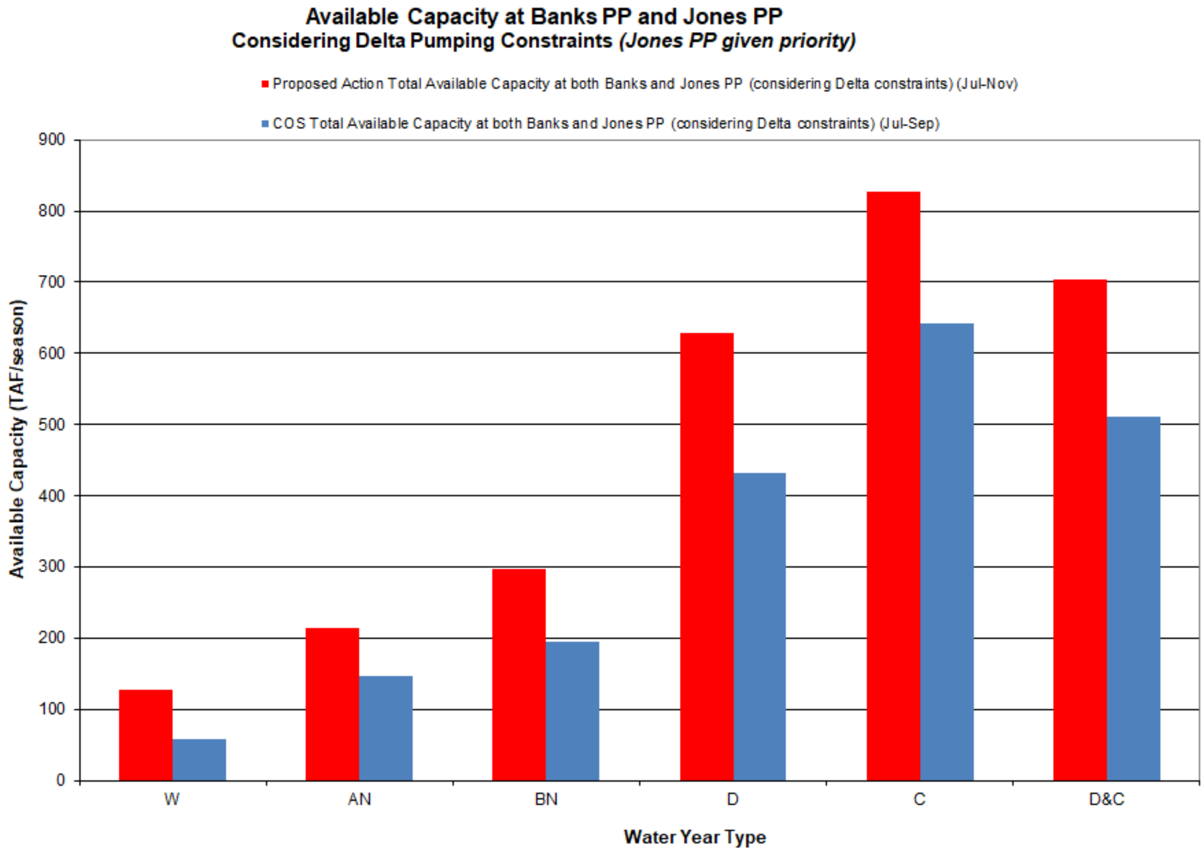


Figure O.3-152. Water Year Type average available capacity at Jones and Banks Pumping Plants

Egg, alevin, fry, and adult life stages of Spring-Run Chinook Salmon would not be exposed to the effects of increased water transfers as they do not occur in the Delta during July through November. Juvenile Central Valley Steelhead are detected at Chipps Island between December and July with the highest abundance in March to May (Reclamation 2019). Thus, only the very early or late migrants could potential be exposed to water transfers that occur during this time. These early or late migrant juvenile Spring-Run Chinook Salmon could be exposed to increased effects of entrainment, routing, and decreased Delta survival (see OMR management section) as a result of the expanded water transfer window. Increased flows during conveyance in the Sacramento River could provide small survival benefits to migrating juveniles (Perry et al. 2018).

Potential changes to aquatic resources from Clifton Court aquatic weed removal

Few if any juvenile Spring-Run Chinook Salmon would be expected to be exposed to the Clifton Court Forebay Aquatic Weed Control Program. Juvenile Spring-Run are present in the Delta between mid-November and early June with a peak in April (Reclamation 2019). The application of aquatic herbicide to the waters of Clifton Court Forebay will occur during the summer months of July and August. Thus, the probability of exposing Spring-Run Chinook Salmon to the herbicide is very low. Based on typical water temperatures in the vicinity of the salvage facilities during this period, the temperatures would be incompatible with salmonid life history preferences, generally exceeding 70°F by mid-June.

As discussed in Appendix D, treatment of harmful algal blooms with peroxide-based algaecide is proposed to occur as needed, year-round, but there are no anticipated impacts to fish because the oxidation reaction occurs immediately upon contact with the water, destroying algal cell membranes and chlorophyll, with hydrogen peroxide and oxygen as byproducts.

Potential changes to aquatic resources due to changes from Tracy and Skinner Fish Facility improvements

A number of programmatic actions are proposed to improve salvage efficiency of TFCF, including installing a carbon dioxide injection device to allow remote controlled anesthetization of predators in the secondary channels of the Tracy Fish Facility. These actions could potentially benefit juvenile Spring-Run Chinook Salmon through greater salvage efficiency.

Few if any juvenile Spring-Run Chinook Salmon would be expected to be exposed to construction of the CO_2 injection device proposed for the Tracy Fish Facility Improvements, based on lack of observed salvage during the August to October in-water work window (see figures in Appendix F of the ROC LTO BA: WR_salvage_unclipped_date, WR_salvage_clipped_date, and WR_salvage_clipped_CWT_race). Risks to these few individuals would be minimized through appropriate mitigation measures for aquatic resources (Appendix E, *Mitigation Measures*), the selected in-water work window, and the small scale of the in-water construction. For juvenile Spring-Run Chinook Salmon that arrive at the facility, the proposed improvements are likely to increase survival through the facility.

Predator control efforts at Skinner Fish Facility under Alternative 4 to reduce predation on listed fishes following entrainment into Clifton Court Forebay could reduce pre-screen loss of juvenile Spring-Run Chinook Salmon entrained into Clifton Court Forebay. Spring-Run Chinook Salmon are unlikely to be in the area during predator control efforts.

Potential changes to aquatic resources due to changes from Suisun Marsh facilities

Operation of the SMSCG from October through May to meet salinity standards set by the State Water Resources Control Board and Suisun Marsh Preservation Agreement provides water quality benefits to Spring-Run Chinook Salmon habitat. This beneficial operation coincides with downstream migration of juvenile Spring-Run Chinook Salmon (Reclamation 2019). Montezuma Slough provides an alternative route to their primary migration corridor through Suisun Bay. No data are available to estimate the abundance of juvenile Spring-Run Chinook Salmon in Montezuma Slough thus, the proportion of the total run utilizing this route is unknown. Spring-Run Chinook Salmon typically migrate through the estuary several months before spawning, but an extended delay in the estuary may affect their ability to access their natal spawning streams. Spring-Run generally utilize high stream flow conditions during the spring snowmelt to assist their upstream migration. Rapid upstream movement may be needed to take advantage of a short duration high stream flow event, particularly in dry years when high flow events may be uncommon. If the destination of a pre-spawning adult Salmon is among the smaller tributaries of the Central Valley, it may be important for migration to be unimpeded, since access to a spawning area could diminish with receding flows. However, NMFS (2009) determined that operation of the SWSCG is unlikely to impede migration of juvenile salmonids or produce conditions that support unusually high numbers of predators.

As described by NMFS (2009: 437-438), the Roaring River Distribution System (RRDS)'s water intake (eight 60-inch-diameter culverts) is equipped with fish screens (3/32-inch opening, or 2.4 mm) operated to maintain screen approach velocity of 0.7 ft/s, so that juvenile Spring-Run Chinook Salmon would be excluded from entrainment.

The Morrow Island Distribution System (MIDS) diverts water from Goodyear Slough through three 48-inch diameter culverts during high tide. Although the MIDS intakes do not currently have fish screens, its unlikely juvenile Central Valley Spring-Run Chinook Salmon will be entrained into the water distribution system, since Spring-Run Chinook have not been caught in past surveys. Also, the large size and better swimming ability of juvenile listed salmonids in the Delta allow these fish to avoid entrainment at MIDS. In addition, the location of the MIDS intake on Goodyear Slough further reduces the risk of entrainment. Goodyear Slough is not a migratory corridor Spring-Run Chinook Salmon.

Goodyear Slough Outfall improves water circulation in the marsh. This structure consists of four 48-inch diameter culverts with flap gates designed to drain water from the southern end of Goodyear Slough into Suisun Bay. On flood tides, the gates reduce the amount of tidal inflow into Goodyear Slough. Due to its location and design, Spring-Run Chinook Salmon are not likely to encounter this structure or be negatively affected by its operation. Improved water circulation by the operation of the Goodyear Slough Outfall likely benefits juvenile Spring-Run Chinook Salmon in Suisun Marsh by improving water quality and increasing foraging opportunities.

Potential changes to aquatic resources from actions for Delta Smelt summer-fall habitat No Spring-Run Chinook Salmon are detected in the Delta between June and September. Therefore, no effects would occur as a result of the Suisun Marsh Salinity Control Gate operation.

Potential changes to aquatic resources due to changes from Clifton Court predator management

Predator control efforts at Clifton Court Forebay under Alternative 4 could reduce pre-screen loss of juvenile Spring-Run Chinook Salmon entrained into Clifton Court Forebay. Spring-Run Chinook Salmon are unlikely to be in the area during predator control efforts during the summer in-water work window.

Potential changes to aquatic resources due to the San Joaquin Basin steelhead telemetry study

Potential changes to aquatic resources due to reintroduction changes from the fish conservation and culture laboratory

Potential changes to aquatic resources from monitoring

Less than 2% of the estimated Spring-Run Chinook Salmon population, as indexed by the Red Bluff Rotary Screw Trap data, is collectively captured by the salmonid monitoring programs that support CVP operations (Reclamation 2019). Because such a small percentage of the estimated Spring-Run Chinook Salmon juvenile production is captured in the monitoring programs, the effects of the monitoring programs are not likely to have effects to the Spring-Run population.

O.3.9.8.5 Central Valley Fall-Run Chinook Salmon

Potential changes to aquatic resources due to seasonal operations

Hydrodynamic changes associated with river inflows and South Delta exports have been hypothesized to adversely affect juvenile Chinook Salmon in two distinct ways: 1) “near-field” mortality associated with entrainment to the export facilities, 2) “far-field” mortality resulting from altered hydrodynamics. Near-field or entrainment effects of proposed seasonal operations can be most appropriately assessed by examining patterns of proportional population entrainment available from decades of coded wire tag studies (e.g., Zeug and Cavallo 2014). A foundation for assessing far-field effects has been provided by work of the Collaborative Adaptive Management Team’s (CAMT) Salmonid Scoping Team (SST). The SST completed a thorough review of this subject and defined a driver- linkage-outcome (DLO) framework for specifying how water project operations (the "driver") can influence juvenile salmonid behavior (the "linkage") and potentially cause changes in survival or routing (the "outcome"). The SST concluded altered "Channel Velocity" and altered "Flow Direction" were the only two hydrodynamic mechanisms by which exports and river inflows could affect juvenile salmonids in the Delta. Figure O.3-153 provides a simplified conceptual model of the DLO defined by the CAMT SST.

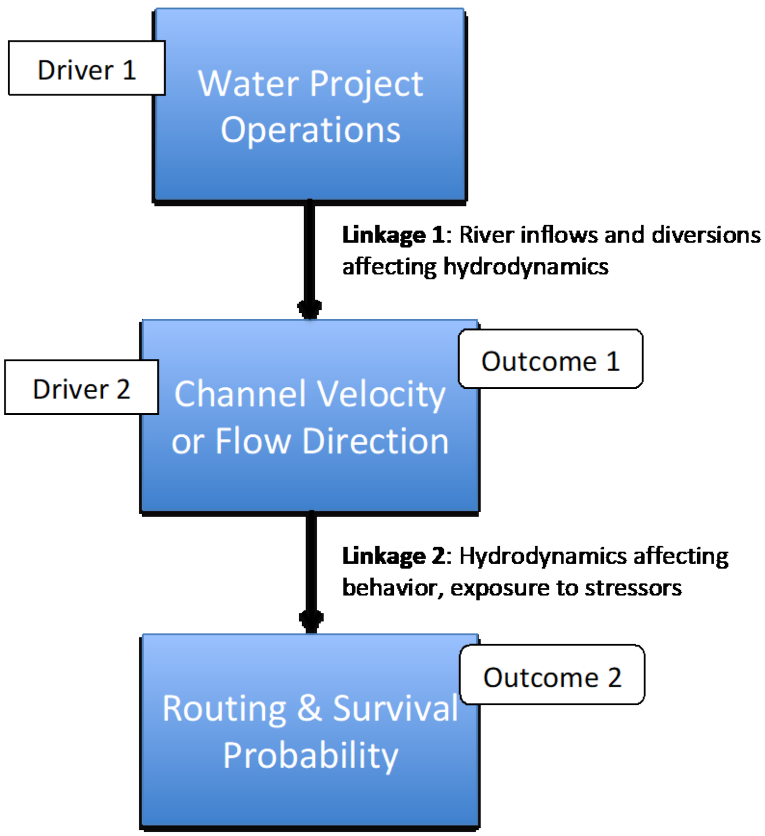


Figure O3-153. Conceptual model for far-field effects of water project operations on juvenile salmonids in the Delta. This CM is a simplified version of the information provided by the CAMT SST.

Though many juvenile salmonid tagging studies have been conducted in the Delta, the focus has primarily been on estimating reach survival and routing- not assessing export-related hydrodynamic mechanisms defined by the SST's DLO. In fact, most tagging studies have targeted areas of the Delta where "Channel Velocity" and "Flow Direction" may not be appreciably affected by exports (e.g., Newman and Brandes 2010; Perry et al. 2010; Perry et al. 2012; Perry et al. 2015; Michel et al. 2013).

In order to assess the potential for water project operations to influence survival and routing, we analyzed Delta hydrodynamic conditions by utilizing outputs from DSM2 Hydro modeling. Our analysis of DSM2 output is based on our previous work creating map-based visualizations of spatial hydrodynamic patterns at the scale of the Delta. The map-based approach allows us to identify a 'footprint' of the hydrodynamic differences between scenarios. The maps are based on a comparative metric, proportion overlap (more below), to capture channel-level hydrodynamic details as a single number for color-scaled mapping of

Delta channels. Our previous work made clear that spatial patterns were more easily discerned by mapping comparative metrics than by mapping descriptive metrics in multiple panels.

The objective of the comparative metric is to summarize the water velocity time series for each channel and scenario such the channel-level comparison is captured in a single number. For the proportion overlap metric, kernel density estimates are calculated on each time series. The kernel density estimates represent a non-parametric smoothing of the empirical distribution of time series values. The proportion overlap of two kernel density estimates is calculated with the following steps: 1) calculate the total area under the curve (AUC_t) as the sum of the AUC for each density estimate, 2) calculate the AUC of the overlapping portions (AUC_o) of the two density distributions being compared, and 3) calculate the overlapping proportion of the density distributions as AUC_o/AUC_t. Proportion overlap is naturally bound by zero and one; a value of zero indicates no overlap and a value of one indicates complete overlap. Lower values of proportion overlap identify channels demonstrating larger differences in a scenario comparison.

The proportion overlap metric is best applied over relatively short time periods because seasonal and annual variation in water velocity can overwhelm differences between scenarios. Thus, we calculated proportion overlap for every DSM2 channel for two seasons (Dec-Feb, May-Mar) in each water year (1922–2003). We excluded DSM2 output from water year 1921 to allow for an extensive burn-in period. We calculated proportion overlap based on hourly DSM2 output. Because each season was roughly 90 days, each comparison involved roughly 4,300 DSM2 values (2 scenarios * 24 hours * 90 days) for each channel.

Because we calculated proportion overlap for each channel in each water year, we summarized the proportion overlap values prior to mapping (i.e., not feasible to map proportion overlap for every comparison in every water year). To summarize, we found the minimum proportion overlap for each channel for each water year type for each comparison. The minimum values represent the maximum expected effect. Note that the year with the minimum proportion overlap for one channel might not be the same year as for another channel.

Entrainment

Zeug and Cavallo (2014) analyzed > 1000 release groups representing, more than 28 million coded wire tagged juvenile fish including winter, late fall and Fall-Run Chinook Salmon. This data is extremely useful because it represents large release groups of tagged smolts where the number of fish representing each release group lost to entrainment at the export facilities has been estimated. Estimating loss from "raw" salvage is problematic because the actual stock or basin of origin is often unknown (e.g., poor performance of length-at-date curves). Furthermore, with "raw" salvage, the number of smolts produced and potentially exposed to entrainment is unknown. The CWT salvage data analyzed by Zeug and Cavallo (2014) overcomes these deficiencies and provides the most appropriate basis for defining stock-specific categories of entrainment risk.

The average proportion Sacramento River-origin Fall-Run Chinook salvaged over a 15-year period was 0.0001 and the proportion of mortality accounted for by entrainment averaged 0.0003 (Zeug and Cavallo 2014). Salvage increased with increasing exports, but loss never exceeded 1% regardless of export rate. Late Fall-Run juveniles were salvaged at a higher rate than any other race (0.02% of each release group) and entrainment related mortality accounted for almost 1% of total mortality on average (Zeug and Cavallo 2014). Proportional loss of Late-Fall remained low until exports exceeded ~9,000 cfs when proportional loss could approach 8% (Zeug and Cavallo 2014). In the December through February period when Late Fall-Run are most abundant, Alternative 4 proposes an average total export rate slightly higher than No Action Alternative (119 cfs; Figure O1-1) and will therefore have a slightly higher entrainment risk. Total exports proposed for Alternative 4 in March-June (554 cfs lower than No Action Alternative; Figure O1-2) when juvenile Fall-Run are most abundant in the Delta, will decrease entrainment risk relative to No Action Alternative.

Routing

Routing of juvenile Chinook Salmon into alternative migration routes is closely related to hydrodynamics (Perry et al. 2015; Cavallo et al. 2015; Steel et al. 2012). Changes to hydrodynamics in Delta channels resulting from Alternative 4 were evaluated using DSM2 as described above. Juvenile Fall-Run Chinook Salmon abundance in the Delta is greatest between February and May and Late Fall-Run are present in the Delta between November and July with peaks in January through February and April through May (Table FR_1, LFR_1). In the December through February period, velocity overlap between Alternative 4 and No Action Alternative in the Sacramento River main stem between the Sutter-Steamboat and DCC/Georgiana Slough Junctions, was more than 92%, 76%, 63%, 71%, and 8% in critically dry, dry, below normal, above normal, and wet years, respectively (Figure O1-53 in Appendix O, Attachment 1). During the December through February period, velocities were higher under Alternative 4 in all water year types indicating routing into the interior Delta would be lower relative to No Action Alternative (Perry et al. 2015; Figure O1-57 in Appendix O, Attachment 1). During the March to May period, velocity overlap between No Action Alternative and Alternative 4 was more than 91%, 69%, 48%, 46%, and 62% in critically dry, dry, below normal, above normal, and wet years, respectively (Figure O1-54).

Fall-Run and Late Fall-Run juveniles originating from the Sacramento River that enter the interior Delta via Georgiana Slough and the Delta Cross Channel can be exposed to hydrodynamic project effects that could affect routing. Once these fish arrive at the junction of the Mokelumne River and the San Joaquin River, they can move south toward the export facilities or west toward the ocean. In the December through February period analysis of DSM2 data indicates that there is little change to velocities in the region of the junction of the Mokelumne and San Joaquin Rivers between Alternative 4 and the No Action Alternative (Figure O1-55). Similar results were obtained when comparing Alternative 4 to the No Action Alternative in the March to May period (Figure O1-56).

Through-Delta Survival

A recent study by Perry et al. (2018) found that the effect of flow on survival is not uniform throughout the Delta. Relationships between flow and survival were significant only in reaches where flow changes from bi-directional to unidirectional when discharge increases. To examine potential effects of the proposed project, changes in velocity distributions were examined for the Sacramento River at Walnut Grove and Steamboat Slough which are both in this “transitional” region. During the December to February period at Walnut Grove, velocity distributions for Alternative 4 relative to No Action Alternative were most different in wet years (70.5%) with higher velocities in Alternative 4. Velocities were also greater for Alternative 4 relative to No Action Alternative in dry, below normal, and above normal years although overlap was greater (>80%; Figure O1-57 in Appendix O, Attachment 1). In critically dry years, velocity distributions were more similar (>95%; Figure O1-57 in Appendix O, Attachment 1). At Steamboat Slough in the December to February period, velocities under Alternative 4 were similar or higher than No Action Alternative in all water year types (Figure O1-58 in Appendix O, Attachment 1).

In the March through May period at Walnut Grove, velocity overlap between Alternative 4 and No Action Alternative was lowest in below normal (61.5%) and above normal (65.4%) years with higher mean velocities under Alternative 4 (Figure O1-59 in Appendix O, Attachment 1). In critically dry, dry, and wet water years, overlap was higher (>78%) with similar velocities under Alternative 4 (Figure O1-59 in

Appendix O, Attachment 1). At Steamboat Slough in the March through May period, overlap between Alternative 4 and No Action Alternative was lowest in below normal (68.4%) and above normal (70.7%) years with higher mean velocities under Alternative 4 (Figure O1-60 in Appendix O, Attachment 1). In critically dry, dry, and wet water years, overlap was higher (>81%) with similar velocities under Alternative 4 (Figure O1-60 in Appendix O, Attachment 1).

A recent study by Perry et al. (2018) found that the effect of flow on survival is not uniform throughout the Delta. Relationships between flow and survival were significant only in reaches where flow changes from bi-directional to unidirectional when discharge increases. To examine potential effects of Alternative 4, changes in velocity distributions were examined for the San Joaquin River at Highway 4 and the Head of Middle River which are both in the "transitional" region of the San Joaquin River. During the December to February period at the San Joaquin River at Highway 4, velocity distributions for Alternative 4 relative to No Action Alternative exhibited high overlap in all water year types (≥84.2%; Figure O1-61 in Appendix O, Attachment 1). At the Head of Middle River during the December through February period, overlap was high between Alternative 4 and No Action Alternative in critically dry, dry, and below normal water years (≥88%) and moderate in wet and above normal years (53% to 75%; Figure O1-62 in Appendix O, Attachment 1).

In the March to May period in the San Joaquin River at Highway 4, velocity overlap was high between Alternative 4 and No Action Alternative (>83%; Figure O1-63 in Appendix O, Attachment 1). Velocities were similar in all water year types (Figure O1-63). At the Head of Middle River in the March –May period, overlap between Alternative 4 and No Action Alternative was moderate in most water year types (55-75%) and higher in critically dry years >93% (Figure O1-64 in Appendix O, Attachment 1). Velocities were generally lower under Alternative 4 than No Action Alternative (Figure O1-64 in Appendix O, Attachment 1).

Potential changes to aquatic resources OMR Management

See section on seasonal operations which includes OMR management

Potential changes to aquatic resources due to Delta Cross Channel operations

The Delta Cross Channel may be closed for up to 45 days from November through January for fishery protection purposes. From February 1 through May 20, the gates are closed for fishery protection purposes. The gates may also be closed for 14 days from May 21 through June 15 for fishery protection purposes. The peak migration of juvenile Fall-Run Chinook Salmon in the Sacramento River past West Sacramento, which is near the DCC, occurs from February through May (Table FR_1). Therefore, the DCC is closed for the majority of the juvenile Fall-Run migration period in the Sacramento River and as such the proportion of fish exposed to an open DCC would be low. Juvenile Fall-Run Chinook Salmon that are entrained into an open DCC and transported to the interior Delta have reduced survival (Perry et al. 2010).

Potential changes to aquatic resources due to the Temporary Barriers Project

The Temporary Barriers Project (TBP) consists of three rock barriers across south Delta channels to improve water levels for agricultural diversions and one rock barrier to improve San Joaquin River salmonid migration in the south Delta. The temporary rock barriers are installed and removed at Middle River near Victoria Canal, Old River near Tracy, Grant Line Canal near Tracy Boulevard Bridge, and the head of Old River. The TBP is operated based on San Joaquin River flow conditions. The agricultural barriers at Middle River and Old River near Tracy can begin operating as early as April 15 but the tide gates are tied open from May 16 to May 31. After May 31, the barriers in Middle River, Old River near Tracy, and Grant Line Canal are permitted to be operational until they are completely removed by November 30. The head of Old River Barrier is only installed from September 16 to November 30 to improve flow and dissolved oxygen conditions in the San Joaquin River for the immigration of adult Fall-Run Chinook Salmon.

The proportion of juvenile Fall-Run exposed to the TBP depends on their annual timing of installation and removal. Due to their location, primarily migrants originating from the San Joaquin River would be exposed to the TBP. The peak relative abundance of juvenile Fall-Run in the Delta at Mossdale is February through May (Table FR_1). The Head of Old River Barrier would have no effect on juvenile Fall-Run if installed from September 16 to November 30 as juvenile Fall-Run are largely absent from this section of the San Joaquin River during this time period (FR_1). If the agricultural barriers are operating as early as April 15 then they have the potential to expose a large proportion of the juvenile Fall-Run migrating down the San Joaquin River. When the Head of Old River barrier is not in place, acoustically tagged juvenile Chinook Salmon have demonstrated a high probability of selecting the Old River route (Buchanan 2018), which would expose them to the agricultural barriers. When the agricultural barriers are operating with tidal flap gates down, a significant decline in passage and reach survival of acoustically tagged juvenile Chinook Salmon migrating past the barrier has been observed compared to when the barrier is not present (DWR 2018). When flap gates are tied up, Chinook Salmon passage past the agricultural barrier was improved (DWR 2018). Flap gates tied up on agricultural barriers from May 16 to May 31 would help to reduce the negative effect of the barriers during this period. However, juveniles migrating before or after this period could be exposed to the agricultural barriers with flaps down which apparently decreases passage success and survival (DWR 2018). Therefore, the potential negative effects of the agricultural barriers depend on when they are installed and whether the flap gates are down or tied up but overall would be medium to high.

Potential changes to aquatic resources due to Contra Costa Water District operations

CCWD’s operations in Alternative 4 are consistent with the operational criteria specified in separate biological opinions and permits that govern operations at CCWD’s intakes and Los Vaqueros Reservoir (NMFS 1993, 2007, 2010, 2017; USFWS 1993a, 1993b, 2000, 2007, 2010, 2017; CDFG 1994, 2009a). Therefore, CCWD’s operations, including operation of the Rock Slough Intake, under Alternative 3 would remain unchanged from the current operations.

Fish monitoring prior to the construction of the Rock Slough Fish Screen (RSFS) indicates the timing and magnitude of Fall-Run/Late Fall-Run Chinook Salmon presence near the Rock Slough Intake. From 1999 to 2011, the 11 years prior to construction of the RSFS, CCWD’s Fish Monitoring Program collected 23 juvenile Fall-Run/Late Fall-Run Chinook Salmon at the Rock Slough Headworks and Contra Costa Pumping Plant #1. Since construction of the Rock Slough Fish Screen in 2012, no Fall-Run/Late Fall-Run Chinook Salmon have been collected behind the fish screen. CCWD’s Fish Monitoring Program also samples at CCWD’s other south Delta intakes. Since the intakes have been in operation, CCWD’s Fish Monitoring Program has never collected Fall-Run/Late Fall-Run Chinook Salmon at CCWD’s Old River Intake or Middle River Intake (CCWD 2019).

CCWD’s operations, including operation of the Rock Slough, Old River, and Middle River intakes and Los Vaqueros Reservoir, are simulated in the CalSim model. Thus, CalSim results discussed throughout this appendix include the effects of CCWD’s operations in combination with all other water diversions and reservoir operations. A further analysis was undertaken to isolate the maximum possible effects of CCWD’s operations on Delta hydrodynamics by determining the effect that CCWD pumping at

maximum capacity would have on Delta channel water velocity. Results of this analysis are shown below; in all cases the maximum possible effect of CCWD's operations is de minimis.

Due to the location of the Rock Slough Intake near the end of a dead-end slough, far from the main migratory routes, juvenile Central Valley Fall-Run/Late Fall-Run are not likely to be in the vicinity of the Rock Slough Intake. However, according to NMFS (2017), juvenile Salmon can be “drawn” into the south Delta under reverse flows and high CVP and SWP pumping rates.

One indicator of reverse flows is the net flow in Old and Middle Rivers (OMR). Rock Slough Intake is located on Rock Slough, approximately 3.5 miles west of the junction of Rock Slough and Old River, which is over 12 river miles north of the gates to the SWP Clifton Court Forebay. Given its location, the Rock Slough Intake does not affect net reverse flow in Old and Middle Rivers (OMR), and any effect that diversions at Rock Slough Intake would have in the Old and Middle River corridor would be to increase the northerly (positive) flow away from the Banks and Jones Pumping Plants. For juveniles that migrate down the Old and Middle River corridor that are not salvaged at TFCF or Skinner Fish Facility, any effect of Rock Slough Intake diversions would be a positive effect on OMR.

For juveniles that migrate down the mainstems of the Sacramento River or the San Joaquin River and for juveniles that were salvaged, trucked, and released in the western Delta, the potential effect of Rock Slough diversions on the net reverse flow in San Joaquin River may be relevant. The effect of water diversions at Rock Slough Intake on the velocity in the San Joaquin River at Jersey Point is presented in the effects analysis for juvenile Winter-Run. As detailed in that section, the maximum potential effect of water diversions at Rock Slough Intake (assuming diversions at the maximum permitted capacity of 350 cfs and all water diverted by the Rock Slough Intake comes from the San Joaquin River at Jersey Point) is 0.00625 ft/sec in the San Joaquin River at Jersey Point. For comparison, the velocity threshold for design of fish screens to prevent impingement of salmonids is 0.33 ft/sec, which is 50 times the maximum possible contribution from the Rock Slough diversions.

Recognizing that CCWD owns and operates two additional intakes in the south Delta, we examine the combined effect of all three intakes. CCWD’s Old River Intake and Middle River Intake have a physical capacity of 250 cfs at each intake. If CCWD were to divert at all three intakes at the maximum capacity at the same time, total CCWD diversions would be 850 cfs. The corresponding effect on velocity in the San Joaquin River at Jersey Point would be 0.015 ft/sec. The velocity threshold used to protect salmonids from diversions in the vicinity of fish screens (0.33 ft/sec) is over 21 times greater than the maximum possible contribution from CCWD’s combined physical capacity. The water diversions at the Rock Slough Intake when combined with diversions at CCWD’s Old River Intake and Middle River Intake have a negligible effect on velocity along the migratory path for juvenile Central Valley Fall-Run/Late Fall-Run Salmon and are not likely to affect the movement of juvenile salmonids.

Nonetheless, even extremely small changes in velocity can affect the movement of neutrally buoyant particles such as phytoplankton. As shown in the Winter-Run section, the diversions at the Rock Slough Intake could move a neutrally buoyant particle in the San Joaquin River at Jersey Point approximately 540 ft over the course of the day. For comparison, the tidal excursion on the San Joaquin River at Jersey Point during a flood tide (i.e., the distance a particle will travel tidally upstream during a flood tide) is about 34,000 ft on average (or 6.4 miles), which is about 63 times the distance that diversions at Rock Slough could move a particle at the same location over the course of a full day. Therefore, the maximum possible contribution of diversions at Rock Slough on movement of neutrally buoyant particles such as phytoplankton is not significant in comparison to the tidal excursion and mixing at this location.

In summary, CCWD's operations under Alternative 4 would remain consistent with the operational criteria specified in separate biological opinions and permits that govern operations at CCWD's intakes and Los Vaqueros Reservoir, and as shown above, the effect of CCWD's operations on Delta hydrodynamics is negligible.

Potential changes to aquatic resources due to North Bay Aqueduct operations

Listed salmonids may be present in the waterways adjacent to the Barker Slough Pumping Plant, however several years of monitoring have failed to consistently capture any salmonids during the winter Delta Smelt surveys (1996 to 2004) in Lindsey Slough or Barker Slough. Captures of Chinook Salmon have usually occurred in the months of February and March and typically are only a single fish per net haul (http://www.delta.dfg.ca.goc/data/nba). Most Chinook Salmon captured have come from Miner Slough, which is a direct distributary from the Sacramento River via Steamboat and Sutter Sloughs. Few if any San Joaquin River-origin Fall-Run Chinook Salmon are expected to be exposed to the North Bay aqueduct because it is not on the migration route of this species.

Potential changes to aquatic resources from Clifton Court aquatic weed removal

Few if any juvenile Fall-Run Chinook Salmon would be expected to be exposed to the Clifton Court Forebay Aquatic Weed Control Program. Juvenile Fall-Run are present in the Delta between mid-November and early June with a peak in April (Table_WR1). The application of aquatic herbicide to the waters of Clifton Court Forebay will occur during the summer months of July and August. Thus, the probability of exposing Spring-Run to the herbicide is very low. Based on typical water temperatures in the vicinity of the salvage facilities during this period, the temperatures would be incompatible with salmonid life history preferences, generally exceeding 70°F by mid-June. Mechanical harvesting would occur on an as-needed basis and therefore listed salmonids could be exposed to this action, if entrained into the Forebay.

As discussed in Appendix D, treatment of harmful algal blooms with peroxide-based algaecide is proposed to occur as needed, year-round, but there are no anticipated impacts to fish because the oxidation reaction occurs immediately upon contact with the water, destroying algal cell membranes and chlorophyll, with hydrogen peroxide and oxygen as byproducts.

Potential changes to aquatic resources due to changes from Tracy and Skinner Fish Facility improvements

Although actions at the Tracy facility could positively affect juvenile Fall-Run Chinook Salmon through greater salvage efficiency, only small proportions of Fall-Run Chinook Salmon are lost at the CVP (Zeug and Cavallo 2014).

Skinner Fish Facility improvements from predator control efforts to reduce predation on listed fishes following entrainment into Clifton Court Forebay could reduce pre-screen loss of juvenile Chinook Salmon entrained into Clifton Court Forebay. However, given that only small proportions of Fall-Run Chinook Salmon are lost at the SWP (Zeug and Cavallo 2014), the population-level positive effect of this action would be low. Larger proportions of Late Fall-Run Chinook Salmon are lost at the facilities and this action would have a larger effect for this run.

Potential changes to aquatic resources due to changes from Suisun Marsh facilities

Operation of the SMSCG from October through May coincides with downstream migration of juvenile Fall-Run Chinook Salmon (Table FR_1). NMFS (2009) determined that operation of the SWSCG is unlikely to impede migration of juvenile salmonids or produce conditions that support unusually high numbers of predators.

As described by NMFS (2009: 437-438), the Roaring River Distribution System (RRDS)'s water intake (eight 60-inch-diameter culverts) is equipped with fish screens (3/32-inch opening, or 2.4 mm) operated to maintain screen approach velocity of 0.2 ft/s (for Delta Smelt protection), so that juvenile Fall-Run Chinook Salmon would be excluded from entrainment.

NMFS (2009: 438) considered it unlikely that juvenile Winter-Run Chinook Salmon, would be entrained by the three unscreened 48-inch culverts that form the Morrow Island Distribution System (MIDS) water intake, as a result of their larger size and better swimming ability relative to the size of Fall-Run Chinook Salmon observed to have been entrained (<45 mm), and also because the location of the MIDS intake on Goodyear Slough is not on a migratory corridor for listed juvenile salmonids. Although Fall-Run have been entrained at this facility, only a small proportion of total migrants are likely to encounter it.

NMFS (2009: 438) concluded that it would be unlikely that Chinook Salmon would encounter or be negatively affected by the Goodyear Slough outfall given its location and design, which is intended to improve water circulation in Suisun Marsh and therefore was felt by NMFS (2009: 438) to likely be of benefit to juvenile salmonids by improving water quality and increasing foraging opportunities.

Potential changes to aquatic resources from actions for Delta Smelt summer-fall habitat

Juvenile Fall-Run Chinook Salmon are abundant in the Delta in December and January and April and May (Reclamation 2019). Late Fall-Run are most abundant from January through April. Small fractions of each run could be exposed to Fall Delta Smelt habitat actions. For fish that are exposed, increased turbidity may reduce susceptibility to predation and increase through-Delta survival.

Potential changes to aquatic resources due to changes from Clifton Court predator management

Pre-screen survival of juvenile Chinook Salmon has been shown to be low (Gingras 1997) and predation is thought to be a major source of mortality. Analyses by Zeug and Cavallo (2014) indicate that only small proportions of Sacramento River-origin Fall-Run Chinook Salmon arrive at the facilities. However, moderate proportions of San Joaquin River-origin Fall-Run arrive at the facilities. For fish that are entrained into Clifton Court Forebay, predator control may increase pre-screen survival. The overall effect of the action is low for Sacramento River-Origin fish and moderate for San Joaquin River and Mokelumne River-origin fish

Potential changes to aquatic resources due to the San Joaquin Basin steelhead telemetry study

Potential changes to aquatic resources due to reintroduction changes from the fish conservation and culture laboratory

No effect

O.3.9.8.6 Central Valley Steelhead

Potential changes to aquatic resources due to seasonal operations

Entrainment

ICF (2018) analyzed salvage of Central Valley Steelhead at the CVP and SWP between 2003 and 2017 and found that salvage increased with export rate and decreased with San Joaquin River flow. Salvage also decreased with OMR flow. However, OMR is a metric comprised of both exports and San Joaquin River flow which complicates attempts to understand individual effects.

In the December through February period, Alternative 4 proposes an average total export rate slightly higher than the No Action Alternative (119 cfs; Figure O1-1 in Appendix O, Attachment 1) and will therefore have slightly higher entrainment risk. Total exports proposed for Alternative 4 in March-June (554 cfs lower than No Action Alternative; Figure O1-2 in Appendix O, Attachment 1) when juvenile Central Valley Steelhead are most abundant in the Delta at Chipps Island (Reclamation 2019), will decrease entrainment risk relative to No Action Alternative.

Routing

Routing of juvenile Central Valley Steelhead into alternative migration routes is closely related to hydrodynamics (Perry et al. 2015; Cavallo et al. 2015; Steel et al. 2012). Changes to hydrodynamics in Delta channels resulting from Alternative 4 were evaluated using DSM2. Juvenile Central Valley Steelhead are present in the Sacramento River at Hood upstream of the first distributary junctions between November and early June with peak abundance from February to early June (Reclamation 2019). In the December to February period, velocity overlap between Alternative 4 and No Action Alternative in the Sacramento River mainstem between the Sutter-Steamboat and DCC/Georgiana Slough Junctions, was more than 92%, 76%, 63%, 71%, and 58% in critically dry, dry, below normal, above normal, and wet years, respectively (Figure O1-53 in Appendix O, Attachment 1). During the December to February period, velocities were similar or higher under Alternative 4 in all water year types indicating routing into the interior Delta would be lower relative to No Action Alternative (Perry et al. 2015; Figure O1-57 in Appendix O, Attachment 1). During the March to May period, velocity overlap between No Action Alternative and Alternative 4 was more than 91%, 69%, 48%, 46%, and 62% in critically dry, dry, below normal, above normal, and wet years, respectively (Figure O1-54 in Appendix O, Attachment 1).

Through-Delta Survival

A recent study by Perry et al. (2018) found that the effect of flow on survival is not uniform throughout the Delta. Relationships between flow and survival were significant only in reaches where flow changes from bi-directional to unidirectional when discharge increases. To examine potential effects of Alternative 4, changes in velocity distributions were examined for the Sacramento River at Walnut Grove and Steamboat Slough which are both in this “transitional” region. During the December to February period at Walnut Grove, velocity distributions for Alternative 4 relative to No Action Alternative were most different in wet years (70.5%) with higher velocities in Alternative 4. Velocities were also greater for Alternative 4 relative to No Action Alternative in dry, below normal, and above normal years although overlap was greater (>80%; Figure O1-57 in Appendix O, Attachment 1). In critically dry years, velocity distributions were more similar (95%; Figure O1-57 in Appendix O, Attachment 1). At Steamboat Slough in the December to February period, velocities under Alternative 4 were higher than No Action Alternative in most water year types and similar in critically dry years (Figure O1-58 in Appendix O, Attachment 1).

In the March through May period at Walnut Grove, velocity overlap between Alternative 4 and No Action Alternative was >78% in critically dry, dry, and wet water types with similar velocities under Alternative 4 (Figure O1-59 in Appendix O, Attachment 1). Overlap was most different in below normal (61.5%) and above normal (65.4%) years with higher mean velocities under Alternative 4 (Figure O1-59). At Steamboat Slough in the March through May period, overlap was most different in below normal (68.4%) and above normal years (70.7%) with higher mean velocities under Alternative 4 (Figure O1-60 in Appendix O, Attachment 1). Velocity overlap between Alternative 4 and No Action Alternative scenarios was >81% in critically dry, dry, and wet years with similar velocities under Alternative 4 (Figure O1-60 in Appendix O, Attachment 1).

A recent study by Perry et al. (2018) found that the effect of flow on survival is not uniform throughout the Delta. Relationships between flow and survival were significant only in reaches where flow changes from bi-directional to unidirectional when discharge increases. To examine potential effects of Alternative 4, changes in velocity distributions were examined for the San Joaquin River at Highway 4 and the Head of Middle River which are both in the "transitional" region of the San Joaquin River. During the December to February period at the San Joaquin River at Highway 4, velocity distributions for Alternative 4 relative to No Action Alternative exhibited high overlap in all water year types (>84%; Figure O1-61 in Appendix O, Attachment 1). At the Head of Middle River during the December to February period, overlap was high between Alternative 4 and No Action Alternative in critically dry, dry, and below normal water years (>88%) and moderate in wet and above normal years (53% to 75%; Figure O1-62 in Appendix O, Attachment 1).

In the March to May period in the San Joaquin River at Highway 4, velocity overlap was high between Alternative 4 and No Action Alternative (>83%; Figure O1-63 in Appendix O, Attachment 1). Velocities were similar in all water year types (Figure O1-63). At the Head of Middle River in the March –May period, overlap between Alternative 4 and No Action Alternative was moderate in most water year types (54% to 75%) and higher in critically dry years (93.5%; Figure O1-48 in Appendix O, Attachment 1). Velocities were similar or slightly higher under Alternative 4 than No Action Alternative (Figure O1-64).

Potential changes to aquatic resources OMR Management

See section on Seasonal Operations which includes OMR management

Potential changes to aquatic resources due to Delta Cross Channel operations

Significant flow and many juvenile Central Valley Steelhead enter the central Delta when the DCC gates are open. Mortality of juvenile Central Valley Steelhead entering the central Delta is higher than for those continuing downstream in the Sacramento River. The peak migration of juvenile Central Valley Steelhead in the Sacramento River past Knights Landing, which is upstream of the DCC, occurs from January through February (Reclamation 2019). Therefore under Alternative 4, the continued operation of the DCC to protect the majority of the juvenile Central Valley Steelhead during their migration period in the Sacramento River would reduce the proportion of fish exposed to an open DCC and result in beneficial impacts to this life stage when compared to the No Action Alternative.

Potential changes to aquatic resources due to the Temporary Barriers Project

The Temporary Barriers Project (TBP) consists of three rock barriers across south Delta channels to improve water levels for agricultural diversions and one rock barrier to improve San Joaquin River salmonid migration in the south Delta. The temporary rock barriers are installed and removed at Middle River near Victoria Canal, Old River near Tracy, Grant Line Canal near Tracy Boulevard Bridge, and the head of Old River. The TBP is operated based on San Joaquin River flow conditions. The agricultural barriers at Middle River and Old River near Tracy can begin operating as early as April 15 but the tide gates are tied open from May 16 to May 31. After May 31, the barriers in Middle River, Old River near

Tracy, and Grant Line Canal are permitted to be operational until they are completely removed by November 30. The Head of Old River Barrier is only installed from September 16 to November 30 to improve flow and dissolved oxygen conditions in the San Joaquin River for the immigration of adult Fall-Run Chinook Salmon.

The proportion of juvenile Central Valley Steelhead exposed to the TBP depends on their annual timing of installation and removal. Due to their location, primarily juvenile Central Valley Steelhead migrants originating from the San Joaquin River would be exposed to the TBP. The peak relative abundance of juvenile Central Valley Steelhead in the San Joaquin River in the vicinity of the TBP (Mossdale) occurs in April and May (Reclamation 2019). If the agricultural barriers are operating as early as April 15, there is potential exposure to a large proportion of the juvenile Central Valley Steelhead migrating down the San Joaquin River.

When the Head of Old River barrier is not in place, acoustically tagged juvenile Central Valley Steelhead have demonstrated a high probability of selecting the Old River route (Buchanan 2018[PC1]), which would expose them to the agricultural barriers. When the agricultural barriers are operating with tidal flap gates down, a significant decline in passage and reach survival of acoustically tagged juvenile Central Valley Steelhead migrating past the barrier has been observed compared to when the barrier is not present (DWR 2018). When flap gates are tied up, Central Valley Steelhead passage past the agricultural barrier was improved (DWR 2018). Therefore, although Alternative 4 does not include HORB, which could result in negative impacts to Central Valley Steelhead juvenile migration, the improvements to the agricultural barriers (including flap gates tied up from May 16 to May 31) would help to reduce the negative effect of the barriers on migrating juvenile Central Valley Steelhead during this period relative to No Action Alternative. However, juvenile Central Valley Steelhead migrating before or after this period could be exposed to the agricultural barriers with flaps down, which apparently decreases passage success and survival (DWR 2018). Therefore, the potential negative effects of the agricultural barriers under Alternative 4 on juvenile Central Valley Steelhead depends on when they are installed and whether the flap gates are down.

Potential changes to aquatic resources due to Contra Costa Water District operations

CCWD’s operations in Alternative 4 are consistent with the operational criteria specified in separate biological opinions and permits that govern operations at CCWD’s intakes and Los Vaqueros Reservoir (NMFS 1993, 2007, 2010, 2017; USFWS 1993a, 1993b, 2000, 2007, 2010, 2017; CDFG 1994, 2009a). Therefore, CCWD’s operations, including operation of the Rock Slough Intake, under Alternative 3 would remain unchanged from the current operations.

Fish monitoring prior to the construction of the Rock Slough Fish Screen (RSFS) indicates the timing and magnitude of Central Valley Steelhead presence near the Rock Slough Intake. From 1999 to 2011, the 11 years prior to construction of the RSFS, CCWD’s Fish Monitoring Program collected 15 juvenile Central Valley Steelhead at the Rock Slough Headworks and Pumping Plant #1. Since construction of the Rock Slough Fish Screen, no Central Valley Steelhead have been collected behind the fish screen. CCWD’s Fish Monitoring Program also samples at CCWD’s other south Delta intakes. Since the intakes have been in operation, CCWD’s Fish Monitoring Program has never collected Central Valley Steelhead at CCWD’s Old River Intake or Middle River Intake (CCWD 2019).

CCWD’s operations, including operation of the Rock Slough, Old River, and Middle River intakes and Los Vaqueros Reservoir, are simulated in the CalSim model. Thus, CalSim results discussed throughout this appendix include the effects of CCWD’s operations in combination with all other water diversions and reservoir operations. A further analysis was undertaken to isolate the maximum possible effects of

CCWD’s operations on Delta hydrodynamics by determining the effect that CCWD pumping at maximum capacity would have on Delta channel water velocity. Results of this analysis are shown below; in all cases the maximum possible effect of CCWD's operations is de minimis.

Due to the location of the Rock Slough Intake near the end of a dead-end slough, far from the main migratory routes, juvenile Central Valley Steelhead are not likely to be in the vicinity of the Rock Slough Intake. However, according to NMFS (2017), juvenile salmonids can be “drawn” into the south Delta under reverse flows and high CVP and SWP pumping rates. One indicator of reverse flows is the net flow in OMR. Rock Slough Intake is located on Rock Slough, approximately 3.5 miles west of the junction of Rock Slough and Old River, which is over 12 river miles north of the gates to the SWP Clifton Court Forebay. Given its location, the Rock Slough Intake does not affect OMR, and any effect that diversions at Rock Slough Intake under Alternative 3 would have in the OMR corridor would be to increase the northerly (positive) flow away from the Banks and Jones Pumping Plants. For juveniles that migrate down the Old and Middle River corridor that are not salvaged at TFCF or Skinner Fish Facility, any effect of Rock Slough Intake diversions would be a positive effect on OMR.

For juveniles that migrate down the mainstems of the Sacramento or San Joaquin Rivers and for juveniles that were salvaged, trucked, and released in the western Delta, the potential effect of Rock Slough diversions on the net reverse flow in San Joaquin River may be relevant. The effect of water diversions at Rock Slough Intake on the velocity in the San Joaquin River at Jersey Point is presented in the effects analysis for juvenile Winter-Run. As detailed in that section, the maximum potential effect of water diversions at Rock Slough Intake (assuming diversions at the maximum permitted capacity of 350 cfs and all water diverted by the Rock Slough Intake comes from the San Joaquin River at Jersey Point) is 0.00625 ft/sec in the San Joaquin River at Jersey Point. For comparison, the velocity threshold for design of fish screens to prevent impingement of salmonids is 0.33 ft/sec, which is 50 times the maximum possible contribution from the Rock Slough diversions.

Recognizing that CCWD owns and operates two additional intakes in the south Delta, the combined effect of all three intakes was examined. CCWD’s Old River Intake and Middle River Intake have a physical capacity of 250 cfs at each intake. If CCWD were to divert at all three intakes at the maximum capacity at the same time, total CCWD diversions would be 850 cfs. The corresponding effect on velocity in the San Joaquin River at Jersey Point would be 0.015 ft/sec. The velocity threshold used to protect salmonids from diversions in the vicinity of fish screens (0.33 ft/sec) is over 21 times greater than the maximum possible contribution from CCWD’s combined physical capacity. The water diversions at the Rock Slough Intake when combined with diversions at CCWD’s Old River Intake and Middle River Intake have a negligible effect on velocity along the migratory path for juvenile Central ValleySteelhead.

Nonetheless, even extremely small changes in velocity can affect the movement of neutrally buoyant particles such as phytoplankton. As shown in the Winter-Run section, the diversions at the Rock Slough Intake could move a neutrally buoyant particle in the San Joaquin River at Jersey Point approximately 540 ft over the course of the day. For comparison, the tidal excursion on the San Joaquin River at Jersey Point during a flood tide (i.e., the distance a particle will travel tidally upstream during a flood tide) is about 34,000 ft on average (or 6.4 miles), which is about 63 times the distance that diversions at Rock Slough could move a particle at the same location over the course of a full day. Therefore, the maximum possible contribution of diversions at Rock Slough on movement of neutrally buoyant particles such as phytoplankton is insignificant in comparison to the tidal excursion and mixing at this location. Although the diversions at Rock Slough Intake are not likely to impact juvenile Central Valley Steelhead, the aggregate effect of all water diversions in the Delta, including exports at Jones and Banks Pumping Plants can affect channel velocity.

In summary, CCWD's operations under Alternative 4 would remain consistent with the operational criteria specified in separate biological opinions and permits that govern operations at CCWD's intakes and Los Vaqueros Reservoir, and as shown above, the effect of CCWD's operations on Delta hydrodynamics is negligible.

Potential changes to aquatic resources due to North Bay Aqueduct operations

Under Alternative 4, there would be no changes to operational criteria at the NBA's BSPP relative to current op. Juvenile Central Valley Steelhead could occur in the vicinity of the BSPP; however, the fish screens used at the facility are designed to protect juvenile salmonids per NMFS criteria and should prevent entrainment and greatly minimize impingement of fish against the screen itself (NMFS 2009). In addition, the location of the facility is well off the typical migration corridor of juvenile Central Valley Steelhead (NMFS 2009: 417). No juvenile Central Valley Steelhead have been captured during CDFW monitoring surveys from 1996 to 2004 (http://www.delta.dfg.ca.goc/data/nba).

Potential changes to aquatic resources due to water transfers

Central Valley Steelhead juveniles could be exposed to increased entrainment, predation, and decreased through-Delta survival as a result of the expanded transfer window under Alternative 4, but as the peak of the juvenile out-migration is in the spring, effects are anticipated to be minimal. No other life stages of Central Valley Steelhead would co-occur in time and space with water transfers from the Delta.

Potential changes to aquatic resources from Clifton Court aquatic weed removal

Under Alternative 4, the application of aquatic herbicide to the waters of CCF will occur during the summer months of July and August. Juvenile Central Valley Steelhead abundance in the Delta peaks between March and May (Reclamation 2019). Based on typical water temperatures in the vicinity of the salvage facilities during this period, the water temperatures would be incompatible with salmonid life history preferences, generally exceeding 70°F by mid-June. As such, it is unlikely that juvenile Central Valley Steelhead would be rearing near this location after mid-June and the potential application of aquatic herbicide would only occur well after the peak out-migration period (Reclamation 2019) and therefore Central Valley Steelhead are not expected to be exposed to herbicide application activities.

As discussed in Appendix D, treatment of harmful algal blooms with peroxide-based algaecide is proposed to occur as needed, year-round, but there are no anticipated impacts to fish because the oxidation reaction occurs immediately upon contact with the water, destroying algal cell membranes and chlorophyll, with hydrogen peroxide and oxygen as byproducts.

Potential changes to aquatic resources due to changes from Tracy and Skinner Fish Facility improvements

Small proportions of Sacramento River-origin Central Valley Steelhead and moderate proportions of Mokelumne River and San Joaquin River-origin Central Valley Steelhead are expected to be exposed to the Tracy Fish Facility. However, for fish that arrive at the facility, the proposed improvements resulting in greater salvage efficiency under Alternative 4 are likely to increase survival of juvenile Central Valley Steelhead.

As previously described, juvenile Central Valley Steelhead are largely absent from the Delta between August and November (Reclamation 2019) and, therefore, none to a few late migrants or early migrants have the potential to be exposed to the effects of construction of the carbon dioxide injection device proposed for the Tracy Fish Facility Improvements. Risks of decrease Central Valley Steelhead juvenile salvage during construction would be minimized through appropriate mitigation measures.

Skinner Fish Facility improvements under Alternative 4 to reduce predation on listed fishes following entrainment into CCF could reduce pre-screen loss of juvenile Central Valley Steelhead entrained into CCF; therefore, providing a benefit for all life stages of Central Valley Steelhead.

Potential changes to aquatic resources due to changes from Suisun Marsh facilities

Operation of the SMSCG from October through May under Alternative 4 coincides with downstream migration of juvenile Central Valley Steelhead (Reclamation 2019). Montezuma Slough provides an alternative route to their primary migration corridor through Suisun Bay. No data are available to estimate the abundance of juvenile Central Valley Steelhead thus, the proportion of the total run utilizing this route is unknown. However, NMFS (2009) determined that operation of the SWSCG is unlikely to impede migration of juvenile salmonids or produce conditions that support unusually high numbers of predators.

Under Alternative 4, the Roaring River Distribution System water diversion intake is equipped with fish screens (3/32-inch opening, or 2.4 mm) operated to maintain screen approach velocity of 0.2 ft/s (for Delta Smelt protection), excluding juvenile Central Valley Steelhead from entrainment (NMFS 2009: 437).

The MIDS diverts water from Goodyear Slough through three 48-inch diameter culverts during high tide. Although the MIDS intakes do not currently have fish screens, it is unlikely juvenile Central Valley Steelhead will be entrained into the water distribution system because Central Valley Steelhead have not been caught in past surveys. Also, the large size and better swimming ability of juvenile listed salmonids in the Delta allow these fish to avoid entrainment at MIDS. In addition, the location of the MIDS intake on Goodyear Slough further reduces the risk of entrainment. Goodyear Slough is not a migratory corridor for Central Valley Steelhead. The operation of the MIDS under Alternative 4 would not impact Central Valley Steelhead.

Goodyear Slough Outfall improves water circulation in the Suisun Marsh. This structure consists of four 48-inch diameter culverts with flap gates designed to drain water from the southern end of Goodyear Slough into Suisun Bay. On flood tides, the gates reduce the amount of tidal inflow into Goodyear Slough. Due to its location and design, Central Valley Steelhead are not likely to encounter this structure or be negatively affected by its operation. Improved water circulation by the operation of the Goodyear Slough Outfall likely benefits Central Valley Steelhead in Suisun Marsh by improving water quality and increasing foraging opportunities.

Potential changes to aquatic resources due to changes from Delta Smelt fall habitat operations

Central Valley Steelhead juveniles are in the Delta in the spring. Reclamation proposes to conduct actions for Fall Delta Smelt Habitat in the fall, as adult Central Valley Steelhead are migrating upstream. Fall Delta Smelt Habitat actions are unlikely to affect adult Central Valley Steelhead.

Potential changes to aquatic resources due to changes from Clifton Court predator management

Clifton Court predator management under Alternative 4 could reduce pre-screen loss of juvenile Central Valley Steelhead entrained into CCF; therefore, providing a benefit for all life stages of Central Valley Steelhead.

Potential changes to aquatic resources due to the San Joaquin Basin steelhead telemetry study

No effect

Potential changes to aquatic resources due to reintroduction changes from the fish conservation and culture laboratory

Potential changes to aquatic resources from monitoring

Population estimates for wild Steelhead remain outstanding in the Central Valley therefore, it is difficult to quantify the effects of the monitoring on Steelhead populations. However, most existing monitoring programs in the Central Valley and Delta/SF Estuary are not designed to capture Steelhead, which are much larger than Chinook Salmon upon river and Delta entry. Existing programs likely have poor capture efficiency for collecting and retaining Steelhead. Therefore, it is unlikely the monitoring programs have any effects to the population.

O.3.9.8.7 North American Green Sturgeon Southern DPS

Potential changes to aquatic resources due to seasonal operations

Hydrodynamic changes associated with river inflows and South Delta exports have been suggested to negatively impact southern DPS Green Sturgeon in two distinct ways: 1) “near-field” mortality associated with entrainment to the export facilities, 2) “far-field” mortality resulting from altered hydrodynamics. The SST completed a thorough review of this subject and defined a driver- linkage-outcome (DLO) framework for specifying how water project operations (the “driver”) can influence juvenile salmonid behavior (the “linkage”) and potentially cause changes in survival or routing (the “outcome”). A similar analysis is not available for southern DPS Green Sturgeon.

Entrainment

As described by NMFS (2009: 386), impacts to the migratory corridor function of juvenile and subadult Green Sturgeon critical habitat from south Delta exports are less clear than for juvenile salmonids because Green Sturgeon spend 1 to 3 years rearing in the Delta environment before transitioning to their marine life history stage. During this Delta rearing phase, Green Sturgeon are free to migrate throughout the Delta. In the conceptual model, it is hypothesized that higher rates of exports may result in higher rates of entrainment. However, estimating entrainment risk from raw salvage data is not possible due to a lack of information on the number of juvenile Green Sturgeon potentially exposed to salvage.

Juvenile southern DPS Green Sturgeon (> 5 mo) are present in the Delta all year and subadults are most abundant from June through November. In the June through September period under Alternative 4 Reclamation proposes an average total export rate slightly higher than No Action Alternative (440 cfs; Figure O1-15 in Appendix O, Attachment 1) and are unlikely to measurably increase entrainment risk. Total exports proposed for Alternative 4 in September-November (904 cfs higher than No Action Alternative; Figure O1-16 in Appendix O, Attachment 1) are unlikely to measurably increase entrainment risk relative to No Action Alternative.

Juvenile White and Green Sturgeon are infrequent at the TFCF but may occur in the facility salvage year-round. Salvage is expected to be similar and slightly higher than No Action Alternative under Alternative 4.

Routing

Juvenile Green Sturgeon (>5 mo) are present in the Delta all year and subadults are most abundant from June to November (Reclamation 2019). Juvenile Green Sturgeon swim and behave quite differently and have distinct body morphologies and habitat associations in the Delta compared to outmigrating salmonids, so it is hypothesized that juvenile Green Sturgeon have different routing-hydrology survival relationships. Per NMFS (2009: 338), Green Sturgeon are likely to be found in the main channels of the Delta and the larger interconnecting sloughs and waterways, with western Delta waterways having a higher likelihood of presence than eastern Delta waterways. It is highly uncertain how Green Sturgeon routing would change with Alternative 4.

Through-Delta Survival

Little is known about the relationship between survival of juvenile Green Sturgeon and Delta hydrology. Green Sturgeon reside in the Delta for 1 to 3 years suggesting they encounter a variety of daily, seasonal, and annual hydrological conditions. The majority of Green Sturgeon in the Delta are likely not surviving through the Delta per se, but using these habitats for rearing and foraging. Per NMFS (2009: 338), Green Sturgeon are likely to be found in the main channels of the Delta and the larger interconnecting sloughs and waterways, with western Delta waterways having a higher likelihood of presence than eastern Delta waterways. For juvenile outmigrating Green Sturgeon present in these regions, increasing negative velocities under Alternative 4 may result in lower survival. However, as described above, there is a lower probability of juvenile Green Sturgeon residing in this area.

Potential changes to aquatic resources OMR Management

See section above on Seasonal operations which includes OMR management

Potential changes to aquatic resources due to Delta Cross Channel operations

Delta Cross Channel operations under Alternative 4 are changed to allow Reclamation to predict water quality exceedances and open the DCC if D-1641 criteria are predicted to be exceeded. This results in greater opening times of the DCC.

Little is known about the migratory behavior of juvenile Green Sturgeon in the Sacramento River basin. It is likely that juvenile Green Sturgeon (larger than the 75 mm) will not enter the Delta prior to their first winter and thus would not be exposed to the open DCC gates. If juvenile Green Sturgeon are exposed to the open DCC gates, they could be entrained into the central / south Delta and exposed to biological and physical conditions in this area, including potentially greater predation. It is likely that these fish will enter the Delta sometime in the winter or spring following their hatching upriver and encounter both types of gate configurations as they enter the Delta.

Potential changes to aquatic resources due to the Temporary Barriers Project

Agricultural Barriers (Temporary Barrier Project, TBP) are included in Alternative 4 and consists of three rock barriers across south Delta channels to improve water levels for agricultural diversions. The temporary rock barriers are installed and removed at Middle River near Victoria Canal, Old River near Tracy, and Grant Line Canal near Tracy Boulevard Bridge. The TBP is operated based on San Joaquin River flow conditions. The agricultural barriers at Middle River and Old River near Tracy can begin operating as early as April 15 but the tide gates are tied open from May 16 to May 31. After May 31, the barriers in Middle River, Old River near Tracy, and Grant Line Canal are permitted to be operational until they are completely removed by November 30.

Juvenile Green Sturgeon are present in the Delta in all months of the year. However, little is known about their spatial distribution. When the south Delta agricultural barriers are operating with tidal flap gates down, a significant decline in passage and reach survival of acoustically tagged juvenile Chinook Salmon migrating past the barrier has been observed compared to when the barrier is not present (DWR 2018). When flap gates are tied up (May 16 to May 31), outmigrating Chinook Salmon passage past the agricultural barrier was improved (DWR 2018). It could be inferred that passage of outmigrating juvenile Green Sturgeon may also be improved when flap gates are tied up. Therefore, the potential negative effects of the agricultural barriers under Alternative 4 depends on when they are installed and whether the flap gates are down or tied up.

Potential changes to aquatic resources due to Contra Costa Water District operations

CCWD's operations in Alternative 4 are consistent with the operational criteria specified in separate biological opinions and permits that govern operations at CCWD's intakes and Los Vaqueros Reservoir (NMFS 1993, 2007, 2010, 2017; USFWS 1993a, 1993b, 2000, 2007, 2010, 2017; CDFG 1994, 2009a). Therefore, CCWD's operations, including operation of the Rock Slough Intake, for Alternative 3 remain unchanged from current conditions and the No Action Alternative.

The Contra Costa Canal Rock Slough Intake is located on a dead-end slough, far from the main migratory routes for southern DPS Green Sturgeon (NMFS 2017c), approximately 18 miles from the Sacramento River and 10 miles from the San Joaquin River via the shortest routes. Water temperatures in Rock Slough range from lows of about 40 degrees F in winter (December and January) to over 70 degrees F beginning in May and continuing through October (NMFS 2017c).

A review of the 24 years of fish monitoring data (1994–2018) near the Rock Slough Intake both pre- and post-construction of the Rock Slough Fish Screen (RSFS) showed that southern DPS Green Sturgeon have never been observed in Rock Slough (CDFG 2002c; Reclamation 2016; NMFS 2017c; Tenera Environmental 2018b; ICF 2018). CCWD's Fish Monitoring Program also samples at CCWD's other south Delta intakes. Since the intakes have been in operation, CCWD's Fish Monitoring Program has never observed southern DPS Green Sturgeon at CCWD's Old River Intake or Middle River Intake (CCWD 2019).

It is unlikely that juvenile, subadult, or adult Green Sturgeon would be present in Rock Slough due to the shallow depth, warm water temperatures, and low dissolved oxygenwhich make the area unsuitable habitat during most of the year. Therefore, it is unlikely that Green Sturgeon will be entrained at Rock Slough Intake and unlikely that Green Sturgeon would be impacted by CCWD operations.

Potential changes to aquatic resources due to North Bay Aqueduct operations

Overall, the modeled exports in Alternative 4 represent a significant increase in export levels and, thus, a greater risk to Green Sturgeon in the waters adjacent to the pumping facility compared to their historical vulnerability (NOAA 2009). However, Green Sturgeon are expected to be fully screened out of the facilities by the positive barrier fish screen in place at the pumping facility.

Potential changes to aquatic resources due to water transfers

As discussed under the Spring-Run Chinook Salmon water transfer section, under Alternative 4 Reclamation proposes to expand the transfer window to November. This extended transfer window could result in approximately 50 TAF of additional pumping per year in most years, with associated entrainment, routing, and through-Delta survival impacts. Please see the OMR management section for a discussion of the effects of pumping.

Juveniles older than 5 months, subadults, and adult Green Sturgeon could be exposed to the effects of increased pumping due to water transfers. Although southern DPS Green Sturgeon are present in the Delta in all months of the year, Green Sturgeon are likely to be found in the main channels of the Delta and the larger interconnecting sloughs and waterways, with western Delta waterways having a higher likelihood of presence than eastern Delta waterways (NMFS 2009:338). Therefore, there are no negative impacts of increased pumping at Jones and Banks Pumping Plants due to water transfers under Alternative 4.

Juvenile southern DPS Green Sturgeon are present in the Delta in every month of the year (Reclamation 2019). Thus, some portion of the population would be exposed to this action. Increases in Delta inflow during water transfers may have benefits for juvenile Green Sturgeon. However, there is no information on relationships between flow and juvenile Green Sturgeon ecology.

Potential changes to aquatic resources from Clifton Court aquatic weed removal

Few southern DPS juvenile Green Sturgeon Salmon would be expected to be exposed to the Clifton Court Forebay Aquatic Weed Control Program as part of Alternative 4. Although southern DPS juvenile Green Sturgeon are present in the Delta in all months of the year, Green Sturgeon are likely to be found in the main channels of the Delta and the larger interconnecting sloughs and waterways, with western Delta waterways having a higher likelihood of presence than eastern Delta waterways (NMFS 2009:338). The application of aquatic herbicide to the waters of Clifton Court Forebay will occur during the summer months of July and August. Thus, the likelihood of exposing juvenile Green Sturgeon to the herbicide is very low. Mechanical harvesting would occur on an as-needed basis and, therefore, juvenile Green Sturgeon could be exposed to this action, if entrained into the Forebay.

As discussed in Appendix D, treatment of harmful algal blooms with peroxide-based algaecide is proposed to occur as needed, year-round, but there are no anticipated impacts to fish because the oxidation reaction occurs immediately upon contact with the water, destroying algal cell membranes and chlorophyll, with hydrogen peroxide and oxygen as byproducts.

Potential changes to aquatic resources due to changes from Tracy and Skinner Fish Facility improvements

Upgrades to the TFCF under Alternative 4 will aim to minimize the effects of the salvage process on listed fishes, in particular juvenile salmonids and Green Sturgeon. Salvage improvements will improve survival of salvaged fish, and potentially allow reduction of the expansion factors used to extrapolate take estimates from observed salvage.

Upgrades to the TFCF will aim to minimize the effects of the salvage process on listed fishes, in particular juvenile salmonids and Green Sturgeon. Salvage improvements will improve survival of salvaged fish and potentially allow reduction of the expansion factors used to extrapolate take estimates from observed salvage.

As previously described, juvenile Green Sturgeon can occur in the Delta year-round (Reclamation 2019) and, therefore, have the potential to be exposed to the effects of construction of the CO_2 injection device proposed for the Tracy Fish Facility Improvements. If construction affects the efficiency of Green Sturgeon salvage (which is an element of entrainment risk; Reclamation 2019), there could be a minor effect to a small number of individuals, although risk would be minimized through appropriate mitigation measures for aquatic resources (Appendix E, *Mitigation Measures*).

Skinner Fish Facility improvements under Alternative 4, which involve predator control efforts, can reduce predation on listed fish species, following their entrainment into Clifton Court Forebay. This could also reduce pre-screen loss of juvenile southern DPS Green Sturgeon. It is unknown what proportion of juvenile Green Sturgeon are entrained into CCF but individuals are salvaged infrequently. Thus, Alternative 4 is not likely to negatively impact juvenile Green Sturgeon.

Potential changes to aquatic resources due to changes from Suisun Marsh facilities

Operation of the SMSCG from June through September under Alternative 4 coincides with a portion of the downstream migration of juvenile southern DPS Green Sturgeon, as well as adult southern DPS Green Sturgeon. Montezuma Slough provides an alternative route to their primary migration corridor through Suisun Bay. During full gate operation, the flashboards are installed and the radial gates open and close twice each tidal day. Green Sturgeon are thought to successfully pass through either the boat lock or through the gates during periods when the gates are open. NMFS (2009) determined that operation of the SWSCG is unlikely to produce conditions that support unusually high numbers of predators, change habitat suitability or availability for rearing or migration of juvenile and adult Green Sturgeon. Green Sturgeon are strong swimmers and therefore the operation of the Suisun Marsh Salinity Control Gate will have no impact on adults or juvenile Green Sturgeon.

The low screen velocity at the intake culverts combined with a small screen mesh size are expected to successfully prevent Green Sturgeon from being entrained into the RRDS under Alternative 4. (NOAA 2009).

The MIDS intakes under Alternative 4 do not currently have fish screens, and juvenile Green Sturgeon are more prone to entrainment than other species such as White Sturgeon (Poletto et al. 2014). However, fisheries monitoring performed in 2004-05 and 2005-06 identified entrainment of 20 fish species, none of which were Green Sturgeon (NOAA 2009). Presence of Green Sturgeon in the area of the MIDS intake is not well studied or documented, but it if Green Sturgeon are present, they may potentially avoid entrainment as they do not typically swim along the surface where the diversion is located.

Due to its location and design, Green Sturgeon are not likely to encounter this structure or be negatively affected by its operation. Improved water circulation by the operation of the Goodyear Slough Outfall under Alternative 4 likely benefits juvenile Green Sturgeon in Suisun Marsh by improving water quality and increasing foraging opportunities (NOAA 2009).

Potential changes to aquatic resources due to changes from Clifton Court predator management

Predator control efforts under Alternative 4 can reduce predation on listed fish species, following their entrainment into Clifton Court Forebay. This could also reduce pre-screen loss of juvenile southern DPS Green Sturgeon. It is unknown what proportion of juvenile Green Sturgeon are entrained into CCF but individuals are salvaged infrequently.

Potential changes to aquatic resources due to the San Joaquin Basin steelhead telemetry study

Potential changes to aquatic resources due to reintroduction changes from the fish conservation and culture laboratory

Potential changes to aquatic resources from monitoring

No effect

Population estimates for Green Sturgeon also remain outstanding in the Central Valley. Similar to Steelhead, the existing monitoring programs very rarely catch Green Sturgeon because most monitoring programs are not designed to capture them. Similar to Steelhead, it is unlikely the monitoring programs have an effect to the population.

O.3.9.9 *Nearshore Pacific Ocean on the California Coast*

O.3.9.9.1 Southern Resident Killer Whale

Potential changes to Southern Killer Whale from Chinook Salmon prey abundance

Under Alternative 4, water operations would include increases in flow as a result of unimpaired flow percentage requirements. Potential effects to Chinook Salmon, which as described in Section O.3.2.9 *Nearshore Pacific Ocean of the California Coast* are important prey to Southern Resident Killer Whale, are analyzed above in Sections O.3.6.1.1 *Trinity River*, O.3.6.1.2 *Sacramento River*, O.3.6.1.3 *Clear Creek*, O.3.6.1.4 *Feather River*, O.3.6.1.5 *American River*, O.3.6.1.6 *Stanislaus River*, O.3.6.1.7 *San Joaquin River*, and O.3.6.1.8 *Bay Delta*. These analyses suggest that Alternative 4 may result in some potential positive and negative effects to Central Valley Chinook Salmon stocks relative to the No Action Alternative. There is uncertainty in the extent to which any such changes would affect Southern Resident Killer Whale given that effects are potentially limited by the medium importance of Central Valley Chinook Salmon stocks to Southern Resident Killer Whale diet and the relatively high representation of hatchery-origin juvenile Chinook Salmon, many of which are released downstream of the Delta (Reclamation 2019).

O.3.10 Alternative 4 – Program-Level Effects

O.3.10.1 *Sacramento River*

Potential changes to aquatic resources from Battle Creek restoration

Acceleration of the Battle Creek restoration program will not occur under either Alternative 4 or the No Action Alternative. Therefore, Alternative 4 and the No Action Alternative are likely to have similar effects on aquatic resources with respect to potential effects of this measure.

Potential changes to aquatic resources from lower intakes near Wilkins Slough

Lowering intakes of diversions near Wilkins Slough will not occur under either Alternative 4 or the No Action Alternative. Therefore, Alternative 4 and the No Action Alternative are likely to have similar effects on aquatic resources with respect to potential effects of this measure.

Potential changes to aquatic resources from Shasta TCD Improvements

Improvement of the Shasta TCD will not occur under either Alternative 4 or the No Action Alternative. Therefore, Alternative 4 and the No Action Alternative are likely to have similar effects on aquatic resources with respect to potential effects of this measure.

Potential changes to aquatic resources from operation of the Livingston-Stone National Fish hatchery (Winter-Run Chinook Salmon)

Increased production of Winter-Run Chinook Salmon at the Livingston-Stone National Fish Hatchery will not occur under either Alternative 4 or the No Action Alternative. Therefore, Alternative 4 and the

No Action Alternative are likely to have similar effects on aquatic resources with respect to potential effects of this measure.

Potential changes to aquatic resources from small screen program

Increased installation and improvements to screens on small diversions in the Sacramento River will not occur under either Alternative 4 or the No Action Alternative. Therefore, Alternative 4 and the No Action Alternative are likely to have similar effects on aquatic resources with respect to potential effects of this measure.

Potential changes to aquatic resources from spawning habitat restoration

Increased spawning habitat restoration will not occur under either Alternative 4 or the No Action Alternative. Therefore, Alternative 4 and the No Action Alternative are likely to have similar effects on aquatic resources with respect to potential effects of this measure.

Potential changes to aquatic resources from rearing habitat restoration

Increased rearing habitat restoration will not occur under either Alternative 4 or the No Action Alternative. Therefore, Alternative 4 and the No Action Alternative are likely to have similar effects on aquatic resources with respect to potential effects of this measure.

Potential changes to aquatic resources due to adult rescue activities

Additional adult rescue (beyond what CDFW is currently doing, as noted for Alternative 1) will not occur under either Alternative 4 or the No Action Alternative. Therefore, Alternative 4 and the No Action Alternative are likely to have similar effects on aquatic resources.

Potential changes to aquatic resources due to trap and haul activities

The juvenile trap and haul strategy is not being implemented under either Alternative 4 or the No Action Alternative. Therefore, Alternative 4 is likely to have similar effects on aquatic resources as the No Action Alternative.

O.3.10.2 *Bay-Delta*

O.3.10.2.1 <u>Delta Smelt</u>

Potential changes to Delta Smelt from tidal habitat restoration

The effects of completion of 8,000 acres of tidal habitat restoration under Alternative 4 generally would be expected to be similar to those described for Alternative 1, although given that Delta outflow is greater in spring/summer than under the No Action Alternative, restoration may add to potential positive operations effects, rather than offsetting negative operations effects.

O.3.10.2.2 <u>Longfin Smelt</u>

Potential changes to Longfin Smelt from tidal habitat restoration

The effects of completion of 8,000 acres of tidal habitat restoration under Alternative 4 generally would be expected to be similar to those described for Alternative 1, although given that Delta outflow is greater in spring than under the No Action Alternative, restoration may add to potential positive operations effects, rather than offsetting negative operations effects.

O.3.10.2.3 Sacramento Winter-Run Chinook Salmon

Potential changes to aquatic resources from the Sacramento Deepwater Ship Channel food study

This action would hydrologically connect the Sacramento River with the Sacramento Deepwater Ship Channel (SDWSC) via the Stone Lock facility from mid-spring to late fall. Juvenile Winter-Run Chinook Salmon may be exposed to the Sacramento Deepwater Ship Channel (SDWSC) component of Alternative 4. This action would hydrologically connect the Sacramento River with the SDWSC via the Stone Lock facility from mid-spring to late fall (Wood Rodgers 2018) to provide food web benefits to Delta Smelt. Juvenile Winter-Run Chinook Salmon abundance downstream of Stone Lock at Sherwood Harbor is highest in February and March, declines in April, and is moderate in November (Reclamation 2019). Juvenile Winter-Run Chinook Salmon passing the Stone Lock facility when there is a hydrologic connection between the waterways could potentially be routed into the SDWSC. Estimates of salmonid survival in the SDWSC are not available to compare with rates in the Sacramento River route. However, if survival rates are similar, fish entering the SDWSC would not be exposed to entrainment into the interior Delta through the DCC or Georgiana Slough which would provide a benefit associated with Alternative 4. A hydrologically connected SDWSC could potentially attract adult Winter-Run Chinook Salmon. If the connection is maintained there would likely not be impacts to adults. However, if the connection is not maintained there could be migratory delays and stranding.

Potential changes to aquatic resources from the North Delta food subsidies/Colusa Basin Drain study

Provision of north Delta food subsidies by routing Colusa Basin drain water to the Cache Slough area through the Yolo Bypass would occur in summer/fall and therefore would have limited effects on Winter-Run Chinook Salmon, who are in the Delta between December and May for juveniles, and December to July for adults.

Potential changes to aquatic resources from the Suisun Marsh Roaring River Distribution System food subsidies study

Under Alternative 4, provision of Suisun Marsh food subsidies through coordination of managed wetland flood and drain operations in Suisun Marsh and draining of RRDS to Grizzly Bay/Suisun Bay in conjunction with reoperation of the SMSCG would occur in summer/fall and therefore would have limited effects on Winter-Run Chinook Salmon, who are in the Delta between December and May for juveniles, and December to July for adults.

Potential changes to aquatic resources due to tidal habitat restoration

Although migration through the Delta represents a short period, a large proportion of juvenile Winter-Run Chinook Salmon are expected to be exposed to 8,000 acres of tidal habitat restoration in the Delta. Tidal habitat restoration is expected to benefit juvenile Winter-Run Chinook Salmon in several aspects represented by the Winter-Run Chinook Salmon conceptual model including increased food availability and quality and refuge habitat from predators (Reclamation 2019). These benefits can manifest in higher growth rates and increased survival through the Delta. Reclamation and DWR will consult on future tidal habitat restoration with USFWS and NMFS on potential effects to fish from construction-related effects.

Potential changes to aquatic resources from the predator hot spot removal program

Predator hot spot removal is primarily focused on providing positive effects to downstream-migrating juvenile salmonids including Winter-Run Chinook Salmon. Although Alternative 4 would not be limited to existing identified hot spots (e.g., those identified by Grossman et al. 2013), the existing hotspots that may be representative of where removal efforts may be most concentrated are in the primary migratory routes of juvenile Winter-Run Chinook Salmon. All hotspots are limited in scale relative to overall available habitat and previous research has not found a consistent positive effect of predator removal on juvenile salmon survival (Cavallo et al. 2012; Michel et al. 2017; Sabal et al. 2016). Winter-Run Chinook Salmon juveniles in the Bay-Delta are unlikely to be exposed to the effects of construction at predator hot spot removal locations in the Sacramento River, as the in-water work window is in the summer / fall when Winter-Run Chinook Salmon juveniles are generally in the upper river.

Potential changes to aquatic resources from Delta Cross Channel gate improvements

The DCC is an older structure which requires manual operation and increased use could result in locks braking in either open or closed positions. Migrating Winter-Run Chinook Salmon would benefit from faster operations that prevent straying into the central Delta and catastrophic failure of the facility. Few Winter-Run Chinook Salmon are expected to be exposed to improvements to the Delta Cross Channel. Seasonal closure periods would still be in place to protect migrating salmonids. Potential diurnal operation during closure periods could increase exposure of Winter-Run Chinook Salmon juveniles to entrainment into the interior Delta. Improved biological and physical monitoring associated with improvements would likely minimize potentially increased routing into the interior Delta and subsequent entrainment. Greater operational flexibility and increased gate reliability resulting from improvements would reduce the risk of gate failure that could result in higher rates of entrainment.

Potential changes to aquatic resources due to changes to Tracy and Skinner Fish Facility improvements

A small proportion of juvenile Winter-Run Chinook Salmon are expected to be exposed to the Tracy Fish Facility (Zeug and Cavallo 2014). However, for fish that arrive at the facility, the proposed improvements are likely to increase survival through the facility. Winter-Run Chinook Salmon adults would not be expected to be exposed to the effects of construction of the carbon dioxide injection device proposed for the Tracy Fish Facility, based on the timing of in-water construction (August to October) and the typical seasonal occurrence of this life stage in the Delta (Reclamation 2019).

Few if any juvenile Winter-Run Chinook Salmon would be expected to be exposed to construction of the carbon dioxide injection device proposed for the Tracy Fish Facility Improvements based on lack of observed salvage during the August to October in-water work window (see Figures F.2.7, F.2.8, and F.2.9 in Appendix F of the ROC LTO BA). However, a few early migrants could occur during the in-water work window based on occurrence in the north Delta (see Figures WR_Seines and WR_Sherwood in Appendix F of the ROC LTO BA).

To the extent that the construction affects the ability of juvenile Winter-Run Chinook Salmon to be efficiently salvaged (as part of the entrainment risk habitat attribute in the SAIL conceptual model; Figure 5.6-44), there could be a minor effect to a small number of individuals, although risk would be minimized through appropriate mitigation measures for aquatic resources (Appendix E, *Mitigation Measures*). There is low potential exposure because of the in-water work window, the application of mitigation measures, and the small scale of the in-water construction.

Skinner Fish Facility improvements from predator control efforts to reduce predation on listed fishes following entrainment into CCF could reduce pre-screen loss of juvenile Chinook Salmon entrained into

CCF. It is important to note that only small proportions of Winter-Run Chinook Salmon are lost at the SWP (Zeug and Cavallo 2014).

Potential changes to aquatic resources due to changes to the small screen program

There may be some overlap Winter-Run Chinook Salmon with the main late spring-fall irrigation period for small diversions. Diversion screening could reduce entrainment of late migrating individuals. It is important to note that only a small proportion of the population would be exposed.

Few if any juvenile Winter-Run Chinook Salmon rearing and outmigrating in the Bay-Delta are expected to be exposed to the effects of construction of screens on water diversion intakes. Juvenile Winter-Run Chinook Salmon primarily migrate from November through early May (NMFS 2014c), largely outside of the timing of in-water construction (July 15 to October 15). In addition, the work area for these projects is small, limiting exposure to construction.

Potential changes to aquatic resources from the Delta fish species conservation hatchery

The operation of the Delta Fish Species Conservation Hatchery would not provide benefits to any life stage of Winter-Run Chinook Salmon. Potential negative effects of the Delta Fish Species Conservation Hatchery include inadvertent propagation and spread of invasive or nuisance species, which could affect juvenile Winter-Run Chinook Salmon through changes in food web structure, for example, in the case of invasive quagga and zebra mussels (Fera et al. 2017). Additional impacts could include reduced water quality resulting from hatchery discharge. Potential negative effects from discharged water are expected to be minimal due to the water treatment and the very small size of the discharge compared to flows in the Sacramento River near the hatchery location. Mitigation and minimization measures detailed in the EIR/EIS for the facility (Horizon Water and Environment 2017) indicate that potential impacts are less than significant. Potential exposure of juvenile Winter-Run Chinook Salmon would be restricted to a small spatial area within the primary migration route.

As with the other proposed construction activities in the Bay-Delta, few if any juvenile Winter-Run Chinook Salmon would be expected to be exposed to the effects of construction of the Delta Fishes Conservation Hatchery based on the timing of in-water construction (August to October) and the typical seasonal occurrence of this life stage in the Delta (Reclamation 2019). There may be some exposure of early migrants to in-water and shoreline construction of the hatchery intake and outfall, as illustrated by timing of occurrence in Sacramento seines and trawls (see Figures F.2.4 and F.2.5 in Appendix F of the ROC LTO BA). The relatively few individuals occurring near the construction site could be subject to effects similar to those previously described for habitat restoration (e.g., temporary loss of habitat leading to predation, degraded water quality, reduced foraging ability caused by reduced visibility, noise-related delay in migration, and direct effects from contact with construction equipment or isolation/stranding within enclosed areas). The risk from these potential effects would be minimized through application of mitigation measures (Appendix E, *Mitigation Measures*). There is low potential exposure because of the in-water work window, the application of mitigation measures, and the small scale of the in-water construction.

Winter-Run Chinook Salmon adults would not be expected to be exposed to the effects of construction of construction of the Delta Fish Species Conservation Hatchery based on the timing of in-water construction (August to October) and the typical seasonal occurrence of this life stage in the Delta (Reclamation 2019).

O.3.10.2.4 Central Valley Spring-Run Chinook Salmon

Potential changes to aquatic resources from the Sacramento Deepwater Ship Channel food study

This action would hydrologically connect the Sacramento River with the Sacramento Deepwater Ship Channel (SDWSC) via the Stone Lock facility from mid-spring to late fall. Juvenile Spring-Run Chinook Salmon abundance in the Delta is moderate in March and peaks in April (Reclamation 2019). Juvenile Spring-Run Chinook Salmon passing the Stone Lock facility when there is a hydrologic connection between the waterways could potentially enter the SDWSC. There are potential benefits to Spring-Run Chinook Salmon from this action. Fish entering the SDWSC would not be exposed to entrainment into the interior Delta through the DCC or Georgiana Slough which would provide a benefit if survival rates are similar. However, estimates of salmonid survival in the SDWSC are not available to compare with rates in the Sacramento River route. Also, there is potential for decreased migration time to the ocean and exposure to larger food sources of Liberty Island, but this is currently uncertain.

Potential changes to aquatic resources from the North Delta food subsidies/Colusa Basin Drain study

Provision of north Delta food subsidies by routing Colusa Basin drain water to the Cache Slough area through the Yolo Bypass would occur in summer/fall and therefore would have limited effects on Spring-Run Chinook Salmon, who are in the Delta January through February for adults, and November through June for juveniles, with a peak of juvenile migration from March to April.

Potential changes to aquatic resources from the Suisun Marsh Roaring River Distribution System food subsidies study

Under Alternative 4, provision of Suisun Marsh food subsidies through coordination of managed wetland flood and drain operations in Suisun Marsh and draining of RRDS to Grizzly Bay/Suisun Bay in conjunction with reoperation of the SMSCG would occur in summer/fall and therefore would have limited effects on Spring-Run Chinook Salmon, who are in the Delta January through February for adults, and November through June for juveniles, with a peak of juvenile migration from March to April.

Potential changes to aquatic resources due to tidal habitat restoration

A large proportion of juvenile Spring-Run Chinook Salmon are expected to benefit from continuing to construct the 8,000 acres of tidal habitat restoration in the Delta under Alternative 4. Benefits include increased food availability and quality and refuge habitat from predators. These benefits can manifest in higher growth rates and increased survival through the Delta.

Few if any juvenile Spring-Run Chinook Salmon would be expected to be exposed to the effects of construction of 8,000 acres of tidal habitat restoration, based on the timing of in-water construction (August to October) and the typical seasonal occurrence of this life stage in the Delta (Reclamation 2019). There may be some exposure of yearling migrants that enter the Delta in the fall. Individuals being exposed to construction could experience risk of potential effects similar to those suggested in recent restoration projects such as the Lower Yolo Restoration Project (NMFS 2014c). This includes the following: temporary loss of aquatic and riparian habitat leading to increased predation, increased water temperature, and reduced food availability; degraded water quality from contaminant discharge by heavy equipment and soils, and increased discharges of suspended solids and turbidity, leading to direct toxicological impacts on fish health/performance, indirect impairment of aquatic ecosystem productivity, loss of aquatic vegetation providing physical shelter, and reduced foraging ability caused by decreased visibility; impediments and delay in migration caused by elevated noise levels from machinery; and direct injury or mortality from in-water equipment strikes or isolation/stranding within dewatered cofferdams.

Many of these are elements highlighted in the SAIL conceptual model (Figure 5.6-4). The risk from these potential effects would be minimized through application of mitigation measures MM-AQUA-1, MM-AQUA-2, MM-AQUA-4 through MM-AQUA-12 and MM-AQUA-17. (Appendix E, *Mitigation Measures*).

Potential changes to aquatic resources from the predator hot spot removal program

Predator hot spot removal under Alternative 4 is primarily focused on providing positive effects to downstream-migrating juvenile salmonids including Spring-Run Chinook Salmon. Although the action would not be limited to existing identified hot spots (e.g., those identified by Grossman et al. 2013), the existing hotspots that may be representative of where removal efforts may be most concentrated are in the primary migratory routes of juvenile Spring-Run Chinook. All hotspots are limited in scale relative to overall available habitat and previous research has not found a consistent positive effect of predator removal on juvenile salmon survival (Cavallo et al. 2012; Michel et al. 2017; Sabal et al. 2016).

Potential changes to aquatic resources from Delta Cross Channel gate improvements

Greater operational flexibility and increased gate reliability resulting from improvements to the Delta Cross Channel under Alternative 4 would reduce the risk of gate failure that could result in higher rates of entrainment of Spring-Run Chinook Salmon, if left open. Few Spring-Run Chinook Salmon are expected to be exposed to in-water construction related improvements to the Delta Cross Channel due to observance of species protective work windows. Seasonal closure periods would still be in place to protect Spring-Run Chinook Salmon. The DCC is an older structure which requires manual operation and increased use could result in locks braking in either open or closed positions. Migrating Spring-Run Chinook Salmon would benefit from faster operations that prevent straying into the central Delta and catastrophic failure of the facility. However, improved biological and physical monitoring associated with improvements would likely minimize potentially increased entrainment.

Potential changes to aquatic resources due to changes to Tracy and Skinner Fish Facility improvements

A number of programmatic actions are proposed to improve salvage efficiency of TFCF, including installing a carbon dioxide injection device to allow remote controlled anesthetization of predators in the secondary channels of the Tracy Fish Facility. These actions could potentially benefit juvenile Spring-Run Chinook Salmon through greater salvage efficiency.

Few if any juvenile Spring-Run Chinook Salmon would be expected to be exposed to construction of the CO_2 injection device proposed for the Tracy Fish Facility Improvements, based on lack of observed salvage during the August to October in-water work window (see figures in Appendix F of the ROC LTO BA*:* WR_salvage_unclipped_date, WR_salvage_clipped_date, and WR_salvage_clipped_CWT_race). Risks to these few individuals would be minimized through appropriate mitigation measures for aquatic resources (Appendix E, *Mitigation Measures*), the selected in-water work window, and the small scale of the in-water construction. For juvenile Spring-Run Chinook Salmon that arrive at the facility, the proposed improvements are likely to increase survival through the facility.

Predator control efforts at Skinner Fish Facility under Alternative 4 to reduce predation on listed fishes following entrainment into Clifton Court Forebay could reduce pre-screen loss of juvenile Spring-Run Chinook Salmon entrained into Clifton Court Forebay. Spring-Run Chinook Salmon are unlikely to be in the area during predator control efforts.

Potential changes to aquatic resources due to changes to the small screen program

Few if any juvenile Spring-Run Chinook Salmon rearing and outmigrating in the Bay-Delta are expected to be exposed to the effects of construction of screens on water diversion intakes. Juvenile Sacramento River Spring-Run Chinook Salmon primarily from November through early May (NMFS 2014c), largely outside of the timing of in-water construction (July 15 to October 15). In addition, the work area for these projects is small, limiting exposure to construction.

Potential changes to aquatic resources from the Delta fish species conservation hatchery

The operation of the Delta Fish Species Conservation Hatchery would not provide benefits to any life stage of Winter-Run Chinook Salmon. Potential negative effects of the Delta Fish Species Conservation Hatchery include inadvertent propagation and spread of invasive or nuisance species, which could affect juvenile Winter-Run Chinook Salmon through changes in food web structure, for example, in the case of invasive quagga and zebra mussels (Fera et al. 2017). Additional impacts could include reduced water quality resulting from hatchery discharge. Potential negative effects from discharged water are expected to be minimal due to the water treatment and the very small size of the discharge compared to flows in the Sacramento River near the hatchery location. Mitigation and minimization measures detailed in the EIR/EIS for the facility (Horizon Water and Environment 2017) indicate that potential impacts are less than significant. Potential exposure of juvenile Winter-Run Chinook Salmon would be restricted to a small spatial area within the primary migration route.

As with the other proposed construction activities in the Bay-Delta, few if any juvenile Winter-Run Chinook Salmon would be expected to be exposed to the effects of construction of the Delta Fishes Conservation Hatchery based on the timing of in-water construction (August to October) and the typical seasonal occurrence of this life stage in the Delta (Reclamation 2019). There may be some exposure of early migrants to in-water and shoreline construction of the hatchery intake and outfall, as illustrated by timing of occurrence in Sacramento seines and trawls (see Figures F.2.4 and F.2.5 in Appendix F of the ROC LTO BA). The relatively few individuals occurring near the construction site could be subject to effects similar to those previously described for habitat restoration (e.g., temporary loss of habitat leading to predation, degraded water quality, reduced foraging ability caused by reduced visibility, noise-related delay in migration, and direct effects from contact with construction equipment or isolation/stranding within enclosed areas). The risk from these potential effects would be minimized through application of mitigation measures (Appendix E, *Mitigation Measures*). There is low potential exposure because of the in-water work window, the application of mitigation measures, and the small scale of the in-water construction.

Winter-Run Chinook Salmon adults would not be expected to be exposed to the effects of construction of construction of the Delta Fish Species Conservation Hatchery based on the timing of in-water construction (August to October) and the typical seasonal occurrence of this life stage in the Delta (Reclamation 2019).

O.3.10.2.5 <u>Central Valley Fall-Run Chinook Salmon</u>

Potential changes to aquatic resources from the Sacramento Deepwater Ship Channel food study

Moderate to high proportions of juvenile Fall-Run Chinook Salmon are expected to be exposed to the Sacramento Deepwater Ship Channel (SDWSC) action. This action would hydrologically connect the Sacramento River with the SDWSC via the Stone Lock facility from mid-spring to late fall (Wood Rodgers 2018). Juvenile Fall-Run abundance in the Delta is moderate in peaks in April and May (Table FR_1). Juvenile Fall-Run passing the Stone Lock facility when there is a hydrologic connection between the waterways could potentially be entrained into the SDWSC. Estimates of salmonid survival in the

SDWSC are not available to compare with rates in the Sacramento River route. However, fish entering the SDWSC would not be exposed to entrainment into the interior Delta through the DCC or Georgiana Slough which would provide a benefit if survival rates are similar. The effect of this action on juvenile Fall-Run Chinook Salmon is moderate.

No San Joaquin River-origin Fall-Run are expected to be exposed to the Sacramento Deepwater Ship Channel.

Potential changes to aquatic resources from the North Delta food subsidies/Colusa Basin Drain study

This action is proposed to occur in July or September which is largely outside of the migration period for juvenile Fall-Run and Late Fall-Run Chinook Salmon in the Delta (Table _FR1, Table LFR1). For fish that are exposed, increased food production could potentially enhance growth. The effect of this action is expected to be low.

Potential changes to aquatic resources from the Suisun Marsh Roaring River Distribution System food subsidies study

This action is proposed to occur in July or September which is largely outside of the migration period for juvenile Fall-Run and Late Fall-Run Chinook Salmon in the Delta (Table _FR1, Table LFR1). For fish that are exposed, increased food production could potentially enhance growth. The effect of this action is expected to be low.

Potential changes to aquatic resources due to tidal habitat restoration

A large proportion of juvenile Fall-Run and Late Fall-Run Chinook Salmon are expected to be exposed to 8,000 acres of tidal habitat restoration in the Delta. Tidal habitat restoration is expected to benefit juvenile Chinook Salmon in several aspects represented by the Winter-Run conceptual model (Figure WR_CM4) including, increased food availability and quality and refuge habitat from predators. These benefits can manifest in higher growth rates and increased survival through the Delta. Migration through the Delta represents a short period in the migration of juvenile Fall-Run and Late Fall-Run Chinook Salmon. Thus, the total effect of this action is moderate.

Few juvenile Fall-Run or Late Fall-Run Chinook Salmon would be expected to be exposed to the effects of construction of 8,000 acres of tidal habitat restoration, based on the timing of in-water construction (August to October) and the typical seasonal occurrence of this life stage in the Delta (Reclamation 2019). Individuals being exposed to construction could experience risk of potential effects similar to those suggested in recent restoration projects such as the Lower Yolo Restoration Project (NMFS 2014c). This includes temporary loss of aquatic and riparian habitat leading to increased predation, increased water temperature, and reduced food availability; degraded water quality from contaminant discharge by heavy equipment and soils, and increased discharges of suspended solids and turbidity, leading to direct toxicological impacts on fish health/performance (e.g., gill damage and reduced ability to take in oxygen, increasing metabolic cost), indirect impairment of aquatic ecosystem productivity (e.g., reduction in benthic macroinvertebrate production and availability), loss of aquatic vegetation providing physical shelter, and reduced foraging ability caused by decreased visibility; impediments and delay in migration caused by elevated noise levels from machinery; and direct injury or mortality from in-water equipment strikes or isolation/stranding within dewatered cofferdams. Many of these are elements highlighted in the SAIL conceptual model (Reclamation 2019). The risk from these potential effects would be minimized through application of MM-AQUA-1, MM-AQUA-2, MM-AQUA-4 through MM-AQUA-12, and MM-AQUA-14 (Appendix E, *Mitigation Measures*).

Potential changes to aquatic resources from the predator hot spot removal program

Predator hot spot removal is primarily focused on providing positive effects to downstream-migrating juvenile salmonids including Fall-Run and Late Fall-Run Chinook Salmon. Although the action would not be limited to existing identified hot spots (e.g., those identified by Grossman et al. 2013), the existing hotspots that may be representative of where removal efforts may be most concentrated are in the primary migratory routes of juvenile Spring-Run Chinook. All hotspots are limited in scale relative to overall available habitat and previous research has not found a consistent positive effect of predator removal on juvenile salmon survival (Cavallo et al. 2012; Michel et al. 2017; Sabal et al. 2016).

Potential changes to aquatic resources from Delta Cross Channel gate improvements

Greater operational flexibility and increased gate reliability resulting from improvements to the Delta Cross Channel under Alternative 4 would reduce the risk of gate failure that could result in higher rates of entrainment of Fall-Run and Late Fall-Run Chinook Salmon, if left open. Few Fall-Run or Late fall-Run Chinook Salmon are expected to be exposed to in-water construction related improvements to the Delta Cross Channel due to observance of species protective work windows. Seasonal closure periods would still be in place to protect Chinook Salmon. The DCC is an older structure which requires manual operation and increased use could result in locks braking in either open or closed positions. Migrating Fall-Run and Late fall-Run Chinook Salmon would benefit from faster operations that prevent straying into the central Delta and catastrophic failure of the facility. However, improved biological and physical monitoring associated with improvements would likely minimize potentially increased entrainment.

Potential changes to aquatic resources due to changes to Tracy and Skinner Fish Facility improvements

A small proportion of juvenile Fall-Run Chinook Salmon are expected to be exposed to the Tracy Fish Facility (Zeug and Cavallo 2014). However, for fish that arrive at the facility, the proposed improvements are likely to increase survival through the facility.

Few juvenile Fall-Run or Late Fall-Run Chinook Salmon would be expected to be exposed to construction of the CO_2 injection device proposed for the Tracy Fish Facility Improvements, based on lack of observed salvage during the August to October in-water work window (see Figures WR_salvage_unclipped_date, WR_salvage_clipped_date, and WR_salvage_clipped_CWT_race in Appendix F of the ROC LTO BA). To the extent that the construction affects the ability of juvenile Fall-Run, and Late Fall-Run Chinook Salmon to be efficiently salvaged (as part of the entrainment risk habitat attribute in the SAIL conceptual model; Figure WR_CM4), there could be a minor effect to a small number of individuals, although risk would be minimized through appropriate mitigation measures (Appendix E, *Mitigation Measures*). Given the low potential exposure because of the in-water work window, the application of mitigation measures, and the small scale of the in-water construction, it is concluded that the negative population-level effects of Tracy Fish Facility Improvements construction would be low on this life stage.

Skinner Fish Facility improvements from predator control efforts to reduce predation on listed fishes following entrainment into Clifton Court Forebay could reduce pre-screen loss of juvenile Chinook Salmon entrined into Clifton Cout Forebay. However, given that only small proportions of Fall-Run Chinook Salmon are lost at the SWP (Zeug and Cavallo 2014), the population-level positive effect of this action would be low. Larger proportions of Late Fall-Run Chinook Salmon are lost at the facilities and this action would have a larger effect for this run.

Potential changes to aquatic resources due to changes to the small screen program

Although there may be moderate overlap Fall-Late Fall-Run Chinook Salmon with the main late spring-fall irrigation period for small diversions, and small diversion screening could reduce entrainment of late migrating individuals, the potential population-level positive effect would be low because only a small proportion of the population would be exposed.

Few if any juvenile Fall- /Late Fall-Run Chinook Salmon rearing and outmigrating in the Bay-Delta are expected to be exposed to the effects of construction of screens on water diversion intakes. Juvenile Sacramento River Fall- /Late Fall-Run Chinook Salmon primarily migrate from November through early May (NMFS 2014c), largely outside of the timing of in-water construction (July 15 to October 15). In addition, the work area for these projects is small, limiting exposure to construction.

Potential changes to aquatic resources from the Delta fish species conservation hatchery

Potential effects of the Delta Fishes Conservation Hatchery include inadvertent propagation and release of nuisance species and reduced water quality resulting from hatchery discharge. Mitigation and minimization measures detailed in the EIR/EIS for the facility (Horizon Water and Environment 2017) indicate that potential impacts are less than significant. Potential exposure of juvenile Fall-Run Chinook Salmon would be restricted to a small spatial area within the primary migration route. The overall impact of the operation of this facility is low.

As with the other proposed construction activities in the Bay-Delta, few juvenile Fall-Run or Late Fall-Run Chinook Salmon would be expected to be exposed to the effects of construction of the Delta Fishes Conservation Hatchery based on the timing of in-water construction (August to October) and the typical seasonal occurrence of this life stage in the Delta (Table FR_1, LFR_1). The relatively few individuals occurring near the construction site could be subject to effects similar to those previously described for habitat restoration (e.g., temporary loss of habitat leading to predation, degraded water quality, reduced foraging ability caused by reduced visibility, noise-related delay in migration, and direct effects from contact with construction equipment or isolation/stranding within enclosed areas). The risk from these potential effects would be minimized through application of mitigation measures (Appendix E, *Mitigation Measures*). There is low potential exposure because of the in-water work window, the application of mitigation measures will reduce effects, and the in-water construction is of a small scale.

O.3.10.2.6 Central Valley Steelhead

Potential changes to aquatic resources from the Sacramento Deepwater Ship Channel food study

Moderate to high proportions of Central Valley Steelhead are expected to be exposed to the Sacramento Deepwater Ship Channel (SDWSC) conservation measure under Alternative 4. This conservation measure would hydrologically connect the Sacramento River with the SDWSC via the Stone Lock facility from mid-spring to late fall (Wood Rodgers 2018), allowing food to enter the Delta and an alternate migration pathway. Juvenile Central Valley Steelhead abundance in the Delta peaks in February through May (Reclamation 2019). Juvenile Central Valley Steelhead passing the Stone Lock facility when there is a hydrologic connection between the waterways could potentially be entrained into the SDWSC. Estimates of salmonid survival in the SDWSC are not available to compare with rates in the Sacramento River route. However, fish entering the SDWSC would not be exposed to entrainment into the interior Delta through the DCC or Georgiana Slough which would provide a benefit if survival rates are similar.

No Central Valley Steelhead are expected to be exposed to the Sacramento Deepwater Ship Channel construction, as the in-water work window does not overlap with their occurrence in the Delta.

Potential changes to aquatic resources from the North Delta food subsidies/Colusa Basin Drain study

Provision of north Delta food subsidies by routing Colusa Basin drain water to the Cache Slough area through the Yolo Bypass would occur in summer/fall and does not overlap in time or space with juvenile Central Valley Steelhead occurrence in the Delta. There would not be any effect to Central Valley Steelhead adults.

Potential changes to aquatic resources from the Suisun Marsh Roaring River Distribution System food subsidies study

Under Alternative 4, provision of Suisun Marsh food subsidies through coordination of managed wetland flood and drain operations in Suisun Marsh and draining of RRDS to Grizzly Bay/Suisun Bay in conjunction with reoperation of the SMSCG would occur in summer/fall and therefore would have limited effects on Central Valley Steelhead juveniles, who are in the Delta between December and July. The action is not expected to have any effect on Central Valley Steelhead adults.

Potential changes to aquatic resources due to tidal habitat restoration

A large proportion of juvenile Central Valley Steelhead are expected to benefit from 8,000 acres of tidal habitat restoration in the Delta under Alternative 4. Tidal habitat restoration is expected to benefit juvenile Central Valley Steelhead in several aspects represented by the Winter-Run Chinook Salmon conceptual model (Figure 5.6-4) including, increased food availability and quality and refuge habitat from predators. These benefits can manifest in higher growth rates and increased survival through the Delta; however, the Delta only represents a small fraction of the total migration route.

Few if any juvenile Central Valley Steelhead would be expected to be exposed to the effects of construction of 8,000 acres of tidal habitat restoration, based on the timing of in-water construction (August to October) and the typical seasonal occurrence of this life stage in the Delta (Reclamation 2019). There may be exposure of a few late migrants, as illustrated by timing of occurrence in Chipps mid-water trawls (Reclamation 2019). Individuals being exposed to construction could experience risk of potential effects similar to those suggested in recent restoration projects such as the Lower Yolo Restoration Project (NMFS 2014c). This includes temporary loss of aquatic and riparian habitat leading to increased predation, increased water temperature, and reduced food availability; degraded water quality from contaminant discharge by heavy equipment and soils, and increased discharges of suspended solids and turbidity, leading to direct toxicological impacts on fish health/performance (e.g., gill damage and reduced ability to take in oxygen, increasing metabolic cost), indirect impairment of aquatic ecosystem productivity (e.g., reduction in benthic macroinvertebrate production and availability), loss of aquatic vegetation providing physical shelter, and reduced foraging ability caused by decreased visibility; impediments and delay in migration caused by elevated noise levels from machinery; and direct injury or mortality from in-water equipment strikes or isolation/stranding within dewatered cofferdams. The risk from these potential effects would be minimized through application of MM-AQUA-1, MM-AQUA-2, MM-AQUA-4 through MM-AQUA-12, and MM-AQUA-14.

Potential changes to aquatic resources from the predator hot spot removal program

Predator hot spot removal under Alternative 4 is primarily focused on providing positive effects to downstream-migrating juvenile salmonids, including Central Valley Steelhead. Although the action would not be limited to existing identified hot spots (e.g., those identified by Grossman et al. 2013), the existing hotspots that may be representative of where removal efforts may be most concentrated are in the primary migratory routes of Central Valley Steelhead. All hotspots are limited in scale relative to overall available habitat, and previous research has not found a consistent positive effect of predator removal on juvenile salmon survival (Cavallo et al. 2012; Michel et al. 2017; Sabal et al. 2016). However, implementation of this action would likely improve conditions for all life stages of Central Valley Steelhead.

Potential changes to aquatic resources from Delta Cross Channel gate improvements

Completion of DCC gate improvements would benefit Central Valley Steelhead of all life stages within the CVP watershed systems. The peak migration of juvenile Central Valley Steelhead in the Sacramento River past Hood, which is near the DCC, occurs from February through mid-June (Reclamation 2019). No San Joaquin River-origin Central Valley Steelhead are expected to be exposed to the DCC. As previously described, juvenile Central Valley Steelhead are largely absent from the Delta between August and November (Reclamation 2019) and, therefore, few late migrants or early migrants have the potential to be exposed to potential construction from improvements to the DCC under Alternative 4.

Potential changes to aquatic resources due to changes to Tracy and Skinner Fish Facility improvements

Small proportions of Sacramento River-origin Central Valley Steelhead and moderate proportions of Mokelumne River and San Joaquin River-origin Central Valley Steelhead are expected to be exposed to the Tracy Fish Facility. However, for fish that arrive at the facility, the proposed improvements resulting in greater salvage efficiency under Alternative 4 are likely to increase survival of juvenile Central Valley Steelhead.

As previously described, juvenile Central Valley Steelhead are largely absent from the Delta between August and November (Reclamation 2019) and, therefore, none to a few late migrants or early migrants have the potential to be exposed to the effects of construction of the carbon dioxide injection device proposed for the Tracy Fish Facility Improvements. Risks of decrease Central Valley Steelhead juvenile salvage during construction would be minimized through appropriate mitigation measures.

Skinner Fish Facility improvements under Alternative 4 to reduce predation on listed fishes following entrainment into CCF could reduce pre-screen loss of juvenile Central Valley Steelhead entrained into CCF; therefore, providing a benefit for all life stages of Central Valley Steelhead.

Potential changes to aquatic resources due to changes to the small screen program

Fish screens under Alternative 4 would also benefit this life stage in the same ways described above. Juvenile Central Valley Steelhead outmigrating in the Bay-Delta may be exposed to the effects of construction of screens since they migrate downstream during most months of the year, with a peak emigration period in the spring and a smaller peak in the fall (Hallock et al. 1961). Juvenile Central Valley Steelhead may be found in the work area of these projects; however, mitigation measures would minimize impacts.

Potential changes to aquatic resources from the Delta fish species conservation hatchery

Potential effects of the Delta Fishes Conservation Hatchery include inadvertent propagation and release of nuisance species and reduced water quality resulting from hatchery discharge. Mitigation and minimization measures detailed in the EIR/EIS for the facility (Horizon Water and Environment 2017) indicate that potential impacts are less than significant. Potential exposure of juvenile Central Valley Steelhead would be restricted to a small spatial area within the primary migration route.

As with the other proposed construction activities in the Delta under Alternative 4, juvenile Central Valley Steelhead are largely absent from the Delta between August and November (Reclamation 2019) which means that none to a few late or early migrants of this life stage could be exposed to Delta Fishes

Conservation Hatchery construction. The in-water work constructing the hatchery intake and outfall could result in a small number of individuals experiencing effects such as temporary loss of habitat leading to predation, degraded water quality, noise-related delay in migration, and direct effects from contact with construction equipment or isolation/stranding within enclosed areas. The risk from these potential effects would be minimized through application of mitigation measures (Appendix E, *Mitigation Measures*).

O.3.10.2.7 North American Green Sturgeon Southern DPS

Potential changes to aquatic resources from the Sacramento Deepwater Ship Channel food study

As described above, juvenile Green Sturgeon may potentially be entrained into the DWSC. Fish entering the SDWSC would not, however, be exposed to entrainment into the interior Delta through the DCC or Georgiana Slough which would provide a benefit if survival rates are similar between the SDWSC and the Sacramento main stem

Potential changes to aquatic resources from the North Delta food subsidies/Colusa Basin Drain study

Provision of north Delta or Suisun Marsh food subsidies by routing drain water would occur in summer/fall and therefore could provide food benefits to Green Sturgeon juveniles, who are in the Delta in the fall.

Potential changes to aquatic resources from the Suisun Marsh Roaring River Distribution System food subsidies study

Provision of north Delta or Suisun Marsh food subsidies by routing drain water would occur in summer/fall and therefore could provide food benefits to Green Sturgeon juveniles, who are in the Delta in the fall.

Potential changes to aquatic resources due to tidal habitat restoration

A large proportion of juvenile southern DPS Green Sturgeon are expected to be exposed to continuing to implement the 8,000 acres of tidal habitat restoration in the Delta under Alternative 4. Tidal habitat restoration is expected to benefit juvenile Green Sturgeon in several aspects represented by the Green Sturgeon juvenile conceptual model including, increased food availability and quality and refuge habitat from predators (Reclamation 2019). These benefits can manifest in higher growth rates and increased survival through the Delta.

Potential changes to aquatic resources from the predator hot spot removal program

Predator hot spot removal under Alternative 4 is primarily focused on providing positive effects to downstream-migrating juvenile salmonids. It is currently unknown if predation on juvenile Green Sturgeon in the Delta is limiting their productivity. Although the action would not be limited to existing identified hot spots (e.g., those identified by Grossman et al. 2013), the existing hotspots that may be representative of where removal efforts may be most concentrated are in the rearing and migratory corridors of juvenile Green Sturgeon.

Potential changes to aquatic resources from Delta Cross Channel gate improvements

Little is known about the migratory behavior of juvenile Green Sturgeon in the Sacramento River basin. It is likely that juvenile Green Sturgeon (larger than the 75 mm) will not enter the Delta prior to their first winter and thus would not be exposed to the open DCC gates. It is likely that these fish will enter the

Delta sometime in the winter or spring following their hatching upriver and encounter both types of gate configurations as they enter the Delta. More information is required to accurately assess the migratory movements of juvenile Green Sturgeon in the river system, as well as their movements within the Delta during their rearing phase in estuarine/Delta waters. Greater operational flexibility and increased gate reliability resulting from improvements would reduce the risk of gate failure that could result in higher rates of entrainment.

Potential changes to aquatic resources due to changes to Tracy and Skinner Fish Facility improvements

Upgrades to the TFCF will aim to minimize the effects of the salvage process on listed fishes, in particular juvenile salmonids and Green Sturgeon. Salvage improvements will improve survival of salvaged fish and potentially allow reduction of the expansion factors used to extrapolate take estimates from observed salvage.

As previously described, juvenile Green Sturgeon can occur in the Delta year-round (Reclamation 2019) and, therefore, have the potential to be exposed to the effects of construction of the CO_2 injection device proposed for the Tracy Fish Facility Improvements. If construction affects the efficiency of Green Sturgeon salvage (which is an element of entrainment risk; Figure 5.12-3), there could be a minor effect to a small number of individuals, although risk would be minimized through appropriate mitigation measures (Appendix E, *Mitigation Measures*).

Skinner Fish Facility improvements under Alternative 4, which involve predator control efforts, can reduce predation on listed fish species, following their entrainment into Clifton Court Forebay. This could also reduce pre-screen loss of juvenile southern DPS Green Sturgeon. It is unknown what proportion of juvenile Green Sturgeon are entrained into CCF but individuals are salvaged infrequently. Thus, Alternative 4 is not likely to negatively impact juvenile Green Sturgeon.

Potential changes to aquatic resources due to changes to the small screen program

Southern DPS Green Sturgeon are expected to be present in the Delta during the main irrigation period for small diversions (late spring-fall). Diversion screening under Alternative 4 could reduce entrainment of individual Green Sturgeon. However, there is currently no information on the proportion of juvenile Green Sturgeon that are entrained into small unscreened diversions. North American Green Sturgeon in the juvenile to subadult/adult life stage may be exposed to the effects of construction of screens since they are present in the Sacramento River year-round (Reclamation 2019). Effects are the same as described above for juveniles. Mitigation measures would minimize risk (Appendix E, Mitigation Measures).

Potential changes to aquatic resources from the Delta fish species conservation hatchery

None of the Green Sturgeon life stages would benefit from the Delta Fish Species Conservation Hatchery under Alternative 4. As with the other proposed construction activities in the Delta, the year-round occurrence of juvenile Green Sturgeon in the Delta (Reclamation 2019) means that this life stage, as well as the timing of the adult Green Sturgeon occurring in the Delta during May to October, could be exposed to Delta Fish Species Conservation Hatchery construction under Alternative 4. The in-water work constructing the hatchery intake and outfall could result in a small number of individuals experiencing effects such as temporary loss of habitat leading to predation, degraded water quality, noise-related delay in migration, and direct effects from contact with construction equipment or isolation/stranding within enclosed areas. The risks from these potential changes would be minimized with through the application of mitigation measures (Appendix E, *Mitigation Measures*).

O.3.10.3 *Nearshore Pacific Ocean on the California Coast*

O.3.10.3.1 Southern Resident Killer Whale

Potential changes to Southern Killer Whale from Chinook Salmon prey abundance

Consistent with Alternative 2, which has the same limited suite of programmatic activities as Alternative 4 (i.e., completion of 8,000 acres of tidal habitat restoration required by the USFWS 2008 BO), Alternative 4's programmatic activities would not be expected to have population-level effects to Southern Resident Killer Whale Chinook Salmon prey. This suggests limited effects of Alternative 4 programmatic activities on Southern Resident Killer Whale.

O.3.11 Mitigation Measures

Mitigation measures are included in this document to avoid, minimize, or compensate for adverse environmental effects of alternatives as compared to the No Action Alternative. A summary of how each of the measures will mitigate effects for each alternative is provided below.

O.3.11.1 *Species-Specific Mitigation Measures*

Reclamation will implement the following mitigation measures to avoid or minimize effects on aquatic resources. Mitigation Measures measures described below have been developed to avoid and minimize effects that could result from the proposed action on aquatic resources addressed in this appendix. Table O.3-75 below briefly summarizes the species-specific measures.

Table O.3-75. Mitigation Measures for Aquatic Resources in the Study Area

Number	Title	Summary
MM AQUA-1	Worker Awareness Training	Includes procedures and training requirements to educate construction personnel on the applicable environmental rules and regulations, the types of sensitive resources in the project area, and the measures required to avoid and minimize effects on these resources.
MM AQUA-2	Construction Best Management Practices and Monitoring	Standard practices and measures that will be implemented prior to, during, and after construction to avoid or minimize effects of construction activities on sensitive resources (e.g., species, habitat), and monitoring protocols for verifying the protection provided by the implemented measures.
MM AQUA-3	Develop and Implement Program to Expand Adult Holding, Spawning, Egg Incubation, and Fry/Juvenile Rearing Habitat.	Develop and implement a program to expand suitable adult holding, spawning, egg incubation, and fry/juvenile rearing habitat for Central Valley Spring-Run Chinook Salmon, Fall-/Late Fall-Run Chinook Salmon, and Central Valley Steelhead elsewhere in the Northwestern California Diversity Group.
MM AQUA-4	Erosion and Sediment Control Plan	Includes measures that will be implemented for ground-disturbing activities to control short-term and long-term erosion and sedimentation effects and to restore soils and vegetation in areas affected by construction activities, and that will be incorporated into plans developed and implemented as part of the National Pollutant Discharge Elimination System permitting process for covered activities.

Number	Title	Summary
MM AQUA-5	Spill Prevention, Containment, and Countermeasure Plan	Includes measures to prevent and respond to spills of hazardous material that could affect navigable waters, as well as emergency notification procedures.
MM AQUA-6	Disposal and Reuse of Spoils and Dredged Material	Includes measures for handling, storage, and disposal of excavation or dredge spoils, including procedures for the chemical characterization of this material or the decant water to comply with permit requirements, and reducing potential effects on aquatic habitat, as well as specific measures to avoid and minimize effects on species in the areas where materials would be used or disposed.
MM AQUA-7	Fish Rescue and Salvage Plan	Includes measures that detail procedures for fish rescue and salvage to avoid and minimize the number of Chinook salmon, steelhead, green sturgeon, and other listed species of fish stranded during construction activities, especially during the placement and removal of enclosures (e.g., cofferdams or exclusion netting) at construction sites.
MM AQUA-8	Underwater Sound Control and Abatement Plan	Includes measures to minimize the effects of underwater construction noise on fish, particularly from any required impact pile driving activities. Potential effects of pile driving will be minimized by restricting work to the least sensitive period of the year and by controlling or abating underwater noise generated during pile driving.
MM AQUA-9	Methylmercury Management	Design and construction of tidal wetland restoration and mitigation sites to minimize ecological risks of methylmercury production.
MM AQUA-10	Noise Abatement	Develop and implement a plan to avoid or reduce the potential in-air noise impacts related to construction, maintenance, and operations.
MM AQUA-11	Hazardous Material Management	Develop and implement site-specific plans that will provide detailed information on the types of hazardous materials used or stored at all sites associated with facilities and required emergency-response procedures in case of a spill. Before construction activities begin, establish a specific protocol for the proper handling and disposal of hazardous materials.
MM AQUA-12	Construction Site Security	Provide all security personnel with environmental training similar to that of onsite construction workers, so that they understand the environmental conditions and issues associated with the various areas for which they are responsible at a given time.
MM AQUA-13	Notification of Activities in Waterways	Before in-water construction or maintenance activities begin, notify appropriate agency representatives when these activities could affect water quality or aquatic species.
MM-AQUA-14	Fugitive Dust Control	Implement basic and enhanced control measures at all construction and staging areas to reduce construction-related fugitive dust and ensure the project commitments are appropriately implemented before and during construction, and that proper documentation procedures are followed.

MM AQUA-1: Worker Awareness Training

Reclamation or its designees will provide training to field management and construction personnel on the importance of protecting sensitive natural resources (i.e., listed species and designated critical and/or suitable habitat for listed species). Training will be conducted during preconstruction meetings so that construction personnel are aware of their responsibilities and the importance of compliance. All trainees will be required to sign a sheet indicating their attendance and completion of environmental training. The training sheets will be provided to the fish and wildlife agencies if requested. These requirements also pertain to operations and maintenance personnel working in and adjacent to suitable habitat for listed species.

Construction personnel will be educated on the types of sensitive resources located in the project area and the measures required to avoid and minimize effects on these resources. Materials covered in the training program will include environmental rules and regulations for the specific project, requirements for limiting activities to approved work areas, timing restrictions, and avoidance of sensitive resource areas. In general, trainings will include the following components.

- Important timing windows for listed species (i.e., timing of fish migration, spawning, and rearing; and wildlife mating, nesting, and fledging).
- Specific training related to the relevant mitigation measures that will be implemented during construction for the protection of listed species and their habitat.
- The legal requirements for resource avoidance and protection.
- Identification of listed species potentially affected at the worksite, which will depend upon the work to be performed and the location of the work.
- Protocol for identifying the proper mitigation measures to implement for the protection of listed species based upon the nature, timing, and location of construction activities to be performed.
- Brief discussions of listed species of concern.
- Boundaries of the work area.
- Avoidance and minimization commitments.
- Exclusion and construction fencing methods.
- Roles and responsibilities.
- What to do when listed species are encountered (dead, injured, stressed, or entrapped) in work areas.
- Penalties for noncompliance.

A fact sheet or other supporting materials containing this information will be prepared and will be distributed along with a list of contacts (names, numbers, and affiliations) prior to initiating construction activities. A representative will be appointed by the project proponent to be the primary point of contact for any employee or contractor who might inadvertently take a listed species, or a representative will be identified during the employee education program and the representative's name and telephone number provided to the fish and wildlife agencies.

If new construction personnel are added to the project, the contractor will ensure that the personnel receive the mandatory training and sign a sheet indicating their attendance and completion of the environmental training before starting work. The training sheets for new construction personnel will be provided to the fish and wildlife agencies, if requested.

MM AQUA-2 Construction Best Management Practices and Monitoring

All construction and operation and maintenance activities in and adjacent to suitable habitat for listed species will implement BMPs and have construction monitored by a qualified technical specialist(s). Depending on the resource of concern and construction timing, construction activities and areas will be monitored for compliance with water quality regulations (SWPPP monitoring) and with Mitigation Measures developed for sensitive biological resources (biological monitoring).

Before initiating construction, Reclamation or its designee will prepare a construction monitoring plan for the protection of listed species. The plan will include, but not be limited to, the following elements.

- Reference to or inclusion of the SWPPP prepared under the Construction General Permit (CGP), where one is needed.
- Summaries or copies of planning and preconstruction surveys (if applicable) for listed species.
- Description of Mitigation Measures to be implemented.
- Descriptions of monitoring parameters (e.g., turbidity), including the specific activities to be monitored (e.g., dredging, grading activities) and monitoring frequency and duration (e.g., once per hour during all in-water construction activities), as well as parameters and reporting criteria.
- Description of the onsite authority of the monitors to modify construction activity and protocols for notifying CDFW, NMFS, and USFWS, if needed.
- A daily monitoring log prepared by the construction monitor, which documents the day's construction activities, notes any problems identified and solutions implemented to rectify those problems, and notifies the construction superintendent and/or the fish and wildlife agencies of any exceedances of specific parameters (e.g., turbidity) or observations of listed species. The monitoring log will also document construction start/end times, weather and general site conditions, and any other relevant information.

The following measures will be implemented prior to and during performance of the proposed action, for the protection of listed species and their habitat.

- All in-water construction activities within jurisdictional waters will be conducted during the following in-water work windows:
  - Within the legal Delta and Suisun Bay/Suisun Marsh: August 1 to October 31;
  - Sacramento River upstream of the Delta:
    - Keswick Dam (RM 302) to approximately 1.5 miles downstream (Zone 1): year-round (any time flows are less than 15,000 cfs);
    - Approximately 1.5 miles downstream of Keswick Dam (RM 300.5) to Cow Creek (RM 280) (Zone 2): October 1 to May 15 (any time flows are less than 10,000 cfs; pre-construction salmonid redd surveys conducted);
    - Cow Creek (RM 280) to Red Bluff Diversion Dam (RM 243): October 1 to March 1 (any time flows are less than 10,000 cfs; pre-construction salmonid redd surveys conducted);
    - Downstream of Red Bluff Diversion Dam (RM 243) to the boundary with the legal Delta: June 1 to October 1.

- American River:
  - July 1 to September 30.
- Feather River:
  - August 1 to October 31.
- Stanislaus River:
  - July 15 to October 15.
- Other locations proposed through programmatic actions (e.g., San Joaquin River, Battle Creek):
  - To be developed through coordination with NMFS, USFWS, and DFW.
- Note: Work windows will be refined as necessary through coordination with NMFS, USFWS, and DFW. Work windows for some activities such as pile driving may be lengthened subject to agency approval based on demonstrated success of mitigation (e.g., bubble curtains) and real-time monitoring for fish presence. In-water activities associated with mobilization and demobilization are not subject to the work windows. Apart from impact pile driving, any other work may occur within a dewatered cofferdam regardless of the timing of in-water work windows. In-water impact pile installation may occur outside of the work windows if performed within a dewatered cofferdam and with in-channel acoustic monitoring to verify that generated sound thresholds do not exceed the 150-dB behavioral criterion. Any extension/reduction of work windows would focus on half-month increments.

- To the extent possible, in-water work will only occur for up to 12 hours per day, or from at least one hour after sunrise to at least one before sunset, in order to provide a crepuscular/nocturnal time window for fish migration without disturbance. Timing of this daily in-water work window will be refined as necessary through coordination with NMFS, USFWS, and DFW.
- Qualified biologists will monitor construction activities in areas identified as having listed species or their designated critical habitat. The intent of the biological monitoring is to ensure that specific Mitigation Measures that have been integrated into the project design and permit requirements are being implemented correctly during construction and are working appropriately and as intended for the protection of listed species.
- Biological monitors will be professional biologists selected for their knowledge of the listed species that may be affected by construction activities. The qualifications of the biologist(s) will be presented to the fish and wildlife agencies for review and written approval prior to initiating construction. The biological monitors will have the authority to temporarily stop work in any area where a listed species has been observed until that individual has passively or physically been moved outside of the work area, or when any Mitigation Measures are not functioning appropriately for the protection of listed species.
- Exclusionary fencing may be placed at the edge of active construction activities and staging areas (after having been cleared by biological surveys) to restrict wildlife access from the adjacent habitats. The need for exclusionary fencing will be determined during the preconstruction surveys and the construction planning phase and may vary depending on the species and habitats present. Exclusionary fencing will consist of taut silt fabric (non-monofilament), 24 inches high (36 inches high for California red-legged frog and giant garter snake), staked at 10-foot intervals, with the bottom buried 6 inches below grade. Fence stakes will face toward the work area (on the

opposite side of adjacent habitat) to prevent wildlife from using stakes to climb over the exclusionary fencing. Exclusionary fencing will be maintained such that it is intact during rain events. Fencing will be checked by the biological monitor or construction foreman periodically throughout each work day. If fencing becomes damaged, it will be immediately repaired upon detection and the monitoring biologist will stop work in the vicinity of the fencing as needed to ensure that no sensitive wildlife species have entered. Active construction and staging areas will be delineated with high-visibility temporary fencing at least 4 feet in height, flagging, or other barrier to prevent encroachment of construction personnel and equipment outside the defined project footprint. Such fencing will be inspected and maintained daily by the construction foreman until completion of the project. Fencing will be removed from work areas only after all construction activities are completed and equipment is removed. No project-related construction activities will occur outside the delineated project construction areas.

- Project-related vehicles will observe a speed limit of 20 miles per hour in construction areas where it is safe and feasible to do so, except on county roads and state and federal highways. A vehicle speed limit of 20 miles per hour will be posted and enforced on all nonpublic access roads, particularly on rainy nights when California tiger salamanders and California red-legged frogs are most likely to be moving between breeding and upland habitats. Extra caution will be used on cool days when giant garter snakes may be basking on roads.
- All ingress/egress at the project site will be restricted to those routes identified in the project plans and description.
- All vehicle parking will be restricted to established areas, existing roads, or other suitable areas.
- To avoid attracting predators, all food-related trash items such as wrappers, cans, bottles, and food scraps will be disposed of in enclosed containers and trash will be removed and disposed of at an appropriate facility at least once a week from the construction or project site.
- To avoid injury or death to wildlife, no firearms will be allowed on the project site except for those carried by authorized security personnel or local, state, or federal law enforcement officials.
- To prevent harassment, injury, or mortality of sensitive wildlife by dogs or cats, no canine or feline pets will be permitted in the construction area.
- To prevent inadvertent entrapment of wildlife during construction, all excavated, steep-walled holes or trenches more than 1 foot deep will be covered at the close of each working day with plywood or similar material, and/or provided with one or more escape ramps constructed of earth fill or wooden planks. Before such holes or trenches are filled, they will be thoroughly inspected for trapped animals. If a listed species is encountered during construction work, to the extent feasible, construction activities should be diverted away from the animal until it can be moved by a USFWS- or CDFW-approved biologist.
- Capture and relocation of trapped or injured wildlife will only be performed by personnel with appropriate USFWS and CDFW handling permits. Any sightings and any incidental take will be reported to CDFW and USFWS via email within 1 working day of the discovery. A follow-up report will be sent to these agencies, including dates, locations, habitat description, and any corrective measures taken to protect listed species encountered. For each listed species encountered, the biologist will submit a completed CNDDB field survey form (or equivalent) to CDFW no more than 90 days after completing the last field visit to the project site.

- Plastic monofilament netting or similar material will not be used for erosion control, because smaller wildlife may become entangled or trapped in it. This includes products that use photodegradable or biodegradable synthetic netting, which can take several months to decompose. Acceptable materials include natural fibers such as jute, coconut, twine, or other similar fibers or tackified hydroseeding compounds. This limitation will be communicated to the contractor through specifications or special provisions included in the construction bid solicitation package.
- Listed species of wildlife can be attracted to den-like structures such as pipes and may enter stored pipes and become trapped or injured. All construction pipes, culverts, or similar structures, construction equipment, or construction debris left overnight in areas that may be occupied by wildlife will be inspected by the biological monitor or the contractor prior to being used for construction. Such inspections will occur at the beginning of each day’s activities, for those materials to be used or moved that day. If necessary, and under the direct supervision of the biologist, the structure may be moved up to one time to isolate it from construction activities, until the listed species has moved from the structure of their own volition, been captured and relocated, or otherwise been removed from the structure.
- Rodenticides and herbicides will be used in accordance with the manufacturer-recommended uses and applications and in such a manner as to prevent primary or secondary poisoning of listed species and depletion of prey populations upon which they depend. All uses of such compounds will observe label and other restrictions mandated by the U.S. Environmental Protection Agency (EPA), the California Department of Pesticide Regulation, and other appropriate state and federal regulations, as well as additional project-related restrictions imposed by USFWS, NMFS and/or CDFW. If rodent control must be conducted in San Joaquin kit fox habitat, zinc phosphide should be used because of its proven lower risk to kit fox. In addition, the method of rodent control will comply with provisions of the 4(d) rule published in the final listing rule for California tiger salamander (69 *Federal Register* [FR] 47211–47248).
- Nets or bare hands may be used to capture and handle individuals of listed species. A professional biologist will be responsible for and direct any efforts to capture and handle listed species. Any person who captures and handles listed species will not use soaps, oils, creams, lotions, insect repellents, solvents, or other potentially harmful chemicals of any sort on their hands within 2 hours before handling listed species. Latex gloves will not be used either. To avoid transferring diseases or pathogens between aquatic habitats during the course of surveys or the capture and handling of listed species, all species captured and handled will be released in a safe, aquatic environment as close to the point of capture as possible, and not transported and released to a different water body. When capturing and handling listed species of amphibians, the biologists will follow the Declining Amphibian Task Force’s *Code of Practice* (U.S. Fish and Wildlife Service no date). While in captivity, individual amphibians will be kept in a cool, moist, aerated environment such as a dark (i.e., green or brown) bucket containing a damp sponge. Containers used for holding or transporting these species will be sanitized and will not contain any standing water.
- CDFW, NMFS and/or USFWS will be notified within 1 working day of the discovery of, injury to, or mortality of a listed species that results from project-related construction activities or is observed at the project site. Notification will include the date, time, and location of the incident or of the discovery of an individual listed species that is dead or injured. For a listed species that is

injured, general information on the type or extent of injury will be included. The location of the incident will be clearly indicated on a U.S. Geological Survey 7.5-minute quadrangle and/or similar map at a scale that will allow others to find the location in the field, or as requested by CDFW, NMFS and/or USFWS. The biologist is encouraged to include any other pertinent information in the notification.

- Permanent and temporary construction disturbances and other types of ongoing project-related disturbance activities in suitable habitat for listed species will be minimized by adhering to the following activities.
  - Project designs will limit or cluster permanent project features to the smallest area possible while still permitting achievement of project goals.
  - To minimize temporary disturbances, all project-related vehicle traffic and material storage will be restricted to established and/or designated ingress/egress points, construction areas, and other designated staging/storage areas. These areas will be included in preconstruction surveys and, to the extent possible, will be established in locations disturbed by previous activities to prevent further effects.
  - To the extent possible, minimize effects to sensitive habitats outside of construction footprints. For example, in upstream areas, conduct aerial or boat pre-construction redd surveys downstream of construction areas and implement avoidance and minimization measures to limit potential effects, e.g., modification of work area, turbidity management (such as a sediment curtain), or placement of a gravel berm to redirect flow away from sensitive areas.
  - Upon completion of the project, all areas subject to temporary ground disturbance will be recontoured to preproject elevations, as appropriate and necessary, and revegetated with native vegetation to promote restoration of the area to preproject conditions. An area subject to “temporary” disturbance is any area that is disturbed to allow for construction of the project, but is not required for operation or maintenance of any project-related infrastructure, will not be subject to further disturbance after project completion, and has the potential to be revegetated. Appropriate methods and native plant species used to revegetate such areas will be determined on a site-specific basis in consultation with USFWS, NMFS, and/or CDFW, and biologists.
- Equipment will be inspected prior to arrival at the construction area, including the physical removal of plant seed and parts from equipment, and freezing equipment and saturation of equipment in chemical solution(s) to avoid the spread of invasive species such as zebra and quagga mussels, New Zealand mudsnails and Chytrid Fungus.

Mitigation Measure AQUA-3 Develop and Implement Program to Expand Adult Holding, Spawning, Egg Incubation, and Fry/Juvenile Rearing Habitat.

Reclamation will develop and implement a program to expand suitable adult holding, spawning, egg incubation, and fry/juvenile rearing habitat for Central Valley Spring-Run Chinook Salmon, Fall-/Late Fall-Run Chinook Salmon, and Central Valley Steelhead elsewhere in the Northwestern California Diversity Group. The program will be designed to prevent hybridization and improve genetic integrity of Spring-Run Chinook Salmon, and to improve spawning success, fry/juvenile survival, and production of all three species, thereby contributing to their recovery. Increases in Salmon and Steelhead production potential created by the program will equal or exceed the reduced production potential in Clear Creek that would result from cessation of the Clear Creek Restoration

Program and reduced flows below Whiskeytown Dam. The program will be developed in coordination with and subject to approval by NMFS and CDFW.

Mitigation Measure AQUA-4 Erosion and Sediment Control Plan

An erosion and sediment control plan is typically required for ground-disturbing projects as part of the NPDES permitting process (U.S. Environmental Protection Agency 2007), depending on the size of the disturbed area. The proposed Phase II EPA rules would cover projects with greater than 1 acre of ground disturbance. Reclamation commits to implementing measures as described below as part of the construction activities and in advance of any necessary permit. In accordance with these environmental commitments, Reclamation will ensure the preparation and implementation of erosion and sediment control plans to control short-term and long-term erosion and sedimentation effects and to restore soils and vegetation in areas affected by construction activities. It is anticipated that multiple erosion and sediment control plans will be prepared for the construction activities included in the proposed action, each taking into account site-specific conditions such as proximity to surface water, erosion potential, drainage, etc. The plans will include all the necessary state requirements regarding erosion control and will implement BMPs for erosion and sediment control that will be in place for the duration of construction activities. These BMPs will be incorporated into the SWPPP (Section 3.F.1.1.1, *Conduct Planning-Level Surveys*).

The following erosion control measures will be included in the SWPPP.

- Install physical erosion control stabilization BMPs (hydroseeding with native seed mix, mulch, silt fencing, fiber rolls, sand bags, and erosion control blankets) to capture sediment and control both wind and water erosion. Erosion control may not utilize plastic monofilament netting or similar materials.
- Maintain emergency erosion control supplies onsite at all times during construction and direct contractor(s) to use these emergency stockpiles as needed. Ensure that supplies used from the emergency stockpiles are replaced within 48 hours. Remove materials used in construction of erosion control measures from the work site when no longer needed (property of the contractor).
- Design grading to be compatible with adjacent areas and result in minimal disturbance of the terrain and natural land features and minimize erosion in disturbed areas to the extent practicable.
- Divert runoff away from steep, denuded slopes, or other critical areas with barriers, berms, ditches, or other facilities.
- Retain native trees and vegetation to the extent feasible to stabilize hillsides, retain moisture, and reduce erosion.
- Limit construction, clearing of native vegetation, and disturbance of soils to areas of proven stability.
- Implement construction management and scheduling measures to avoid exposure to rainfall events, runoff, or flooding at construction sites to the extent feasible.
- Conduct frequent site inspections (before and after significant storm events) to ensure that control measures are intact and working properly and to correct problems as needed.
- Install drainage control features (e.g., berms and swales, slope drains) as necessary to avoid and minimize erosion.
- Install wind erosion control features (e.g., application of hydraulic mulch or bonded fiber matrix).

The following sediment control measures will be included in the SWPPP.

- Use sediment ponds, silt traps, wattles, straw bale barriers, or similar measures to retain sediment transported by onsite runoff.
- Collect and direct surface runoff at non-erosive velocities to the common drainage courses.
- When ground-disturbing activities are required adjacent to surface water, wetlands, or aquatic habitat, use of sediment and turbidity barriers, and implement measures for soil stabilization and revegetation of disturbed surfaces.
- Prevent mud from being tracked onto public roadways by installing gravel on primary construction ingress/egress points, and/or truck tire washing.
- Deposit or store excavated materials away from drainage courses and cover if left in place for more than 5 days or if storm events are forecast within 48 hours.

After construction is complete, site-specific restoration efforts will include grading, erosion control, and revegetation. Self-sustaining, local native plants that require little or no maintenance and do not create an extreme fire hazard will be used. All disturbed areas will be recontoured to preproject contours as feasible, and seeded with a native seed mix. Consideration will also be given to additional replacement of or upgrades to drainage facilities to avoid and minimize erosion. Paved areas damaged from use over and above ordinary wear-and-tear from lawful use by construction activities will be repaved to avoid erosion due to pavement damage.

Mitigation Measure AQUA-5 Spill Prevention, Containment, and Countermeasure Plan

As required by local, state, or federal regulations, Reclamation will require that construction contractors develop an SPCC plan for implementation at each site where ground-disturbing activities occur. Each SPCC plan will comply with the regulatory requirements of the Spill Prevention, Control, and Countermeasure Rule (40 Code of Federal Regulations [CFR] 112) under the Oil Pollution Act of 1990. This rule regulates non-transportation-related onshore and offshore facilities that could reasonably be expected to discharge oil into navigable waters of the United States or adjoining shorelines. The rule requires the preparation and implementation of site-specific SPCC plans to prevent and respond to oil discharges that could affect navigable waters. Each SPCC plan will address actions used to prevent spills in addition to specifying actions that will be taken should any spills occur, including emergency notification procedures. The SPCC plans will include the following measures and practices.

- Discharge prevention measures will include procedures for routine handling of products (e.g., loading, unloading, and facility transfers) (*40 CFR 112.7(a)(3)(i)*).
- Discharge or drainage controls will be implemented such as secondary containment around containers and other structures and equipment, and procedures for the control of a discharge (*40 CFR 112.7(a)(3)(ii)*).
- Countermeasures will be implemented for discharge discovery, response, and cleanup (both the facility's capability and those that might be required of a contractor) (*40 CFR 112.7(a)(3)(iii)*).
- Methods of disposal of recovered materials will comply with applicable legal requirements (*40 CFR 112.7(a)(3)(iv)*).
- Personnel will be trained in emergency response and spill containment techniques, and will also be made aware of the pollution control laws, rules, and regulations applicable to their work.

- Petroleum products will be stored in nonleaking containers at impervious storage sites from which an accidental spill cannot escape.
- Absorbent pads, pillows, socks, booms, and other spill containment materials will be stored and maintained at the hazardous materials storage sites for use in the event of an accidental spill.
- Watertight forms and other containment structures will be used to prevent spills or discharge of raw concrete, wash water, and other contaminants from entering surface waters and other sensitive habitats during overwater activities (e.g., casting of barge decks).
- Contaminated absorbent pads, pillows, socks, booms, and other spill containment materials will be placed in nonleaking sealed containers until transported to an appropriate disposal facility.
- When transferring oil or other hazardous materials from trucks to storage containers, absorbent pads, pillows, socks, booms, or other spill containment material will be placed under the transfer area.
- Refueling of construction equipment will occur only in designated areas that will be a minimum of 150 feet from surface waters and other sensitive habitats, such as wetlands.
- Equipment used in direct contact with water will be inspected daily for oil, grease, and other petroleum products. All equipment will be cleaned of external petroleum products prior to beginning work where contact with water may occur in order to prevent the release of such products to surface waters.
- Oil-absorbent booms will be used when equipment is used in or immediately adjacent to waters.
- All reserve fuel supplies will be stored only within the confines of a designated staging area, to be located a minimum of 150 feet from surface waters and other sensitive habitats, such as wetlands.
- Fuel transfers will take place a minimum of 150 feet from surface waters and other sensitive habitats, such as wetlands, and absorbent pads will be placed under the fuel transfer operation.
- Staging areas will be designed to contain contaminants such as oil, grease, fuel, and other petroleum products so that should an accidental spill occur they do not drain toward receiving waters or storm drain inlets.
- All stationary equipment will be staged in appropriate staging areas and positioned over drip pans.
- In the event of an accidental spill, personnel will identify and secure the source of the discharge and contain the discharge with sorbents, sandbags, or other material from spill kits and will contact appropriate regulatory authorities (e.g., National Response Center will be contacted if the spill threatens navigable waters of the United States or adjoining shorelines, as well as other appropriate response personnel).

Methods of cleanup may include the following.

- Physical methods for the cleanup of dry chemicals include the use of brooms, shovels, sweepers, or plows.
- Mechanical methods could include the use of vacuum cleaning systems and pumps.
- Chemical methods include the use of appropriate chemical agents such as sorbents, gels, and foams.

Mitigation Measure AQUA-6 Disposal of Spoils and Dredged Material

In the course of constructing or operating project facilities, substantial quantities of material are likely to be removed from their existing locations based upon their properties or the need for excavation of particular features. Spoils refer to excavated native soils and are associated with construction of proposed new facilities. Dredged material refers to sediment removed from the bottom of a body of water for the purposes of in-water construction. The quantities of these materials generated by construction or operation of proposed facilities will vary based on various factors, such as location, topography, and structure being constructed. These materials will require handling, storage, and disposal, as well as chemical characterization. Storage areas are designated for these materials. Many of these materials will be suitable for reuse (e.g., as engineered fill or for purposes of habitat restoration), but such use is not part of the PA and projects using this material have not been identified.

Storage Area Determination

Spoils and dredged material will be stored in designated storage areas, with these locations to be provided by Reclamation during consultation with NMFS and USFWS.

The designated storage areas are sized to accommodate all material expected to be generated by the proposed action, i.e., it is assumed that none of that material will be reused, sold, or otherwise relocated under the proposed action. In practice, the area that will be needed for material storage will depend on several factors.

- The speed with which material is brought to the surface, stored, dried, tested, and moved to storage locations will be important in determining the final size of storage areas. If alternative end uses for the material can be identified and if those uses can be permitted within the timeframe of the proposed action (such permitting is not included in the proposed action, so separate authorizations would have to be obtained), then a smaller area may be needed for material storage.
- The depth to which the material is stacked. Material that is stored in deeper piles will require less area but may dry more slowly. Calculation of needed materials storage areas has assumed that materials would be placed in piles with a depth of six feet.

Storage Site Preparation

A portion of the storage sites selected for storage of spoils and dredged material will be set aside for topsoil storage. The topsoil will be saved for reapplication to disturbed areas postconstruction. Vegetative material from work site clearing will be chipped, stockpiled, and spread over the topsoil after earthwork is completed, when practicable and appropriate to do so and where such material does not contain seeds of undesirable nonnative species (i.e., nonnative species that are highly invasive and threaten the ecological function of the vegetation community to be restored in that location). Cleared areas will be grubbed as necessary to prepare them for grading or other construction activities. Rocks and other inorganic grubbed materials will be used to backfill borrow areas. The contractor will remove from the work site all debris, rubbish, and other materials not directed to be salvaged, and will dispose of them in an approved disposal site after obtaining all permits required.

Draining, Chemical Characterization, and Treatment

In instances of spoils and dredged material being deemed unsuitable for reuse, the material will be disposed of at a site for which disposal of such material is approved.

Hazardous materials excavated during construction will be segregated from other construction spoils and properly handled in accordance with applicable federal, state, and local regulations. Riverine or in-Delta sediment dredging and dredged material disposal activities may involve potential contaminant discharges not addressed through typical NPDES or SWRCB CGP processes. Construction of dredge material disposal sites will likely be subject to the SWRCB General Permit (Order No. 2009-0009-DWQ).

To better define potential effects to listed species or aquatic habitat, and to streamline the collection and incorporation of newer information (i.e., monitoring data or site-specific baseline information), the following protocol will be followed. Reclamation will work with State and Federal resource agencies with authorization and jurisdiction to identify the timeline for information gathering in relation to initiation of the specific action, but it is anticipated to be at least several months prior to the initiation of the action. At that time, Reclamation will follow the protocol below.

- Reclamation will ensure the preparation and implementation of a pre-dredge sampling and analysis plan (SAP). The SAP will be developed and submitted by the contractor(s) as part of the water plan required per standard DWR contract specifications (Section 01570). Prior to initiating any dredging activity, the SAP will evaluate the presence of contaminants that may affect water quality from the following discharge routes.
    - Instream discharges during dredging.
    - Direct exposure to contaminants in the material through ingestion, inhalation, or dermal exposure.
    - Effluent (return flow) discharge from an upland disposal site.
    - Leachate from upland dredge material disposal that may affect groundwater or surface water.
- Concentrations of the identified chemical constituents in the core samples will be screened through appropriate contaminant screening tables to ensure compliance with applicable agency guidelines.
- Results of the sediment analyses and the quality guidelines screening will determine the risk associated with the disturbance of the sediment horizons by identifying specific pathways of exposure to adverse effects.
- Results of the testing will be provided to all relevant State and Federal agencies for their use in monitoring or regulating the activities under consideration.
- If the results of the chemical analyses of the sediment samples indicate that one or more chemical constituents are present at concentrations exceeding screening criteria, then additional alternative protocols to further minimize or eliminate the release of sediments into the surrounding water column must be implemented.
- The applicant must provide to CDFW, NMFS and USFWS a plan to reduce or eliminate the release of contaminated sediment prior to the start of any actions that will disturb the sediments in the proposed construction area. Plans using a shrouded hydraulic cutterhead, or an environmentally sealed clamshell bucket may be acceptable provided that adequate supporting information is provided with the proposed plan. Plans should also include descriptions of the methods employed to treat, transport, and dispose of the contaminated sediment, as well as any resulting decant waters.

The following list of BMPs will be implemented during handling and disposal of any potentially hazardous dredged material.

- Conduct dredging within the allowable in-water work windows specified in Mitigation Measure AQUA-2 *Construction Best Management Practices*.
- Conduct dredging activities in a manner that will not cause turbidity in the receiving water, as measured in surface waters 300 feet down-current from the construction site, to exceed the Basin Plan objectives beyond an approved averaging period by the Central Valley Regional Water Quality Control Board and CDFW. Existing threshold limits in the Basin Plan for turbidity generation are as follows.
    - Where natural turbidity is between 0 and 5 NTUs, increases will not exceed 1 NTU.
    - Where natural turbidity is between 5 and 50 NTUs, increases will not exceed 20%.
    - Where natural turbidity is between 50 and 100 NTUs, increases will not exceed 10 NTUs.
    - Where natural turbidity is greater than 100 NTUs, increases will not exceed 10%.
- If turbidity generated during dredging exceeds implementation requirements for compliance with the Basin Plan objectives, silt curtains will be used to control turbidity. Exceptions to turbidity limits set forth in the Basin Plan may be allowed for dredging operations; in this case, an allowable zone of dilution within which turbidity exceeds the limits will be defined and prescribed in a discharge permit.
- The dredged material disposal sites will be designed to contain all of the dredged material. All systems and equipment associated with necessary return flows from the dredged material disposal site to the receiving water will be operated to maximize treatment of return water and optimize the quality of the discharge.
- The dredged material disposal sites will be designed by a registered professional engineer.
- The dredged material disposal sites will be designed, constructed, operated, and maintained to prevent inundation or washout due to floods with a 100-year return frequency.
- Two feet of freeboard above the 100-year flood event elevation will be maintained in all dredged material disposal site settling ponds at all times when they may be subject to washout from a 100-year flood event.
- Dredging equipment will be kept out of riparian areas and dredged material will be disposed of outside of riparian corridors.

Temporary storage sites will be constructed using appropriate BMPs such as erosion and sediment control measures (Mitigation Measure AQUA-*4 Erosion and Sediment Control Plan*) to prevent discharges of contaminated stormwater to surface waters or groundwater.

Once the excavated spoils or dredged material have been suitably dewatered, and as the constituents of the material will allow, it will be placed in either a lined or unlined storage area suitable for long-term storage. These long-term storage areas may be the same areas in which the material was previously dewatered or it may be a new area adjacent to the dewatering site. The storage areas will be created by excavating and stockpiling the native topsoil for future reuse. Once the area has been suitably excavated, and if a lined storage area is required, an impervious liner will be placed on the invert of the material storage area and along the interior slopes of the berms surrounding the pond. Due to the expected high groundwater tables at some storage areas, it is anticipated that there will be minimal excavation for construction of the long-term material storage areas. Additional features of the long-term material storage areas will include berms and erosion protection measures to contain storm runoff as necessary and provisions to allow for truck traffic during construction.

Mitigation Measure AQUA-7 Fish Rescue and Salvage Plan

Fish rescue operations will occur at any in-water construction site where dewatering and resulting isolation of fish may occur, or where fish exclusion netting is placed to exclude fish. Fish rescue and salvage plans will be developed by Reclamation or its contractors and will include detailed procedures for fish rescue and salvage to minimize the number of individuals of listed fish species subject to stranding during placement and removal of cofferdams or enclosure by exclusion netting. The plans will identify the appropriate procedures for removing fish from construction zones and preventing fish from reentering construction zones prior to dewatering and other construction activities. A draft plan will be submitted to the fish and wildlife agencies for review and approval. An authorization letter from NMFS, USFWS, and CDFW will be required before in-water construction activities with the potential for stranding fish can proceed.

Some construction activities may involve placement of cofferdams to isolate construction areas and minimize adverse effects to aquatic species and habitat during construction activities. However, these species can become trapped within the cofferdam and will need to be rescued or salvaged prior to dewatering. Although the following discussion focuses primarily on the application of this plan to cofferdam construction, the plan will also need to describe potential fish protection methods that may be implemented during other in-water activities with the potential to trap fish. For example, potential measures to exclude fish from active dredging areas may include deployment of silt curtains in a manner that directs fish away from the silt curtains and prevents fish from re-entering these areas during dredging operations. To the extent possible, fish will be gently encouraged (e.g., swept with seine nets; see below) to leave any areas that are scheduled to be dewatered or otherwise disturbed.

All fish rescue and salvage operations will be conducted under the guidance of a qualified fish biologist and in accordance with required permits. Each fish rescue plan will identify the appropriate procedures for excluding fish from the construction zones, and procedures for removing fish, should they become trapped. The primary procedure will be to block off the construction area and use seines (nets) and/or dip nets to collect and remove fish, although electrofishing techniques may also be authorized under certain conditions. It is critical that fish rescue and salvage operations begin as soon as possible and be completed within 48 hours after isolation of a construction area to minimize potential predation and adverse water quality impacts (high water temperature, low dissolved oxygen) associated with confinement. In the case of cofferdam construction, the cofferdam will be installed to block off the construction area before fish removal activities occur. For other in-water construction activities, block nets or other temporary exclusion methods (e.g., silt curtains) could be used to exclude fish or isolate the construction area prior to the fish removal process. The appropriate fish exclusion or collection method will be determined by a qualified fish biologist, in consultation with a designated fish and wildlife agency biologist, based on site-specific conditions and construction methods. Capture, release, and relocation measures will be consistent with the general guidelines and procedures set forth in Part IX of the most recent edition of the California Salmonid Stream Habitat Restoration Manual (currently, California Department of Fish and Game 2010) to minimize impacts on listed species of fish and their habitat.

All fish rescue and salvage operations will be conducted under the guidance of a fish biologist meeting the qualification requirements of Section 3.F.2.8.1 Qualifications of Fish Rescue Personnel. The following description includes detailed fish collection, holding, handling, and release procedures of the plan. Unless otherwise required by project permits, the construction contractor will provide the following:

- A minimum 7-day notice to the appropriate fish and wildlife agencies, prior to an anticipated activity that could result in isolating fish, such as installation of a cofferdam.
- A minimum 48-hour notice to the appropriate fish and wildlife agencies of dewatering activities that are expected to require fish rescue.
- Unrestricted access for the appropriate fish and wildlife agency personnel to the construction site for the duration of implementation of the fish rescue plan.
- Temporary cessation of dewatering if fish rescue workers determine that water levels may drop too quickly to allow successful rescue of fish.
- A work site that is accessible and safe for fish rescue workers.

Qualifications of Fish Rescue Personnel

Personnel active in fish rescue efforts will include at least one person with a 4-year college degree in fisheries or biology, or a related degree. This person also must have at least 2 years of professional experience in fisheries field surveys and fish capture and handling procedures. The person will have completed an electrofishing training course such as Principles and Techniques of Electrofishing (USFWS, National Conservation Training Center), or similar course, if electrofishing is used. In order to avoid and minimize the risk of injury to fish, attempts to seine and/or net fish will always precede the use of electrofishing equipment.

Seining and Dipnetting

Fish rescue and salvage operations will begin prior to or immediately after completing the cofferdam. For example, it may be necessary to herd fish from the construction area before installing the last sections of the cofferdam. Where larger areas are being enclosed by cofferdams, fish exclusion and/or rescue activities may need to be conducted incrementally in coordination with cofferdam placement to minimize the number of fish subjected to prolonged confinement and stressful conditions associated with crowding, capture, and handling. If the enclosed area is wadable (less than 3 feet deep), fish can be herded out of the cofferdam enclosure by dragging a seine (net) through the enclosure, starting from the enclosed end and continuing to the cofferdam opening. Depending on conditions, this process may need to be conducted several times. After completing this fish herding process, the net or an exclusion screen will be positioned at the cofferdam opening to prevent fish from reentering the enclosure while the final section of the cofferdam is installed. The net or screen mesh will be no greater than 0.125 inch, with the bottom edge of the net (lead line) securely weighted down to prevent fish from entering the area by moving under the net. Screens will be checked periodically and cleaned of debris to permit free flow of water.

After installing the last sections of the cofferdam, remaining fish in the enclosed area will be removed using seines, dip nets, electrofishing techniques, or a combination of these depending on site conditions. If the water depth within the cofferdam is too deep to effectively remove fish using these methods, dewatering activities may be used to reduce the water level to an appropriate and safe depth (Section 3.F.2.8.5, *Contingency Plans*). Dewatering activities will also conform to the guidelines specified below (Section 3.F.2.8.4, *Dewatering*).

Following each sweep of a seine through the enclosure, the fish rescue team will do the following.

- Carefully bring the ends of the net together and pull in the wings, ensuring the lead line is kept as close to the substrate as possible.
- Slowly turn the seine bag inside out to reveal captured fish, ensuring fish remain in the water as long as possible before transfer to an aerated container.

- Follow the procedures outlined in Section 3.F.2.8.3, *Electrofishing*, and relocate fish to a predetermined release site.

Dipnetting is best suited for very small, shallow pools in which fish are concentrated and easily collected. Dip nets will be made of soft (nonabrasive) nylon material and small mesh size (0.125 inch) to collect small fish.

Electrofishing

After conducting the herding and netting operations described above, electrofishing may be necessary to remove as many fish as possible from the enclosure. Electrofishing will be conducted in accordance with NMFS electrofishing guidelines (NMFS 2000) and other appropriate fish and wildlife agency guidelines. Electrofishing will be conducted by one or two 3- to 4-person teams, with each team having an electrofishing unit operator and two or three netters. At least three passes will be made through the enclosed cofferdam areas to remove as many fish as possible. Fish initially will be placed in 5-gallon buckets filled with river water. Following completion of each pass, the electrofishing team will do the following.

- Transfer fish into 5-gallon buckets filled with clean river water at ambient temperature.
- Hold fish in 5-gallon buckets equipped with a lid and an aerator, and add fresh river water or small amounts of ice to the fish buckets if the water temperature in the buckets becomes more than 2°F warmer than ambient river waters.
- Maintain a healthy environment for captured fish, including low densities in holding containers to avoid effects of overcrowding.
- Use water-to-water transfers whenever possible.
- Release fish at predetermined locations.
- Segregate larger fish from smaller fish to minimize the risk of predation and physical damage to smaller fish from larger fish.
- Limit holding time to about 10 minutes, if possible.
- Avoid handling fish during processing unless absolutely necessary. Use wet hands or dip nets if handling is needed.
- Handle fish with hands that are free of potentially harmful products, including but not limited to sunscreen, lotion, and insect repellent.
- Avoid anesthetizing or measuring fish.
- Note the date, time, and location of collection; species; number of fish; approximate age (e.g., young-of-the-year, yearling, adult); fish condition (dead, visibly injured, healthy); and water temperature.
- If positive identification of fish cannot be made without handling the fish, note this and release fish without handling.
- In notes, indicate the level of accuracy of visual estimates to allow appropriate reporting to the appropriate fish and wildlife agencies (e.g., “Approx. 10–20 young-of-the-year steelhead”).
- Release fish in appropriate habitat either upstream or downstream of the enclosure, noting release date, time, and location.

- Stop efforts and immediately contact the appropriate fish and wildlife agencies if mortality during relocation or the limits on take (harm or harassment) of federally listed species exceeds 5%.
- Place dead fish of listed species in sealed plastic bags with labels indicating species, location, date, and time of collection, and store them on ice.
- Freeze collected dead fish of listed species as soon as possible and provide the frozen specimens to the appropriate fish and wildlife agencies, as specified in the permits.
- Sites selected for release of rescued fish either upstream or downstream of the construction area will be similar in temperature to the area from which fish were rescued, contain ample habitat, and have a low likelihood of fish reentering the construction area or being impinged on exclusion nets/screens.

Dewatering

Dewatering will be performed in coordination with fish rescue operations as described above. A dewatering plan will be submitted as part of the SWPPP/Water Pollution Control Program detailing the location of dewatering activities, equipment, and discharge point. Dewatering pump intakes will be screened to prevent entrainment of fish in accordance with NMFS screening criteria for salmonid fry (National Marine Fisheries Service 1997), including the following.

- Perforated plate: screen openings shall not exceed 3/32 inch (2.38 mm), measured in diameter.
- Profile bar: screen openings shall not exceed 0.0689 inch (1.75 mm) in width.
- Woven wire: screen openings shall not exceed 3/32 inch (2.38 mm), measured diagonally (e.g., 6–14 mesh).
- Screen material shall provide a minimum of 27% open area.

During the dewatering process, a qualified biologist or fish rescue team will remain onsite to observe the process and remove additional fish using the rescue procedures described above.

Contingency Plans

Where fish rescue and salvage operations cannot be conducted effectively or safely by fish rescue workers, it may be necessary to begin the dewatering process prior to fish rescue. During the dewatering process, a qualified biologist or fish rescue team will be onsite with the aim of minimizing the number of fish that become trapped in isolated areas or impinged on pump screen(s) or isolation nets, based on the professional judgment of the onsite fish biologist and the terms and conditions of the incidental take permit. In the event that the proposed methods are found to be insufficient to avoid undue losses of fish, the qualified biologist will modify these methods or implement alternative methods to minimize subsequent losses.

Final Inspections and Reporting

Upon dewatering to water depths at which neither electrofishing nor seining can effectively occur (e.g., less than 3 inches [0.1 meter]), the fish rescue team will inspect the dewatered areas to locate any remaining fish. Collection by dip net, data recording, and relocation will be performed as necessary according to the procedures outlined in Section 3.F.2.8.3, *Electrofishing*. The fish rescue team will notify the contractor when the fish rescue has been completed and construction can recommence. The results of the fish rescue and salvage operations (including date, time, location, comments, method of capture, fish species, number of fish, approximate age, condition, release location, and release time) will be reported to the appropriate fish and wildlife agencies, as specified in the pertinent permits.

Mitigation Measure AQUA-8 Underwater Sound Control and Abatement Plan

Reclamation will develop and implement an underwater sound control and abatement plan outlining specific measures that will be implemented to avoid and minimize the effects of underwater construction noise on listed species of fish, particularly the underwater noise effects associated with impact pile driving activities. Potential underwater noise effects on listed species from impact pile driving will be avoided and minimized by regulating the period during which impact pile driving is permitted and by controlling and/or abating underwater noise generated during impact pile driving.

The underwater sound control and abatement plan will be provided to the appropriate fish and wildlife agencies for their review and approval prior to implementation of any in-water impact pile driving activities. The plan will evaluate the potential effects of underwater noise on listed species of fish in the context of applicable and interim underwater noise thresholds established for disturbance and injury of fish (California Department of Transportation 2009). The thresholds include the following.

- Injury threshold for fish of all sizes includes a peak sound pressure level of 206 decibels (dB) relative to 1 micropascal.
- Injury threshold for fish less than 2 grams is 183 dB relative to 1 micropascal cumulative sound exposure level, and 187 dB relative to 1 micropascal cumulative sound exposure level for fish greater than or equal to 2 grams.
- Disturbance threshold for fish of all sizes is 150 dB root mean square relative to 1 micropascal.

The specific number of pilings that will be driven per day with an impact pile driver, and thus the number of pile strikes per day, will be defined as part of the design of project elements that require pilings.

The sound control and abatement plan will restrict in-water work to the in-water work windows specified in specified in Mitigation Measure AQUA-2 *Construction Best Management Practices*.

The underwater noise generated by impact pile driving will be abated using the best available and practicable technologies. Examples of such technologies include, but are not limited to, the use of cast-in-drilled-hole rather than driven piles; use of vibratory rather than impact pile driving equipment; using an impact pile driver to proof piles initially placed with a vibratory pile driver; noise attenuation using pile caps (e.g., wood or micarta), bubble curtains, air-filled fabric barriers, or isolation piles; or installation of piling-specific cofferdams. Specific techniques to be used will be selected based on site-specific conditions.

In addition to primarily using vibratory pile driving methods and establishing protocols for attenuating underwater noise levels produced during in-water construction activities, Reclamation will develop and implement operational protocols for when impact pile driving is necessary. These operational protocols will be used to minimize the effects of impact pile driving on listed species of fish. These protocols may include, but not be limited to, the following: monitoring the in-water work area for fish that may be showing signs of distress or injury as a result of pile driving activities and stopping work when distressed or injured fish are observed; initiating impact pile driving with a "soft-start," such that pile strikes are initiated at reduced impact and increase to full impact over several strikes to provide fish an opportunity to move out of the area; restricting impact pile driving activities to specific times of the day and for a specific duration to be determined through coordination with the fish and wildlife agencies; and, when more than one pile driving rig is employed, ensure pile driving activities are initiated in a way that provides an escape route and avoids "trapping" fish between pile drivers in waters exposed to underwater noise levels that could potentially cause injury. These protocols are expected to avoid and minimize the overall extent, intensity, and duration of potential underwater noise effects associated with impact pile driving activities.

Mitigation Measure AQUA-9 Methylmercury Management

Tidal and other habitat restoration under the proposed action has the potential to result in increased availability of mercury, and specifically the bioavailable form methylmercury, to the foodweb in the Delta and river systems where restoration would occur. Due to the complex and very site-specific factors that will determine if mercury becomes mobilized into the foodweb, Mitigation Measure AQUA-9 *Methylmercury Management* is included to provide for site-specific evaluation for each restoration project. Mitigation Measure AQUA-9 will be implemented in coordination with other similar efforts to address mercury in the Delta and other waterways, and specifically with the DWR Mercury Monitoring and Analysis Section, as further described below.

This Mitigation Measure will promote the following actions.

- Assessment of pre-restoration conditions to determine the risk that the project could result in increased mercury methylation and bioavailability
- Definition of design elements that minimize conditions conducive to generation of methylmercury in restored areas
- Definition of strategies that can be implemented to monitor and minimize actual postrestoration creation and mobilization of methylmercury into environmental media and biota

The restoration design will always focus on the ecosystem restoration objectives and design elements to mitigate mercury methylation that will not interfere with restoration objectives. Design elements that help to mitigate mercury methylation will be integrated into site-specific restoration designs based on site conditions, community type (tidal marsh, nontidal marsh, floodplain, riverine habitats), and potential concentrations of mercury in pre-restoration sediments. Strategies to minimize postrestoration creation and mobilization of methylmercury can be applied where site conditions indicate a high probability of methylmercury generation and effects on listed species.

Implementation

Mitigation Measure AQUA-9 will be developed and implemented in coordination with the Sacramento-San Joaquin Delta Methylmercury Total Maximum Daily Load (Methylmercury TMDL) (Central Valley Regional Water Quality Control Board 2011a) and Amendments to the Water Quality Control Plan for the Sacramento River and San Joaquin River Basins for the Control of Methylmercury and Total Mercury in the Sacramento-San Joaquin Delta Estuary (Mercury Basin Plan Amendments)(Central Valley Regional Water Quality Control Board 2010 and 2011). Mitigation Measure AQUA-9 will also be implemented to meet requirements of the U.S. Environmental Protection Agency (EPA) or the California Department of Toxic Substances Control actions.

The DWR Mercury Monitoring and Evaluation Section is currently working on DWR’s compliance with the Methylmercury TMDL and Mercury Basin Plan Amendments. The Methylmercury TMDL programs are responsible for developing measures to control methylmercury generation and loading into the Delta in accordance with Methylmercury TMDL goals. Phase I emphasizes studies and pilot projects to develop and evaluate management practices to control methylmercury. Phase I (effective October 2011) will be underway for the next 7 years, with an additional 2 years to evaluate Phase I results and plan for Phase II. Phase II involves implementation of mercury control measures.

The DWR Mercury Monitoring and Evaluation Section is required as part of Phase I to submit final reports that present the results and descriptions of methylmercury control options, their preferred methylmercury controls, and proposed methylmercury management plan(s) (including implementation schedules) for achieving methylmercury allocations. Results will be integrated into Project-Specific Mercury Management Plans, which will be developed for each tidal wetland restoration project. The Plans will include the components listed below.

- A brief review of available information on levels of mercury expected in site sediments/soils based on proximity to sources and existing analytical data.
- A determination if sampling for characterization of mercury concentrations
- A plan for conducting the sampling, if characterization sampling is recommended.
- A determination of the potential for the restoration action to result in increased mercury methylation
- If a potential for increased mercury methylation under the restoration action is identified, the following will also be included:
    - Identification of any restoration design elements, mitigation measures, adaptive management measures that could be used to mitigate mercury methylation, and the probability of success of those measures, including uncertainties
    - Conclusion on the resultant risk of increased mercury methylation, and if appropriate, consideration of alternative restoration areas

Because methylmercury is an area of active research in the Delta and elsewhere in the Central Valley, each new project-specific methylmercury management plan will be updated based on the latest information about the role of mercury in Delta and other ecosystems or methods for its characterization or management. Results from monitoring of methylmercury in previous restoration projects will also be incorporated into subsequent project-specific methylmercury management plans.

In each of the project-specific methylmercury management plans developed under Mitigation Measure AQUA-9, relevant findings and mercury control measures identified as part of TMDL Phase I control studies will be considered and integrated into restoration design and management plans.

Mitigation Measure AQUA-10 Noise Abatement

In addition to the underwater sound control and abatement plan (Mitigation Measure AQUA-8), Reclamation and contractors hired to construct any components of proposed facilities will implement a noise abatement plan to avoid or reduce potential in-air noise impacts related to construction, maintenance, and operations. As applicable, the following components will be included in the plan.

Construction and Maintenance Noise

- To the extent feasible, the contractor will employ best practices to reduce construction noise during daytime and evening hours (7:00 a.m. to 10:00 p.m.) such that construction noise levels do not exceed 60 dBA (A-weighted decibel) L_{eq} (1 hour) at the nearest residential land uses.
- Limit construction during nighttime hours (10:00 p.m. to 7:00 a.m.) such that construction noise levels do not exceed 50 dBA L_{max} (L_{max} is the maximum sound level measured for a given interval of time) at the nearest residential land uses. Limit pile driving to daytime hours (7 a.m. to 7 p.m.).
- In the event of complaints by nearby residents due to construction noise generated during nighttime hours, the contractor will monitor noise levels intermittently between 10:00 p.m. to 7:00 a.m. at the property line of the nearest residential use. In the event that construction noise during nighttime hours exceeds 50 dBA L_{max}, the construction contractor will cease nighttime

construction activity in the area until sound-attenuating mitigation measures, such as temporary sound walls, are implemented, and nighttime construction noise at the nearest residential use is reduced to a level of 50 dBA L_{max} or lower.

- Locate, store, and maintain portable and stationary equipment as far as possible from nearby residents.
- Employ preventive maintenance including practicable methods and devices to control, prevent, and minimize noise.
- Route truck traffic in order to reduce construction noise impacts and traffic noise levels at noise-sensitive land uses (i.e., places where people reside, schools, libraries, and places of worship).
- To the extent feasible, schedule construction activities so that the loudest noise events, such as blasting, occur during peak traffic commute hours.
- Limit offsite trucking activities (e.g., deliveries, export of materials) to the hours of 7:00 a.m. to 10:00 p.m. to minimize impacts on nearby residences.

Operation Noise

Facilities will be designed and constructed such that facility operation noise levels at nearby residential land uses do not exceed 50 dBA L_{eq} during daytime hours (7:00 a.m. to 10:00 p.m.) and 45 dBA L_{eq} during nighttime hours (10 p.m. to 7 a.m.). Acoustical measures such as terrain shielding, enclosures, and acoustical building treatments will be incorporated into the facility design to meet this performance standard.

Mitigation Measure AQUA-11 Hazardous Materials Management

Reclamation will ensure that each contractor responsible for site work under the proposed action will develop and implement a hazardous materials management plan (HMMP) before beginning construction. It is anticipated that multiple HMMPs will be prepared for the various construction sites, each taking into account site-specific conditions such as hazardous materials present onsite and known historical site contamination. A database on historical instances of contamination and results of any field inspections regarding the presence of hazardous chemicals will be maintained. The HMMPs will provide detailed information on the types of hazardous materials used or stored at all sites associated with the water conveyance facilities (e.g., intake pumping plants, maintenance facilities); phone numbers of applicable city, county, state, and federal emergency response agencies; primary, secondary, and final cleanup procedures; emergency-response procedures in case of a spill; and other applicable information. The HMMPs will include appropriate practices to reduce the likelihood of a spill of toxic chemicals and other hazardous materials during construction and facilities operation and maintenance. A specific protocol for the proper handling and disposal of hazardous materials will be established before construction activities begin and will be enforced by Reclamation.

The HMMPs will include, but not be limited to, the following measures or practices.

- Fuel, oil, and other petroleum products will be stored only at designated sites.
- Hazardous materials containment containers will be clearly labeled with the identity of the hazardous materials contained therein, handling and safety instructions, and emergency contact.
- Storage, use, or transfer of hazardous materials in or near wet or dry streams will be consistent with California Fish and Game Code (Section 5650) and/or with the permission of CDFW.

- Material Safety Data Sheets will be made readily available to the contractor's employees and other personnel at the work site.
- The accumulation and temporary storage of hazardous wastes will not exceed 90 days.
- Soils contaminated by spills or cleaning wastes will be contained and removed to an approved disposal site.
- Hazardous waste generated at work sites, such as contaminated soil, will be segregated from other construction spoils and properly handled, hauled, and disposed of at an approved disposal facility by a licensed hazardous waste hauler in accordance with state and local regulations. The contractor will obtain permits required for such disposal.
- Emergency spill containment and cleanup kits will be located at the facility site. The contents of the kits will be appropriate to the type and quantities of chemical or goods stored at the facility.

Mitigation Measure AQUA-12 Construction Site Security

To ensure adequate construction site security, Reclamation or their contractors will arrange to provide for 24-hour onsite security personnel. Security personnel will monitor and patrol construction sites, including staging and equipment storage areas. Security personnel will serve as the first line of defense against criminal activities and nuisances at construction sites. Private patrol security operators hired to provide site security will have the appropriate licenses from the California Bureau of Security and Investigative Services. Individual security personnel will have a minimum security guard registration license that meets the California Bureau of Security and Investigative Services requirements for training and continuation training as required for that license. All security personnel will also receive environmental training similar to that of onsite construction workers so that they understand the environmental conditions and issues associated with the various areas for which they are responsible at a given time.

Security operations and field personnel will be given the emergency contact phone numbers of environmental response personnel for rapid response to environmental issues resulting from vandalism or incidents that occur when construction personnel are not onsite. Security operations will also maintain a contact list of backup support from city police, county sheriffs, California Highway Patrol, water patrols (such as the Contra Costa County Marine Patrol), helicopter response, and emergency response (including fire departments, ambulances/emergency medical technicians). The appropriate local and regional contact list will be made available to security personnel by Reclamation or their contractors, as will the means to make that contact via landline phones, mobile phones, or radios. When on patrol, security personnel will always have the ability to contact backup using mobile phones or two way radios. Security personnel who are on patrol will have the appropriate geographic contact list for their location and the ability to summon appropriate backup or response via the security patrol local dispatch site or outside authorities.

Mitigation Measure AQUA-13 Notification of Activities in Waterways

Similar to the requirements specified in the fish rescue and salvage plan (Mitigation Measure AQUA-7), and underwater sound control and abatement plan (Mitigation Measure AQUA-8), before in-water construction or maintenance activities begin, Reclamation will ensure notification of appropriate fish and wildlife agency representatives when these activities could affect water quality or aquatic species. The notification procedures will follow stipulations included in applicable permit documents for the construction operations. However, in general, the notification information will include site location(s), schedules, and work activities. Information on detours will include site-specific details regarding any temporary partial channel closures, including contacting the U.S. Coast Guard, boating organizations, marina operators, city or county parks departments, and the California Department of Pesticide Regulation, where applicable.

Mitigation Measure AQUA-14 Fugitive Dust Control

Reclamation or their contractors will implement basic and enhanced control measures at all construction and staging areas to reduce construction-related fugitive dust. Although the following measures are outlined in the Sacramento Metropolitan Air Quality Management District's (SMAQMD) CEQA guidelines, they are required for the entirety of the construction area, including areas within the Bay Area Air Quality Management District (BAAQMD), San Joaquin Valley Air Pollution Control District (SJVAPCD), and Yolo-Solano Air Quality Management District (YSAQMD), and are sufficient to address BAAQMD, SJVAPCD, and YSAQMD fugitive dust control requirements. Reclamation or their contractors will ensure the project commitments are appropriately implemented before and during construction, and that proper documentation procedure is followed.

Basic Fugitive Dust Control Measures

Reclamation or their contractors will take steps to ensure that the following measures will be implemented to the extent feasible to control dust during general construction activities.

- Water will be applied to all exposed surfaces as reasonably necessary to prevent visible dust from leaving work areas. Frequency will be increased during especially dry or windy periods or in areas with a lot of construction activity. Exposed surfaces include (but are not limited to) soil piles, graded areas, unpaved parking areas, staging areas, and access roads.
- Cover or maintain at least 2 feet of freeboard space on haul trucks transporting soil, sand, or other loose material on the site. Any haul trucks that will be traveling along freeways or major roadways should be covered.
- Use wet power vacuum street sweepers to remove any visible trackout mud or dirt onto adjacent public roads at least once a day. Use of dry power sweeping is prohibited.
- Limit vehicle speeds on unpaved roads to 15 miles per hour.
- All roadway, driveway, sidewalk, and parking lot paving should be completed as soon as possible. In addition, building pads should be laid as soon as possible after grading unless seeding or soil binders, or other reasonable mitigation measures are used.

Enhanced Fugitive Dust Control Measures for Land Disturbance

Reclamation or their contractors will take steps to ensure that the following measures will be implemented to the extent feasible to control dust during soil disturbance activities.

- Water exposed soil with adequate frequency for continued moist soil. However, do not overwater to the extent that sediment flows off the site.
- Suspend excavation, grading, and/or demolition activity when wind speeds exceed 20 miles per hour.
- Install wind breaks (e.g., plant trees, solid fencing) on windward side(s) of construction areas.
- Plant vegetative ground cover (fast-germinating native grass seed) in disturbed areas as soon as possible after construction is completed. Water appropriately until vegetation is established.

Measures for Entrained Road Dust

Reclamation or their contractors will take steps to ensure that the following measures will be implemented to the extent feasible to control entrained road dust from unpaved roads.

- Install wheel washers for all exiting trucks, or wash off all trucks and equipment leaving the site.
- Treat site accesses to a distance of 100 feet from the paved road with a 6- to 12-inch layer of wood chips, mulch, or gravel to reduce generation of road dust and road dust carryout onto public roads.
- Post a publicly visible sign with the telephone number and person to contact at the lead agency regarding dust complaints. This person will respond and take corrective action within 48 hours. The phone number of the air quality management district will also be visible to ensure compliance.

Measures for Concrete Batching

Reclamation or their contractors will take steps to ensure that the following measures will be implemented to the extent feasible to control dust during concrete batching activities.

- Implementation of fugitive dust control measures to achieve a 70% reduction in dust from concrete batching.
- Implementation of fugitive dust control measures to achieve an 80% reduction in dust from aggregate and sand pile erosion at the concrete batch plants.
- Use of a hood system vented to a fabric filter/baghouse during cement delivery and hopper and central mix loading.

O.3.12 Summary of Impacts

Table O.3-76 includes a summary of impacts, the magnitude and direction of those impacts, and potential mitigation measures for consideration.

Table O.3-76. Summary of Aquatic Resources Impacts

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
Trinity River			
Seasonal Operations			
Potential changes to aquatic resources from changes in reservoir storage	No Action	No effect on focal fish species	
	Alternative 1	No effect on focal fish species	
	Alternative 2	No effect on focal fish species	
	Alternative 3	No effect on focal fish species	
	Alternative 4	No effect on focal fish species	
Potential changes to aquatic resources from variation in flow	No Action	Likely to continue to improve habitat conditions	
	Alternative 1	Possible minimal, negative effect due to increased likelihood of egg mortality due to red scour	

Impact	**Alternative**	**Magnitude and Direction of Impacts**	**Potential Mitigation Measures**
	Alternative 2	Possible minimal, negative effect due to increased likelihood of egg mortality due to red scour	
	Alternative 3	Possible minimal, negative effect due to increased likelihood of egg mortality due to red scour	
	Alternative 4	Possible minimal, negative effect due to increased likelihood of egg mortality due to red scour	
Potential changes to aquatic resources due to variation in temperature	No Action	Likely to continue to improve habitat conditions	
	Alternative 1	Possible minimal, negative and positive effects of water temperature; negligible overall effect	
	Alternative 2	Possible minimal, negative and positive effects of water temperature; negligible overall effect	
	Alternative 3	Some possible negative effects of water temperature; effects vary with species	
	Alternative 4	Potential beneficial effects associated with reduced water temperature	
Trinity River Downstream of Lewiston Dam			
Potential changes in fishery resources due to contributing factors not included in seasonal operations	No Action		
	Alternative 1		
	Alternative 2		
	Alternative 3		
	Alternative 4		
Trinity River Record of Decision			
Potential changes to aquatic resources due to implementing variable annual flow regime under the Trinity ROD	No Action	Likely to continue to improve habitat conditions	
	Alternative 1	Similar to No Action	
	Alternative 2	Similar to No Action	
	Alternative 3	Similar to No Action	
	Alternative 4	Similar to No Action	
Potential changes to aquatic resources due to implementing restoration actions under the Trinity ROD	No Action	Likely beneficial effect on habitat conditions	
	Alternative 1	Similar to No Action	
	Alternative 2	Similar to No Action	
	Alternative 3	Similar to No Action	
	Alternative 4	Similar to No Action	

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
Potential changes to aquatic resources due to implementing monitoring and adaptive management under the Trinity ROD	No Action	Likely beneficial effects	
	Alternative 1	Similar to No Action	
	Alternative 2	Similar to No Action	
	Alternative 3	Similar to No Action	
	Alternative 4	Similar to No Action	
Potential changes to fishery resources due to other contributing factors not included in the Trinity ROD	No Action	Multiple minor changes in effects possible but uncertain or unlikely	
	Alternative 1	Similar to No Action	
	Alternative 2	Similar to No Action	
	Alternative 3	Similar to No Action	
	Alternative 4	Similar to No Action	
Potential changes to aquatic resources due to Trinity River flow during late summer	No Action	Range of potential effects from negligible to considerable and positive	
	Alternative 1	Similar to No Action	
	Alternative 2	Similar to No Action	
	Alternative 3	Similar to No Action	
	Alternative 4	Similar to No Action	
Potential changes to aquatic resources due to Trinity River water temperatures	No Action	Range of potential effects from negligible to considerable and positive	
	Alternative 1	Similar to No Action	
	Alternative 2	Similar to No Action	
	Alternative 3	Similar to No Action	
	Alternative 4	Similar to No Action	
Grass Valley Creek Flows from Buckhorn Dam			
Potential changes to aquatic resources due to climate change in Grass Valley Creek	No Action	Possible minor, negative effects	
	Alternative 1	Similar to No Action	
	Alternative 2	Similar to No Action	
	Alternative 3	Similar to No Action	
	Alternative 4	Similar to No Action	
Potential changes to aquatic resources due to past and ongoing restoration in Grass Valley Creek	No Action	Potential positive effects	
	Alternative 1	Similar to No Action	
	Alternative 2	Similar to No Action	

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
	Alternative 3	Similar to No Action	
	Alternative 4	Similar to No Action	
Potential changes to aquatic resources from the decreasing storage capacity of Buckhorn Reservoir on Grass Valley Creek	No Action	Possible minor, negative temperature effects	
	Alternative 1	Similar to No Action	
	Alternative 2	Similar to No Action	
	Alternative 3	Similar to No Action	
	Alternative 4	Similar to No Action	
Potential changes to aquatic resources due to changes in pulse flows in Grass Valley Creek	No Action	Likely continuation of current trends	
	Alternative 1	Net beneficial effect of channel maintenance and attraction flows	
	Alternative 2	Similar to No Action	
	Alternative 3	Net beneficial effect of channel maintenance and attraction flows	
	Alternative 4	Net beneficial effect of increased attraction flows	
Sacramento River			
Potential changes to aquatic resources from adult rescue activities (Program Level)	No Action	Limited negative effects possible with the potential for increased flooding and stranding frequency	
	Alternative 1	Minor, net positive effect	
	Alternative 2	Similar to No Action	
	Alternative 3	Similar to Alternative 1	
	Alternative 4	Similar to No Action	
Potential changes to aquatic resources from trap and haul activities (Program Level)	No Action	Limited negative effects possible with the potential for increased exposure to lower flows and elevated water temperatures	
	Alternative 1	Potential beneficial effect	
	Alternative 2	Similar to No Action	
	Alternative 3	Similar to Alternative 1	
	Alternative 4	Similar to No Action	
Potential changes to aquatic resources in the Sacramento River from seasonal operations (Project Level)	No Action	Not included in this alternative	

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
	Alternative 1	Potential increases in survival of winter-run and spring-run eggs and alevins from improved water temperature management and TCD; potential reductions in juvenile winter-run and spring-run rearing habitat and smolt survival and quality of green sturgeon holding habitat from reduced September and November flow in Wet and Above Normal years	
	Alternative 2	Potential reductions in survival of winter-run and spring-run eggs and alevins from higher water temperatures in September of Wet and Above Normal years; potential reductions in winter-run and spring-run juvenile rearing habitat and smolt survival and quality of green sturgeon holding habitat from reduced September and November flow in Wet and Above Normal years	
	Alternative 3	Potential reductions in survival of winter-run and spring-run eggs and alevins from higher water temperatures in September of Wet and Above Normal years; potential reductions in winter-run and spring-run juvenile rearing habitat and smolt survival and quality of green sturgeon holding habitat from reduced September and November flow in Wet and Above Normal years	
	Alternative 4	Potential increases in survival of winter-run and spring-run eggs and alevins from improved water temperature management; potential reductions in juvenile winter-run and spring-run rearing habitat and smolt survival and quality of green sturgeon holding habitat from reduced September and November flow in Wet and Above Normal years	
Potential changes to aquatic resources in the Sacramento River from Shasta cold water pool management (Project level)	No Action	Not included in this alternative (however, NMFS RPA Action I.2.4 cold water pool management actions are included)	

Impact	**Alternative**	**Magnitude and Direction of Impacts**	**Potential Mitigation Measures**
	Alternative 1	Potential increases in survival of winter-run and spring-run eggs and alevins from reduced late summer and fall water temperatures	
	Alternative 2	Potential reductions in survival of winter-run and spring-run eggs and alevins from increased water temperatures in September of Wet and Above Normal years	
	Alternative 3	Potential reductions in survival of winter-run and spring-run eggs and alevins from increased water temperatures in September of Wet and Above Normal years	
	Alternative 4	Potential increases in survival of winter-run and spring-run eggs and alevins from reduced late summer and fall water temperatures	
Potential changes to aquatic resources in the Sacramento River from spring pulse flows (Project level)	No Action	Not included in this alternative	
	Alternative 1	Potential improvement in conditions for immigration of adult winter-run, spring-run, and green sturgeon, and potential increase in survival of emigrating spring-run, fall-run, late fall-run and steelhead juveniles; potential reduction in survival of winter-run and spring-run eggs and alevins from increased risk of depleting cold water pool in late summer/early fall	
	Alternative 2	Not included in this alternative	
	Alternative 3	Not included in this alternative	
	Alternative 4	Not included in this alternative	
Potential changes to aquatic resources in the Sacramento River from fall and winter refill and redd maintenance (Project level)	No Action	Not included in this alternative (however, NMFS RPA Action I.2.2 is included)	
	Alternative 1	Potential increase in survival of spring-run eggs and alevins and winter-run alevins from reduced redd dewatering in fall (winter-run eggs already hatched by fall)	
	Alternative 2	Not included in this alternative	
	Alternative 3	Not included in this alternative	

Impact	**Alternative**	**Magnitude and Direction of Impacts**	**Potential Mitigation Measures**
	Alternative 4	Not included in this alternative	
Potential changes to aquatic resources in the Sacramento River from rice decomposition smoothing (Project level)	No Action	Not included in this alternative	
	Alternative 1	Potential increase in survival of winter-run and spring-run eggs and alevins from reduced risk of depleting cold water pool in late summer/early fall; potential increase in survival of fall-run eggs and alevins from reduced redd dewatering; potential reduction in survival of spring-run eggs and alevins from increased redd dewatering	
	Alternative 2	Not included in this alternative	
	Alternative 3	Not included in this alternative	
	Alternative 4	Not included in this alternative	
Potential changes to aquatic resources in the Sacramento River from spring management of spawning locations (Project level)	No Action	Not included in this alternative	
	Alternative 1	Potential increase in survival of winter-run and spring-run eggs and alevins, depending on results of experiments	
	Alternative 2	Not included in this alternative	
	Alternative 3	Not included in this alternative	
	Alternative 4	Not included in this alternative	
Potential changes to aquatic resources from Battle Creek restoration (Program level)	No Action	Battle Creek restoration would continue under No Action, but restoration would not be accelerated as it would be under Alternative 1	
	Alternative 1	Accelerating implementation of restoration projects results in earlier realization of potential benefits, including: increase in population abundance, reduction in extinction risk, and increase in temperature compliance flexibility	
	Alternative 2	Same Battle Creek restoration as No Action	

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
	Alternative 3	Accelerating implementation of restoration projects results in earlier realization of potential benefits, including: increase in population abundance, reduction in extinction risk, and increase in temperature compliance flexibility	
	Alternative 4	Same Battle Creek restoration as No Action	
Potential changes to aquatic resources from lower intakes near Wilkins Slough (Program level)	No Action	Not included in this alternative	
	Alternative 1	Potential increase in survival of winter-run and spring-run eggs and alevins from reduced risk of depleting cold water pool in late summer/early fall; potential increase in survival of juveniles of all fish species from reduced entrainment in diversions; potential reduction in condition or survival of all fish species from construction effects.	
	Alternative 2	Not included in this alternative	
	Alternative 3	Potential increase in survival of winter-run and spring-run eggs and alevins from reduced risk of depleting cold water pool in late summer/early fall; potential increase in survival of juveniles of all fish species from reduced entrainment in diversions; potential reduction in condition or survival of all fish species from construction effects.	
	Alternative 4	Not included in this alternative	
Potential changes to aquatic resources due to Shasta TCD Improvements (Program level)	No Action	Not included in this alternative	
	Alternative 1	Potential increase in survival of winter-run and spring-run eggs and alevins from reduced risk of depleting cold water pool in late summer/early fall	
	Alternative 2	Not included in this alternative	

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
	Alternative 3	Potential increase in survival of winter-run and spring-run eggs and alevins from reduced risk of depleting cold water pool in late summer/early fall	
	Alternative 4	Not included in this alternative	
Potential changes to aquatic resources from operation of the Livingston-Stone National Fish Hatchery (Winter-run Chinook Salmon) (Program level)	No Action	Not included in this alternative	
	Alternative 1	Potential increase in survival of winter-run early life stages during drought years; potential reduction in winter-run genetic fitness from genetic introgression with hatchery stock	
	Alternative 2	Not included in this alternative	
	Alternative 3	Potential increase in survival of winter-run early life stages during drought years; potential reduction in winter-run genetic fitness from genetic introgression with hatchery stock	
	Alternative 4	Not included in this alternative	
Potential changes to aquatic resources from small screen program installation (Program level)	No Action	Reclamation and DWR would continue existing small screen program	
	Alternative 1	Reclamation would accelerate existing small screen program resulting in potential increase in survival of rearing and emigrating juveniles of all focal species from reduced entrainment.	
	Alternative 2	Same small screen program as No Action	
	Alternative 3	Reclamation would accelerate existing small screen program resulting in potential increase in survival of rearing and emigrating juveniles of all focal species from reduced entrainment.	
	Alternative 4	Same small screen program as No Action	

Impact	**Alternative**	**Magnitude and Direction of Impacts**	**Potential Mitigation Measures**
Potential changes to aquatic resources from spawning habitat restoration (Program level)	No Action	Not included in this alternative (existing smaller restoration program would continue)	
	Alternative 1	Potential increase spawning and survival of eggs and alevins of anadromous salmonids and sturgeon from greater quantity and quality of spawning habitat	
	Alternative 2	Same spawning habitat restoration as No Action	
	Alternative 3	Potential increase spawning and survival of eggs and alevins from greater quantity and quality of spawning habitat	
	Alternative 4	Same spawning habitat restoration as No Action	
Potential changes to aquatic resources from rearing habitat restoration (Program level)	No Action	Not included in this alternative	
	Alternative 1	Potential increase in growth and survival of juveniles of anadromous salmonids and most other focal species from increased quantity and quality of rearing habitat	
	Alternative 2	Not included in this alternative	
	Alternative 3	Potential increase in growth and survival of juveniles of anadromous salmonids and most other focal species from increased quantity and quality of rearing habitat	
	Alternative 4	Not included in this alternative	
Clear Creek			
Whiskeytown Reservoir Operations			
Potential changes to aquatic resources in Whiskeytown Reservoir due to operations	No Action		
	Alternative 1		
	Alternative 2		
	Alternative 3		
	Alternative 4		
Potential changes to aquatic resources in Clear Creek from seasonal variation in water surface elevation	No Action	Likely continuation of current population trends	

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
	Alternative 1	Potential beneficial effect of increased usable stream habitat	
	Alternative 2	Potential for minor beneficial and adverse effects	
	Alternative 3	Potential for minor beneficial and adverse effects	
	Alternative 4	Potential for minor beneficial and adverse effects	
Clear Creek Flows			
Potential changes to aquatic resources in Clear Creek from variation in flow	No Action	Possible negligible, adverse effects due to reduced flows accompanying environmental changes	
	Alternative 1	Potential beneficial effects	
	Alternative 2	Adverse effects associated with reduced flow and lack of channel maintenance and pulse flows	
	Alternative 3	Similar to Alternative 2	
	Alternative 4	Potential beneficial effects	
Potential changes to aquatic resources in Clear Creek from variation in water temperature	No Action	Possible minimal, adverse effects due to increased temperatures accompanying environmental changes	
	Alternative 1	Minimal or slightly beneficial effects	
	Alternative 2	Negligible with implementation of mitigation	MM-AQUA-3
	Alternative 3	Similar to Alternative 2	MM-AQUA-3
	Alternative 4	Potential minimal, beneficial effects	
Spring Creek Debris Dam			
Potential changes to aquatic resources due to Spring Creek Debris Dam operations	No Action	Likely continuation of current trends; negative effects possible but unlikely or uncertain	
	Alternative 1	Potential beneficial effects	
	Alternative 2	Similar to No Action	
	Alternative 3	Similar to No Action	
	Alternative 4	Similar to No Action	
Clear Creek Restoration Program			
Potential changes in aquatic resources due to gravel augmentation and segregation weir operation	No Action	Likely beneficial effects on habitat conditions	

Impact	**Alternative**	**Magnitude and Direction of Impacts**	**Potential Mitigation Measures**
	Alternative 1	Similar to No Action	
	Alternative 2	Negligible with implementation of mitigation	MM-AQUA-3
	Alternative 3	Similar to No Action	
	Alternative 4	Similar to No Action	
Feather River			
FERC Project #2100-134			
Potential changes to aquatic resources in the Feather River due to seasonal variation in flow	No Action	Possible slightly adverse effects due to lower flows associated with climate change	
	Alternative 1	Potential beneficial effects	
	Alternative 2	Negligible or potentially beneficial effects	
	Alternative 3	Negligible or potentially beneficial effects	
	Alternative 4	Potential beneficial effects	
Potential changes to aquatic resources in the Feather River due to changes in water temperature from differences in flow	No Action	Possible slightly adverse effects due to increased temperatures associated with climate change	
	Alternative 1	Negligible temperature-related effects; both slightly beneficial and slightly adverse effects possible	
	Alternative 2	Both slightly beneficial and slightly adverse effects possible	
	Alternative 3	Both slightly beneficial and slightly adverse effects possible	
	Alternative 4	Negligible and slightly adverse effects possible	
American River			
Potential changes to aquatic resources in the American River from flood control	No Action	No change from current conditions	
	Alternative 1	Very similar to the no action alternative. Flood control storage would be slightly greater in dry years, and the same in wet years, compared to the NAA.	
	Alternative 2	No change from current conditions	
	Alternative 3	No change from current conditions	

Impact	**Alternative**	**Magnitude and Direction of Impacts**	**Potential Mitigation Measures**
	Alternative 4	Under average conditions, there would be little difference in flood control storage under Alt 4 in comparison to the NAA for average, dry, and wet years.	
Potential changes to aquatic resources from Folsom Reservoir operations in the American River to meet Delta salinity requirements	No Action	No change from current conditions	
	Alternative 1	No change from current conditions	
	Alternative 2	No change from current conditions	
	Alternative 3	No change from current conditions	
	Alternative 4	No change from current conditions	
Potential changes to aquatic resources from flows in the American River	No Action	No change from current conditions	
	Alternative 1	Lower minimum flows in October through January, higher minimum flows in February and March, and higher flows in July through September compared to the NAA.	
	Alternative 2	No change from current conditions	
	Alternative 3	No change from current conditions	
	Alternative 4	Minor changes would occur and vary by water year type and month. Similar flows in average and wet years compared to NAA. Dry and critically dry years, flows would be higher in February through March, slightly lower in July, and higher in August and September. In low water years, lower minimum flows in October through January, higher minimum flows in February and March, and higher flows in July through September compared to the No Action Alternative.	
Potential changes to aquatic resources in the American River due to changes in water temperature	No Action	No change from current conditions	

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
	Alternative 1	Similar to the no action alternative. May be slightly cooler in summer months compared to NAA.	
	Alternative 2	No temperature objective included, but temperature expected to be similar to current conditions.	
	Alternative 3	No temperature objective included, but temperature expected to be similar to current conditions.	
	Alternative 4	Overall minor differences in water temperature. Lower maximum water temperature in wet versus dry years. Change likely to result in incremental differences that are unlikely to lead to notable impact.	
Potential changes to aquatic resources in the American River from habitat restoration	No Action	No change from current conditions	
	Alternative 1	Increased total spawning habitat area, increased and improved side channel habitat, improved intragravel incubation conditions, increased and improved total rearing habitat area, improved overall habitat complexity, and cover and refugia when compared to the NAA. Minor shortterm impacts due to construction such as sediment or erosion addressed through mitigation measure.	
	Alternative 2	No change from current conditions	
	Alternative 3	Increased total spawning habitat area, increased and improved side channel habitat, improved intragravel incubation conditions, increased and improved total rearing habitat area, improved overall habitat complexity, and cover and refugia when compared to the NAA. Minor shortterm impacts due to construction such as sediment or erosion addressed through mitigation measure.	
	Alternative 4	No change from current conditions	
Stanislaus River			

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
Potential changes to aquatic resources in the Stanislaus River due to changes in flow	No Action	No change from current conditions	
	Alternative 1	Similar flows, but slightly less than the NAA. Very minor differences.	
	Alternative 2	Decreased flows would occur primarily between February through September. Potential limited negative effects. Increased flows during January and February would result in limited positive effects during spawning and emergence for salmonids.	
	Alternative 3	No change from current conditions.	
	Alternative 4	Conditions are the same as Alternative 1	
Potential changes to aquatic resources in the Stanislaus River due to changes in water temperature	No Action	No change from current conditions	
	Alternative 1	Compliance point moved to Orange Blossom Bridge. Increased storage under Alt 1 would result in larger coldwater pool and potentially offset warming or delay warming water due to greater reserves of stored coldwater.	
	Alternative 2	Reduced flows may result in warmer water conditions primarily from March through May. Potential limited negative effects.	
	Alternative 3	No specific temperature objective, but change not expected to current conditions due to same flow schedule as the NAA.	
	Alternative 4	Conditions are the same as Alternative 1	
Potential change to aquatic resources in the Stanislaus River due to changes to dissolved oxygen	No Action	No change from current conditions	
	Alternative 1	Maintain 7mg/l of DO. Overall, similar conditions to the NAA.	

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
	Alternative 2	Reduced flows may lower the amount of available DO incrementally, most notably in March through May. Potential limited negative effects.	
	Alternative 3	No change from current conditions	
	Alternative 4	Conditions are the same as Alternative 1	
Potential changes to salmonid habitat in the Stanislaus River related to habitat restoration (Program Level)	No Action	No change from current conditions	
	Alternative 1	Proposed habitat restoration will offer improved and expanded spawning and rearing habitat, including riparian vegetation. Minor shortterm impacts due to construction such as sediment or erosion addressed through mitigation measure.	
	Alternative 2	No change from current conditions	
	Alternative 3	Proposed habitat restoration will offer improved and expanded spawning and rearing habitat, including riparian vegetation. Minor shortterm impacts due to construction such as sediment or erosion addressed through mitigation measure.	
	Alternative 4	No change from current conditions	
San Joaquin River			
Potential changes to aquatic resources in the San Joaquin River due to changes in flow	No Action	No change from current conditions	
	Alternative 1	No change from current conditions	
	Alternative 2	No change from current conditions	
	Alternative 3	No change from current conditions	
	Alternative 4	No change from current conditions	
Potential changes to aquatic resources in the San Joaquin River due to changes in water temperature	No Action	No change from current conditions	
	Alternative 1	No change from current conditions	

Impact	**Alternative**	**Magnitude and Direction of Impacts**	**Potential Mitigation Measures**
	Alternative 2	No change from current conditions	
	Alternative 3	No change from current conditions	
	Alternative 4	No change from current conditions	
Potential changes to aquatic resources in the San Joaquin River due to restoration activities	No Action	No change from current conditions	
	Alternative 1	No change from current conditions	
	Alternative 2	No change from current conditions	
	Alternative 3	No change from current conditions	
	Alternative 4	No change from current conditions	
Bay-Delta			
Delta Smelt			
Potential changes to Delta Smelt due to seasonal operations (Project-Level)	No Action	No change from current conditions, except effects on food availability potentially offset through completion of 8,000 acres of tidal habitat restoration	
	Alternative 1	Potential reductions in food availability (Eurytemora affinis, Pseudodiaptomus forbesi) and habitat extent relative to No Action, offset by tidal habitat restoration, food subsidies, and Delta Smelt Summer-Fall Habitat operations	
	Alternative 2	Potential increase in south Delta entrainment; reductions in food availability (E. affinis, P. forbesi) and habitat extent relative to No Action, offset to some extent by tidal habitat restoration	
	Alternative 3	Potential increase in south Delta entrainment; reductions in food availability (E. affinis, P. forbesi) and habitat extent relative to No Action, offset by tidal habitat restoration, and food subsidies	
	Alternative 4	Potential reduction in south Delta entrainment; spring/summer increases in food availability (E. affinis, P. forbesi) and habitat extent relative to No Action; reduced fall habitat extent relative to No Action, offset to some extent by tidal habitat restoration	
	No Action	No change from current conditions	

Impact	**Alternative**	**Magnitude and Direction of Impacts**	**Potential Mitigation Measures**
Potential changes to Delta Smelt due to changes in Delta Cross Channel operations (Project-Level)	Alternative 1	Potential limited negative effects	
	Alternative 2	Potential limited negative effects	
	Alternative 3	Potential limited negative effects	
	Alternative 4	Potential limited negative effects	
Potential changes in Delta Smelt survival related to the Temporary Barriers Project (Project-Level)	No Action	No change from current conditions	
	Alternative 1	Similar to No Action, although less near-field and far-field effects from no HOR barrier	
	Alternative 2	Similar to No Action, although less near-field and far-field effects from no HOR barrier, but potentially greater near-field effects from greater presence in south Delta with lower OMR	
	Alternative 3	Similar to No Action, although less near-field and far-field effects from no HOR barrier, but potentially greater near-field effects from greater presence in south Delta with lower OMR	
	Alternative 4	Similar to No Action, although less near-field and far-field effects from no HOR barrier, but potentially less near-field effects from less presence in south Delta with greater OMR	
Potential changes to Delta Smelt from Contra Costa Water District operations (Project-Level)	No Action	No change from current conditions	
	Alternative 1	Similar to No Action	
	Alternative 2	Similar to No Action	
	Alternative 3	Similar to No Action	
	Alternative 4	Similar to No Action	
Potential changes to Delta Smelt from North Bay Aqueduct operations (Project-Level)	No Action	No change from current conditions	
	Alternative 1	Similar to No Action, with potential additional limited negative effect from sediment and aquatic weed removal	
	Alternative 2	Similar to No Action	
	Alternative 3	Similar to No Action, with potential additional limited negative effect from sediment and aquatic weed removal	
	Alternative 4	Similar to No Action	
	No Action	No change from current conditions	

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
Potential changes to Delta Smelt from water transfers (Project-Level)	Alternative 1	Minor increase in entrainment risk from expanded transfer window, although subject to OMR management	
	Alternative 2	No change from current conditions	
	Alternative 3	No change from current conditions	
	Alternative 4	No change from current conditions	
Potential changes to Delta Smelt from Clifton Court aquatic weed and algal bloom management (Project-Level)	No Action	No change from current conditions	
	Alternative 1	Similar to No Action	
	Alternative 2	Similar to No Action	
	Alternative 3	Similar to No Action	
	Alternative 4	Similar to No Action	
Potential changes to Delta Smelt due to changes from Tracy and Skinner fish facilities improvements (Project-Level)	No Action	No change from current conditions	
	Alternative 1	Potential minor increase in salvage efficiency from reduced predation at Tracy (carbon dioxide device)	
	Alternative 2	Potential increases in salvage losses as a result of greater proportion of population in south Delta (reduced OMR flows compared to No Action)	
	Alternative 3	Potential minor increase in salvage efficiency from reduced predation at Tracy (carbon dioxide device), but potential increase in salvage loss as described for Alternative 2	
	Alternative 4	Potential minor decrease in salvage losses as a result of smaller proportion of population in south Delta (greater OMR flows compared to No Action)	
Potential changes to Delta Smelt due to changes from Suisun Marsh facilities (Project-Level)	No Action	No change from current conditions	
	Alternative 1	Similar to No Action (except SMSCG and RRDS related to Delta Smelt Habitat Operations and Food Subsidies)	
	Alternative 2	Similar to No Action	
	Alternative 3	Similar to No Action	
	Alternative 4	Similar to No Action	
Potential changes to Delta Smelt due to changes from tidal habitat restoration (Program-Level)	No Action	Potential increased food availability (to offset seasonal operations effects) and habitat extent relative to current conditions; negative effects from contaminants	MM-AQUA 9

Impact	**Alternative**	**Magnitude and Direction of Impacts**	**Potential Mitigation Measures**
	Alternative 1	Same restoration extent as No Action, but offsetting effect may be less because of less spring outflow than No Action	MM-AQUA 9
	Alternative 2	Same restoration extent as No Action, but offsetting effect may be less because of less spring outflow than No Action	MM-AQUA 9
	Alternative 3	Same restoration extent as No Action, but offsetting effect may be less because of less spring outflow than No Action	MM-AQUA 9
	Alternative 4	Same restoration extent as No Action, but may add to potential positive effect from greater spring outflow than No Action	
Potential changes to Delta Smelt due to OMR management (Project-Level)	No Action	Included under Seasonal Operations	
	Alternative 1	Potential slight increase in entrainment relative to No Action	
	Alternative 2	Included under Seasonal Operations	
	Alternative 3	Included under Seasonal Operations	
	Alternative 4	Included under Seasonal Operations	
Potential changes to Delta Smelt from actions for Delta Smelt summer-fall habitat (Project-Level)	No Action	Not included in this alternative	
	Alternative 1	Potential to increase juvenile to subadult survival from increased habitat extent in summer; potentially less fall habitat and therefore negative effects; effects dependent on specific components of the action that are implemented	
	Alternative 2	Not included in this alternative	
	Alternative 3	Not included in this alternative	
	Alternative 4	Not included in this alternative	
Potential changes to Delta Smelt from the San Joaquin Basin Steelhead Telemetry Study (Project-Level)	No Action	Not included in this alternative	
	Alternative 1	No effect	
	Alternative 2	Not included in this alternative	
	Alternative 3	No effect	
	Alternative 4	Not included in this alternative	
Potential changes to Delta Smelt due to reintroduction by the Fish Conservation and Culture Laboratory (Project-Level)	No Action	Not included in this alternative	
	Alternative 1	Potential positive effect from increase in population abundance, assuming successful risk management	
	Alternative 2	Not included in this alternative	

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
	Alternative 3	Potential positive effect from increase in population abundance, assuming successful risk management	
	Alternative 4	Not included in this alternative	
Potential changes to Delta Smelt from food subsidies (Sacramento Deepwater Ship Channel Food Study; North Delta Food Subsidies/Colusa Basin Drain Study; Suisun Marsh Roaring River Distribution System Food Subsidies Study) (Program-Level)	No Action	Not included in this alternative	
	Alternative 1	Potential positive effect from greater food availability, offsetting negative effects of seasonal operations; potential negative effect from Ship Channel sediment contaminants	
	Alternative 2	Not included in this alternative	
	Alternative 3	Potential positive effect from greater food availability, offsetting negative effects of seasonal operations; potential negative effect from Ship Channel sediment contaminants	
	Alternative 4	Not included in this alternative	
Potential changes to Delta Smelt from the predator hot spot removal program (Program-Level)	No Action	Not included in this alternative	
	Alternative 1	Minor positive effects from reduced predation	
	Alternative 2	Not included in this alternative	
	Alternative 3	Minor positive effects from reduced predation	
	Alternative 4	Not included in this alternative	
Potential changes to Delta Smelt from Delta Cross Channel gate improvements (Program-Level)	No Action	Not included in this alternative	
	Alternative 1	Potential limited effects	
	Alternative 2	Not included in this alternative	
	Alternative 3	Potential limited effects	
	Alternative 4	Not included in this alternative	
Potential changes to aquatic resources due to changes from Tracy and Skinner Fish Facility improvements (Program-Level)	No Action	Not included in this alternative	
	Alternative 1	Minor positive effect to salvage efficiency	
	Alternative 2	Not included in this alternative	
	Alternative 3	Minor positive effect to salvage efficiency	
	Alternative 4	Not included in this alternative	
Potential changes to Delta Smelt from the small screen program (Program-Level)	No Action	Not included in this alternative	
	Alternative 1	Minor positive effect from reduction in entrainment	
	Alternative 2	Not included in this alternative	
	Alternative 3	Minor positive effect from reduction in entrainment	
	Alternative 4	Not included in this alternative	

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
Potential changes to Delta Smelt from the Delta Fish Species Conservation Hatchery (Program-Level)	No Action	Not included in this alternative	
	Alternative 1	Potential positive effect from increase in population abundance, assuming successful risk management	
	Alternative 2	Not included in this alternative	
	Alternative 3	Potential positive effect from increase in population abundance, assuming successful risk management	
	Alternative 4	Not included in this alternative	
Potential changes to Delta Smelt from additional habitat restoration (25,000 acres within the Delta) (Program-Level)	No Action	Not included in this alternative	
	Alternative 1	Not included in this alternative	
	Alternative 2	Not included in this alternative	
	Alternative 3	Potential positive effect from increased food availability and habitat extent; negative effects from contaminants and potential reduction of P.forbesi subsidy to low salinity zone	
	Alternative 4	Not included in this alternative	
Longfin Smelt			
Potential changes to Longfin Smelt due to seasonal operations (Project-Level)	No Action	No change from current conditions	
	Alternative 1	Potential reduction in population abundance from reduction in winter-spring Delta outflow; potential increased south Delta entrainment loss, although low proportional loss expected	
	Alternative 2	Potential reduction in population abundance from reduction in winter-spring Delta outflow; potential increased south Delta entrainment loss, although low proportional loss expected	
	Alternative 3	Potential reduction in population abundance from reductions in winter-spring Delta outflow; potential increased south Delta entrainment loss, although low proportional loss expected	
	Alternative 4	Potential increase in population abundance from increase in winter-spring Delta outflow; potential decreased south Delta entrainment loss, although low proportional loss expected	

Impact	**Alternative**	**Magnitude and Direction of Impacts**	**Potential Mitigation Measures**
Potential changes to Longfin Smelt due to changes in Delta Cross Channel operations (Project-Level)	No Action	No change from current conditions	
	Alternative 1	Potential limited negative effects	
	Alternative 2	Potential limited negative effects	
	Alternative 3	Potential limited negative effects	
	Alternative 4	Potential limited negative effects	
Potential changes in Longfin Smelt survival related to the Temporary Barriers Project (Project-Level)	No Action	No change from current conditions	
	Alternative 1	Potential for slightly greater negative effects than No Action (e.g., near-field predation), although limited by low presence in south Delta	
	Alternative 2	Potential for slightly greater negative effects than No Action (e.g., near-field predation), although limited by low presence in south Delta	
	Alternative 3	Potential for slightly greater negative effects than No Action (e.g., near-field predation), although limited by low presence in south Delta	
	Alternative 4	Potential for slightly less negative effects than No Action (e.g., near-field predation), although limited by low presence in south Delta	
Potential changes to Longfin Smelt from Contra Costa Water District operations (Project-Level)	No Action	No change from current conditions	
	Alternative 1	Similar to No Action	
	Alternative 2	Similar to No Action	
	Alternative 3	Similar to No Action	
	Alternative 4	Similar to No Action	
Potential changes to Longfin Smelt from North Bay Aqueduct operations (Project-Level)	No Action	No change from current conditions	
	Alternative 1	Similar to No Action, with potential additional limited negative effect from sediment and aquatic weed removal.	
	Alternative 2	Similar to No Action	
	Alternative 3	Similar to No Action, with potential additional limited negative effect from sediment and aquatic weed removal.	
	Alternative 4	Similar to No Action	
Potential changes to Longfin Smelt from water transfers (Project-Level)	No Action	No change from current conditions	
	Alternative 1	No change from current conditions	
	Alternative 2	No change from current conditions	
	Alternative 3	No change from current conditions	
	Alternative 4	No change from current conditions	
	No Action	No change from current conditions	

Impact	**Alternative**	**Magnitude and Direction of Impacts**	**Potential Mitigation Measures**
Potential changes to Longfin Smelt from Clifton Court aquatic weed and algal bloom management (Project-Level)	Alternative 1	Similar to No Action	
	Alternative 2	Similar to No Action	
	Alternative 3	Similar to No Action	
	Alternative 4	Similar to No Action	
Potential changes to Longfin Smelt due to changes from Tracy and Skinner fish facilities improvements (Project-Level)	No Action	No change from current conditions	
	Alternative 1	Potential minor increase in salvage efficiency from reduced predation at Tracy (carbon dioxide device) , but potential increases in salvage losses as a result of greater proportion of population in south Delta (reduced OMR flows compared to No Action), although low proportional loss expected	
	Alternative 2	Potential increases in salvage losses as a result of greater proportion of population in south Delta (reduced OMR flows compared to No Action), but low proportional loss expected	
	Alternative 3	Potential minor increase in salvage efficiency from reduced predation at Tracy (carbon dioxide device), but potential increase in salvage loss as described for Alternative 2, although low proportional loss expected	
	Alternative 4	Potential decreases in salvage losses as a result of greater proportion of population in south Delta (reduced OMR flows compared to No Action), but low proportional loss expected	
Potential changes to Longfin Smelt due to changes from Suisun Marsh facilities (Project-Level)	No Action	No change from current conditions	
	Alternative 1	Similar to No Action	
	Alternative 2	Similar to No Action	
	Alternative 3	Similar to No Action	
	Alternative 4	Similar to No Action	
Potential changes to Longfin Smelt due to changes from tidal habitat restoration (Program-Level)	No Action	Potential increased food availability and habitat extent relative to current conditions; negative effects from contaminants; overall effects limited because of species occurrence further downstream	MM-AQUA 9
	Alternative 1	Same restoration extent as No Action, but offsetting effect may be less because of less winter/spring outflow than No Action	MM-AQUA 9

Impact	**Alternative**	**Magnitude and Direction of Impacts**	**Potential Mitigation Measures**
	Alternative 2	Same restoration extent as No Action, but offsetting effect may be less because of less winter/spring outflow than No Action	MM-AQUA 9
	Alternative 3	Same restoration extent as No Action, but offsetting effect may be less because of less winter/spring outflow than No Action	MM-AQUA 9
	Alternative 4	Same restoration extent as No Action, but may add to potential positive effect from greater winter/spring outflow than No Action	MM-AQUA 9
Potential changes to Longfin Smelt due to OMR management (Project-Level)	No Action	Included under Seasonal Operations	
	Alternative 1	Potential increase in entrainment relative to No Action, although low proportional loss expected	
	Alternative 2	Included under Seasonal Operations	
	Alternative 3	Included under Seasonal Operations	
	Alternative 4	Included under Seasonal Operations	
Potential changes Longfin Smelt from actions for Delta Smelt summer-fall habitat (Project-Level)	No Action	Not included in this alternative	
	Alternative 1	No effect expected given timing/location relative to Longfin Smelt occurrence	
	Alternative 2	Not included in this alternative	
	Alternative 3	No effect expected given timing/location relative to Longfin Smelt occurrence	
	Alternative 4	Not included in this alternative	
Potential changes to Longfin Smelt due to the San Joaquin Basin Steelhead Telemetry Study (Project-Level)	No Action	Not included in this alternative	
	Alternative 1	No effect	
	Alternative 2	Not included in this alternative	
	Alternative 3	No effect	
	Alternative 4	Not included in this alternative	
Potential changes to Longfin Smelt due to the reintroduction by Fish Conservation and Culture Laboratory (Project-Level)	No Action	Not included in this alternative	
	Alternative 1	Potential limited negative effects from hybridization, reduced by risk management strategies	
	Alternative 2	Not included in this alternative	
	Alternative 3	Potential limited negative effects from hybridization, reduced by risk management strategies	
	Alternative 4	Not included in this alternative	
	No Action	Not included in this alternative	

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
Potential changes to Longfin Smelt from food subsidies (Sacramento Deepwater Ship Channel Food Study; North Delta Food Subsidies/Colusa Basin Drain Study; Suisun Marsh Roaring River Distribution System Food Subsidies Study) (Program-Level)	Alternative 1	Limited effects given Longfin Smelt distribution mostly downstream	
	Alternative 2	Not included in this alternative	
	Alternative 3	Limited effects given Longfin Smelt distribution mostly downstream	
	Alternative 4	Not included in this alternative	
Potential changes to Longfin Smelt from predator hot spot removal program (Program-Level)	No Action	Not included in this alternative	
	Alternative 1	Limited positive effects from reduced predation	
	Alternative 2	Not included in this alternative	
	Alternative 3	Limited positive effects from reduced predation	
	Alternative 4	Not included in this alternative	
Potential changes to Longfin Smelt from Delta Cross Channel gate improvements (Program-Level)	No Action	Not included in this alternative	
	Alternative 1	Potential limited effects	
	Alternative 2	Not included in this alternative	
	Alternative 3	Potential limited effects	
	Alternative 4	Not included in this alternative	
Potential changes to Longfin Smelt due to changes from Tracy and Skinner fish facility improvements (Program-Level)	No Action	Not included in this alternative	
	Alternative 1	Minor positive effect to salvage efficiency, although low proportional occurrence expected	
	Alternative 2	Not included in this alternative	
	Alternative 3	Minor positive effect to salvage efficiency, although low proportional occurrence expected	
	Alternative 4	Not included in this alternative	
Potential to Longfin Smelt from the small screen program (Program-Level)	No Action	Not included in this alternative	
	Alternative 1	Minimal positive effect from reduction in entrainment	
	Alternative 2	Not included in this alternative	
	Alternative 3	Minimal positive effect from reduction in entrainment	
	Alternative 4	Not included in this alternative	
Potential changes to Longfin Smelt from the Delta Fish Species Conservation Hatchery (Program-Level)	No Action	Not included in this alternative	
	Alternative 1	Potential limited negative effects from hybridization, reduced by risk management strategies	
	Alternative 2	Not included in this alternative	

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
	Alternative 3	Potential limited negative effects from hybridization, reduced by risk management strategies	
	Alternative 4	Not included in this alternative	
Potential changes to Longfin Smelt from additional habitat restoration (25,000 acres within the Delta) (Program-Level)	No Action	Not included in this alternative	
	Alternative 1	Not included in this alternative	
	Alternative 2	Not included in this alternative	
	Alternative 3	Potential positive effect from increased food availability and habitat extent; negative effects from contaminants; effects limited by general occurrence downstream of restored areas	
	Alternative 4	Not included in this alternative	
Sacramento River Winter Run Chinook Salmon			
Potential changes to aquatic resources due to seasonal operations (Project-Level)	No Action	No change from current conditions, except effects on food availability and rearing habitat potentially offset through completion of 8,000 acres of tidal habitat restoration	
	Alternative 1	Potential increase in south Delta entrainment however proportional entrainment is expected to remain low. These increases may be offset by higher flows in the Sacramento River that could increase survival and reduce routing into the interior Delta. Tidal habitat restoration could also increase survival of rearing winter run.	
	Alternative 2	Potential increase in south Delta entrainment however proportional entrainment is expected to remain low. These increases may be offset by higher flows in the Sacramento River that could increase survival and reduce routing into the interior Delta.	
	Alternative 3	Potential increase in south Delta entrainment however proportional entrainment is expected to remain low. These increases may be offset by higher flows in the Sacramento River that could increase survival and reduce routing into the interior Delta.	

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
	Alternative 4	Potential increase in survival and reduced routing into the interior Delta due to higher Sacramento River flows	
Potential changes to aquatic resources due to OMR management (Project-Level)	No Action	Included under Seasonal Operations	
	Alternative 1	Included under Seasonal Operations	
	Alternative 2	Included under Seasonal Operations	
	Alternative 3	Included under Seasonal Operations	
	Alternative 4	Included under Seasonal Operations	
Potential changes to aquatic resources due to Delta Cross Channel operations (Project-Level)	No Action	No change from current conditions	
	Alternative 1	Potential limited negative effects	
	Alternative 2	Potential limited negative effects	
	Alternative 3	Potential limited negative effects	
	Alternative 4	Potential limited negative effects	
Potential changes to aquatic resources due to the Temporary Barriers Project (Project-Level)	No Action	No change from current conditions	
	Alternative 1	Similar to No Action	
	Alternative 2	Similar to No Action	
	Alternative 3	Similar to No Action	
	Alternative 4	Similar to No Action	
Potential changes to aquatic resources due to Contra Costa Water District operations (Project-Level)	No Action	No change from current conditions	
	Alternative 1	Similar to No Action	
	Alternative 2	Similar to No Action	
	Alternative 3	Similar to No Action	
	Alternative 4	Similar to No Action	
Potential changes to aquatic resources due to North Bay Aqueduct operations (Project-Level)	No Action	No change from current conditions	
	Alternative 1	Potential limited negative effects	
	Alternative 2	Similar to No Action	
	Alternative 3	Potential limited negative effects	
	Alternative 4	Similar to No Action	

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
Potential changes to aquatic resources due to water transfers (Project-Level)	No Action	No change from current conditions	
	Alternative 1	No change from current conditions	
	Alternative 2	No change from current conditions	
	Alternative 3	No change from current conditions	
	Alternative 4	No change from current conditions	
Potential changes to aquatic resources from Clifton Court aquatic weed removal (Project-Level)	No Action	No change from current conditions	
	Alternative 1	Similar to No Action	
	Alternative 2	Similar to No Action	
	Alternative 3	Similar to No Action	
	Alternative 4	Similar to No Action	
Potential changes to aquatic resources due to changes from Tracy and Skinner fish facility improvements (Project-Level)	No Action	No change from current conditions	
	Alternative 1	Potential minor increase in salvage efficiency from reduced predation at Tracy (carbon dioxide device)	
	Alternative 2	Similar to Alternative 1	
	Alternative 3	Similar to Alternative 1	
	Alternative 4	Similar to Alternative 1	
Potential changes to aquatic resources due to changes from Suisun Marsh facilities (Project-Level)	No Action	No change from current conditions	
	Alternative 1	Similar to No Action	
	Alternative 2	Similar to No Action	
	Alternative 3	Similar to No Action	
	Alternative 4	Similar to No Action	
Potential changes to aquatic resources from actions for Delta Smelt summer-fall habitat (Project-Level)	No Action	Not included in this Alternative	
	Alternative 1	Minor benefits due to few fish being exposed to this action	
	Alternative 2	Not included in this alternative	
	Alternative 3	Not included in this alternative	
	Alternative 4	Not included in this alternative	

Impact	**Alternative**	**Magnitude and Direction of Impacts**	**Potential Mitigation Measures**
Potential changes to aquatic resources from Clifton Court predator management efforts (Project-Level)	No Action		
	Alternative 1		
	Alternative 2		
	Alternative 3		
	Alternative 4		
Potential changes to aquatic resources due to the San Joaquin Basin steelhead telemetry study (Project-Level)	No Action	Not included in this alternative	
	Alternative 1	No effect	
	Alternative 2	Not included in this alternative	
	Alternative 3	No effect	
	Alternative 4	Not included in this alternative	
Potential changes to aquatic resources due to reintroduction changes from Fish Conservation and Culture Laboratory (Project-Level)	No Action	Not included in this alternative	
	Alternative 1	No effect	
	Alternative 2	Not included in this alternative	
	Alternative 3	No effect	
	Alternative 4	Not included in this alternative	
Potential changes to aquatic resources from monitoring (Project-Level)	No Action		
	Alternative 1		
	Alternative 2		
	Alternative 3		
	Alternative 4		
Potential changes to aquatic resources from the Sacramento Deepwater Ship Channel food study (Program-Level)	No Action	Not included in this alternative	
	Alternative 1	Minor benefits due to few fish being exposed to the actions; potential negative effect if connection to DWSC is not maintained	
	Alternative 2	Similar to Alternative 1	
	Alternative 3	Similar to Alternative 1	
	Alternative 4	Similar to Alternative 1	

Impact	**Alternative**	**Magnitude and Direction of Impacts**	**Potential Mitigation Measures**
Potential changes to aquatic resources from the North Delta food subsidies/Colusa Basin drain study (Program-Level)	No Action		
	Alternative 1	Limited effects	
	Alternative 2	Similar to Alternative 1	
	Alternative 3	Similar to Alternative 1	
	Alternative 4	Similar to Alternative 1	
Potential changes to aquatic resources from the Suisun Marsh Roaring River Distribution System food study (Program-Level)	No Action		
	Alternative 1	Limited effects	
	Alternative 2	Similar to Alternative 1	
	Alternative 3	Similar to Alternative 1	
	Alternative 4	Limited effects	
Potential changes to aquatic resources due to tidal habitat restoration (Program-Level)	No Action	Potential increased food availability and rearing habitat availability (to offset seasonal operations effects) and habitat extent relative to current conditions; negative effects from contaminants	MM-AQUA-1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14
	Alternative 1	Same restoration extent as No Action	MM-AQUA-1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14
	Alternative 2	Same restoration extent as No Action	MM-AQUA-1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14
	Alternative 3	Same restoration extent as No Action	MM-AQUA-1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14
	Alternative 4	Same restoration extent as No Action	
Potential changes to aquatic resources from the predator hot spot removal program (Program-Level)	No Action	Not included in this alternative	
	Alternative 1	Minor to moderate positive effects from reduced predation.	
	Alternative 2	Not included in this alternative	
	Alternative 3	Similar to Alternative 1	
	Alternative 4	Not included in this alternative	

Impact	**Alternative**	**Magnitude and Direction of Impacts**	**Potential Mitigation Measures**
Potential changes to aquatic resources from Delta Cross Channel gate improvements (Program-Level)	No Action	Not included in this alternative	
	Alternative 1	Potential limited effects	
	Alternative 2	Not included in this alternative	
	Alternative 3	Similar to Alternative 1	
	Alternative 4	Not included in this alternative	
Potential changes to aquatic resources due to changes from Tracy and Skinner fish facility improvements (Program-Level)	No Action	Not included in this alternative	
	Alternative 1	Minor positive effect to salvage efficiency	MM AQUA-1, 2, 7, 8, 10, 12
	Alternative 2	Not included in this alternative	
	Alternative 3	Similar to Alternative 1	MM AQUA-1, 2, 7, 8, 10, 12
	Alternative 4	Not included in this alternative	
Potential changes to aquatic resources from the small screen program (Program-Level)	No Action	Not included in this alternative	
	Alternative 1	Minor positive effect from reduction in entrainment	
	Alternative 2	Not included in this alternative	
	Alternative 3	Similar to Alternative 1	
	Alternative 4	Not included in this alternative	
Potential changes to aquatic resources from the Delta Fish Species Conservation Hatchery (Program-Level)	No Action	Not included in this alternative	
	Alternative 1	No effect	
	Alternative 2	Not included in this alternative	
	Alternative 3	No effect	
	Alternative 4	Not included in this Alternative	
Spring Run Chinook Salmon			
Potential changes to aquatic resources due to seasonal operations (Project-Level)	No Action	No change from current conditions, except effects on food availability and rearing habitat potentially offset through completion of 8,000 acres of tidal habitat restoration.	

Impact	**Alternative**	**Magnitude and Direction of Impacts**	**Potential Mitigation Measures**
	Alternative 1	Potential increase in south Delta entrainment however proportional entrainment is expected to remain low for Sacramento River-origin fish. These increases may be offset by higher flows in the Sacramento River that could increase survival and reduce routing into the interior Delta. Tidal habitat restoration could also increase survival of rearing Spring run. Spring run Chinook salmon originating from the San Joaquin River may experience an increase in entrainment and reduced flow velocities in the Old River migration route.	
	Alternative 2	Potential increase in south Delta entrainment however proportional entrainment is expected to remain low for Sacramento River-origin fish. These increases may be offset by higher flows in the Sacramento River that could increase survival and reduce routing into the interior Delta. Spring run Chinook salmon originating from the San Joaquin River may experience an increase in south Delta entrainment and lower water velocities in the Old River route.	
	Alternative 3	Potential increase in south Delta entrainment however proportional entrainment is expected to remain low for Sacramento River-origin fish. These increases may be offset by higher flows in the Sacramento River that could increase survival and reduce routing into the interior Delta. Spring run Chinook salmon originating from the San Joaquin River may experience an increase in south Delta entrainment and lower water velocities in the Old River route.	
	Alternative 4	Potential increase in survival and reduced routing into the interior Delta for Sacramento River-origin fish during peak migration times. Survival and entrainment for San Joaquin River origin fish will be similar to the No Action Alternative.	

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
Potential changes to aquatic resources due to OMR management (Project-Level)	No Action	Included under Seasonal Operations	
	Alternative 1	Included under Seasonal Operations	
	Alternative 2	Included under Seasonal Operations	
	Alternative 3	Included under Seasonal Operations	
	Alternative 4	Included under Seasonal Operations	
Potential changes to aquatic resources due to Delta Cross Channel operations (Project-Level)	No Action	No change from current conditions	
	Alternative 1	Potential limited negative effects. No effect on San Joaquin-origin fish.	
	Alternative 2	Similar to Alternative 1	
	Alternative 3	Similar to Alternative 1	
	Alternative 4	Similar to Alternative 1	
Potential changes to aquatic resources due to the Temporary Barriers Project (Project-Level	No Action	No change from current conditions.	
	Alternative 1	Similar to No Action	
	Alternative 2	Similar to No Action	
	Alternative 3	Similar to No Action	
	Alternative 4	Similar to No Action	
Potential changes to aquatic resources due to Contra Costa Water District operations)	No Action	No change from current conditions	
	Alternative 1	Similar to No Action	
	Alternative 2	Similar to No Action	
	Alternative 3	Similar to No Action	
	Alternative 4	Similar to No Action	
Potential changes to aquatic resources due to North Bay Aqueduct operations (Project-Level)	No Action	No change from current conditions	
	Alternative 1	Potential limited negative effects for Sacramento River-origin fish	
	Alternative 2	Similar to No Action	
	Alternative 3	Potential limited negative effects for Sacramento River-origin fish	
	Alternative 4	Similar to No Action	
Potential changes to aquatic resources due to water transfers (Project-Level)	No Action	No change from current conditions	

Impact	**Alternative**	**Magnitude and Direction of Impacts**	**Potential Mitigation Measures**
	Alternative 1	Early or late migrant juvenile Spring-Run Chinook Salmon could be exposed to increased effects of entrainment, routing, and decreased Delta survival as a result of the expanded water transfer window, especially San Joaquin River-origin Spring-Run Chinook. Increased flows during conveyance in the Sacramento River could provide small survival benefits to migrating juveniles.	
	Alternative 2	Similar to Alternative 1	
	Alternative 3	Similar to Alternative 1	
	Alternative 4	Similar to Alternative 1	
Potential changes to aquatic resources from Clifton Court aquatic weed removal (Project-Level)	No Action	No change from current conditions	
	Alternative 1	Similar to No Action	
	Alternative 2	Not included in this alternative	
	Alternative 3	Similar to No Action	
	Alternative 4	Similar to No Action	
Potential changes to aquatic resources due to changes from Tracy and Skinner fish facility improvements (Project-Level)	No Action	No change from current conditions	
	Alternative 1	Potential minor increase in salvage efficiency from reduced predation at Tracy (carbon dioxide device)	
	Alternative 2	Not included in this alternative	
	Alternative 3	Same as Alternative 1	
	Alternative 4	Same as Alternative 1	
Potential changes to aquatic resources due to changes from Suisun Marsh facilities (Project-Level)	No Action	No change from current conditions	
	Alternative 1	Similar to No Action	
	Alternative 2	Not included in this alternative	
	Alternative 3	Similar to No Action	
	Alternative 4	Similar to No Action	
Potential changes to aquatic resources from actions for Delta Smelt summer-fall habitat (Project-Level)	No Action	Not included in this alternative	

Impact	**Alternative**	**Magnitude and Direction of Impacts**	**Potential Mitigation Measures**
	Alternative 1	No effect	
	Alternative 2	Not included in this alternative	
	Alternative 3	Not included in this alternative	
	Alternative 4	Not included in this alternative	
Potential changes to aquatic resources from Clifton Court predator management efforts	No Action		
	Alternative 1		
	Alternative 2		
	Alternative 3		
	Alternative 4		
Potential changes to aquatic resources due to the San Joaquin Basin steelhead telemetry study (Project-Level)	No Action	Not included in this alternative	
	Alternative 1	Not included in this alternative	
	Alternative 2	Not included in this alternative	
	Alternative 3	No effect	
	Alternative 4	Not included in this alternative	
Potential changes to aquatic resources due to reintroduction changes from Fish Conservation and Culture Laboratory (Project-Level)	No Action	Not included in this alternative	
	Alternative 1	Not included in this alternative	
	Alternative 2	Not included in this alternative	
	Alternative 3		
	Alternative 4	Not included in this alternative	
Potential changes to aquatic resources from the Sacramento Deepwater Ship Channel food study (Program-Level)	No Action	Not included in this alternative	
	Alternative 1	Minor benefits due to few fish being exposed to the actions	
	Alternative 2	Similar to Alternative 1	
	Alternative 3	Similar to Alternative 1	
	Alternative 4	Similar to Alternative 1	
Potential changes to aquatic resources from the North Delta food subsidies/Colusa Basin drain study (Program-Level)	No Action		
	Alternative 1	Limited effects	
	Alternative 2	Similar to Alternative 1	

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
	Alternative 3	Similar to Alternative 1	
	Alternative 4	Similar to Alternative 1	
Potential changes to aquatic resources from the Suisun Marsh Roaring River Distribution System food study (Program-Level)	No Action		
	Alternative 1	Limited effects	
	Alternative 2	Similar to Alternative 1	
	Alternative 3	Similar to Alternative 1	
	Alternative 4	Limited effects	
Potential changes to aquatic resources due to tidal habitat restoration (Program-Level)	No Action	Potential increased food availability and rearing habitat availability (to offset seasonal operations effects) and habitat extent relative to current conditions; negative effects from contaminants. San Joaquin origin fish will not be affected as they occur below the North Delta.	MM AQUA-1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14
	Alternative 1	Same restoration extent as No Action	MM AQUA-1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14
	Alternative 2	Same restoration extent as No Action	MM AQUA-1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14
	Alternative 3	Same restoration extent as No Action	MM AQUA-1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14
	Alternative 4	Same restoration extent as No Action	MM AQUA-1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14
Potential changes to aquatic resources from the predator hot spot removal program (Program-Level)	No Action	Not included in this alternative	
	Alternative 1	Potential for increased survival	
	Alternative 2	Same as Alternative 1	
	Alternative 3	Potential for increased survival	
	Alternative 4	Same as Alternative 1	
Potential changes to aquatic resources from Delta Cross Channel gate improvements (Program-Level)	No Action	Not included in this alternative	
	Alternative 1	Potential limited effects	
	Alternative 2	Potential limited effects	

Impact	**Alternative**	**Magnitude and Direction of Impacts**	**Potential Mitigation Measures**
	Alternative 3	Potential limited effects	
	Alternative 4	Not included in this alternative	
Potential changes to aquatic resources due to changes from Tracy and Skinner fish facility improvements (Program-Level)	No Action	Not included in this alternative	
	Alternative 1	Minor positive effect to salvage efficiency	MM AQUA-1, 2, 7, 8, 10, 12
	Alternative 2	Not included in this alternative	
	Alternative 3	Same as Alternative 1	MM AQUA-1, 2, 7, 8, 10, 12
	Alternative 4	Not included in this alternative	
Potential changes to aquatic resources from the small screen program (Program-Level)	No Action	Not included in this alternative	
	Alternative 1	Minor positive effect from reduction in entrainment	
	Alternative 2	Not included in this alternative	
	Alternative 3	Same as Alternative 1	
	Alternative 4	Same as Alternative 1	
Potential changes to aquatic resources from the Delta Fish Species Conservation Hatchery (Program-Level)	No Action	Not included in this alternative	
	Alternative 1	The risk of potential effect would be minimized by mitigation and indicate impacts are less than significant.	MM AQUA-1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14,
	Alternative 2	Not included in this alternative	
	Alternative 3	Same as Alternative 1	MM AQUA-1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
	Alternative 4	Not included in this alternative	
Fall-Run Chinook Salmon			
Potential changes to aquatic resources due to seasonal operations (Project-Level)	No Action	No change from current conditions, except effects on food availability and rearing habitat potentially offset through completion of 8,000 acres of tidal habitat restoration.	

Impact	**Alternative**	**Magnitude and Direction of Impacts**	**Potential Mitigation Measures**
	Alternative 1	Potential increase in south Delta entrainment however proportional entrainment is expected to remain low for Sacramento River-origin fish. These increases may be offset by higher flows in the Sacramento River that could increase survival and reduce routing into the interior Delta. Increase in entrainment for San Joaquin River-origin fish and exposure to lower velocities in the Old River route	
	Alternative 2	Similar to Alternative 1	
	Alternative 3	Similar to Alternative	
	Alternative 4	Little to no change compared to No Action alternative. Potential increase in survival and reduced routing into the interior Delta for Sacramento River-origin fish due to higher Sacramento River flows	
Potential changes to aquatic resources due to OMR management (Project-Level)	No Action	Included under Seasonal Operations	
	Alternative 1	Included under Seasonal Operations	
	Alternative 2	Included under Seasonal Operations	
	Alternative 3	Included under Seasonal Operations	
	Alternative 4	Included under Seasonal Operations	
Potential changes to aquatic resources due to Delta Cross Channel operations (Project-Level)	No Action	No change from current conditions	
	Alternative 1	Potential limited negative effects. No effect on San Joaquin-origin fish.	
	Alternative 2	Similar to Alternative 1	
	Alternative 3	Similar to Alternative 1	
	Alternative 4	Similar to Alternative 1	
Potential changes to aquatic resources due to the Temporary Barriers Project (Project-Level	No Action	No change from current conditions	
	Alternative 1	Potential negative effects depending on when they are installed and whether the flap gates are down or tied up but overall would be low to moderate.	
	Alternative 2	Similar to Alternative 1	
	Alternative 3	Similar to Alternative 1	

Impact	**Alternative**	**Magnitude and Direction of Impacts**	**Potential Mitigation Measures**
	Alternative 4	Similar to Alternative 1	
Potential changes to aquatic resources due to Contra Costa Water District operations)	No Action	No change from current conditions	
	Alternative 1	Similar to No Action	
	Alternative 2	Similar to No Action	
	Alternative 3	Similar to No Action	
	Alternative 4	Similar to No Action	
Potential changes to aquatic resources due to North Bay Aqueduct operations (Project-Level)	No Action	No change from current conditions	
	Alternative 1	Potential limited effects	
	Alternative 2	Similar to No Action	
	Alternative 3	Similar to Alternative 1	
	Alternative 4	Similar to No Action	
Potential changes to aquatic resources due to water transfers (Project-Level)	No Action	No change from current conditions	
	Alternative 1	Similar to No Action	
	Alternative 2	Similar to No Action	
	Alternative 3	Similar to No Action	
	Alternative 4	Similar to No Action	
Potential changes to aquatic resources from Clifton Court aquatic weed removal (Project-Level)	No Action	No change from current conditions	
	Alternative 1	Minimal negative effects as Fall-Run Chinook are not expected to be present during the action.	
	Alternative 2	Similar to Alternative 1	
	Alternative 3	Similar to Alternative 1	
	Alternative 4	Similar to Alternative 1	
Potential changes to aquatic resources due to changes from Tracy and Skinner fish facility improvements (Project-Level)	No Action	No change from current conditions	
	Alternative 1	Potential minor increase in salvage efficiency from reduced predation at Tracy (carbon dioxide device); larger proportions of Late-Fall Run lost so this action would have greater effect on this run.	
	Alternative 2	Similar to Alternative 1	

Impact	**Alternative**	**Magnitude and Direction of Impacts**	**Potential Mitigation Measures**
	Alternative 3	Similar to Alternative 1	
	Alternative 4	Similar to Alternative 1	
Potential changes to aquatic resources due to changes from Suisun Marsh facilities (Project-Level)	No Action	No change from current conditions	
	Alternative 1	Minor benefit to juvenile salmonids by improving water quality and increasing foraging opportunities.	
	Alternative 2	Similar to Alternative 1	
	Alternative 3	Similar to Alternative 1	
	Alternative 4	Similar to Alternative 1	
Potential changes to aquatic resources from actions for Delta Smelt summer-fall habitat (Project-Level)	No Action	No change from current conditions	
	Alternative 1	Minor benefits due to few fish being exposed to this action	
	Alternative 2	Not included in this alternative	
	Alternative 3	Not included in this alternative	
	Alternative 4	Not included in this alternative	
Potential changes to aquatic resources from Clifton Court predator management efforts	No Action	No change from current conditions	
	Alternative 1	The overall effect of the action is low for Sacramento River-Origin fish and moderate for San Joaquin River and Mokelumne River-origin fish.	
	Alternative 2	Not included in this alternative	
	Alternative 3	Similar to Alternative 1	
	Alternative 4	Similar to Alternative 1	
Potential changes to aquatic resources due to the San Joaquin Basin steelhead telemetry study (Project-Level)	No Action	No change from current conditions	
	Alternative 1	No effect	
	Alternative 2	Not included in this alternative	
	Alternative 3	No effect	
	Alternative 4	Not included in this alternative	
Potential changes to aquatic resources due to reintroduction changes from Fish Conservation and Culture Laboratory (Project-Level)	No Action		

Impact	**Alternative**	**Magnitude and Direction of Impacts**	**Potential Mitigation Measures**
	Alternative 1		
	Alternative 2		
	Alternative 3		
	Alternative 4		
Potential changes to aquatic resources from the Sacramento Deepwater Ship Channel food study (Program-Level)	No Action		
	Alternative 1	Moderate effect	
	Alternative 2	Similar to Alternative 1	
	Alternative 3	Similar to Alternative 1	
	Alternative 4	Similar to Alternative 1	
Potential changes to aquatic resources from the North Delta food subsidies/Colusa Basin drain study (Program-Level)	No Action		
	Alternative 1	Limited effect	
	Alternative 2	Similar to Alternative 1	
	Alternative 3	Similar to Alternative 1	
	Alternative 4	Similar to Alternative 1	
Potential changes to aquatic resources from the Suisun Marsh Roaring River Distribution System food study (Program-Level)	No Action		
	Alternative 1	Limited effect	
	Alternative 2	Similar to Alternative 1	
	Alternative 3	Similar to Alternative 1	
	Alternative 4	Similar to Alternative 1	
Potential changes to aquatic resources due to tidal habitat restoration (Program-Level)	No Action	Potential increased food availability and rearing habitat availability (to offset seasonal operations effects) and habitat extent relative to current conditions; negative effects from contaminants	MM AQUA-1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14
	Alternative 1	Same restoration extent as No Action	MM AQUA-1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14
	Alternative 2	Same restoration extent as No Action	MM AQUA-1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14
	Alternative 3	Same restoration extent as No Action	MM AQUA-1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
	Alternative 4	Same restoration extent as No Action	MM AQUA-1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14
Potential changes to aquatic resources from the predator hot spot removal program (Program-Level)	No Action	Not included in this alternative	
	Alternative 1	Loss may occur due to removal techniques but would be offset from increases in survival due to predator removal.	
	Alternative 2	Not included in this alternative	
	Alternative 3	Similar to Alternative 1	
	Alternative 4	Not included in this alternative	
Potential changes to aquatic resources from Delta Cross Channel gate improvements (Program-Level)	No Action	Not included in this alternative	
	Alternative 1	Potential limited effects	
	Alternative 2	Not included in this alternative	
	Alternative 3	Similar to Alternative 1	
	Alternative 4	Not included in this alternative	
Potential changes to aquatic resources due to changes from Tracy and Skinner fish facility improvements (Program-Level)	No Action	Not included in this alternative	
	Alternative 1	Minor positive effect to salvage efficiency	MM AQUA-1, 2, 7, 8, 10, 12
	Alternative 2	Not included in this alternative	
	Alternative 3	Similar to Alternative 1	MM AQUA-1, 2, 7, 8, 10, 12
	Alternative 4	Not included in this alternative	
Potential changes to aquatic resources from the small screen program (Program-Level)	No Action	Not included in this alternative	
	Alternative 1	Minor positive effect from reduction in entrainment	
	Alternative 2	Not included in this alternative	
	Alternative 3	Similar to Alternative 1	
	Alternative 4	Not included in this alternative	
Potential changes to aquatic resources from the Delta Fish Species Conservation Hatchery (Program-Level)	No Action	Not included in this alternative	

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
	Alternative 1	The risk of potential effect would be minimized by mitigation and indicate impacts are less than significant.	MM AQUA-1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
	Alternative 2	Not included in this alternative	
	Alternative 3	Similar to Alternative 1	MM AQUA-1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
	Alternative 4	Not included in this alternative	
Central Valley Steelhead			
Potential changes to aquatic resources due to seasonal operations (Project-Level)	No Action	No change from current conditions.	
	Alternative 1	Potential increase in south Delta entrainment. These increases for Sacramento River-origin fish may be offset by higher flows in the Sacramento River that could increase survival and reduce routing into the interior Delta. Increases in entrainment are likely to be greater for San Joaquin River-origin fish and they would be exposed to lower velocities in the Old River route	
	Alternative 2	Similar to Alternative	
	Alternative 3	Similar to Alternative	
	Alternative 4	Potential increase in survival and reduced routing into the interior Delta due to higher Sacramento River flows	
Potential changes to aquatic resources due to OMR management (Project-Level)	No Action	Included under Seasonal Operations	
	Alternative 1	Included under Seasonal Operations	
	Alternative 2	Included under Seasonal Operations	
	Alternative 3	Included under Seasonal Operations	
	Alternative 4	Included under Seasonal Operations	
Potential changes to aquatic resources due to Delta Cross Channel operations (Project-Level)	No Action	No change from current conditions.	
	Alternative 1	Potential limited negative effects. No effect on San Joaquin-origin fish.	
	Alternative 2	Similar to Alternative 1	
	Alternative 3	Similar to Alternative 1	
	Alternative 4	Similar to Alternative 1	

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
Potential changes to aquatic resources due to the Temporary Barriers Project (Project-Level	No Action	No change from current conditions.	
	Alternative 1	Potential negative effects for San Joaquin River-origin fish depending on timing of installation and operation of the flap gates.	
	Alternative 2	Similar to Alternative 1	
	Alternative 3	Similar to Alternative 1	
	Alternative 4	Similar to Alternative 1	
Potential changes to aquatic resources due to Contra Costa Water District operations (Project-Level)	No Action	No change from current conditions.	
	Alternative 1	Similar to No Action	
	Alternative 2	Similar to No Action	
	Alternative 3	Similar to No Action	
	Alternative 4	Similar to No Action	
Potential changes to aquatic resources due to North Bay Aqueduct operations (Project-Level)	No Action	No change from current conditions.	
	Alternative 1	Potential limited negative effects for Sacramento River-origin fish Similar to No Action	
	Alternative 2	Similar to No Action	
	Alternative 3	Potential limited negative effects for Sacramento River-origin fish Similar to No Action	
	Alternative 4	Similar to No Action	
Potential changes to aquatic resources due to water transfers (Project-Level)	No Action	No change from current conditions.	
	Alternative 1	Minimal potential increased risk of entrainment, predation, and decreased through-Delta survival for juveniles only.	
	Alternative 2	Similar to Alternative 1	
	Alternative 3	Similar to Alternative 1	
	Alternative 4	Similar to Alternative 1	
Potential changes to aquatic resources from Clifton Court aquatic weed removal (Project-Level)	No Action	No change from current conditions.	
	Alternative 1	Similar to No Action	

Impact	**Alternative**	**Magnitude and Direction of Impacts**	**Potential Mitigation Measures**
	Alternative 2	Similar to Alternative 1	
	Alternative 3	Similar to Alternative 1	
	Alternative 4	Similar to Alternative 1	
Potential changes to aquatic resources due to changes from Tracy and Skinner Fish Facility improvements (Project-Level)	No Action	No change from current conditions.	
	Alternative 1	Potential minor increase in salvage efficiency from reduced predation at Tracy (carbon dioxide device)	
	Alternative 2	Similar to Alternative 1	
	Alternative 3	Similar to Alternative 1	
	Alternative 4	Similar to Alternative 1	
Potential changes to aquatic resources due to changes from Suisun Marsh facilities (Project-Level)	No Action	No change from current conditions.	
	Alternative 1	Similar to No Action	
	Alternative 2	Not included in this alternative	
	Alternative 3	Similar to No Action	
	Alternative 4	Similar to No Action	
Potential changes to aquatic resources from actions for Delta Smelt summer-fall habitat (Project-Level)	No Action	No change from current conditions.	
	Alternative 1	Not included in this alternative	
	Alternative 2	Not included in this alternative	
	Alternative 3	Not included in this alternative	
	Alternative 4	Not included in this alternative	
Potential changes to aquatic resources from Clifton Court predator management efforts	No Action		
	Alternative 1		
	Alternative 2		
	Alternative 3		
	Alternative 4		
Potential changes to aquatic resources due to the San Joaquin Basin steelhead telemetry study (Project-Level)	No Action		
	Alternative 1		
	Alternative 2		
	Alternative 3		

Impact	**Alternative**	**Magnitude and Direction of Impacts**	**Potential Mitigation Measures**
	Alternative 4		
Potential changes to aquatic resources due to reintroduction changes from Fish Conservation and Culture Laboratory (Project-Level)	No Action		
	Alternative 1		
	Alternative 2		
	Alternative 3		
	Alternative 4		
Potential changes to aquatic resources from monitoring (Project-Level)	No Action		
	Alternative 1		
	Alternative 2		
	Alternative 3		
	Alternative 4		
Potential changes to aquatic resources from the Sacramento Deepwater Ship Channel food study (Program-Level)	No Action		
	Alternative 1	Potential benefit from non-entrainment exposure in interior Delta, and possible entrainment for juveniles	
	Alternative 2	Similar to Alternative 1	
	Alternative 3	Similar to Alternative 1	
	Alternative 4	Similar to Alternative 1	
Potential changes to aquatic resources from the North Delta food subsidies/Colusa Basin drain study (Program-Level)	No Action		
	Alternative 1	No effect	
	Alternative 2	Similar to Alternative 1	
	Alternative 3	Similar to Alternative 1	
	Alternative 4	Similar to Alternative 1	
Potential changes to aquatic resources from the Suisun Marsh Roaring River Distribution System food study (Program-Level)	No Action		
	Alternative 1	No effect	
	Alternative 2	Similar to Alternative 1	
	Alternative 3	Similar to Alternative 1	

Impact	**Alternative**	**Magnitude and Direction of Impacts**	**Potential Mitigation Measures**
	Alternative 4	Similar to Alternative 1	
Potential changes to aquatic resources due to tidal habitat restoration (Program-Level)	No Action	Potential increased food availability and rearing habitat availability (to offset seasonal operations effects) and habitat extent relative to current conditions; negative effects from contaminants.	MM AQUA-1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14
	Alternative 1	Same restoration extent as No Action	MM AQUA-1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14
	Alternative 2	Same restoration extent as No Action	MM AQUA-1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14
	Alternative 3	Same restoration extent as No Action	MM AQUA-1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14
	Alternative 4	Same restoration extent as No Action	MM AQUA-1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14
Potential changes to aquatic resources from the predator hot spot removal program (Program-Level)	No Action	Not included in this alternative	
	Alternative 1	Loss may occur due to removal techniques but would be offset from increases in survival due to predator removal.	
	Alternative 2	Not included in this alternative	
	Alternative 3	Similar to Alternative 1	
	Alternative 4	Not included in this alternative	
Potential changes to aquatic resources from Delta Cross Channel gate improvements (Program-Level)	No Action	Not included in this alternative	
	Alternative 1	Potential limited effects	
	Alternative 2	Not included in this alternative	
	Alternative 3	Similar to Alternative 1	
	Alternative 4	Not included in this alternative	
Potential changes to aquatic resources due to changes from Tracy and Skinner fish facility improvements (Program-Level)	No Action	Not included in this alternative	
	Alternative 1	Minor positive effect to salvage efficiency and reduced pre-screen loss.	MM AQUA-1, 2, 7, 8, 10, 12

Impact	**Alternative**	**Magnitude and Direction of Impacts**	**Potential Mitigation Measures**
	Alternative 2	Not included in this alternative	
	Alternative 3	Similar to Alternative 1	MM AQUA-1, 2, 7, 8, 10, 12
	Alternative 4	Not included in this alternative	
Potential changes to aquatic resources from the small screen program (Program-Level)	No Action	Not included in this alternative	
	Alternative 1	Minor negative effects minimized by mitigation and offset by positive effects of reduced entrainment	MM AQUA-7
	Alternative 2	Not included in this alternative	
	Alternative 3	Similar to Alternative 1	MM AQUA-7
	Alternative 4	Not included in this alternative	
Potential changes to aquatic resources from the Delta Fish Species Conservation Hatchery (Program-Level)	No Action	Not included in this alternative	
	Alternative 1	The risk of potential effect would be minimized by mitigation.	MM AQUA-1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
	Alternative 2	Not included in this alternative	
	Alternative 3	Similar to Alternative 1	MM AQUA-1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
	Alternative 4	Not included in this alternative	
North American Green Sturgeon Southern DPS			
Potential changes to aquatic resources due to seasonal operations (Project-Level)	No Action	No change from current conditions, except effects on food availability and rearing habitat potentially offset through completion of 8,000 acres of tidal habitat restoration.	
	Alternative 1	Increased risk of entrainment over No Action though entrainment expected to remain low. Risk of decreased survival due to lower velocities in the south Delta however, low probability of presence in the area where negative velocities occur.	
	Alternative 2	Similar to Alternative 1	
	Alternative 3	Similar to Alternative 1	
	Alternative 4	Similar to Alternative 1	
Potential changes to aquatic resources due to OMR management (Project-Level)	No Action	Included under Seasonal Operations	

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
	Alternative 1	Included under Seasonal Operations	
	Alternative 2	Included under Seasonal Operations	
	Alternative 3	Included under Seasonal Operations	
	Alternative 4	Included under Seasonal Operations	
Potential changes to aquatic resources due to Delta Cross Channel operations (Project-Level)	No Action	No change from current conditions	
	Alternative 1	Potential limited negative effects	
	Alternative 2	Potential limited negative effects	
	Alternative 3	Potential limited negative effects	
	Alternative 4	Potential limited negative effects	
Potential changes to aquatic resources due to the Temporary Barriers Project (Project-Level)	No Action	No change from current conditions.	
	Alternative 1	Potential negative effects depending on timing of installation and operation of the flap gates. Fish not expected to be common in the area	
	Alternative 2	Similar to Alternative 1	
	Alternative 3	Similar to No Action	
	Alternative 4	Similar to No Action	
Potential changes to aquatic resources due to Contra Costa Water District operations (Project-Level)	No Action	No change from current conditions	
	Alternative 1	Similar to No Action	
	Alternative 2	Similar to No Action	
	Alternative 3	Similar to No Action	
	Alternative 4	Similar to No Action	
Potential changes to aquatic resources due to North Bay Aqueduct operations (Project-Level)	No Action	No change from current conditions	
	Alternative 1	Increase in the risk of vulnerability to entrainment should decrease to no effect as green sturgeon are expected to be 100% screened. Potential for limited effects from sediment removal and weed control	
	Alternative 2	Similar to No Action	

Impact	**Alternative**	**Magnitude and Direction of Impacts**	**Potential Mitigation Measures**
	Alternative 3	Increase in the risk of vulnerability to entrainment should decrease to no effect as green sturgeon are expected to be 100% screened. Potential for limited effects from sediment removal and weed control.	
	Alternative 4	Similar to No Action	
Potential changes to aquatic resources due to water transfers (Project-Level)	No Action	No change from current conditions	
	Alternative 1	Similar to No Action	
	Alternative 2	Similar to No Action	
	Alternative 3	Similar to No Action	
	Alternative 4	Similar to No Action	
Potential changes to aquatic resources from Clifton Court aquatic weed removal (Project-Level)	No Action	No change from current conditions	
	Alternative 1	Not likely to occur making negative exposure impacts limited.	
	Alternative 2	Similar to Alternative 1	
	Alternative 3	Similar to Alternative 1	
	Alternative 4	Similar to Alternative 1	
Potential changes to aquatic resources due to changes from Tracy and Skinner fish facility improvements (Project-Level)	No Action	No change from current conditions	
	Alternative 1	Not likely to occur making exposure impacts very low and balanced with slight increases in survival due to reduced pre-screen loss.	
	Alternative 2	Similar to Alternative 1	
	Alternative 3	Similar to Alternative 1	
	Alternative 4	Similar to Alternative 1	
Potential changes to aquatic resources due to changes from Suisun Marsh facilities (Project-Level)	No Action	No change from current conditions	
	Alternative 1	Juvenile green sturgeon in Suisun Marsh may experience improved water quality and increased foraging opportunities.	
	Alternative 2	Similar to Alternative 1	
	Alternative 3	Similar to Alternative 1	
	Alternative 4	Similar to Alternative 1	

Impact	**Alternative**	**Magnitude and Direction of Impacts**	**Potential Mitigation Measures**
Potential changes to aquatic resources from Clifton Court predator management efforts	No Action		
	Alternative 1		
	Alternative 2		
	Alternative 3		
	Alternative 4		
Potential changes to aquatic resources from actions for Delta Smelt summer-fall habitat (Project-Level)	No Action	Not included in this alternative	
	Alternative 1	Not included in this alternative	
	Alternative 2	Not included in this alternative	
	Alternative 3	Not included in this alternative	
	Alternative 4	Not included in this alternative	
Potential changes to aquatic resources due to the San Joaquin Basin steelhead telemetry study (Project-Level)	No Action		
	Alternative 1		
	Alternative 2		
	Alternative 3		
	Alternative 4		
Potential changes to aquatic resources due to reintroduction changes from Fish Conservation and Culture Laboratory (Project-Level)	No Action		
	Alternative 1		
	Alternative 2		
	Alternative 3		
	Alternative 4		
Potential changes to aquatic resources from monitoring (Project-Level)	No Action		
	Alternative 1		
	Alternative 2		
	Alternative 3		
	Alternative 4		
Potential changes to aquatic resources from the Sacramento Deepwater Ship Channel food study (Program-Level)	No Action		

Impact	**Alternative**	**Magnitude and Direction of Impacts**	**Potential Mitigation Measures**
	Alternative 1	Potential effect from entrainment in the DWSC, and possible benefit from non-entrainment exposure in interior Delta,	
	Alternative 2	Similar to Alternative 1	
	Alternative 3	Similar to Alternative 1	
	Alternative 4	Similar to Alternative 1	
Potential changes to aquatic resources from the North Delta food subsidies/Colusa Basin drain study (Program-Level)	No Action		
	Alternative 1	Potential benefit by providing food	
	Alternative 2	Similar to Alternative 1	
	Alternative 3	Similar to Alternative 1	
	Alternative 4	Similar to Alternative 1	
Potential changes to aquatic resources from the Suisun Marsh Roaring River Distribution System food study (Program-Level)	No Action		
	Alternative 1	Potential benefit by providing food	
	Alternative 2	Similar to Alternative 1	
	Alternative 3	Similar to Alternative 1	
	Alternative 4		
Potential changes to aquatic resources due to tidal habitat restoration (Program-Level)	No Action	Potential increased food availability and rearing habitat availability (to offset seasonal operations effects) and habitat extent relative to current conditions; negative effects from contaminants.	MM AQUA-1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14
	Alternative 1	Same restoration extent as No Action	MM AQUA-1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14
	Alternative 2	Same restoration extent as No Action	MM AQUA-1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14
	Alternative 3	Same restoration extent as No Action	MM AQUA-1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14
	Alternative 4	Same restoration extent as No Action	MM AQUA-1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
Potential changes to aquatic resources from the predator hot spot removal program (Program-Level)	No Action	Not included in this alternative	
	Alternative 1	Potential negative effects from capture during predator removal offset by potential to increase survival by removing predators if juveniles are present.	
	Alternative 2	Not included in this alternative	
	Alternative 3	Similar to Alternative 1	
	Alternative 4	Not included in this alternative	
Potential changes to aquatic resources from Delta Cross Channel gate improvements (Program-Level)	No Action	Not included in this alternative	
	Alternative 1	Potential limited effects	
	Alternative 2	Not included in this alternative	
	Alternative 3	Similar to Alternative 1	
	Alternative 4	Not included in this alternative	
Potential changes to aquatic resources due to changes from Tracy and Skinner fish facility improvements (Program-Level)	No Action	Not included in this alternative	
	Alternative 1	Minor positive effect to salvage efficiency and reduced pre-screen loss.	MM AQUA-1, 2, 7, 8, 10, 12
	Alternative 2	Not included in this alternative	
	Alternative 3	Similar to Alternative 1	MM AQUA-1, 2, 7, 8, 10, 12
	Alternative 4	Not included in this alternative	
Potential changes to aquatic resources from the small screen program (Program-Level)	No Action	Not included in this alternative	
	Alternative 1	Minor negative effects minimized by mitigation and reduced entrainment.	MM AQUA-7
	Alternative 2	Not included in this alternative	
	Alternative 3	Similar to Alternative 1	MM AQUA-7
	Alternative 4	Not included in this alternative	
Potential changes to aquatic resources from the Delta Fish Species Conservation Hatchery (Program-Level)	No Action	Not included in this alternative	

Impact	**Alternative**	**Magnitude and Direction of Impacts**	**Potential Mitigation Measures**
	Alternative 1	The risk of potential effect would be minimized by mitigation.	MM AQUA-1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
	Alternative 2	Not included in this alternative	
	Alternative 3	Similar to Alternative 1	MM AQUA-1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
	Alternative 4	Not included in this alternative	
Southern Resident Killer Whale			
Potential changes to Southern Killer Whale from Chinook Salmon prey abundance (Project-Level)	No Action	No change from current conditions	
	Alternative 1	Limited potential for effect because of medium priority of Central Valley Chinook Salmon stocks as prey and hatchery influence	
	Alternative 2	Potential negative effects, with some uncertainty as a result of medium priority of Central Valley Chinook Salmon stocks as prey and hatchery influence	
	Alternative 3	Potential negative effects, with some uncertainty as a result of medium priority of Central Valley Chinook Salmon stocks as prey and hatchery influence	
	Alternative 4	Potential for mixture of positive/negative effects, with some uncertainty as a result of medium priority of Central Valley Chinook Salmon stocks as prey and hatchery influence	
Potential changes to Southern Killer Whale from Chinook Salmon prey abundance (Program-Level)	No Action	Limited potential for effect because of medium priority of Central Valley Chinook Salmon stocks as prey and hatchery influence	
	Alternative 1	Limited potential for effect because of medium priority of Central Valley Chinook Salmon stocks as prey and hatchery influence	
	Alternative 2	Limited potential for effect because of medium priority of Central Valley Chinook Salmon stocks as prey and hatchery influence	

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
	Alternative 3	Possibly greater potential for positive effect than other alternatives because of greater extent of tidal habitat restoration, but uncertainty because of medium priority of Central Valley Chinook Salmon stocks as prey and hatchery influence	
	Alternative 4	Limited potential for effect because of medium priority of Central Valley Chinook Salmon stocks as prey and hatchery influence	

O.3.13 Cumulative Effects

This cumulative effects analysis evaluates the potential for project alternatives, including the No Action Alternative, to have an effect that would combine with an existing or potential adverse cumulative effect to make a considerable, incremental contribution to the existing or potential cumulative effect. The characterization of existing or probable future non-project effects is based on a qualitative assessment of the past, present, and probable future actions or projects that have affected or could affect aquatic biological resources in the analysis areas. These actions and projects are summarized in Appendix Y, *Cumulative Methodology*. No modeling or quantitative analysis was conducted to quantify the existing or potential future cumulative effects that may have resulted or could result from non-project activities. Further, this analysis does not distinguish between project-level and program-level actions. Therefore, the cumulative effects analysis is the same for both

O.3.13.1 *Trinity River*

Past and present human activities have substantially changed aquatic habitats in the Trinity River compared to historical conditions, resulting in cumulative adverse impacts on the distribution, abundance, population structure, and genetic integrity of native salmonids, and similar effects on other native fishes. Major factors contributing to the cumulative impacts (cumulative effects) on aquatic biological resources in the Trinity River in the project area have included hydropower development and operations, hatchery management, water diversions, recreational use, sport fisheries, introduction of nonnative fish species, and other management actions, water uses, and land uses. These actions have resulted in altered flows on the Trinity River, reducing sediment input to downstream locations, hindered important fluvial processes which support riparian habitat and river channel dynamics, increasing riparian vegetation encroachment through the reduction of vegetation scouring high flow events, reduced channel movement and the creation of natural levees isolating the channel from the floodplain, and other adverse effects on aquatic habitat. These alterations have led to a reduction in channel complexity and aquatic habitat for several fish species in the mainstem Trinity River downstream of Lewiston Dam.

Several management components have been established to mitigate for the adverse effects of dam construction on the Trinity River and are included in the Trinity River Restoration Program (TRRP) and the Trinity River ROD. The TRRP includes instream flow management, mechanical channel rehabilitation, fine and coarse sediment management, watershed restoration, infrastructure improvement, and adaptive environmental assessment and monitoring, and is focused on the 40-mile section of the

Trinity River from Lewiston Dam to the confluence with the North Fork Trinity River (TRRP 2014). Since 2008, over 75 projects have been completed under the TRRP. The ROD documents actions intended to restore and maintain anadromous fishery resources in the Trinity River based on the best available scientific information, while continuing to provide water supplies for beneficial uses and power generation. The ROD sets variable annual instream flows for the Trinity River, physical channel rehabilitation, sediment management, watershed restoration efforts, and infrastructure improvements and modifications (USDOI 2000).

While some projects and actions have had beneficial effects, the net short-term effect of many new and ongoing programs, projects, and restoration efforts remains uncertain. In the long term, however, the net effects are expected to include substantial improvements in river habitat conditions and conservation or recovery of special-status fish populations. Despite ongoing and potential future projects that could benefit native Trinity River fishes and their habitat, it is apparent that the effects of past and present actions have resulted in a cumulative adverse effect on Coho Salmon, Chinook Salmon, Steelhead, Green Sturgeon, White Sturgeon, Pacific Lamprey, and American Shad and designated critical habitat in the Trinity River.

O.3.13.1.1 Seasonal Operations

No Action Alternative

There were no adverse effects identified. Therefore, there would be no cumulative effects on aquatic biological resources under the No Action Alternative.

Alternatives 1-4

There were no adverse effects identified. Therefore, there would be no cumulative effects on aquatic biological resources under the action alternatives.

O.3.13.1.2 Trinity River Record of Decision

No Action Alternative

There were no adverse effects identified. Therefore, there would be no cumulative effects on aquatic biological resources under the No Action Alternative.

Alternatives 1-4

There were no adverse effects identified. Therefore, there would be no cumulative effects on aquatic biological resources under the action alternatives.

O.3.13.1.3 Long Term Plan to Protect Adult Salmon in the Lower Klamath River

No Action Alternative

There were no adverse effects identified. Therefore, there would be no cumulative effects on aquatic biological resources under the No Action Alternative.

Alternatives 1-4

There were no adverse effects identified. Therefore, there would be no cumulative effects on aquatic biological resources under the action alternatives.

O.3.13.1.4 Grass Valley Creek Flows from Buckhorn Dam

No Action Alternative

There were no adverse effects identified. Therefore, there would be no cumulative effects on aquatic biological resources under the No Action Alternative.

Alternatives 1-4

There were no adverse effects identified. Therefore, there would be no cumulative effects on aquatic biological resources under the action alternatives.

O.3.13.2 *Clear Creek*

Past and present human activities have substantially changed aquatic habitats in Clear Creek compared to historical conditions, resulting in cumulative adverse impacts on the distribution, abundance, population structure, and genetic integrity of native salmonids, and similar effects on other native fishes. Major factors contributing to the cumulative impacts (cumulative effects) on aquatic biological resources in Clear Creek have included hydropower development and operations, water withdrawals for irrigation and other uses, agriculture, timber harvest, roadbuilding, mining activities, channelization and levee construction, recreational use and development, sport and commercial fisheries, introduction of nonnative fish species, and other management actions, water uses, and land uses (Appendix Y, *Cumulative Methodology*). These actions have resulted in highly altered flow regimes, loss and disconnection of floodplains from the river channel, altered sediment transport, reduced aquatic habitat complexity, loss of riparian and off-channel aquatic habitat, elevated water temperature, degraded water quality, habitat fragmentation by physical barriers, and other adverse effects on aquatic biological resources. Several ecosystem improvement projects and actions, including the Central Valley Project Improvement Act (CVPIA), the CALFED Bay-Delta Program, the Clear Creek Restoration Program, the CDFW Ecosystem Restoration Program, removal of Saeltzer Dam in 2000, and various other conservation, management, and restoration programs (Appendix Y, *Cumulative Methodology*), have been initiated to offset the adverse effects of previous and ongoing activities.

In addition to the ongoing activities, several probable future projects and programs may affect listed fishes and other aquatic biological resources in Clear Creek. New projects and programs recently implemented or likely to be implemented in the near future are listed in Appendix Y, *Cumulative Methodology*. Some of these projects and programs may adversely affect special-status fishes and critical habitat in Clear Creek, but others are likely to be beneficial. While some projects and actions have had beneficial effects, the net short-term effect of many new and ongoing programs, projects, and restoration efforts remains uncertain. In the long term, however, the net effects are expected to include substantial improvements in river habitat conditions and conservation or recovery of special-status fish populations. Despite ongoing and potential future projects that could benefit native fishes and their habitat in Clear Creek, it is apparent that the effects of past and present actions have resulted in a cumulative adverse effect on Central Valley Spring-Run Chinook Salmon, Central Valley Steelhead and their designated critical habitat in Clear Creek.

O.3.13.2.1 Whiskeytown Reservoir Operations

No Action Alternative

There were no adverse effects identified. Therefore, there would be no cumulative effects on aquatic biological resources under the No Action Alternative.

Alternatives 1-4

There were no adverse effects identified. Therefore, there would be no cumulative effects on aquatic biological resources under the action alternatives.

O.3.13.2.2 Clear Creek Flows

No Action Alternative

There were no adverse effects identified. Therefore, there would be no cumulative effects on aquatic biological resources under the No Action Alternative.

Alternatives 1-4

Under Alternative 1, flows in Clear Creek downstream of Whiskeytown Dam would not differ substantially from the No Action Alternative and there would be no adverse effects on aquatic biological resources. Under Alternative 2 and Alternative 3, average monthly flow in Clear Creek downstream of Whiskeytown Dam would decrease between 41 and 75% throughout the year in all water year types compared to the No Action Alternative. The decreases in flow would result in the following adverse effects:

- Reduced amount and suitability of habitat for all life stages of focal fish species in Clear Creek downstream of Whiskeytown Dam
- Increased likelihood of water temperature-related stress for Spring-Run Chinook Salmon eggs and emerging fry during September and October
- Increased likelihood of water temperature-related stress for Fall- and Late Fall-Run Chinook Salmon eggs and emerging fry and migrating Steelhead adults

With implementation of Mitigation Measure BIO-1, these adverse effects would be avoided or minimized and would not make a considerable contribution to existing adverse cumulative effects on Central Valley Spring-Run Chinook Salmon, Fall- /Late Fall-Run Chinook Salmon, and Central Valley Steelhead in Clear Creek. With mitigation, there would be no cumulative effects on aquatic biological resources under the action alternatives.

O.3.13.2.3 Spring Creek Debris Dam

No Action Alternative

There were no adverse effects identified. Therefore, there would be no cumulative effects on aquatic biological resources under the No Action Alternative.

O.3.13.2.4 Clear Creek Restoration Program

No Action Alternative

There were no adverse effects identified. Therefore, there would be no cumulative effects on aquatic biological resources under the No Action Alternative.

Alternatives 1-4

The Clear Creek Restoration Program would continue under Alternatives 1, 3 and 4 and there would be no cumulative effects on aquatic biological resources under these alternatives. Under Alternative 2, the Clear Creek Restoration Program would be discontinued, resulting in the following adverse effects:

- Reduced salmonid spawning success and egg survival due to decreased spawning habitat availability and increased likelihood of redd superimposition resulting from cessation of gravel injections.
- Reduced genetic integrity of Spring-Run Chinook Salmon due to increased hybridization resulting from discontinued operation of the segregation weir.

With implementation of Mitigation Measure BIO-XX, these adverse effects would be avoided or minimized and would not make a considerable contribution to existing adverse cumulative effects on Central Valley Spring-Run Chinook Salmon, Fall- /Late Fall-Run Chinook Salmon, and Central Valley Steelhead in Clear Creek. With mitigation, there would be no cumulative effects on aquatic biological resources under the action alternatives.

O.3.13.3 *Sacramento River*

Past and present human activities have substantially changed aquatic habitats in the Sacramento River compared to historical conditions, resulting in cumulative adverse impacts on the distribution, abundance, population structure, and genetic integrity of native salmonids, and similar effects on other native fishes. Major factors contributing to the cumulative impacts (cumulative effects) on aquatic biological resources in the Sacramento River in the project area have included major instream water storage dams, hydropower development and operations, hatchery management, water withdrawals for irrigation and other uses, agricultural and urban development, channelization and levee construction, mining activities, recreational use and development, sport and commercial fisheries, introduction of nonnative fish species, and other management actions, water uses, and land uses (Appendix Y, *Cumulative Methodology*). These actions have resulted in highly altered flow regimes, loss and disconnection of floodplains from the river channel, altered sediment transport, reduced aquatic habitat complexity, loss of riparian and off-channel aquatic habitat, loss of upstream habitat, elevated water temperature, degraded water quality, habitat fragmentation by physical barriers, and other adverse effects on aquatic biological resources. Several ecosystem improvement projects and actions, including the Central Valley Project Improvement Act (CVPIA), the CALFED Bay-Delta Program, California EcoRestore, California WaterFix, the CDFW Ecosystem Restoration Program, and various other conservation, management, and restoration programs (Appendix Y, *Cumulative Methodology*), have been initiated to offset the adverse effects of previous and ongoing activities.

In addition to the ongoing activities, several probable future projects and programs may affect listed fishes and other aquatic biological resources in the Sacramento River. New projects and programs recently implemented or likely to be implemented in the near future are listed in Appendix Y, *Cumulative Methodology*. Some of these projects and programs may adversely affect special-status fishes and critical habitat in the Sacramento River, but others are likely to be beneficial. While some projects and actions have had beneficial effects, the net short-term effect of many new and ongoing programs, projects, and restoration efforts remains uncertain. In the long term, however, the net effects are expected to include substantial improvements in river habitat conditions and conservation or recovery of special-status fish populations. Despite ongoing and potential future projects that could benefit native Sacramento River fishes and their habitat, it is apparent that the effects of past and present actions have resulted in a cumulative adverse effect on Sacramento River Winter-Run Chinook Salmon, Central Valley Spring-Run Chinook Salmon, Central Valley Steelhead, Southern DPS Green Sturgeon, and designated critical habitat in the Sacramento River for each of these species.

Anadromous Salmonids

This section addresses cumulative effects on the Sacramento River populations of the following anadromous salmonids: Winter-Run Chinook Salmon, Spring-Run Chinook Salmon, Central Valley Steelhead, Fall-Run Chinoook Salmon and Late fall-run Chinook Salmon. Winter-Run, Spring-Run and steelhead are federally listed, while fall-run and late fall-run are not listed.

The following are the proposed actions that were identified in the evaluation of the alternatives to have potential effects (adverse or beneficial) on one or more of the anadromous salmonid species or runs:

Project-Level Actions

- Seasonal operations
- Shasta coldwater pool management
- Spring pulse flows
- Fall and winter refill and redd maintenance
- Rice decomposition smoothing
- Spring management of spawning locations

Program-Level Actions

- Battle Creek restoration
- Lower intakes near Wilkins Slough
- Shasta TCD improvements
- Conservation hatchery (increased Winter-Run Chinook Salmon production)
- Small screen program
- Spawning habitat restoration
- Rearing habitat restoration
- Adult rescue
- Trap and haul

The No Action Alternative would include none of the proposed actions of the alternatives nor any effects on anadromous salmonids resulting from them and, therefore, by definition, there would be no cumulative effects on anadromous salomonids under the No Action Alternative. Most of the project-level proposed actions are included in Alternative 1 only, while all of the program-level actions are included in

Alternatives 1 and 3, but not in Alternatives 2 and 4. Therefore, with respect to the project-level proposed actions, Alternatives 2 through 4, but not Alternative 1, are largely the same as the No Action Alternative, and with respect to the program-level proposed actions, Alternatives 2 and 4, but not Alternatives 1 and 3, are the same as the No Action Alternative. The one exception is the project-level proposed action, seasonal operations, which for all the action alternatives is different than the No Action Alternative.

All of the program-level proposed actions are expected to benefit the anadromous salmonid species or runs, and only one of these actions, the conservation hatchery increased Winter-Run production, would potentially have an adverse effect as well. On the other hand, all of the project-level proposed actions are expected to have both benefits and adverse effects on some of the anadromous salmonids. The expected benefits and impacts typically involve a tradeoff between the benefit of releasing water from storage in one year and with the impact of conserving insufficient storage for the next year. For instance, seasonal operations (the first proposed action listed above) must balance the benefits to incubating Winter-Run and Spring-Run eggs and alevins of releasing cold water in one year with the impact of providing insufficient storage for conservation of coldwater pool in the following year. This applies to seasonal operations of all the alternatives. For some of the other actions, the tradeoff is between flow releases to benefit migration or to prevent redd dewatering in one year versus sufficient coldwater pool in the following year. In addition to seasonal operations, such trade-offs are a central feature of Shasta coldwater pool management, fall and winter refill and redd maintenance, spring pulse flow, rice decomposition smoothing, and spring management of spawning locations. The costs and benefits of using water in one year versus using it in the following year are difficult to guage and likely vary from year to year, so the net effect on the salmonid populations is uncertain.

The competing benefits of storage releases in successive years described abovc principally affect Winter-Run and Spring-Run because the timing of their life cycles result in frequent exposure of eggs and alevins to injuriously warm water temperatures during summer and fall, falling water levels that lead to redd dewatering during the fall, or inadequate pulse flows for rearing and emigrating juveniles in the spring. Steelhead, fall-run and late fall-run are less affected by the management tradeoffs because they spawn when river water temperatures are cooler.

Past, present, and reasonably foreseeable projects, described in Appendix Y, *Cumulative Methodology*, may have effects on anadromous salmonids of the Sacramento River that are related to the effects of the proposed actions of Alternative 1 described above, including postivie and negative effects. The cumulative projects include actions that affect the timing and magnitidue of flow releases and seasonal water temperatures and actions that improve habitat of rearing and migrating salmonids in the Sacramento River. Flow and temperature effects of completed projects are generally accounted for in the operational modeling of the No Action Alternative. Of the water supply and water quality projects that have not been completed, those most likely to have cumulative effects related to the flow and water temperature effects of Alternative 1 are the Shasta Lake Water Resources Investigation (Shasta Dam Raise Project), the SWRCB Bay-Delta Water Quality Control Plan Update, and the Sites Reservoir Project.

Potential cumulative benefical effects from the Shasta Dam Raise Project would be to increase the volume of the Shasta Reservoir coldwater pool, enhancing the supply of cold water available for release to the river and thereby benefiting early life stages of Winter-Run and Spring-Run salmon. A greater supply of cold water would also alleviate the constraints of balancing requirements for cold water against benefits of other water release benefits for fish, including redd maintenance, emigration pulse flows, immigration attraction flows, and overbank flows to improve rearing habitat.

Potential cumulative beneficial effects of the Sites Reservoir Project would result from supplying some Shasta water demand with Sites water and thereby conserving some Shasta storage for fish benefits, including benefits to anadromous salmonid spawsning and rearing habitat. However, the Sites Project may also have a cumulative adverse effect on salmonids because it would reduce Sacramento River flow as far upstream as the TCCA intake near Red Bluff when diverting water to the Sites Reservoir, which would add to the potential adverse flow effects for rearing and emigrating Winter-Run and Spring-Run smolts under Alternative 1 (See Section 3/12 *Impacts Summary*). However, the Sites diversions would occur primarily in the winter and early spring, when water temperatures remain cool.

The Bay-Delta Water Quality Control Plan has the potential to modify Sacramento River flow, but what the modifications would be and what their effects on Sacramento River salmonids would be are uncertain.

Given the mixture of potential negative and positive effects from the actions in Alternative 1 and related actions in Shasta Dam Raise and Sites, there is some uncertainty in how Alternative 1 would ultimately affect Winter-Run and Spring-Run salmon. However, in consideration of the likely positive effects of Shasta Dam Raise and Sites on Winter-Run and Spring-Run spawning habitat in the upper Sacramento River, as well as the benefits of the non-operations-related programmatic actions included in Alternative 1, Alternative 1's contribution to adverse cumulative effects would not be substantial.

There are many projects listed in Appendix Y designed to improve habitat for Sacramento River salmonids, but most of these target habitat improvements in the Delta or the Yolo and Sutter Bypasses, so the cumulative effects of these projects are addressed in the cumulative effects sections for those areas.

Relative to the No Action Alternative, Alternative 2 and 3 would have no effect on Sacramento River anadromous salmonids except for reduced flows in September and November of wet and above normal years, which would have adverse temperature effects and migration and rearing habitat flow effects on Winter-Run and Spring-Run salmon. Alternatives 4, like Alternative 1, would also have adverse effects from the reduced September and November flow releases on migration and rearing habitat, but not on water temperatures. And Alternative 3, like Alternative 1 would have a number of beneficial programmatic actions. For Alternatives 3 and 4, the potentially adverse impacts are small relative to their potential benefits, and for Alternatives 2, 3 and 4, the potentially adverse impacts are small relative to the potential benefits of the Shasta Dam Raise and Sites projects. Therefore, the cumulative adverse effects of all three alternatives would not be substantial.

<u>Green and White Sturgeon</u>

This section addresses cumulative effects on the Sacramento River populations of Green Sturgeon and White Sturgeon. Southern DPS Green Sturgeon is federally listed; White Sturgeon is not listed.

The proposed actions that were identified in the evaluation of the alternatives as having potential effects (adverse or beneficial); the alternatives that included each of the actions; and a comparison of each of the action alternative to the No Action Alternative are presented above in the section for anadromous salmonids.

Most of the proposed actions primarily target anadromous salmonids, but many of them potentially affect sturgeon as well. Green Sturgeon is generally more likely to be affected than White Sturgeon because its spawning, holding and rearing habitats are further upstream than those of White Sturgeon and most of the proposed actions primarily target conditions in the upper Sacramento River. None of the proposed actions is expected to affect White Sturgeon. Therefore, there are no cumulative effects on White Sturgeon. Potential effects of the actions on Green Sturgeon include reduced quality of holding habitat from lower September and November flow in wet and above normal years relative to the No Action Alternative, and improved quality of spawning habitat from the proposed spawning habitat restoration action.

Past, present, and reasonably foreseeable projects, described in Appendix Y, *Cumulative Methodology*, may have effects on Green Sturgon that are related to the effects of the proposed actions of Alternative 1 described above, including positive and negative effects. The cumulative projects include actions that affect the timing and magnitidue of flow releases and seasonal water temperatures, and actions that improve habitat of rearing and migrating Green Sturgeon in the Sacramento River. Flow and temperature effects of completed projects are generally accounted for in the operational modeling of the No Action Alternative. Of the water supply and water quality projects that have not been completed, those most likely to have cumulative effects related to the flow and water temperature effects of Alternative 1 are the Shasta Lake Water Resources Investigation (Shasta Dam Raise Project), the SWRCB Bay-Delta Water Quality Control Plan Update, and the Sites Reservoir Project.

Potential cumulative benefical effects from the Shasta Dam Raise Project would be to increase the volume of the Shasta Reservoir coldwater pool, enhancing the supply of cold water available for release to the river. A greater supply of cold water would alleviate the constraints of balancing cold water requirements for Winter-Run and Spring-Run salmon against of other water release benefits for species such as Green Sturgeon. Increased flow would potentially improve Green Sturgeon holding and rearing habitat and provide improved conditions for dispersal and emigration of Green Sturgeon larvae and juveniles.

Potential cumulative beneficial effects of the Sites Reservoir Project on Green Sturgeon would be similar to those of Shasta Dam Raise Project for the river upstream of the TCCA intake near Red Bluff. The Sites Project may also have a cumulative adverse effect because it would reduce Sacramento River flow as far upstream as the TCCA intake near Red Bluff when diverting water to the Sites Reservoir, and thereby potentially add to the potential adverse effect on Green Sturgeon holding habitat under Alternative 1 (See Section ?, *Impacts Summary*).

The Bay-Delta Water Quality Control Plan has the potential to modify Sacramento River flow, but what the modifications would be and what their effects on Green Sturgeon would be are uncertain.

Given the mixture of potential negative and positive effects from the actions in Alternative 1 and related actions in Shasta Dam Raise and Sites, there is some uncertainty in how Alternative 1 would ultimately affect Green Sturgeon. However, in consideration of the likely positive effects of Shasta Dam Raise on Green Sturgeon habitat in the upper and middle Sacramento River, as well as the benefits of the non-operations-related programmatic actions included in Alternative 1, Alternative 1's contribution to adverse cumulative effects would not be substantial.

There are many projects listed in Appendix Y designed to improve habitat for Sacramento River salmonids, and while some of these would likely benefit Green Sturgeon as well, most of them target habitat improvements in the Delta or the Yolo and Sutter Bypasses, so the cumulative effects of these projects are addressed in the cumulative effects sections for those areas.

Relative to the No Action Alternative, Alternatives 2, 3, and 4, like Alternative 1, would have no significant effect on Green Sturgeon, except for reduced holding habitat quality from lower flows in September and November of wet and above normal years. This potentially adverse impact is small relative to the potential benefits of spawning and rearing habitat restoration actions under Alternatives 3. Additionally, the impact of the reduced quality of holding habitat under Alternatives 2, 3 and 4 is small relative to the potential benefits of the Shasta Dam Raise Project, so the cumulative adverse effects of all three alternatives would not be substantial.

Other Focal Fish Species

This section addresses cumulative effects on the remaining Sacramento River populations of the focal fish species not included as anadromous salmonids or Green Sturgeon and White Sturgeon: Sacraemtno Spllittail, Pacific Lamprey, River Lamprey, Hardhead, Central California Roach, Striped Bass, American Shad, Largemouth Bass, Smallmouth Bass, and Spotted Bass. None of these is a federally listed species.

The proposed actions that were identified in the evaluation of the alternatives as having potential effects (adverse or beneficial); the alternatives that included each of the actions; and a comparison of each of the action alternative to the No Action Alternative are presented above in the section for anadromous salmonids.

Most of the proposed actions primarily target anadromous salmonids and none of them are expected to affect any of the focal species listed above. Therefore, there are no cumulative effects on these species.

O.3.13.4 *Feather River*

Past and present human activities have substantially changed aquatic habitats in the lower Feather River compared to historical conditions, resulting in cumulative adverse impacts on the distribution, abundance, population structure, and genetic integrity of native salmonids, and similar effects on other native fishes. Major factors contributing to the cumulative impacts (cumulative effects) on aquatic biological resources in the lower Feather River have included hydropower development and operations, hatchery management, water withdrawals for irrigation and other uses, agricultural and urban development, channelization and levee construction, mining activities, recreational use and development, sport and commercial fisheries, introduction of nonnative fish species, and other management actions, water uses, and land uses. These actions have resulted in highly altered flow regimes, loss and disconnection of floodplains from the river channel, altered sediment transport, reduced aquatic habitat complexity, loss of riparian and off-channel aquatic habitat, elevated water temperature, degraded water quality, habitat fragmentation by physical barriers, and other adverse effects on aquatic biological resources. Several ecosystem improvement projects and actions, including the Central Valley Project Improvement Act (CVPIA), the CALFED Bay-Delta Program, California EcoRestore, the CDFW Ecosystem Restoration Program, and various other conservation, management, and restoration programs (Appendix Y, *Cumulative Methodology*), have been initiated to offset the adverse effects of previous and ongoing activities.

In addition to the ongoing activities, several probable future projects and programs may affect listed fishes and other aquatic biological resources in the lower Feather River. New projects and programs recently implemented or likely to be implemented in the near future are listed in Appendix Y, *Cumulative Methodology*. Some of these projects and programs may adversely affect special-status fishes and critical habitat in the lower Feather River, but others are likely to be beneficial. While the net short-term effect of new and ongoing programs, projects, and restoration efforts is uncertain, the net long-term effects are expected to include substantial improvements in river habitat conditions and conservation or recovery of special-status fish populations. Despite ongoing and potential future projects that could benefit native Feather River fishes and their habitat, it is apparent that the effects of past and present actions have resulted in a cumulative adverse effect on Central Valley Spring-Run Chinook Salmon, Central Valley Steelhead, Southern DPS Green Sturgeon, and critical habitat for each of these species in the lower Feather River.

O.3.13.4.1 FERC Project #2100-134

No Action Alternative

There were no adverse effects identified. Therefore, there would be no cumulative effects on aquatic biological resources under the No Action Alternative.

Alternatives 1-4

There were no adverse effects identified. Therefore, there would be no cumulative effects on aquatic biological resources under the action alternatives.

O.3.13.5 *American River*

The American River is a highly altered watershed. Historic actions and management led to the reduction of available habitat, degraded habitat conditions, and substantial reduction of fish populations in the river. While these impacts were acknowledged as a trade-off for other water management priorities in the past, measures have been taken to improve conditions in the lower American river. As such, there are numerous ongoing actions in and around the American River that may result in cumulative effects. Many of these actions are working to restore or improve conditions, so the resultant effect may not necessarily be a negative cumulative impact.

Several processes and measures are under way to that may lead to revision to flows in the Lower American River, with the objective of providing suitable instream flow and temperature conditions for fall-Chinook Salmon and Steelhead, and also benefiting other aquatic species in the river. The implementation of the Lower American River Flow Management Standard Implementation is intended to improve the condition of aquatic resources in the lower American River, particularly Fall-Run Chinook Salmon and Steelhead through management of water temperature and flow. The Lower American River Temperature Reduction Modeling Project would develop predictive tools that will reduce uncertainties in the performance of identified temperature control actions that could be implemented to improve the management of cold water resources in the Folsom/Natoma Reservoir system and the lower American River. Under the Sacramento River Water Reliability Project, Future Water Supply Projects, Reclamation and Placer County Water Agency are investigating the viability of a joint water supply diversion from the Sacramento River that includes the objective of maintaining a reliable water supply while reducing diversions of surface water from the American River in future dry years to preserve the river ecosystem. The proposed Folsom Reservoir Temperature Control Device on the bank of Folsom Reservoir would withdraw water from the warm upper reaches of the lake while preserving the coldwater pool at the bottom of the lake to protect downstream aquatic species. Implementation of these measures to would help to improve habitat conditions in the American River, particularly in dry years, by maintaining minimum instream flows and suitable water temperatures.

O.3.13.6 *Stanislaus River*

Natural hydrologic processes have been altered on the Stanislaus River, as they have been on most California rivers. More than 40 dams exist on the Stanislaus River (Merz, n.d.). The lower Stanislaus River has been extensively developed to provide water, flood control, hydroelectric power, gravel, and conversion of floodplain habitat for agricultural and residential uses (Merz, n.d.). The construction of new Melones Reservoir and its operation have resulted in a highly altered channel that has experienced gravel extraction, levee construction and removal of woody debris. These changes have affected fish and wildlife populations in the lower San Joaquin River. Processes and measures have occurred within the watershed to restore or improve conditions within the river, so the resultant effect may not necessarily be a negative cumulative effect.

A couple of processes and measures are underway in the Stanislaus River watershed. The SWRCB is updating the 2006 Bay-Delta Water Quality Control Plan (WQCP) in two phases (SWRCB 2018). The first Plan amendment (Phase 1) is focused on San Joaquin River flows and southern Delta salinity and would modify water quality objectives (i.e., establishes minimum flows) on the Stanislaus River to protect the beneficial use of fish and wildlife and modifies the water quality objectives in the southern Delta to protect the beneficial use of agriculture. The proposed final amendments to the Bay-Delta Plan and the Final Supplemental Environmental Document for Phase I was released in July 2018 and the SED was approved in December 2018.

Additionally, there are 22 hydroelectric generation Federal Energy Regulatory Commission permits that expire prior to 2030 (FERC 2015). Of the 22 hydroelectric permits, one is on the Stanislaus River. The FERC must complete analyses under NEPA and ESA to consider the effects of the hydropower operations on the environment, including flow regimes, water quality, fish passage, recreation, aquatic and riparian habitat, and special status species. The FERC relicensing activity in the Stanislaus River will eventually result in a new license that may increase flows into the river, and subsequently to the San Joaquin River.

O.3.13.7 *San Joaquin River*

The San Joaquin River is a highly altered watershed that is currently discontinuous. Historic actions and management led to the extirpation of native fishes, including Spring-Run Chinook Salmon that once persisted. While these impacts were acknowledged as a trade-off for other water management priorities in the past, current policy has worked to reverse the degraded river. As such, there are numerous ongoing actions in and around the San Joaquin River that may result in cumulative effects. Many of these actions are working to restore or improve conditions, so the resultant effect may not necessarily be a negative cumulative impact.

The San Joaquin River Restoration Program is a large and comprehensive effort to reverse some of the negative alterations to the upper San Joaquin River aquatic habitat while reintroducing spring-Run Chinook Salmon. The project manages for both Fall- and Spring-Run Chinook Salmon alike, but has reintroduced Spring-Run Chinook through an experimental population. The Salmon population will be supported by a conservation hatchery, which operates under more significant scrutiny considering genetic diversity and overall viability. The program seeks to connect flow from Friant Dam down to the mouth of the Merced River to provide habitat capable of supporting populations of Chinook Salmon in good condition. While water management and habitat restoration are significant components to the project, the overall impact to irrigators is required to be *de minimus*.

Several regulatory processes are currently underway that might lead to general revisions to flow in the San Joaquin River. The Bay-Delta Water Quality Control Plan Update is seeking for 40 to 60% unimpaired flow from the lower San Joaquin, Merced, Tuolumne, and Stanislaus Rivers. This level of unimpaired flow would significantly increase outflow through the lower San Joaquin River to the Delta. FERC relicensing activity in the Merced and Tuolumne Rivers will eventually result in a new license that may increase required base flows from these tributaries to the San Joaquin River.

Any increased flow releases in the upper San Joaquin River may result in lower storage. The upper San Joaquin River basin Storage Investigation is investigating the potential to add 1,260 TAF of storage along the upper San Joaquin River upstream of Millerton Lake in an area known as Temperance Flat.

Additional storage would help to offset additional water demands for agricultural needs, the environment and municipal usage.

Flood risk management in the lower San Joaquin River may modify the channel structure through repair of levee walls. The overall study area includes the mainstem of the San Joaquin River from the Mariposa Bypass downstream to the city of Stockton. The study area also includes Paradise Cut and Old River as far north as Tracy Boulevard and Middle River as far north as Victoria Canal. These areas have commonly flooded and resulted in damage and risk to surrounding homes and property. The project will balance levee repairs by also improving aquatic and riparian habitat.

O.3.13.8 *Bay-Delta*

O.3.13.8.1 <u>Delta Smelt</u>

The following are the main potential effects to Delta Smelt identified in the evaluation of alternatives (effects apply to all alternatives, except as otherwise indicated):

Potential changes to Delta Smelt due to seasonal operations (Project-Level)

Potential changes to Delta Smelt due to OMR management (Project-Level, Alternative 1 only)

Potential Effects from Delta Smelt Habitat Operations (Project-Level, Alternatives 1 and 3 only)

Potential changes to Delta Smelt due to reintroduction by the Fish Conservation and Culture Laboratory (Project-Level, Alternatives 1 and 3 only)

Potential changes to Delta Smelt from food subsidies (Sacramento Deepwater Ship Channel Food Study; North Delta Food Subsidies/Colusa Basin Drain Study; Suisun Marsh Roaring River Distribution System Food Subsidies Study)(Program-Level, Alternatives 1 and 3 only)

Potential changes to Longfin Smelt from tidal habitat restoration (Program-Level)

Potential changes to Delta Smelt from the Delta fFsh Species Conservation Hatchery (Program-Level, Alternatives 1 and 3 only)

Potential changes to Delta Smelt from additional habitat restoration (25,000 acres within the Delta) (Program-Level, Alternative 3 only)

The No Action Alternative would not result in any changes to water operations from current operations and therefore additional effects on Delta Smelt would be avoided by design. Thus, no cumulative effects on aquatic resources under the No Action alternative were identified.

Alternative 1 would contribute to cumulative effects on Delta Smelt from seasonal operations and Delta Smelt habitat operations (e.g., food availability and habitat extent) and OMR management (south Delta entrainment risk). However, Alternative 1 would be subject to the regulatory and permitting requirements of the USACE, USFWS, CDFW, NMFS, and SWRCB. Also, there may be offsetting, potential positive effects to Delta Smelt from food subsidies (studies related to Sacramento Deepwater Ship Channel, North Delta/Colusa Basin Drain, and Suisun Marsh RRDS), reintroduction of Delta Smelt by the Fish Conservation and Culture Laboratory and the Delta Fish Species Conservation Hatchery, and completion of 8,000 acres of tidal habitat restoration.

Past, present, and reasonably foreseeable projects, described in Appendix Y, *Cumulative Methodology*, may have effects on Delta Smelt related to the effects described above related to Alternative 1. The listed projects that have been completed have had their effects accounted for in the operational modeling of Alternative 1, e.g., effects on Delta outflow. Of the water supply and water quality projects not included in the modeling, those most likely to have cumulative effects of the nature described for Alternative 1 are the SWRCB Bay-Delta Water Quality Control Plan Update, the Sites Reservoir Project, and the Delta Wetlands project. The Bay-Delta Water Quality Control Plan has the potential to increase Delta inflow and Delta outflow, and reduce south Delta exports. The Sites Reservoir Project has the potential to reduce winter/early spring Delta inflow and outflow, as well as to increase south Delta exports during the summer water transfer window, but also has the potential to increase summer/fall flows into the north Delta from the Colusa Basin Drain/Yolo Bypass for Delta Smelt food web benefits. The Delta Wetlands project would have potential negative effects from entrainment of Delta Smelt too small to be screened, in addition to reductions in Delta outflow during winter/early spring diversion periods, but may provide positive effects from release of water to contribute to Delta outflow. Given the mixture of potential negative and positive effects from these actions, there is some uncertainty in how Alternative 1 would ultimately affect seasonal operations; for example, increases in Delta outflow requirement under the Bay-Delta Water Quality Control Plan would regulate Delta outflow under the proposed action and any other actions potentially affecting outflow. As previously noted for Alternative 1, other projects would be subject to regulatory and permitting requirements of the USACE, USFWS, CDFW, NMFS, and SWRCB, in order to limit potential negative effects. In consideration of these requirements, as well as the non-operations-related measures included in Alternative 1 such as tidal habitat restoration and food subsidy actions and other projects' restoration activities such as California EcoRestore, Alternative 1's contribution to cumulative effects would not be substantial.

Relative to the No Action Alternative, Alternatives 2 through 4would have somewhat differing effects compared to Alternative 1's effects because of differences in seasonal operations and differing extent of habitat restoration, for example, but the overall conclusion regarding cumulative effects remains the same as Alternative 1 because of the common regulatory and permitting requirements that all Alternatives are subject to.

O.3.13.8.2 Longfin Smelt

The following are the main potential effects to Longfin Smelt identified in the evaluation of alternatives (effects apply to all alternatives, except as otherwise indicated):

Potential changes to Longfin Smelt due to seasonal operations (Project-Level)

Potential changes to Longfin Smelt due to OMR management (Project-Level, Alternative 1 only)

The No Action Alternative would not result in any changes to water operations from current operations and therefore additional effects on Delta Smelt would be avoided by design. Thus, no cumulative effects on aquatic resources under the No Action alternative were identified.

Key aspects of the above effects for Longfin Smelt under Alternative 1 and Alternatives 2 through 4 are potential changes that could occur to Delta outflow in particular, with reductions in winter/spring outflow having the potential to reduce abundance relative to the No Action Alternative. However, Alternative 1 would be subject to the regulatory and permitting requirements of the USACE, USFWS, CDFW, NMFS, and SWRCB. As discussed in more detail for Delta Smelt, completed project effects are captured in the operations modeling for the project. As also discussed for Delta Smelt, other projects (Bay-Delta Water Quality Control updates, Sites Reservoir Project, and Delta Wetlands) could positively or negatively affect Delta outflow, but all projects would be subject to regulatory and permitting requirements of the USACE, USFWS, CDFW, NMFS, and SWRCB. Therefore Alternative 1's contribution to cumulative effects would not be substantial. For the same reason, Alternatives 2 through 4also would not substantially contribute to cumulative effects.

O.3.13.8.3 Sacramento Winter-Run Chinook Salmon

The following are the main potential effects to Sacramento River Winter-Run identified in the evaluation of alternatives (effects apply to all alternatives, except as otherwise indicated):

Potential negative effects from seasonal operations (Project-Level)

Potential negative effects from OMR Management (Project-Level)

Potential negative effects from Delta Cross Channel Operations (Project Level)

Potential positive effects from Tracy and Skinner Fish Facilities (Project-Level)

Potential positive effects from Predator Hot Spot Removal (Program-Level, Alternatives 1 and 3 only)

Potential negative effects from Delta Cross Channel Gate Improvements (Program-Level, Alternatives 1 and 3 only)

Potential positive effects from Tracy and Skinner Fish Facility Improvements (Program-Level, Alternatives 1 and 3 only)

Potential positive effects from Small Screen Program (Program-Level, Alternatives 1 and 3 only)

Potential positive effects from Tidal Habitat Restoration (Complete 8,000 Acres from 2008 BO) (Program-Level)

Potential positive effects from Additional Habitat Restoration (25,000 acres within the Delta) (Program-Level, Alternative 3 only)

The No Action Alternative would not result in any changes to water operations from current operations and therefore additional effects on Winter-Run Chinook Salmon would be avoided by design. Thus, no cumulative effects on aquatic resources under the No Action alternative were identified.

Alternative 1 would contribute to cumulative effects on Winter-Run Chinook Salmon from seasonal operations, OMR management (south Delta entrainment risk), and Delta Cross Channel Operations. However, Alternative 1 would be subject to the regulatory and permitting requirements of the USACE, USFWS, CDFW, NMFS, and SWRCB. Also, there may be offsetting, potential positive effects to Winter Run Chinook salmon from improvements at the Tracy and Skinner Fish Facilities, predator hot-spot removal, the small screen program, and completion of 8,000 acres of tidal habitat restoration.

Past, present, and reasonably foreseeable projects, described in Appendix Y, *Cumulative Methodology*, may have effects on Winter Run Chinook Salmon related to the effects described above related to Alternative 1. The listed projects that have been completed have had their effects accounted for in the operational modeling of Alternative 1, e.g., effects on Delta outflow. Of the water supply and water quality projects not included in the modeling, those most likely to have cumulative effects of the nature described for Alternative 1 are the SWRCB Bay-Delta Water Quality Control Plan Update, the Sites Reservoir Project, and the Delta Wetlands project. The Bay-Delta Water Quality Control Plan has the potential to increase Delta inflow and reduce south Delta exports. The Sites Reservoir Project has the potential to reduce winter/early spring Delta inflow and outflow, as well as to increase south Delta exports during the summer water transfer window. The Delta Wetlands project would have potential reductions in Delta outflow during winter/early spring diversion periods but may provide positive effects from release of water to contribute to Delta outflow. Given the mixture of potential negative and positive effects from these actions, there is some uncertainty in how Alternative 1 would ultimately affect seasonal operations; for example, increases in Delta outflow requirements under the Bay-Delta Water Quality Control Plan would regulate Delta outflow under the proposed action and any other actions potentially affecting flow in migratory channels and south delta exports. As previously noted for Alternative 1, other projects would be subject to regulatory and permitting requirements of the USACE, USFWS, CDFW, NMFS, and SWRCB, in order to limit potential negative effects. In consideration of these requirements, as well as the non-operations-related measures included in Alternative 1 such as tidal habitat restoration and food subsidy actions and other projects' restoration activities such as California EcoRestore, Alternative 1's contribution to cumulative effects would not be substantial.

Relative to the No Action Alternative, Alternatives 2 through 4 would have somewhat differing effects compared to Alternative 1's effects because of differences in seasonal operations and differing extent of habitat restoration, for example, but the overall conclusion regarding cumulative effects remains the same as Alternative 1 because of the common regulatory and permitting requirements that all Alternatives are subject to.

O.3.13.8.4 Central Valley Spring Run Chinook Salmon

The following are the main potential effects to Central Valley Spring Run identified in the evaluation of alternatives (effects apply to all alternatives, except as otherwise indicated):

Potential negative effects from seasonal operations (Project-Level)

Potential negative effects from OMR Management (Project-Level)

Potential negative effects from Delta Cross Channel operations (Project Level)

Potential positive effects from Tracy and Skinner Fish Facilities (Project-Level)

Potential positive effects from predator hot Spot removal (Program-Level, Alternatives 1 and 3 only)

Potential negative effects from Delta Cross Channel Gate improvements (Program-Level, Alternatives 1 and 3 only)

Potential positive effects from Tracy and Skinner Fish Facility improvements (Program-Level, Alternatives 1 and 3 only)

Potential positive effects from small screen program (Program-Level, Alternatives 1 and 3 only)

Potential positive effects from Tidal Habitat Restoration (Program-Level)

Potential positive effects from Additional Habitat Restoration (25,000 acres within the Delta) (Program-Level, Alternative 3 only)

The No Action Alternative would not result in any changes to water operations from current operations and therefore additional effects on Spring-Run Chinook Salmon would be avoided by design. Thus, no cumulative effects on aquatic resources under the No Action alternative were identified.

Alternative 1 would contribute to cumulative effects on Spring-Run Chinook Salmon from seasonal operations, OMR management (south Delta entrainment risk), and Delta Cross Channel Operations (Sacramento River populations). However, Alternative 1 would be subject to the regulatory and permitting requirements of the USACE, USFWS, CDFW, NMFS, and SWRCB. Also, there may be offsetting, potential positive effects to Spring-Run Chinook salmon from improvements at the Tracy and Skinner Fish Facilities, predator hot-spot removal, the small screen program, and completion of 8,000 acres of tidal habitat restoration.

Past, present, and reasonably foreseeable projects, described in Appendix Y, *Cumulative Methodology*, may have effects on Spring Run Chinook Salmon related to the effects described above related to Alternative 1. The listed projects that have been completed have had their effects accounted for in the operational modeling of Alternative 1, e.g., effects on Delta outflow. Of the water supply and water quality projects not included in the modeling, those most likely to have cumulative effects of the nature described for Alternative 1 are the SWRCB Bay-Delta Water Quality Control Plan Update, the Sites Reservoir Project, and the Delta Wetlands project. The Bay-Delta Water Quality Control Plan has the potential to increase Delta inflow and reduce south Delta exports. The Sites Reservoir Project has the potential to reduce winter/early spring Delta inflow and outflow, as well as to increase south Delta exports during the summer water transfer window. The Delta Wetlands project would have potential reductions in Delta outflow during winter/early spring diversion periods but may provide positive effects from release of water to contribute to Delta outflow. Given the mixture of potential negative and positive effects from these actions, there is some uncertainty in how Alternative 1 would ultimately affect seasonal operations; for example, increases in Delta outflow requirements under the Bay-Delta Water Quality Control Plan would regulate Delta outflow under the proposed action and any other actions potentially affecting flow in migratory channels and south delta exports. As previously noted for Alternative 1, other projects would be subject to regulatory and permitting requirements of the USACE, USFWS, CDFW, NMFS, and SWRCB, in order to limit potential negative effects. In consideration of these requirements, as well as the non-operations-related measures included in Alternative 1 such as tidal habitat restoration and food subsidy actions and other projects' restoration activities such as California EcoRestore, Alternative 1's contribution to cumulative effects would not be substantial.

Relative to the No Action Alternative, Alternatives 2 through 4 would have somewhat differing effects compared to Alternative 1's effects because of differences in seasonal operations and differing extent of habitat restoration, for example, but the overall conclusion regarding cumulative effects remains the same as Alternative 1 because of the common regulatory and permitting requirements that all Alternatives are subject to.

O.3.13.8.5 Central Valley Fall Run Chinook Salmon

The following are the main potential effects to Central Valley Fall-Run identified in the evaluation of alternatives (effects apply to all alternatives, except as otherwise indicated):

Potential negative effects from seasonal operations (Project-Level)

Potential negative effects from OMR Management (Project-Level)

Potential negative effects from Delta Cross Channel operations (Project Level)

Potential positive effects from Tracy and Skinner Fish Facilities (Project-Level)

Potential positive effects from predator hot spot removal (Program-Level, Alternatives 1 and 3 only)

Potential negative effects from Delta Cross Channel Gate improvements (Program-Level, Alternatives 1 and 3 only)

Potential positive effects from Tracy and Skinner Fish Facility improvements (Program-Level, Alternatives 1 and 3 only)

Potential positive effects from small screen program (Program-Level, Alternatives 1 and 3 only)

Potential positive effects from tidal habitat restoration

Potential positive effects from additional habitat restoration (25,000 acres within the Delta) (Program-Level, Alternative 3 only)

The No Action Alternative would not result in any changes to water operations from current operations and therefore additional effects on Fall-Run Chinook Salmon would be avoided by design. Thus, no cumulative effects on aquatic resources under the No Action alternative were identified.

Alternative 1 would contribute to cumulative effects on Fall-Run Chinook Salmon from seasonal operations, OMR management (south Delta entrainment risk), and Delta Cross Channel Operations (Sacramento River populations). However, Alternative 1 would be subject to the regulatory and permitting requirements of the USACE, USFWS, CDFW, NMFS, and SWRCB. Also, there may be offsetting, potential positive effects to Fall Run Chinook salmon from improvements at the Tracy and Skinner Fish Facilities, predator hot-spot removal, the small screen program, and completion of 8,000 acres of tidal habitat restoration.

Past, present, and reasonably foreseeable projects, described in Appendix Y, *Cumulative Methodology*, may have effects on Fall-Run Chinook Salmon related to the effects described above related to Alternative 1. The listed projects that have been completed have had their effects accounted for in the operational modeling of Alternative 1, e.g., effects on Delta outflow. Of the water supply and water quality projects not included in the modeling, those most likely to have cumulative effects of the nature described for Alternative 1 are the SWRCB Bay-Delta Water Quality Control Plan Update, the Sites Reservoir Project, and the Delta Wetlands project. The Bay-Delta Water Quality Control Plan has the potential to increase Delta inflow and reduce south Delta exports. The Sites Reservoir Project has the potential to reduce winter/early spring Delta inflow and outflow, as well as to increase south Delta exports during the summer water transfer window. The Delta Wetlands project would have potential reductions in Delta outflow during winter/early spring diversion periods but may provide positive effects from release of water to contribute to Delta outflow. Given the mixture of potential negative and positive effects from these actions, there is some uncertainty in how Alternative 1 would ultimately affect seasonal operations; for example, increases in Delta outflow requirements under the Bay-Delta Water Quality Control Plan would regulate Delta outflow under the proposed action and any other actions potentially affecting flow in migratory channels and south delta exports. As previously noted for Alternative 1, other projects would be subject to regulatory and permitting requirements of the USACE, USFWS, CDFW, NMFS, and SWRCB, in order to limit potential negative effects. In consideration of these requirements, as well as the non-operations-related measures included in Alternative 1 such as tidal habitat restoration and food subsidy actions and other projects' restoration activities such as California EcoRestore, Alternative 1's contribution to cumulative effects would not be substantial.

Relative to the No Action Alternative, Alternatives 2 through 4 would have somewhat differing effects compared to Alternative 1's effects because of differences in seasonal operations and differing extent of habitat restoration, for example, but the overall conclusion regarding cumulative effects remains the same as Alternative 1 because of the common regulatory and permitting requirements that all Alternatives are subject to.

O.3.13.8.6 California Central Valley Steelhead

The following are the main potential effects to California Central Valley steelhead identified in the evaluation of alternatives (effects apply to all alternatives, except as otherwise indicated):

Potential negative effects from seasonal operations (Project-Level)

Potential negative effects from OMR Management (Project-Level)

Potential negative effects from Delta Cross Channel operations (Project Level)

Potential positive effects from Tracy and Skinner Fish Facilities (Project-Level)

Potential positive effects from predator hot spot removal (Program-Level, Alternatives 1 and 3 only)

Potential negative effects from Delta Cross Channel Gate improvements (Program-Level, Alternatives 1 and 3 only)

Potential positive effects from Tracy and Skinner Fish Facility improvements (Program-Level, Alternatives 1 and 3 only)

Potential positive effects from small screen program (Program-Level, Alternatives 1 and 3 only)

Potential positive effects from tidal habitat restoration (Program-Level)

Potential positive effects from additional habitat restoration (25,000 acres within the Delta) (Program-Level, Alternative 3 only)

The No Action Alternative would not result in any changes to water operations from current operations and therefore additional effects on CCV steelhead would be avoided by design. Thus, no cumulative effects on aquatic resources under the No Action alternative were identified.

Alternative 1 would contribute to cumulative effects on CCV steelhead from seasonal operations, OMR management (south Delta entrainment risk), and Delta Cross Channel Operations (Sacramento River populations). However, Alternative 1 would be subject to the regulatory and permitting requirements of the USACE, USFWS, CDFW, NMFS, and SWRCB. Also, there may be offsetting, potential positive effects to CCV steelhead from improvements at the Tracy and Skinner Fish Facilities, predator hot-spot removal, the small screen program, and completion of 8,000 acres of tidal habitat restoration.

Past, present, and reasonably foreseeable projects, described in Appendix Y, *Cumulative Methodology*, may have effects on CCV steelhead related to the effects described above related to Alternative 1. The listed projects that have been completed have had their effects accounted for in the operational modeling of Alternative 1, e.g., effects on Delta outflow. Of the water supply and water quality projects not included in the modeling, those most likely to have cumulative effects of the nature described for

Alternative 1 are the SWRCB Bay-Delta Water Quality Control Plan Update, the Sites Reservoir Project, and the Delta Wetlands project. The Bay-Delta Water Quality Control Plan has the potential to increase Delta inflow and reduce south Delta exports. The Sites Reservoir Project has the potential to reduce winter/early spring Delta inflow and outflow, as well as to increase south Delta exports during the summer water transfer window. The Delta Wetlands project would have potential reductions in Delta outflow during winter/early spring diversion periods but may provide positive effects from release of water to contribute to Delta outflow. Given the mixture of potential negative and positive effects from these actions, there is some uncertainty in how Alternative 1 would ultimately affect seasonal operations; for example, increases in Delta outflow requirements under the Bay-Delta Water Quality Control Plan would regulate Delta outflow under the proposed action and any other actions potentially affecting flow in migratory channels and south delta exports. As previously noted for Alternative 1, other projects would be subject to regulatory and permitting requirements of the USACE, USFWS, CDFW, NMFS, and SWRCB, in order to limit potential negative effects. In consideration of these requirements, as well as the non-operations-related measures included in Alternative 1 such as tidal habitat restoration and food subsidy actions and other projects' restoration activities such as California EcoRestore, Alternative 1's contribution to cumulative effects would not be substantial.

Relative to the No Action Alternative, Alternatives 2 through 4 would have somewhat differing effects compared to Alternative 1's effects because of differences in seasonal operations and differing extent of habitat restoration, for example, but the overall conclusion regarding cumulative effects remains the same as Alternative 1 because of the common regulatory and permitting requirements that all Alternatives are subject to.

O.3.13.8.7 North American Green Sturgeon southern DPS

The following are the main potential effects to North American Green Sturgeon identified in the evaluation of alternatives (effects apply to all alternatives, except as otherwise indicated):

Potential negative effects from seasonal operations (Project-Level)

Potential negative effects from OMR Management (Project-Level)

Potential positive effects from Tracy and Skinner Fish Facilities (Project-Level)

Potential positive effects from predator hot spot removal (Program-Level, Alternatives 1 and 3 only)

Potential negative effects from Delta Cross Channel Gate improvements (Program-Level, Alternatives 1 and 3 only)

Potential positive effects from Tracy and Skinner Fish Facility improvements (Program-Level, Alternatives 1 and 3 only)

Potential positive effects from small screen program (Program-Level, Alternatives 1 and 3 only)

Potential positive effects from tidal habitat restoration (Program-Level)

Potential positive effects from additional habitat restoration (25,000 acres within the Delta) (Program-Level, Alternative 3 only)

The No Action Alternative would not result in any changes to water operations from current operations and therefore additional effects on North American Green Sturgeon would be avoided by design. Thus, no cumulative effects on aquatic resources under the No Action alternative were identified.

Alternative 1 would contribute to cumulative effects on North American Green Sturgeon from seasonal operations, OMR management (south Delta entrainment risk), and Delta Cross Channel Operations (Sacramento River populations). However, Alternative 1 would be subject to the regulatory and permitting requirements of the USACE, USFWS, CDFW, NMFS, and SWRCB. Also, there may be offsetting, potential positive effects to North American Green Sturgeon from improvements at the Tracy and Skinner Fish Facilities, predator hot-spot removal, the small screen program, and completion of 8,000 acres of tidal habitat restoration.

Past, present, and reasonably foreseeable projects, described in Appendix Y, *Cumulative Methodology*, may have effects on North American Green Sturgeon related to the effects described above related to Alternative 1. The listed projects that have been completed have had their effects accounted for in the operational modeling of Alternative 1, e.g., effects on Delta outflow. Of the water supply and water quality projects not included in the modeling, those most likely to have cumulative effects of the nature described for Alternative 1 are the SWRCB Bay-Delta Water Quality Control Plan Update, the Sites Reservoir Project, and the Delta Wetlands project. The Bay-Delta Water Quality Control Plan has the potential to increase Delta inflow and reduce south Delta exports. The Sites Reservoir Project has the potential to reduce winter/early spring Delta inflow and outflow, as well as to increase south Delta exports during the summer water transfer window. The Delta Wetlands project would have potential reductions in Delta outflow during winter/early spring diversion periods but may provide positive effects from release of water to contribute to Delta outflow. Given the mixture of potential negative and positive effects from these actions, there is some uncertainty in how Alternative 1 would ultimately affect seasonal operations; for example, increases in Delta outflow requirements under the Bay-Delta Water Quality Control Plan would regulate Delta outflow under the proposed action and any other actions potentially affecting flow in migratory channels and south delta exports. As previously noted for Alternative 1, other projects would be subject to regulatory and permitting requirements of the USACE, USFWS, CDFW, NMFS, and SWRCB, in order to limit potential negative effects. In consideration of these requirements, as well as the non-operations-related measures included in Alternative 1 such as tidal habitat restoration and food subsidy actions and other projects' restoration activities such as California EcoRestore, Alternative 1's contribution to cumulative effects would not be substantial.

Relative to the No Action Alternative, Alternatives 2 through 4 would have somewhat differing effects compared to Alternative 1's effects because of differences in seasonal operations and differing extent of habitat restoration, for example, but the overall conclusion regarding cumulative effects remains the same as Alternative 1 because of the common regulatory and permitting requirements that all Alternatives are subject to.

O.3.13.9 *Nearshore Pacific Ocean of the California Coast*

O.3.13.9.1 <u>Southern Resident Killer Whale</u>

The following main potential effects on Southern Resident Killer Whale were identified in the evaluation of alternatives:

Potential changes to Southern Killer Whale from Chinook Salmon prey abundance

In general, the analysis of Alternatives 1–4 noted that potential effects on Chinook Salmon prey for Southern Resident Killer Whale may be limited as a result of the medium importance of Central Valley Chinook Salmon stocks in the Southern Resident Killer Whale diet and the relatively high representation in the stocks by hatchery-origin fish, many of which are released downstream of the Delta. As described previously for the smelts above, other projects that could contribute to cumulative effects to Chinook Salmon as Southern Resident Killer Whale prey would be subject to regulatory and permitting requirements of the USACE, USFWS, CDFW, NMFS, and SWRCB, which would tend to limit the potential for effects and would be expected to result in Alternatives 1–4 not substantially contributing to cumulative effects.

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Appendix O Attachment 1

Bay-Delta Aquatics Effects Figures

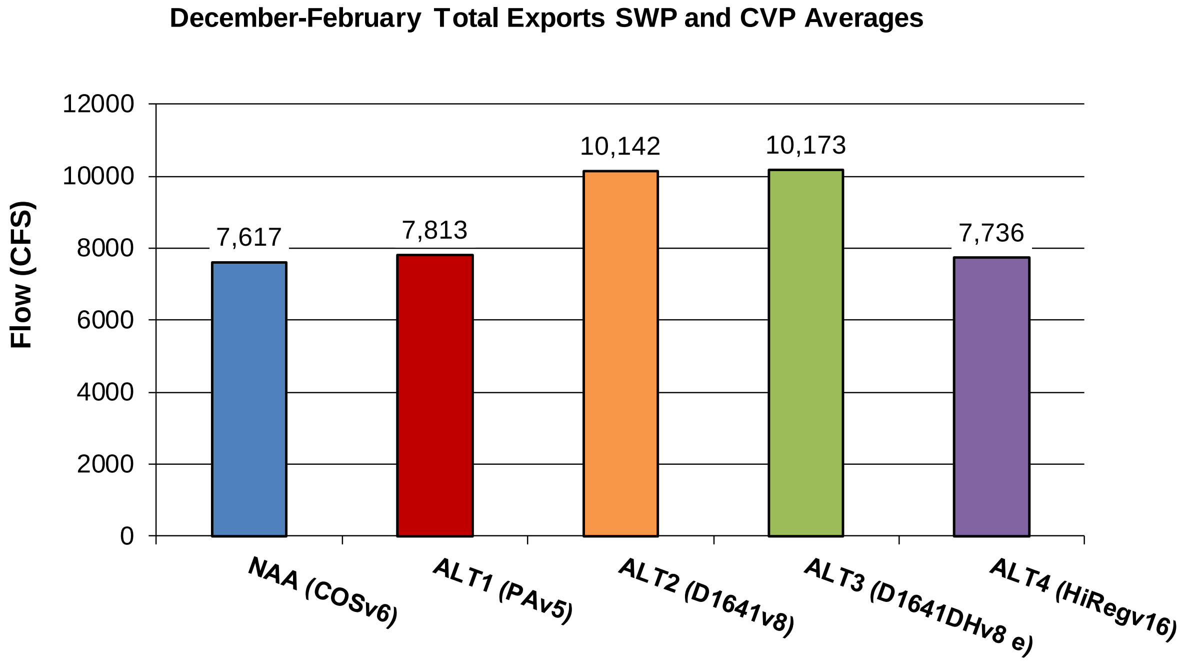


Figure O-1. Total exports December–February

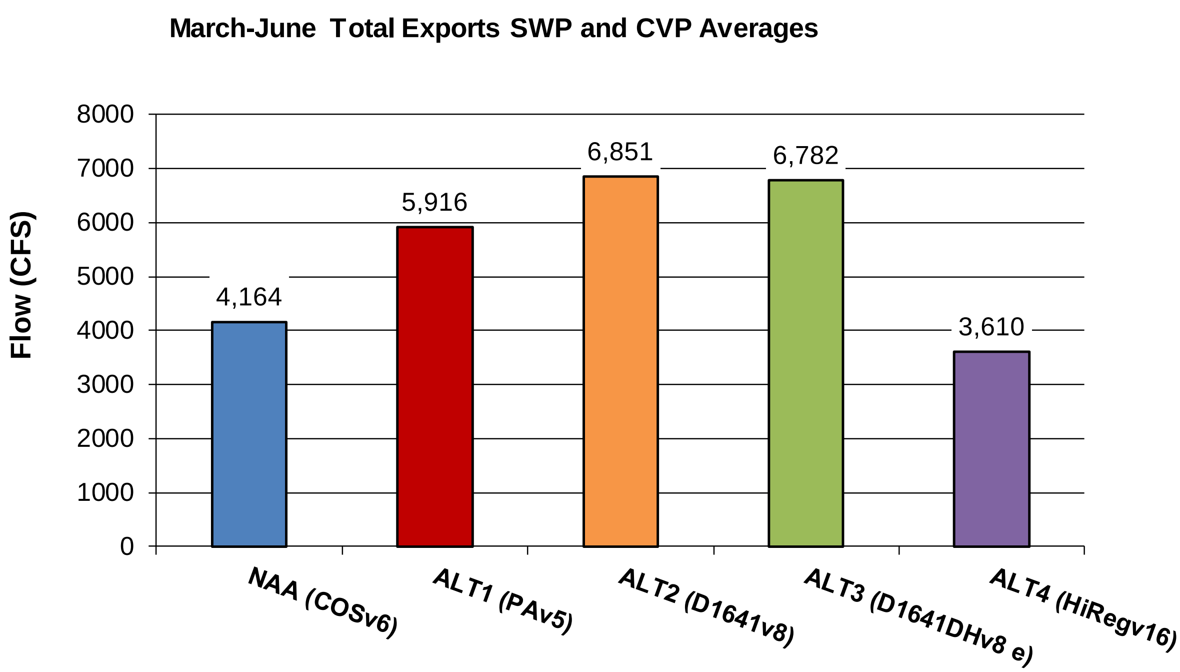


Figure O-2. Total exports March–June

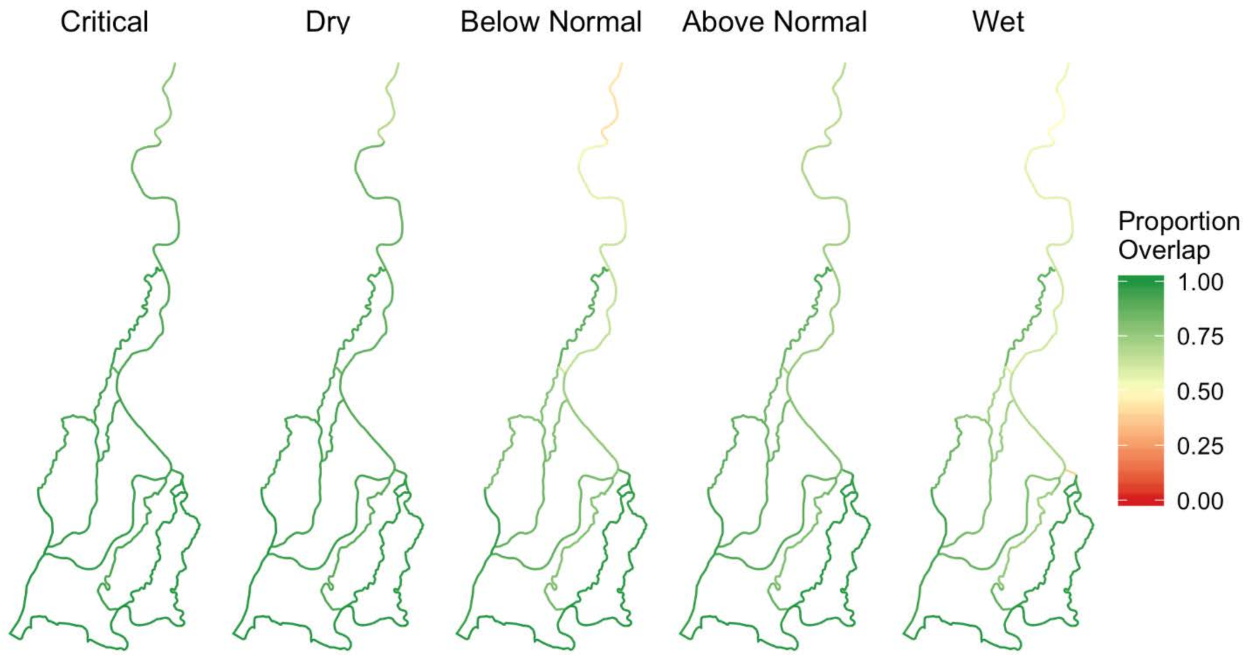


Figure O-3. No Action Alternative vs. Alternative 1, December–February

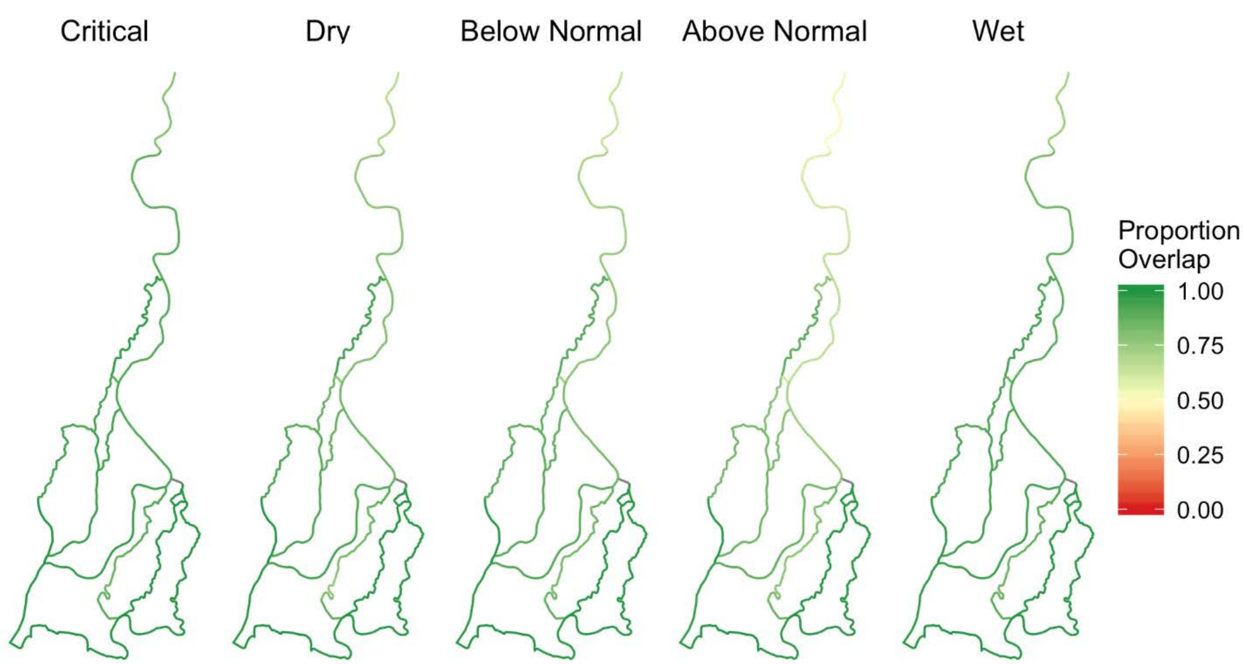


Figure O-4. Alternative 1 vs. No Action Alternative, March–May

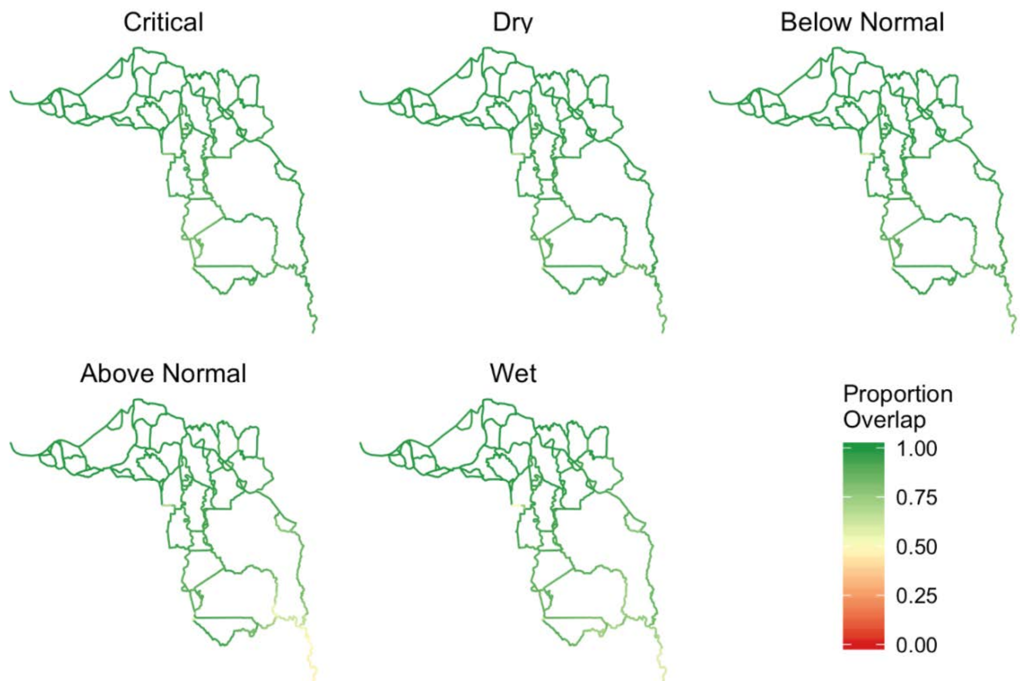


Figure O-5 Alternative 1 vs. No Action Alternative, December–February

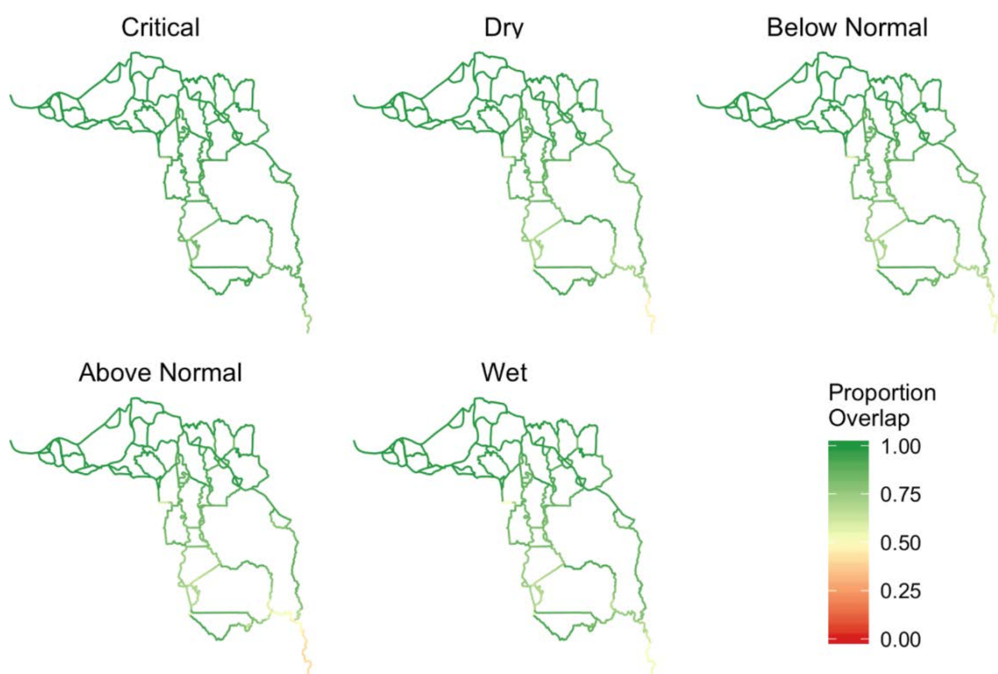
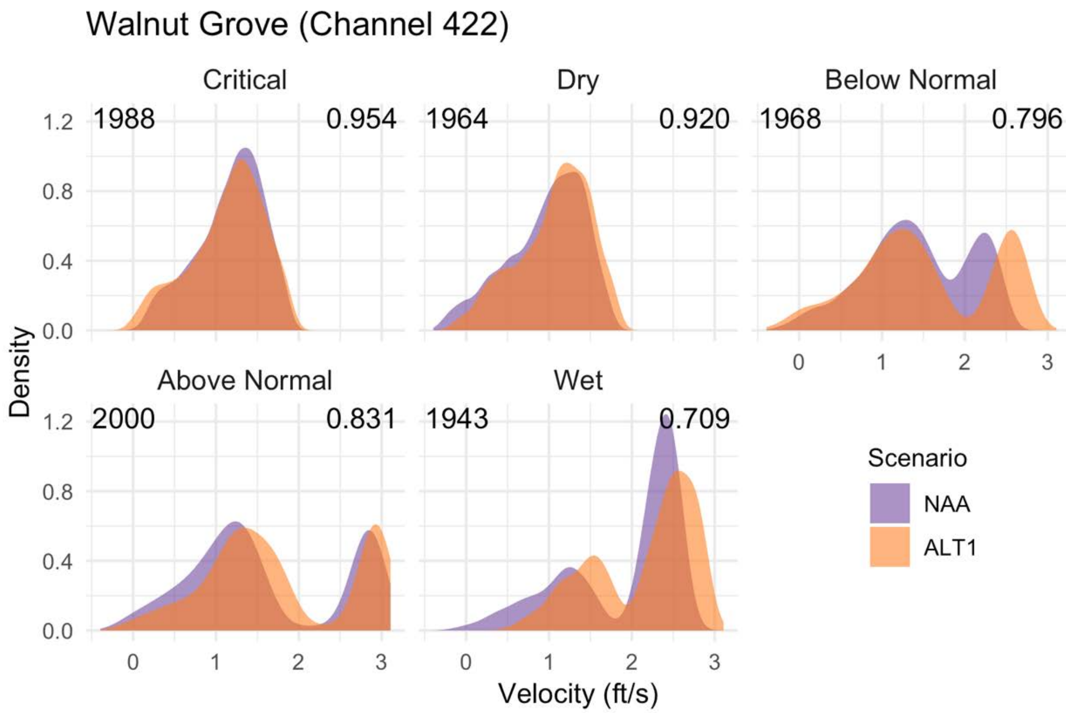


Figure O-6. Alternative 1 vs. No Action Alternative, March–May



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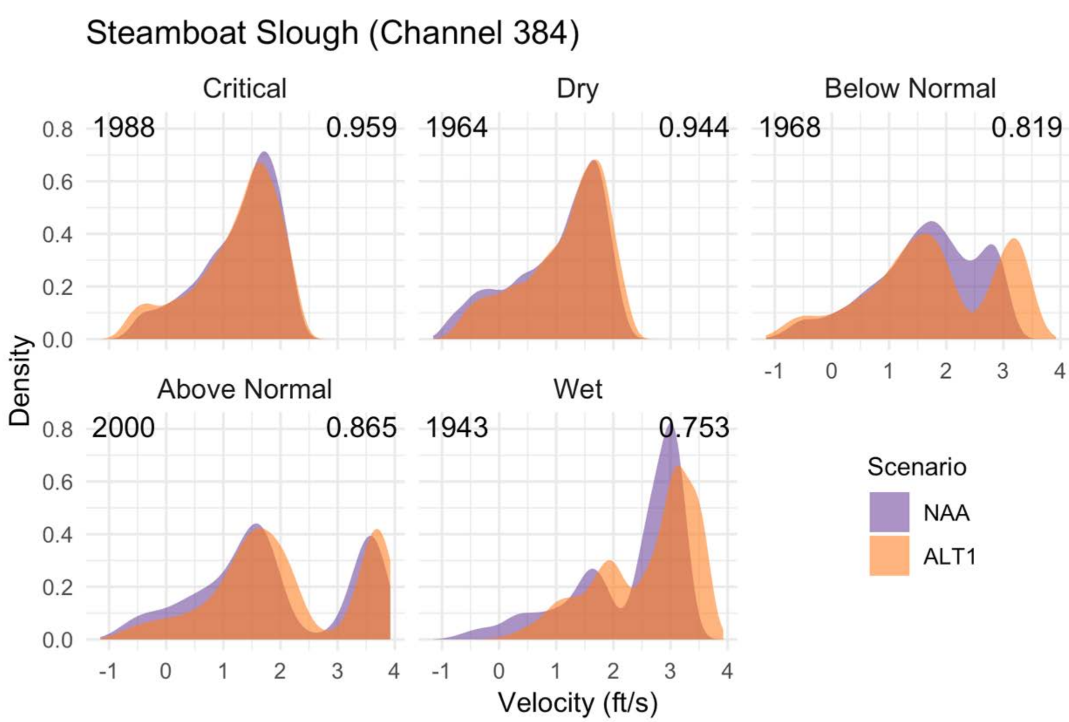

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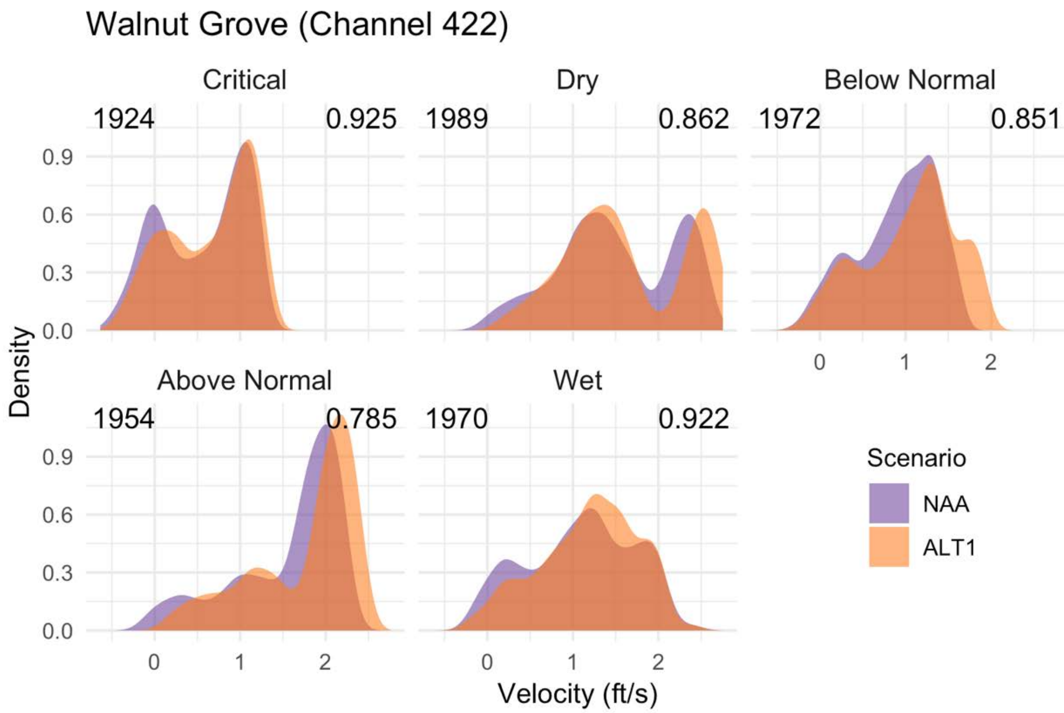


Figure O-9. Alternative 1 vs. No Action Alternative, March–May

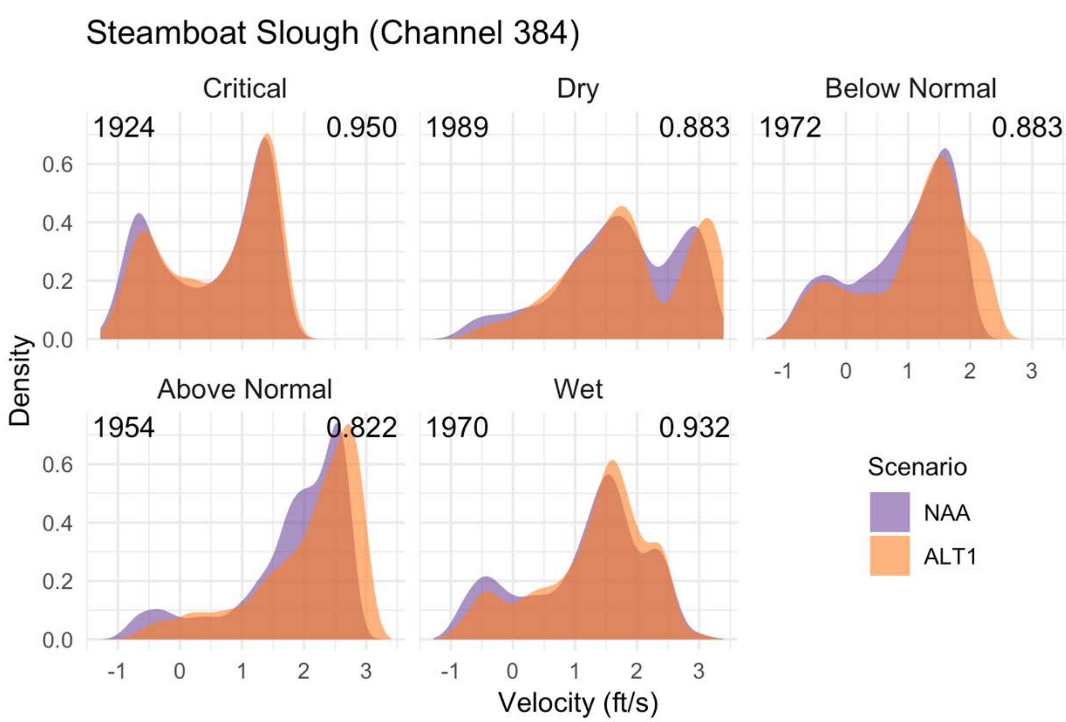


Figure O-10. Alternative 1 vs. No Action Alternative, March–May

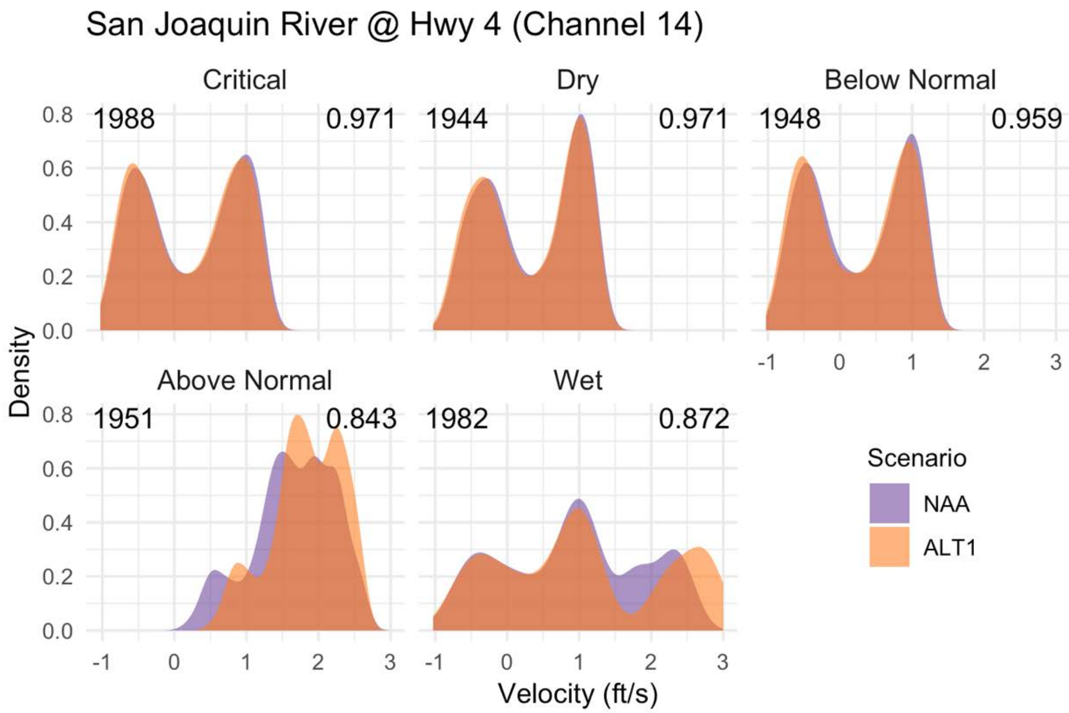
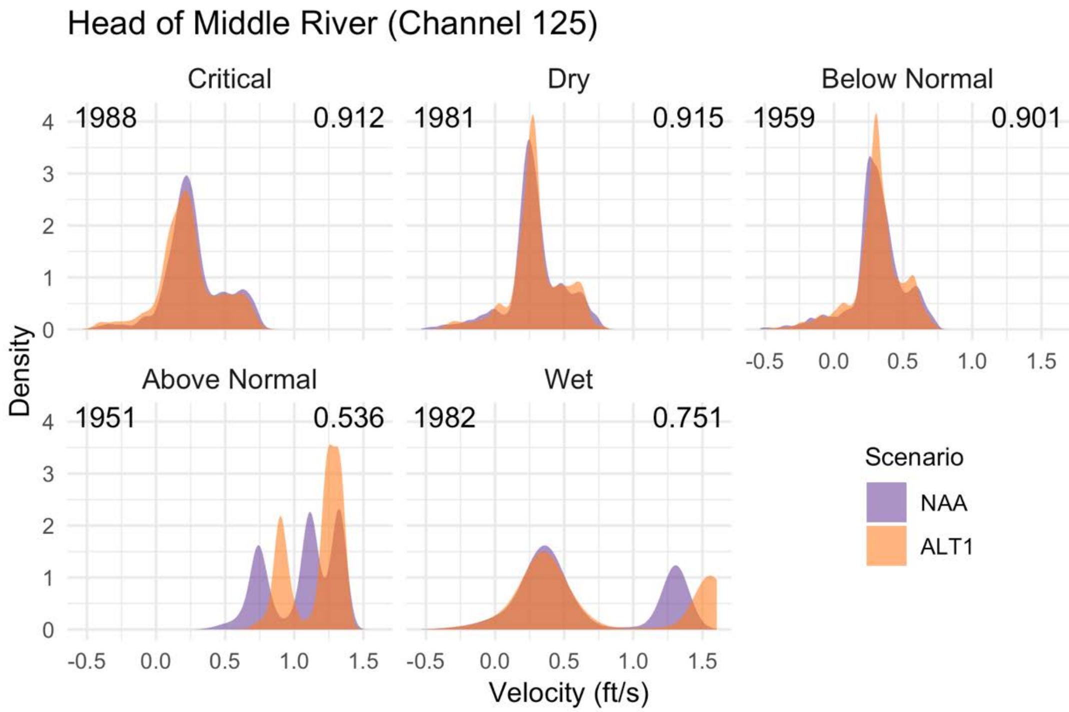


Figure O-11. Alternative 1 vs. No Action Alternative, December–February



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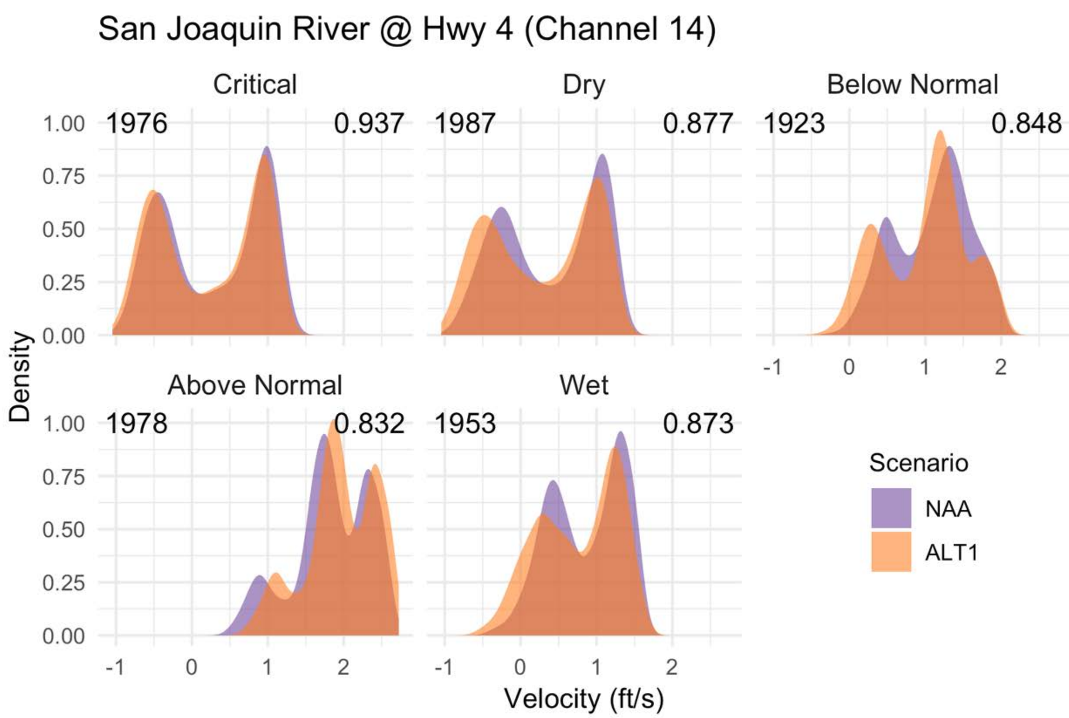


Figure O-13. Alternative 1 vs. No Action Alternative, March–May

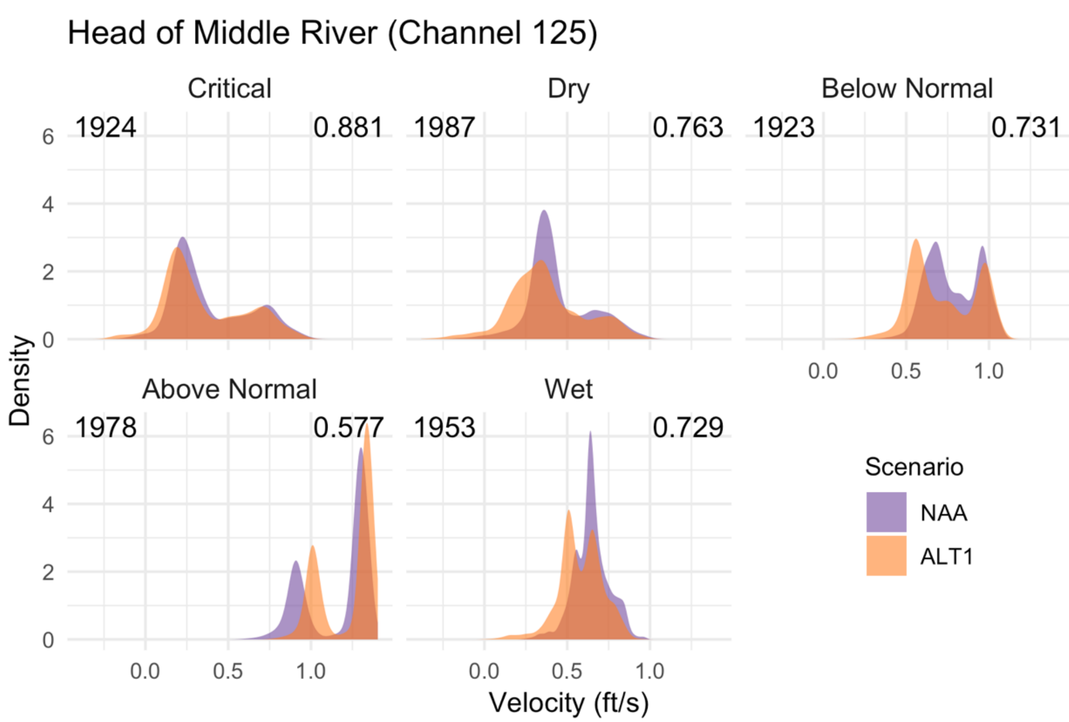


Figure O-14. Alternative 1 vs. No Action Alternative, March–May

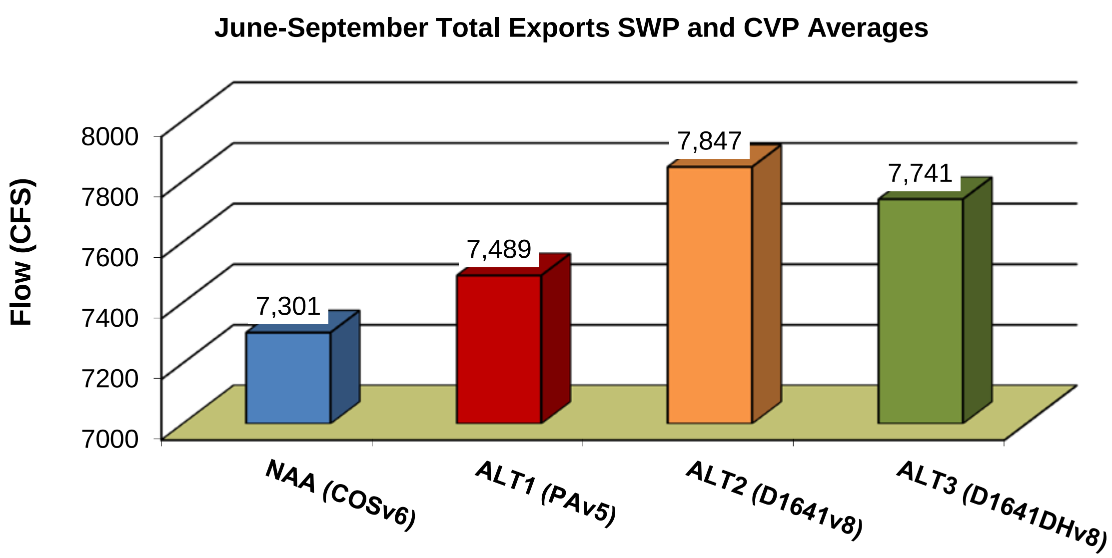


Figure O-15. Mean exports June–September

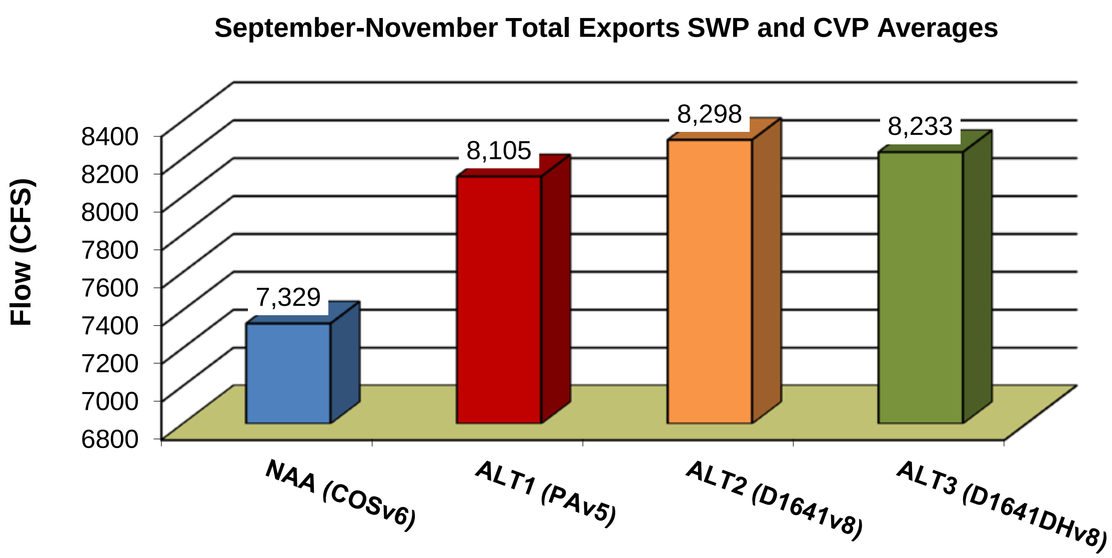


Figure O-16. Mean exports September–November

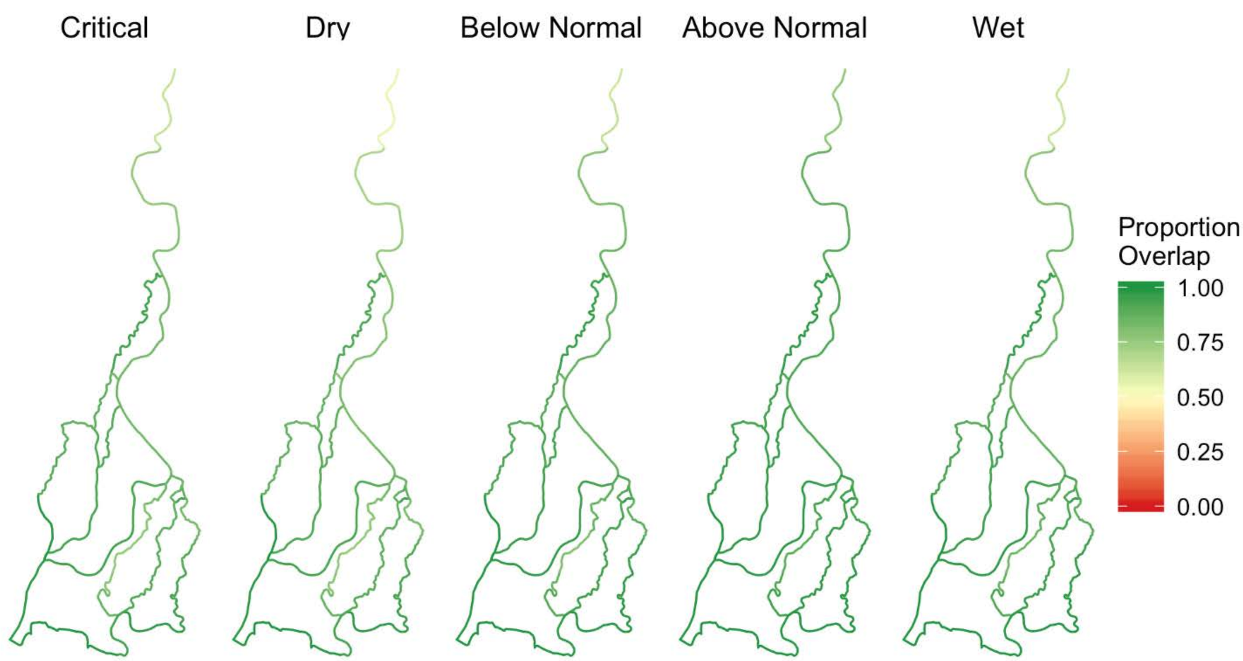
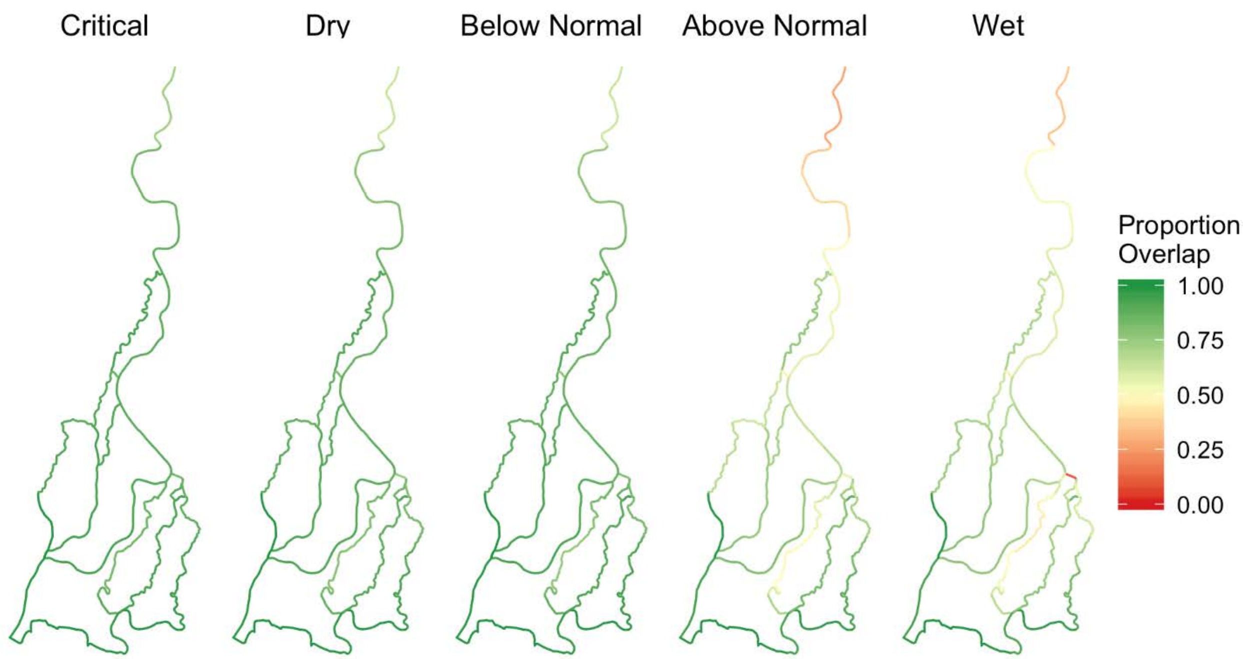


Figure O-17. Alternative 1 vs. No Action Alternative, June–August



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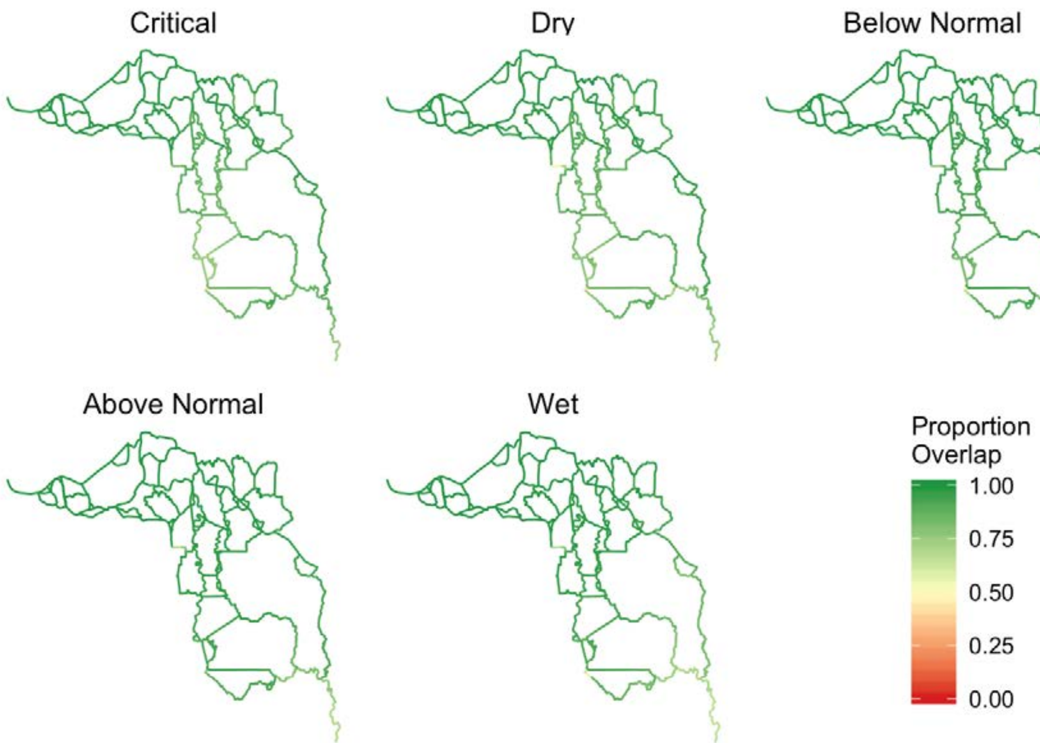
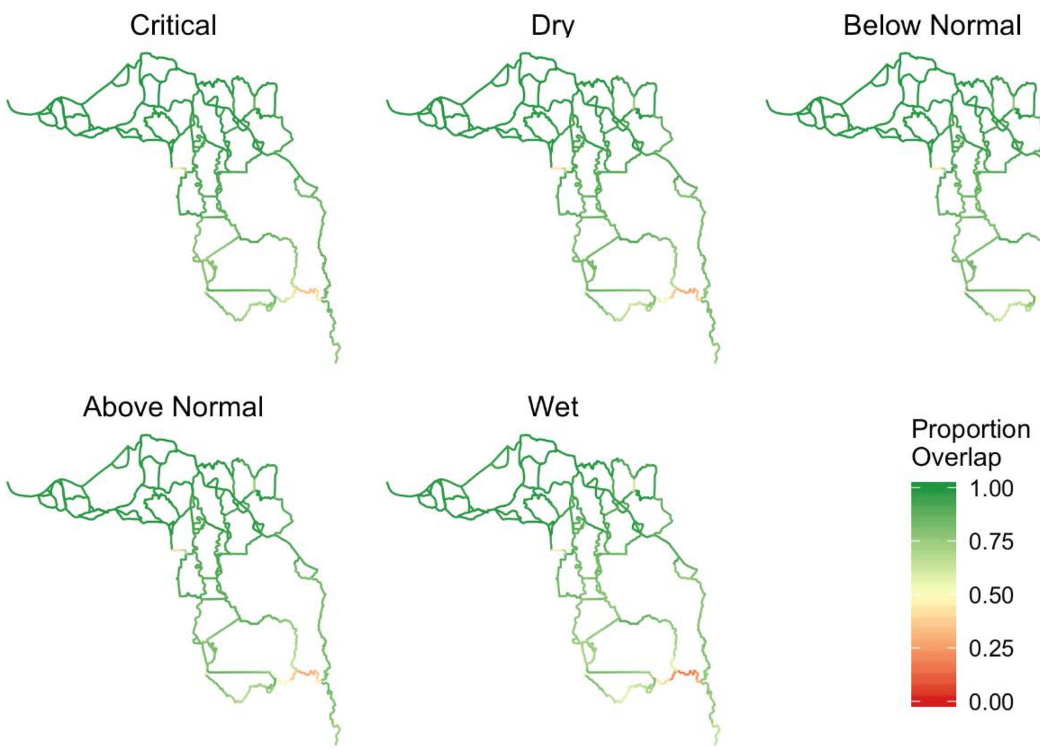


Figure O-19. Alternative 1 vs. No Action Alternative, June–August



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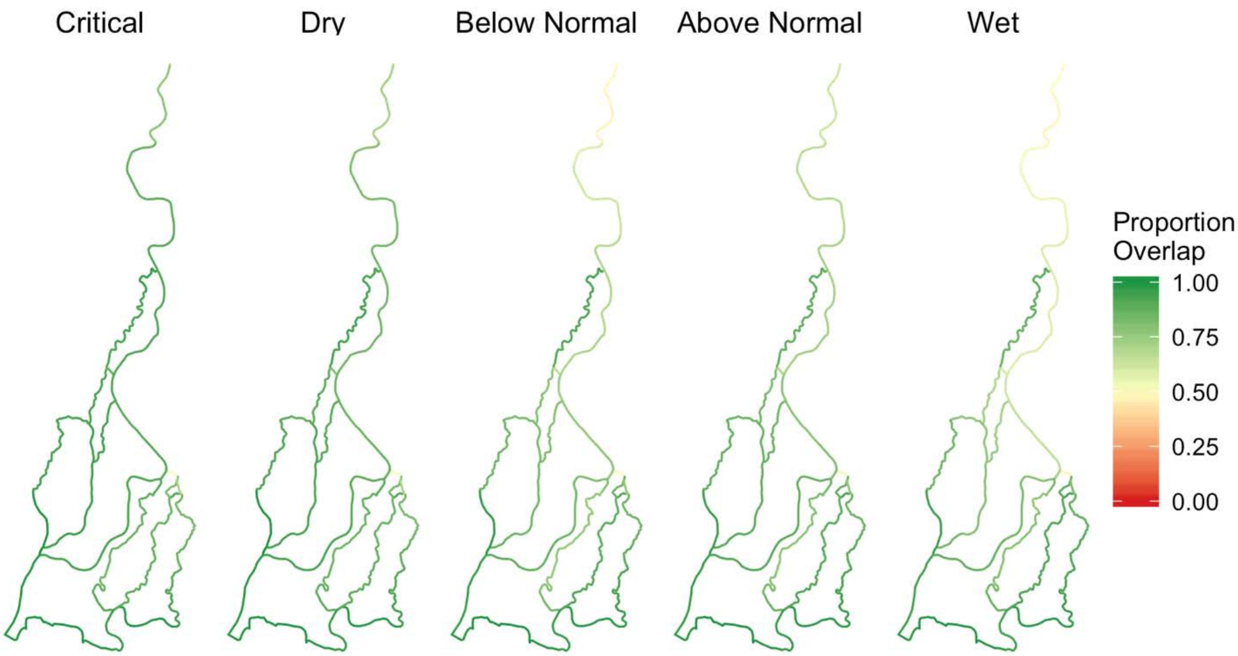
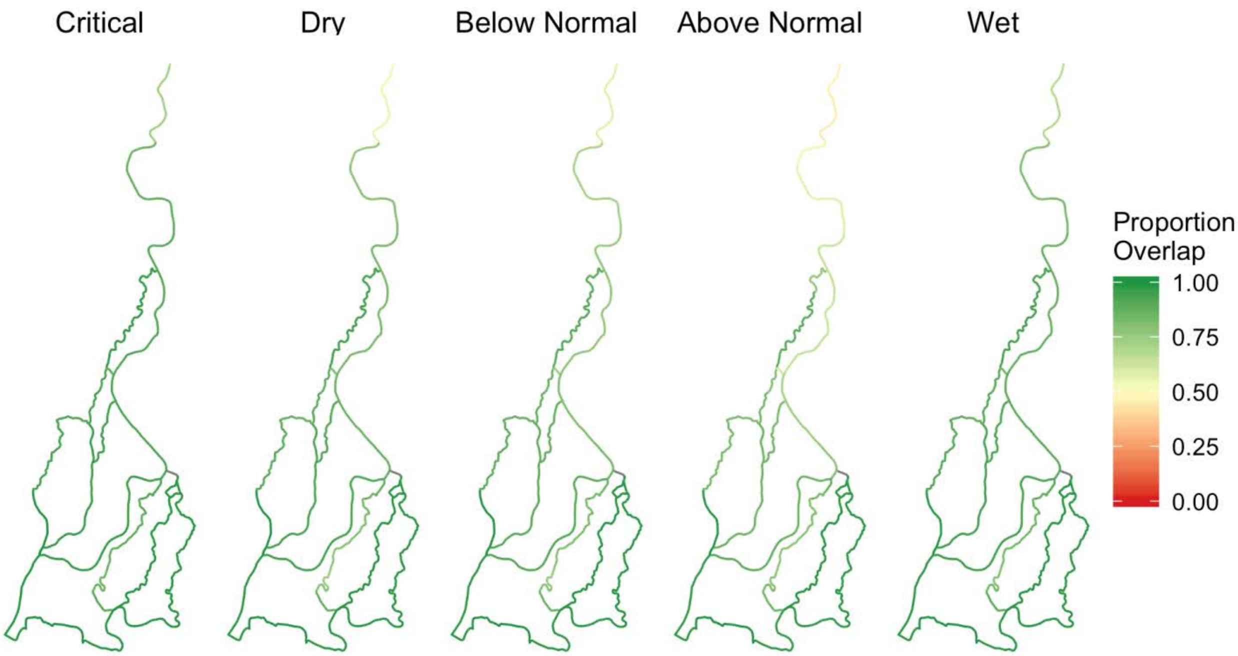


Figure O-21. No Action Alternative vs. Alternative 2, February–December



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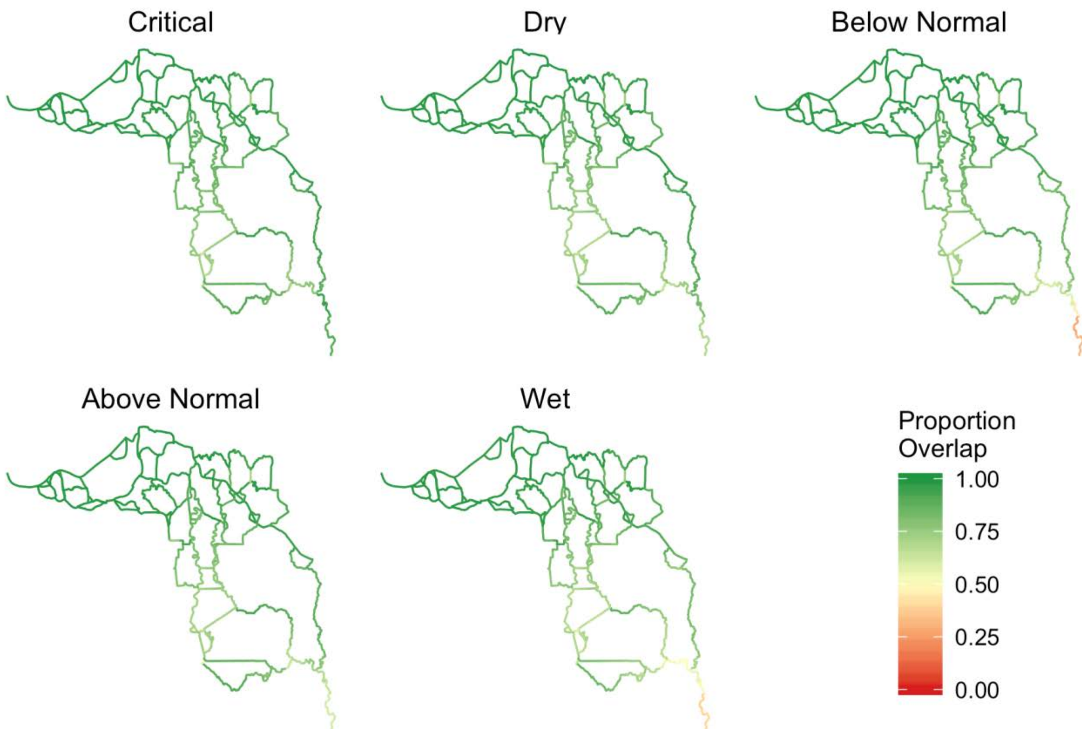

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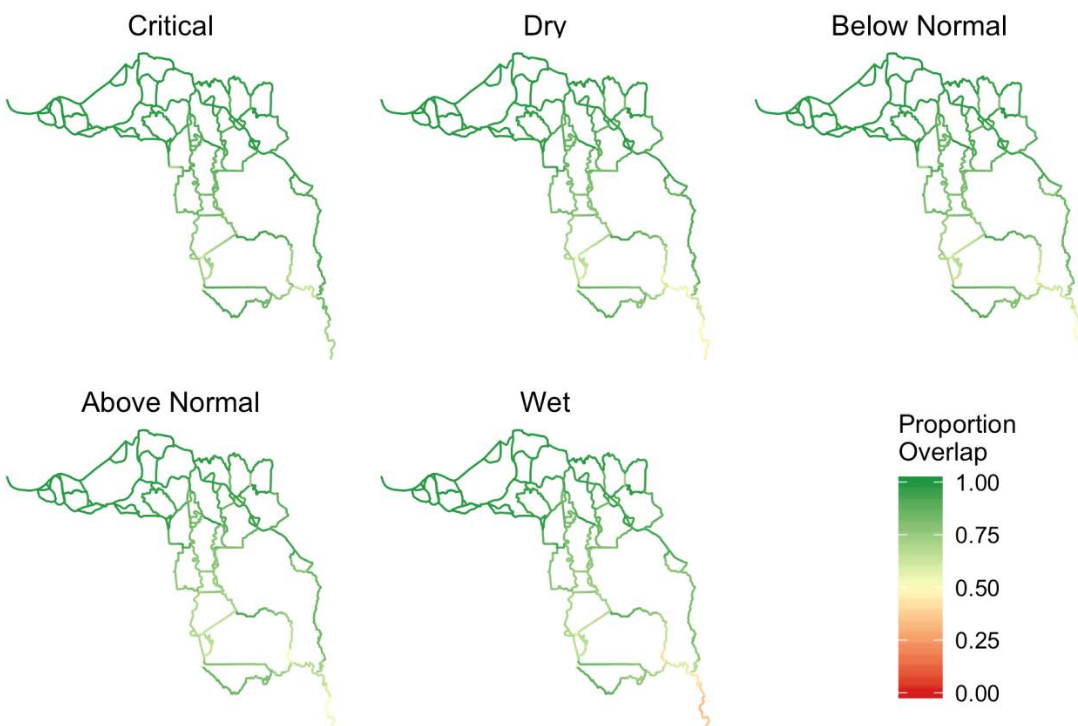

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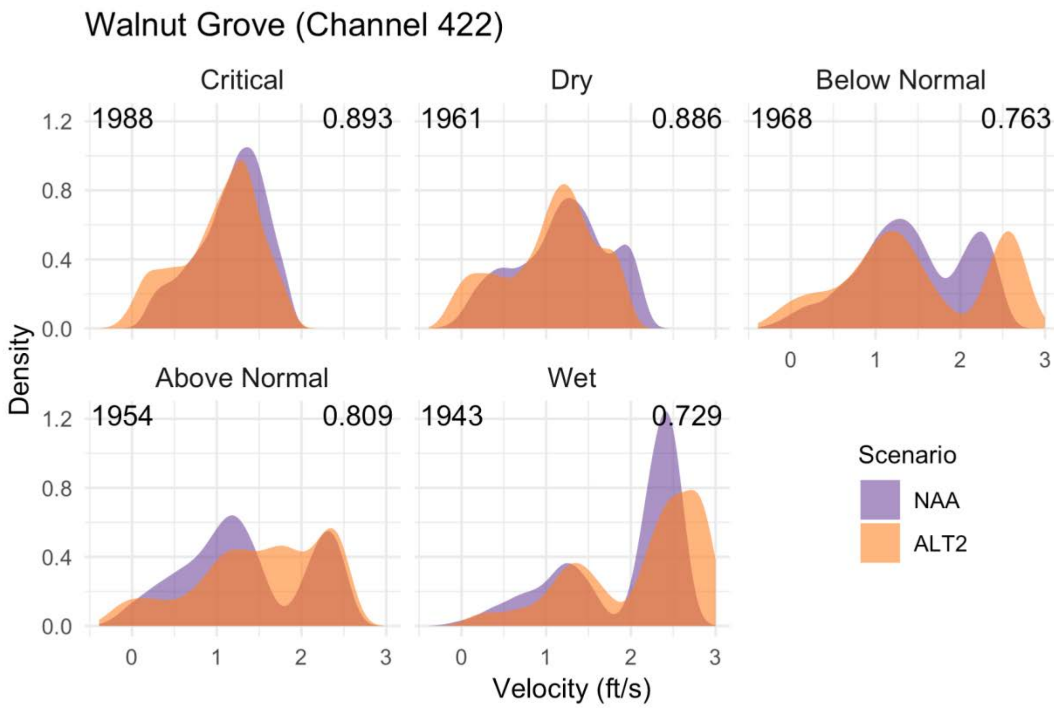

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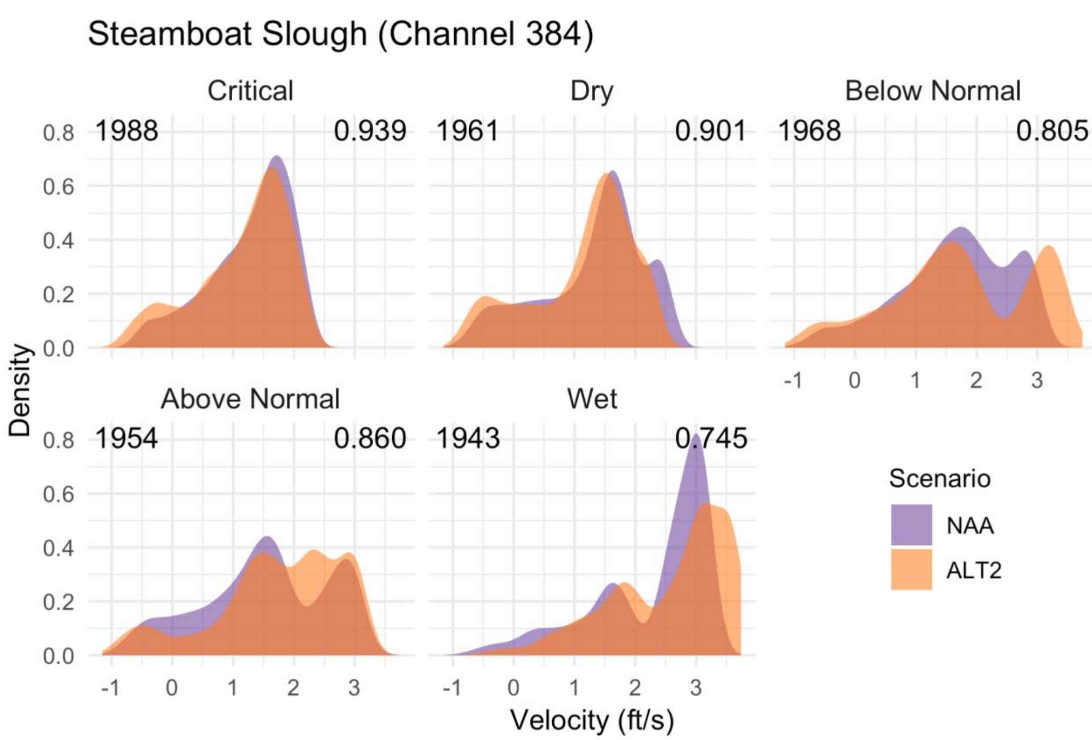
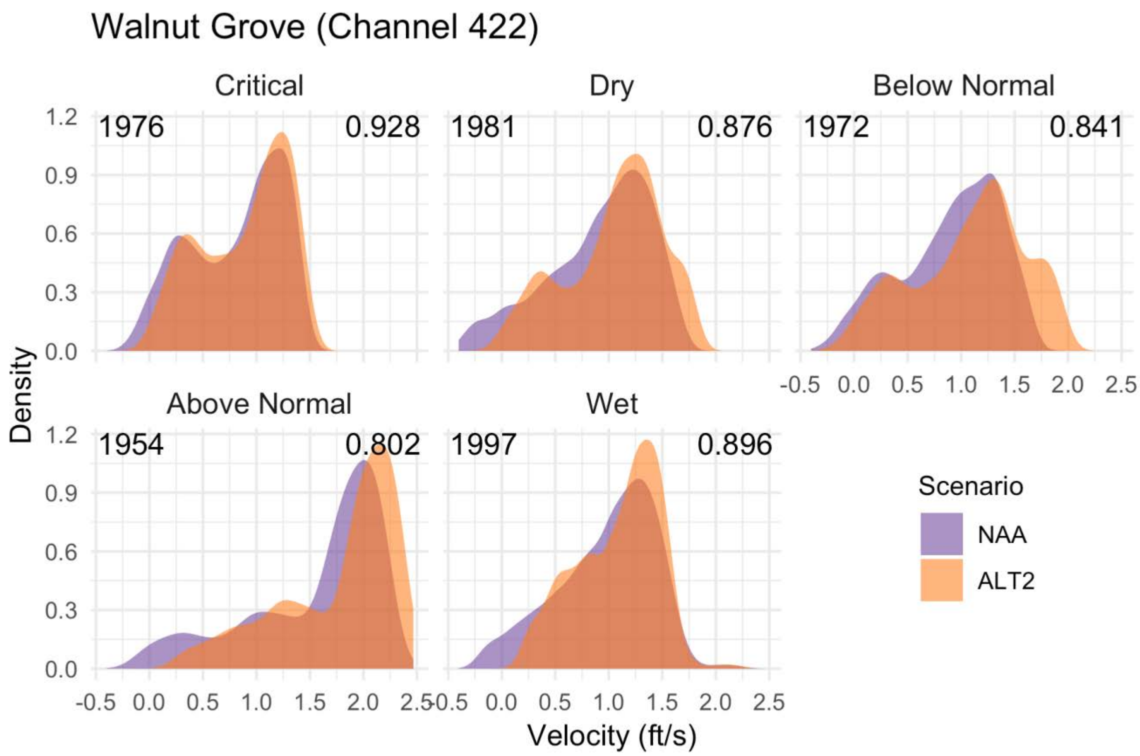


Figure O-26. No Action Alternative vs. Alternative 2, December–February



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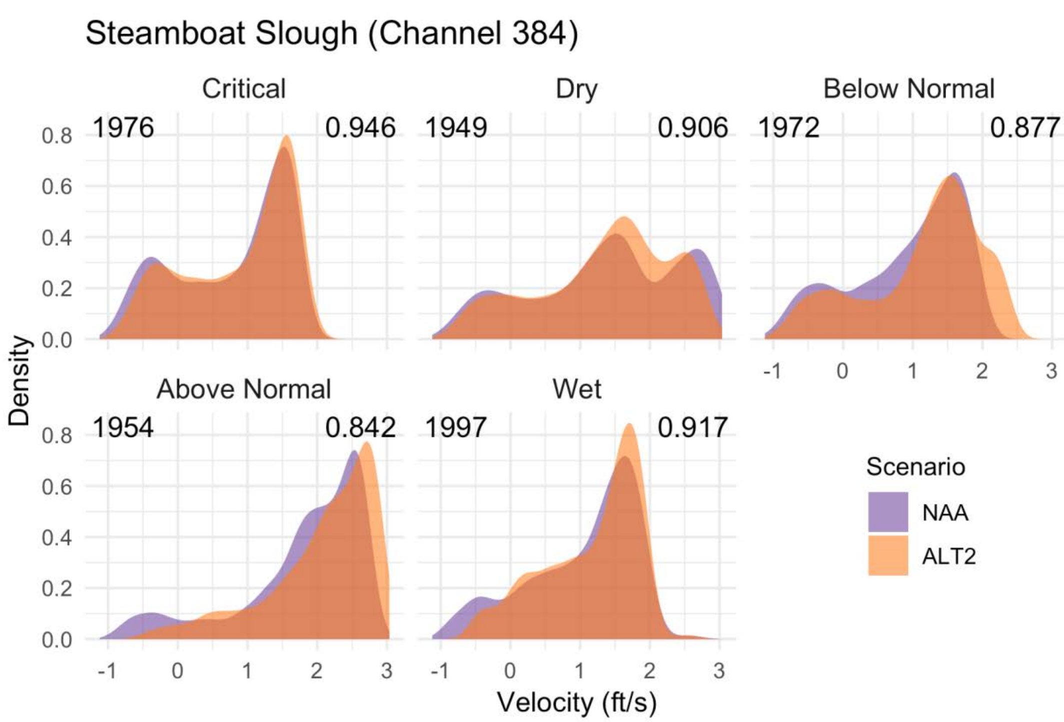

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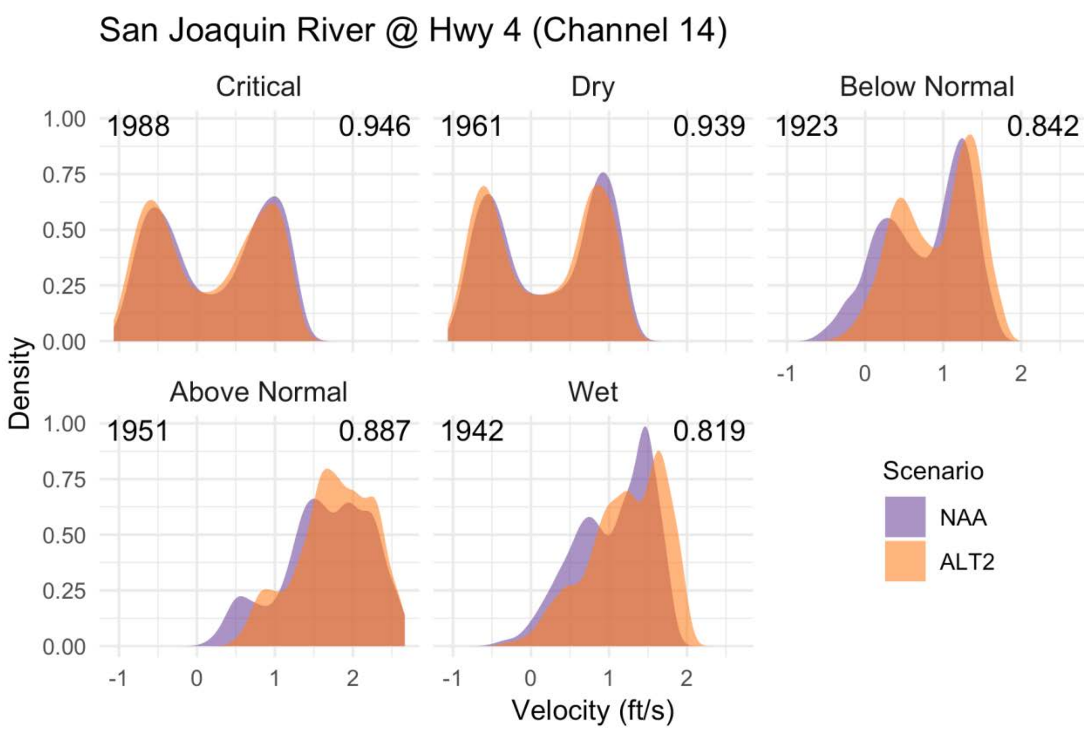
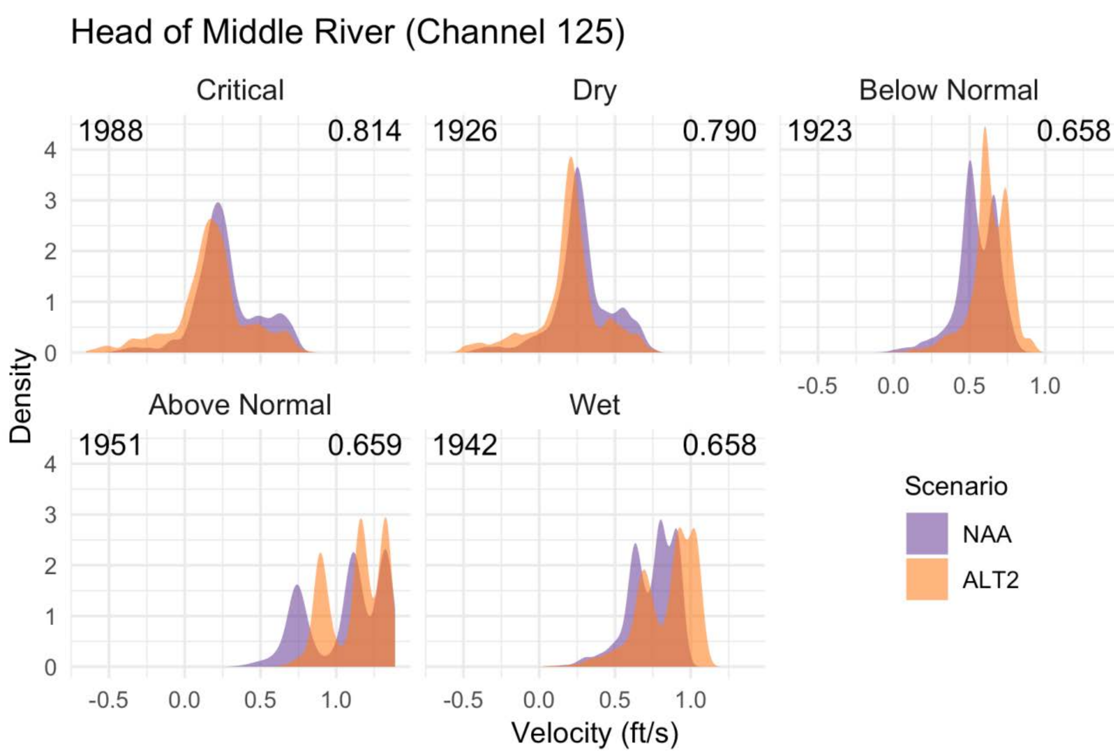


Figure O-29. No Action Alternative vs. Alternative 2, December–February



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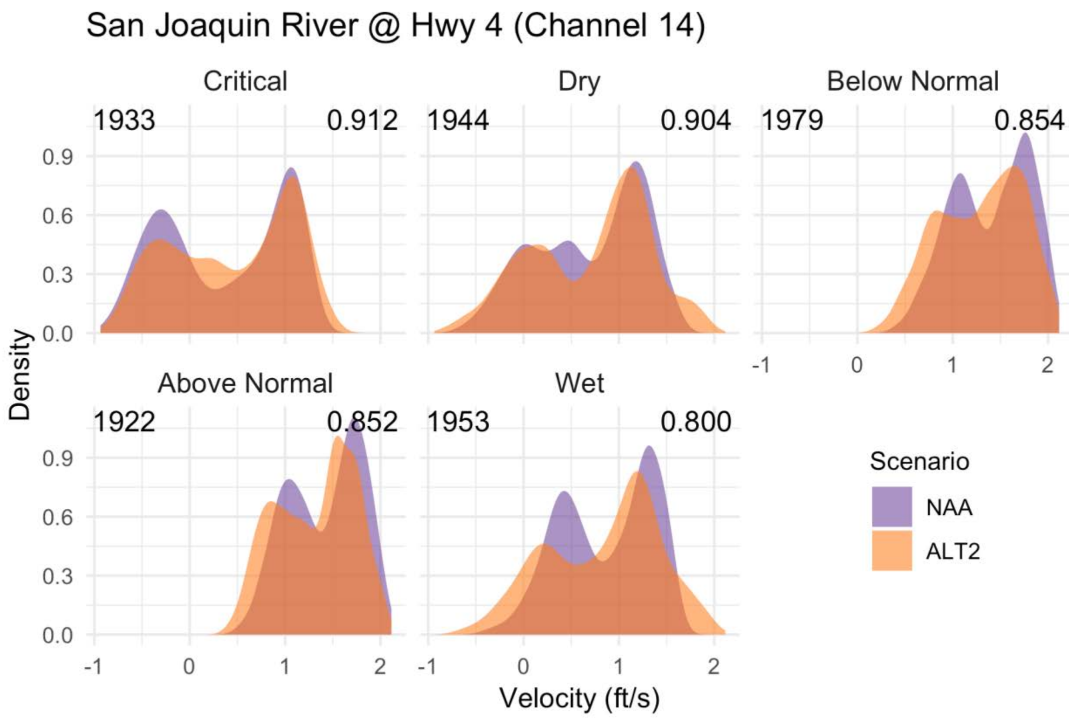

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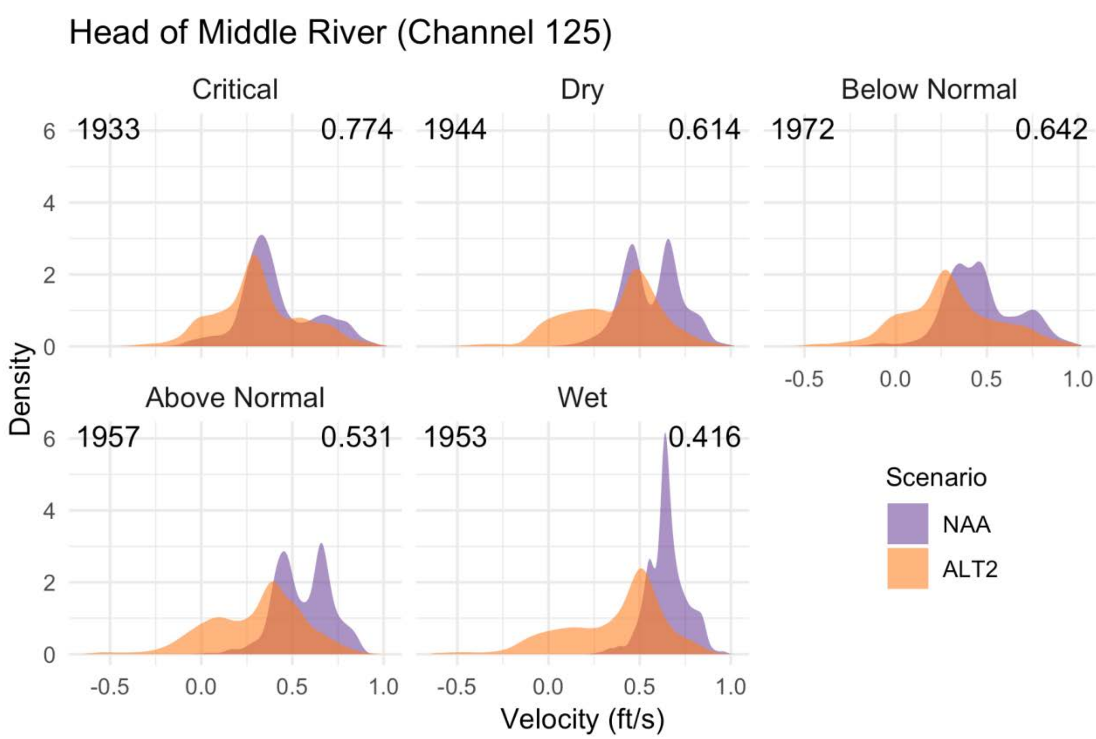

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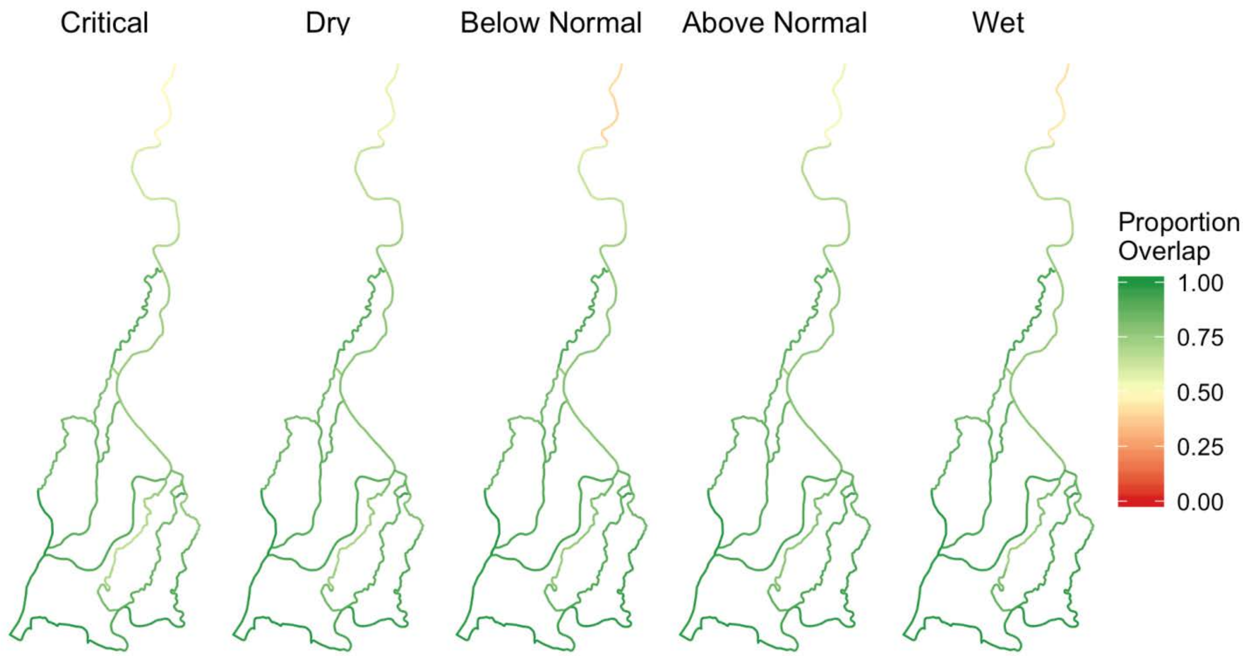

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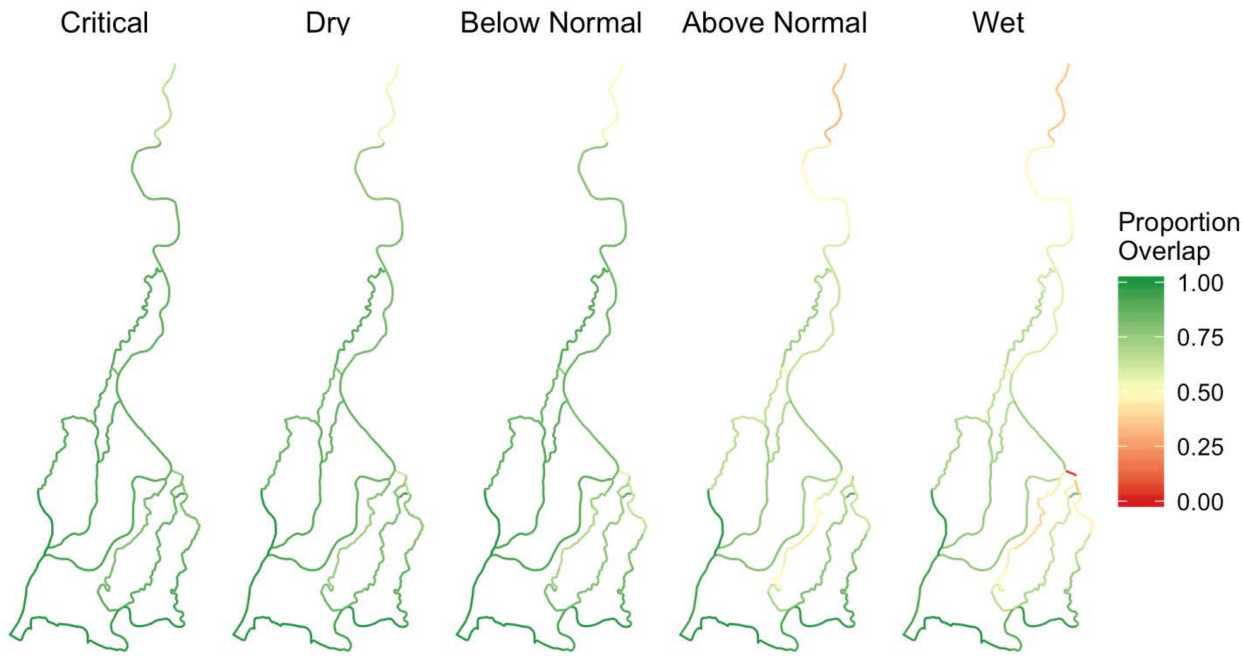

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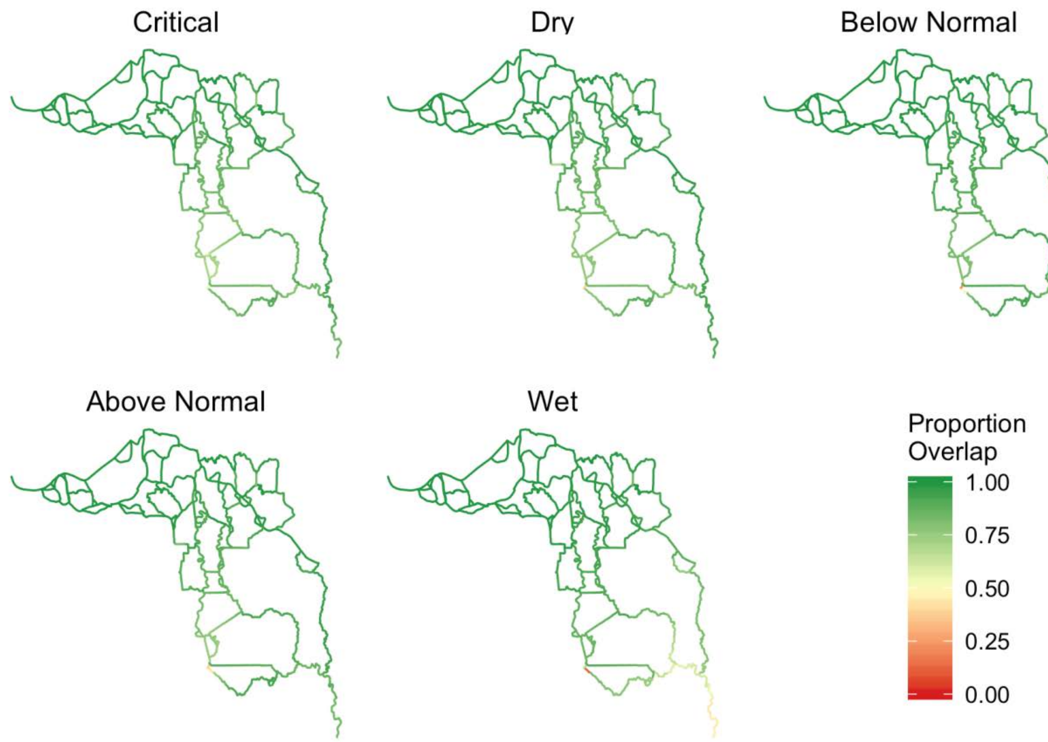

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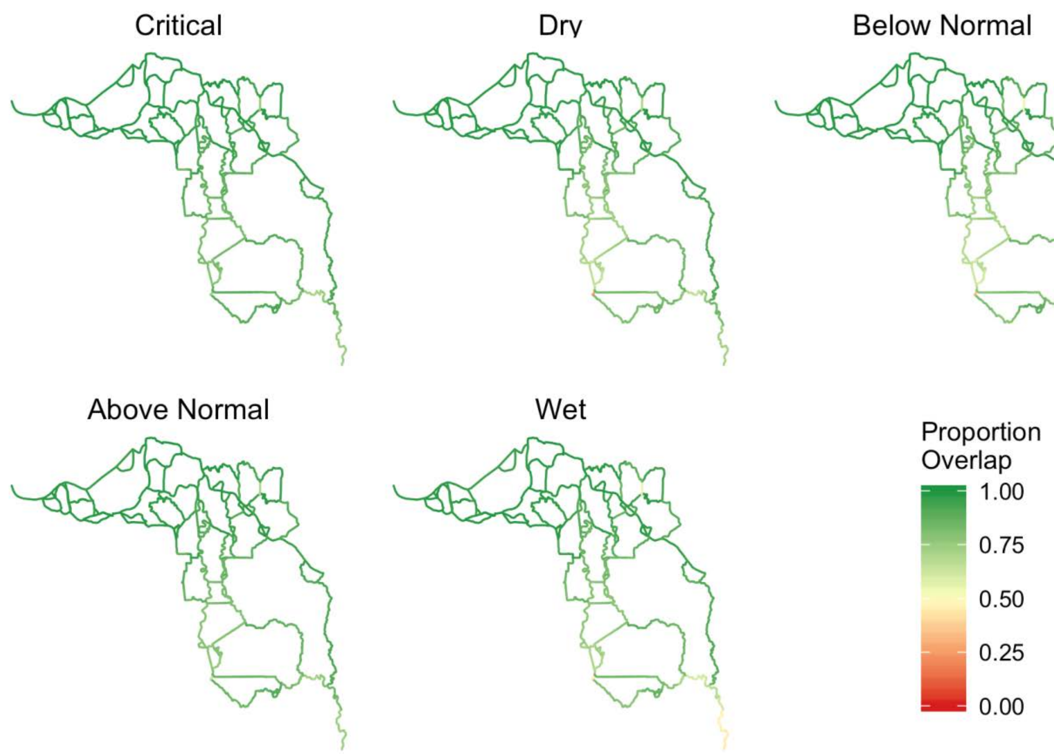

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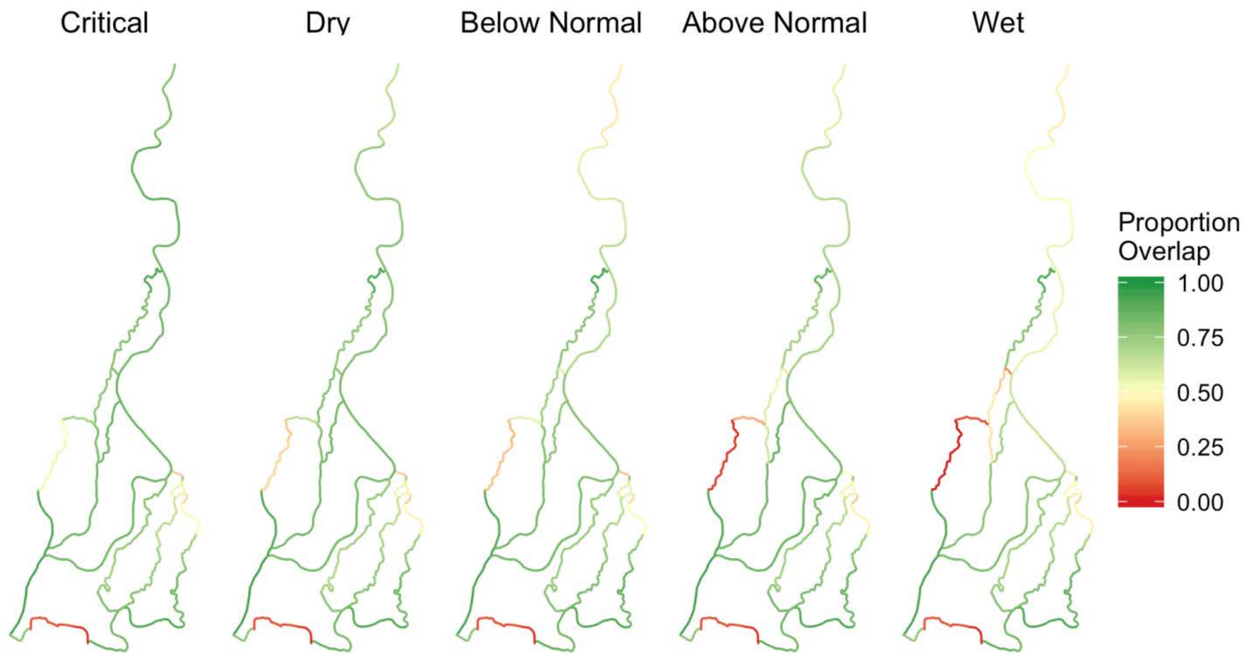

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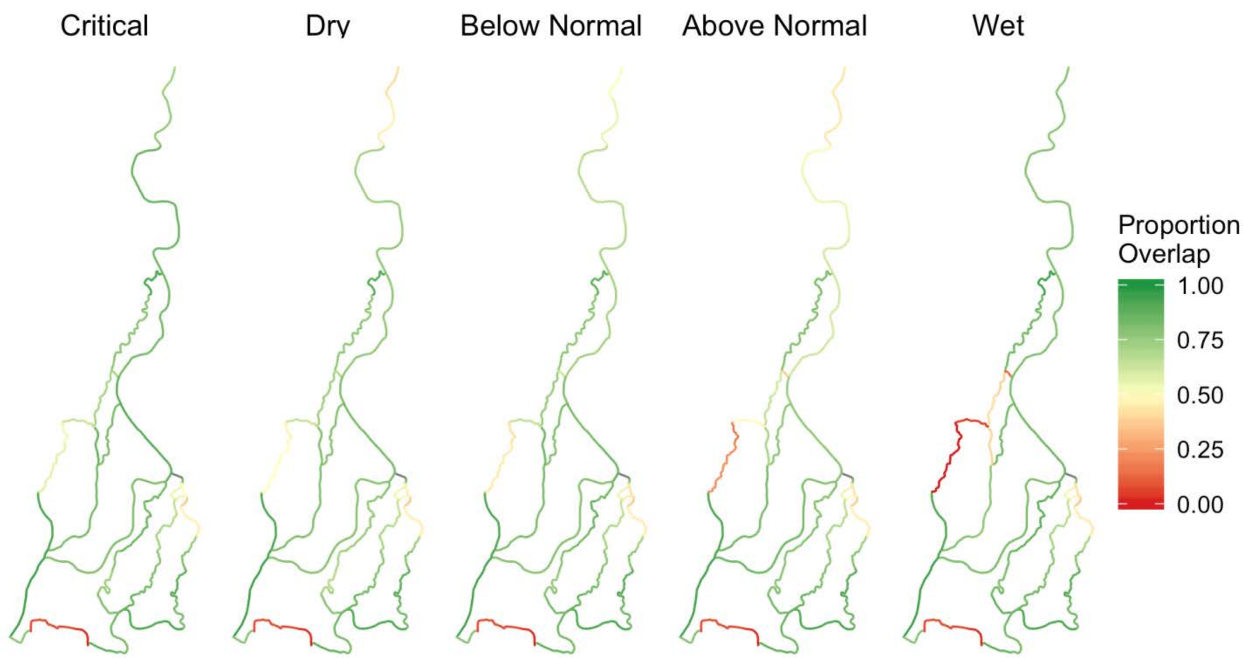

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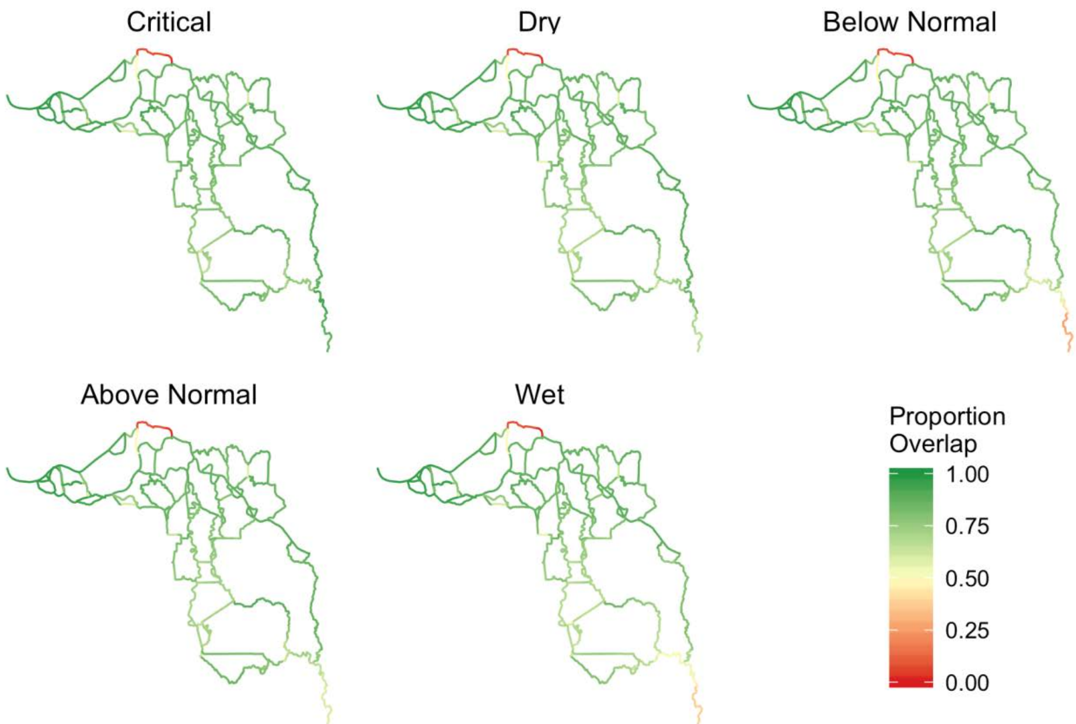

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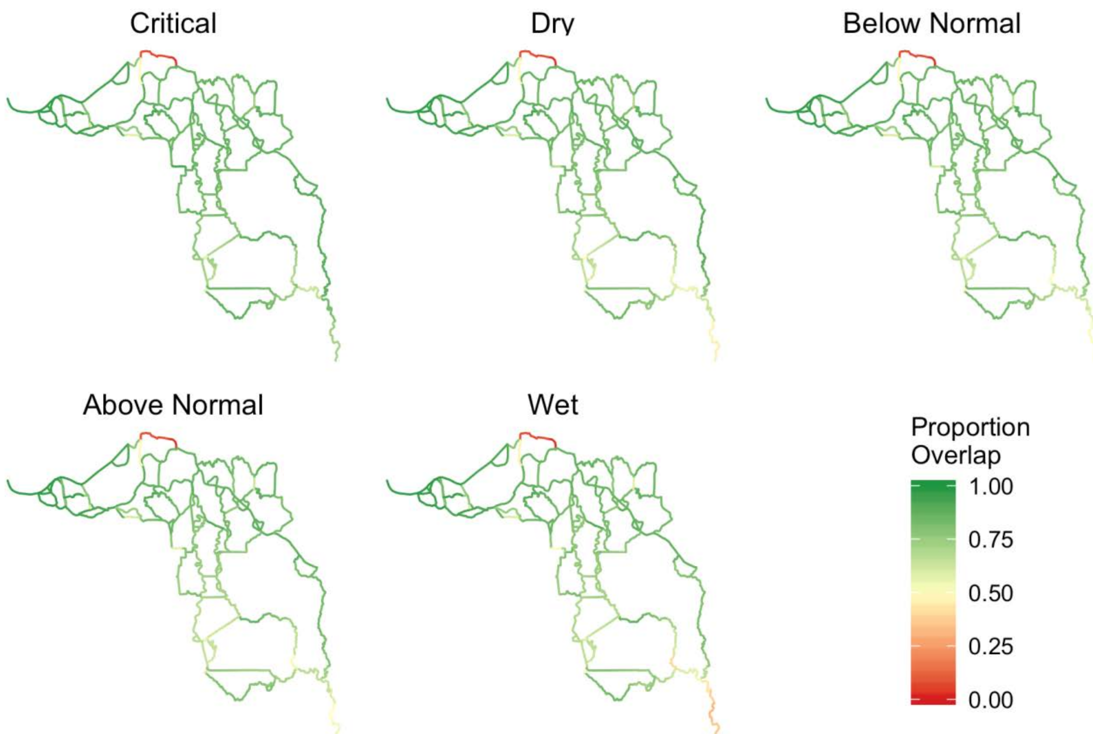

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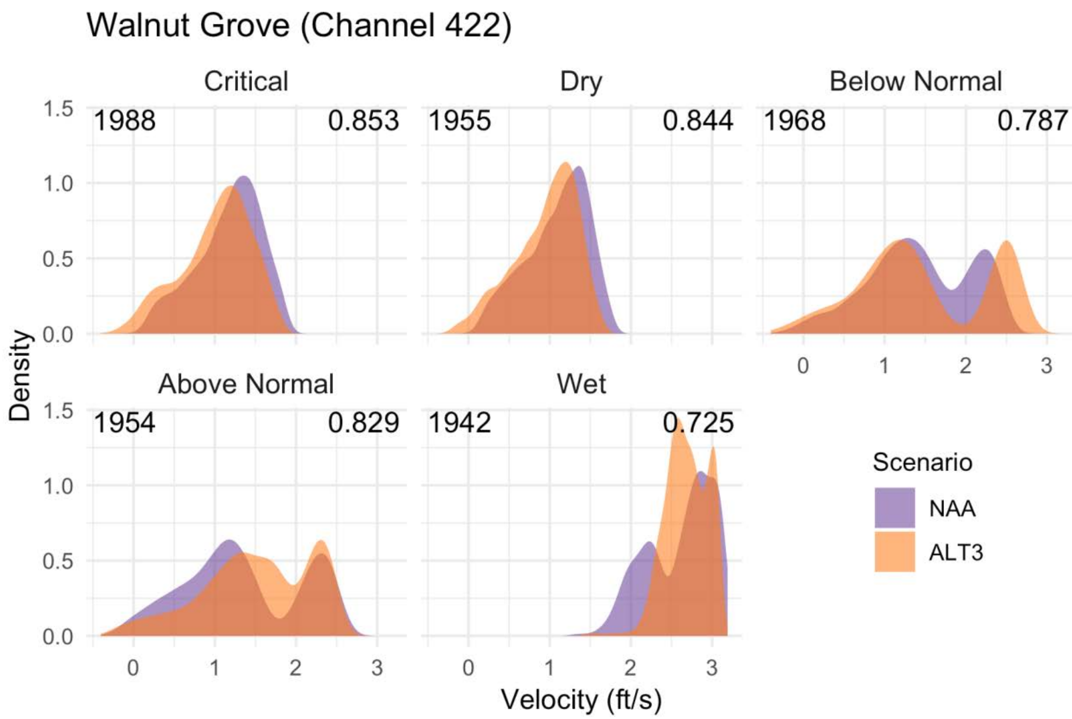

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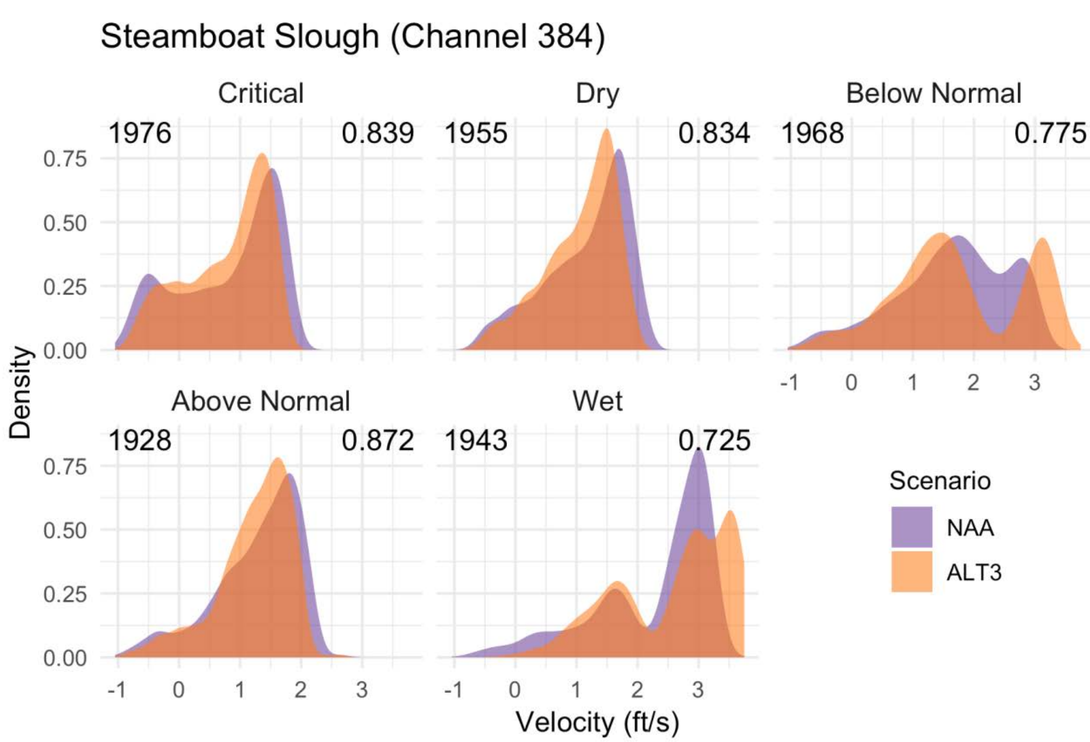

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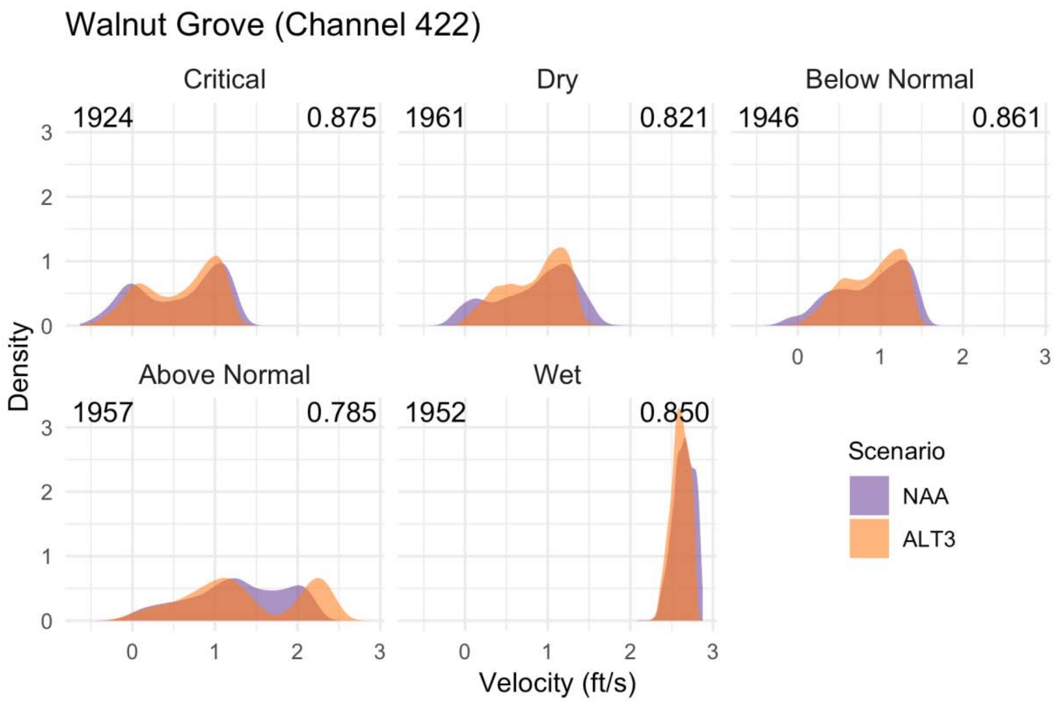

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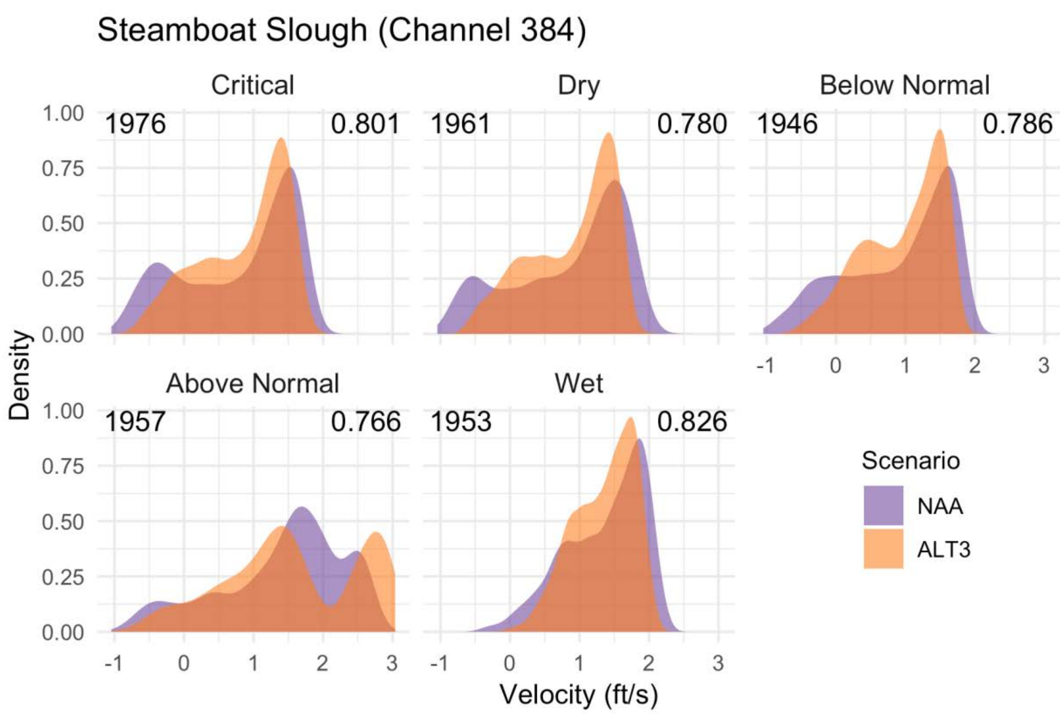

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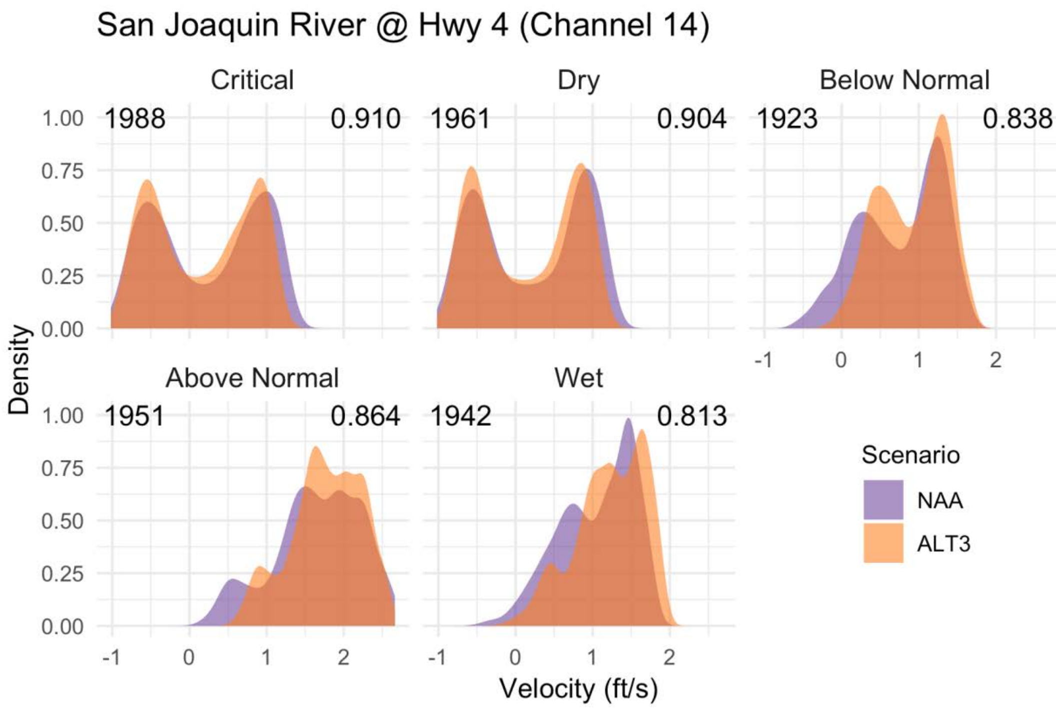

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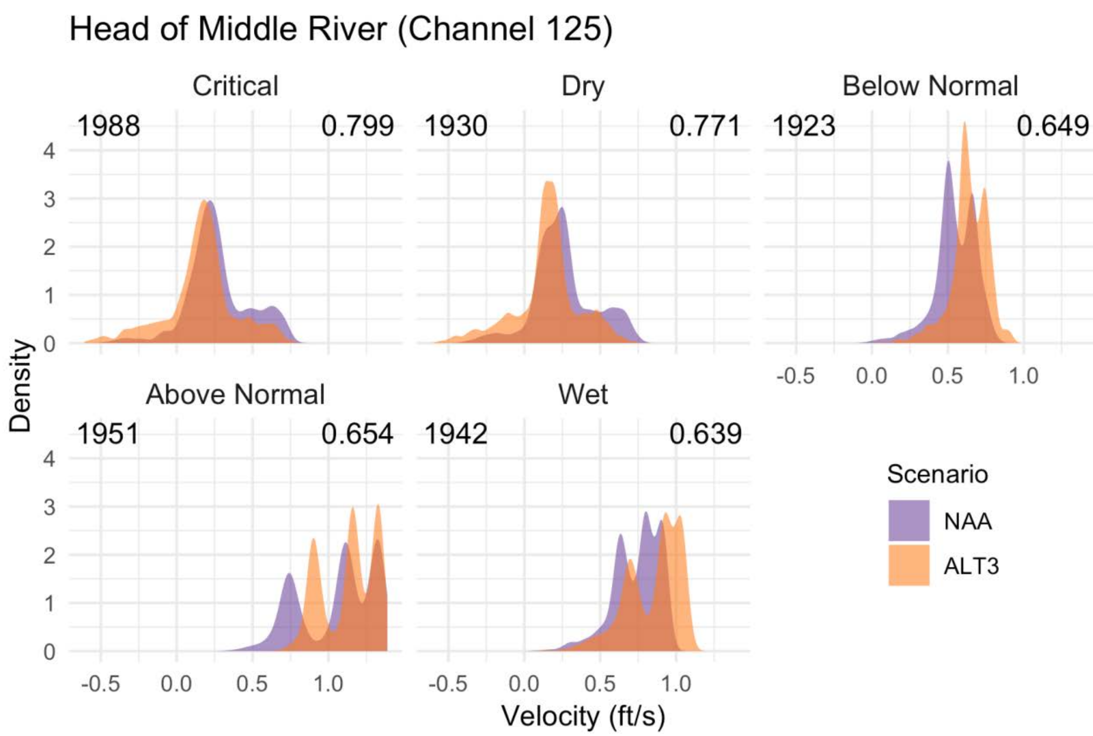

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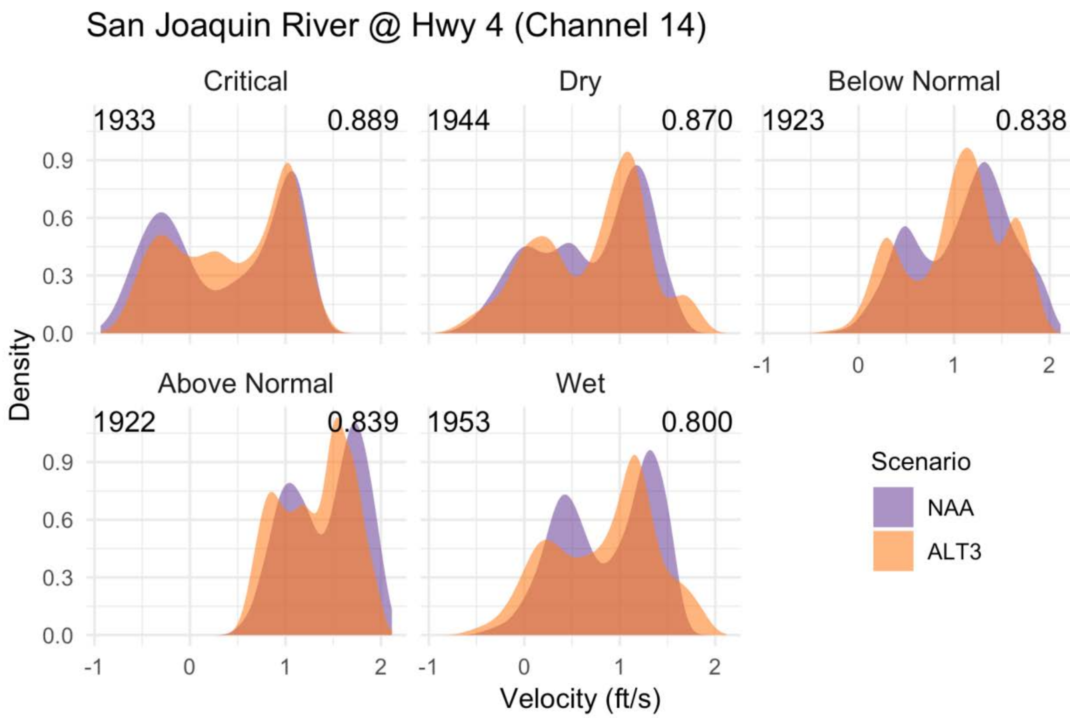

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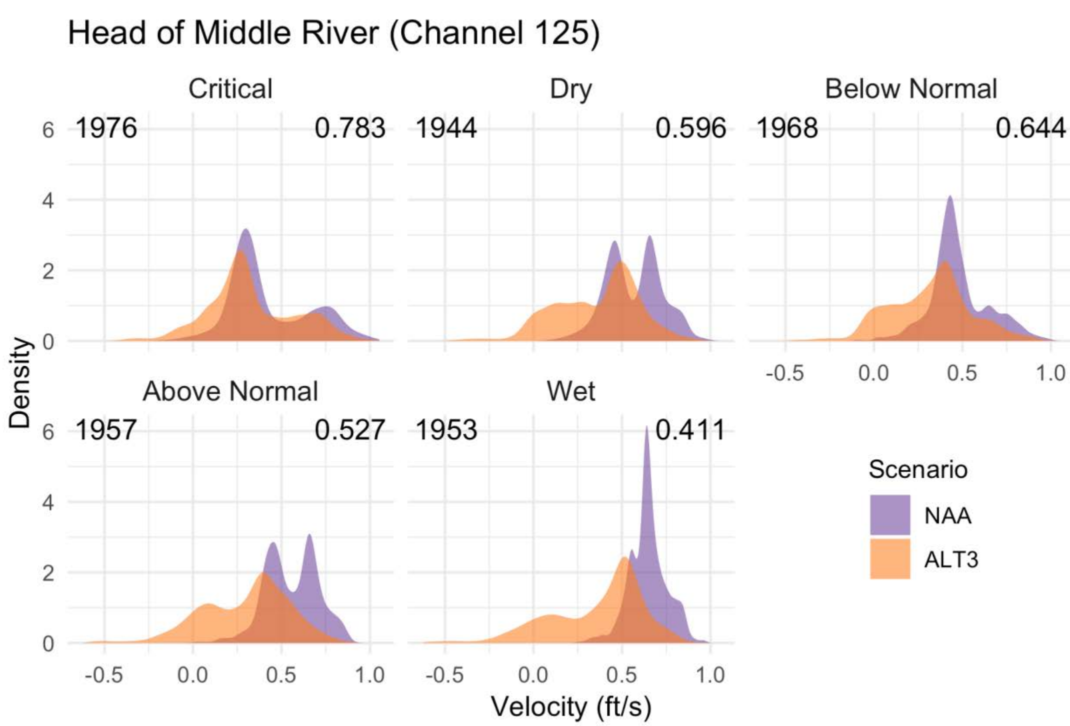

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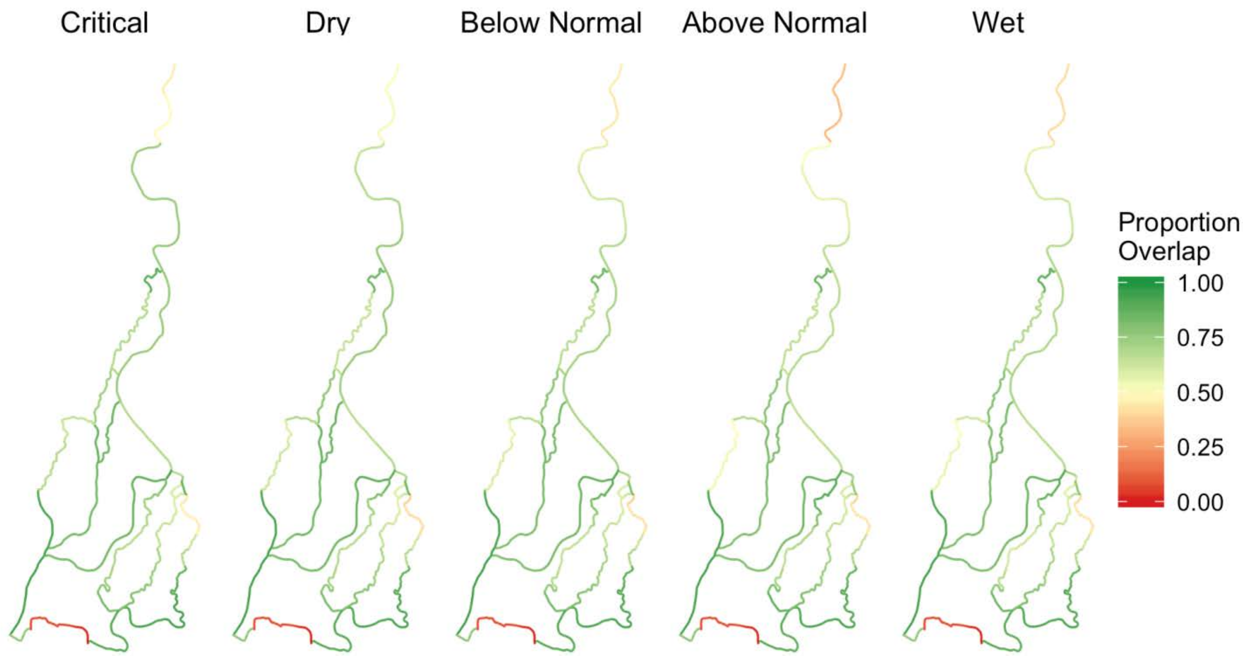
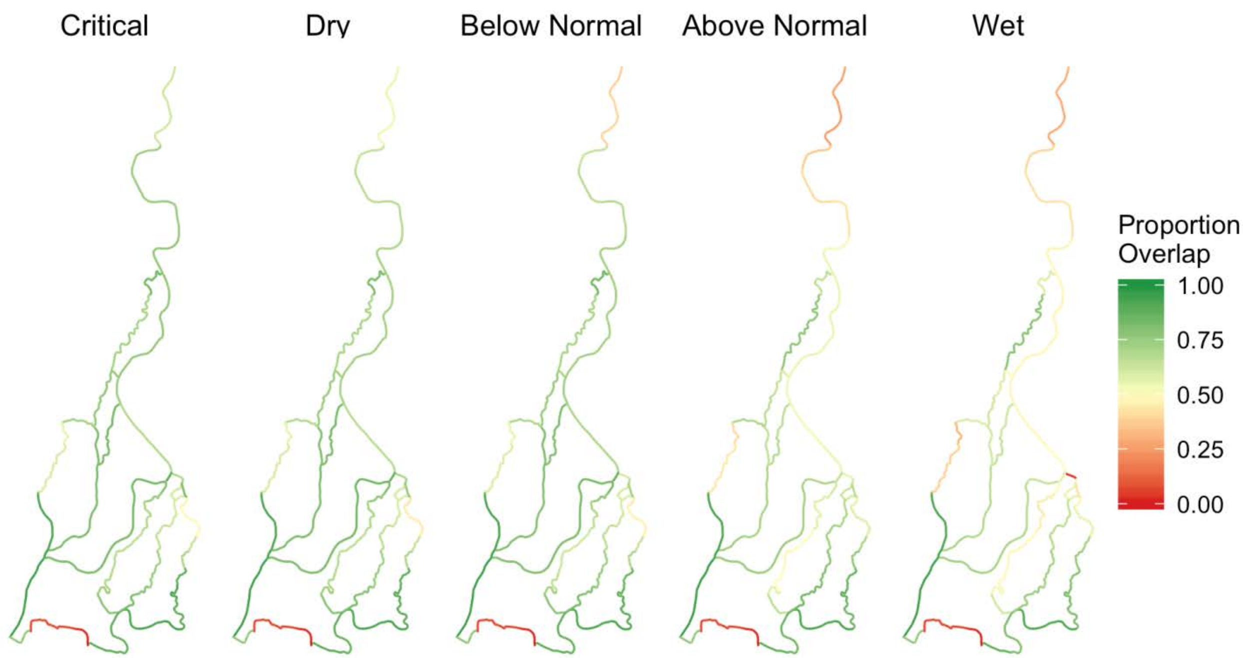


Figure O-49. No Action Alternative vs. Alternative 3, June–August



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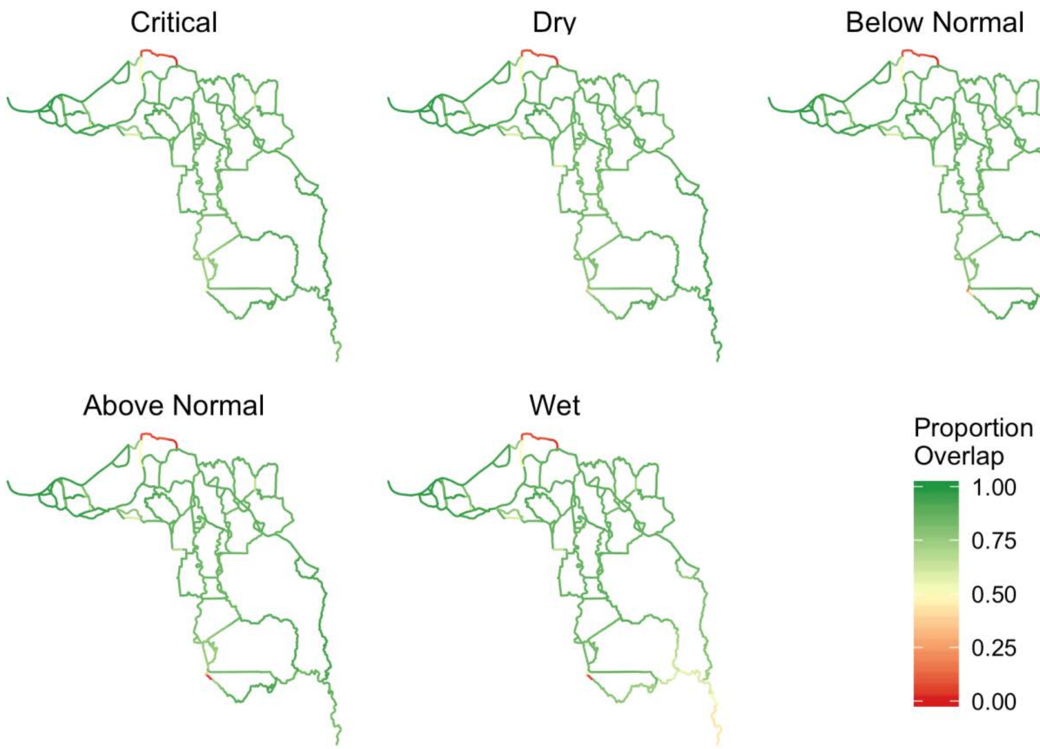

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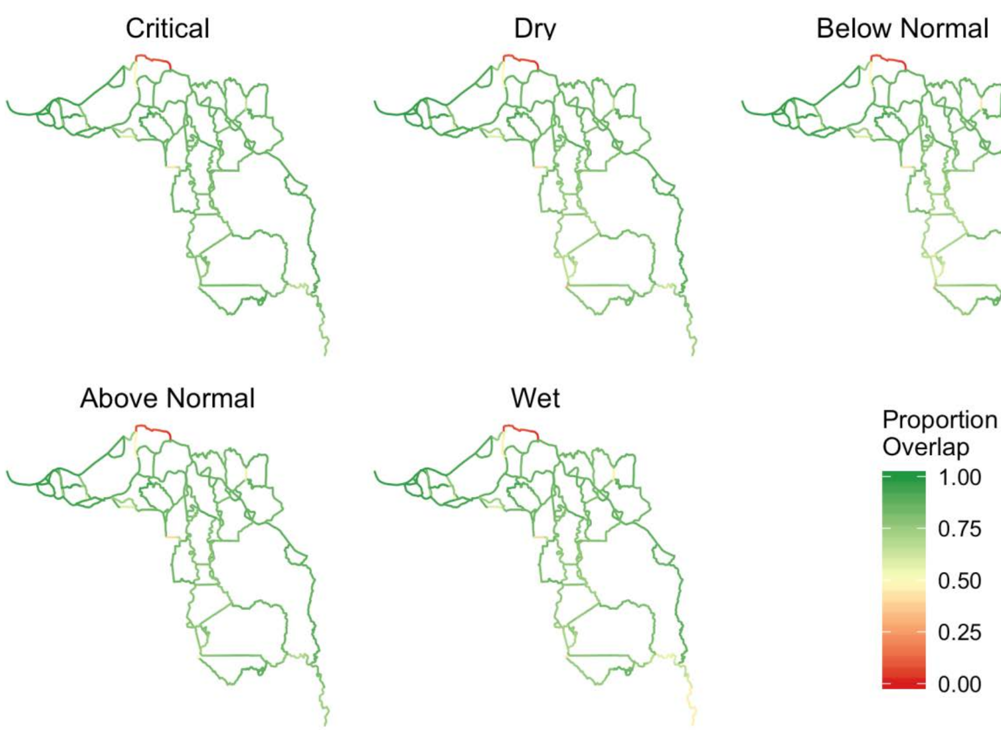

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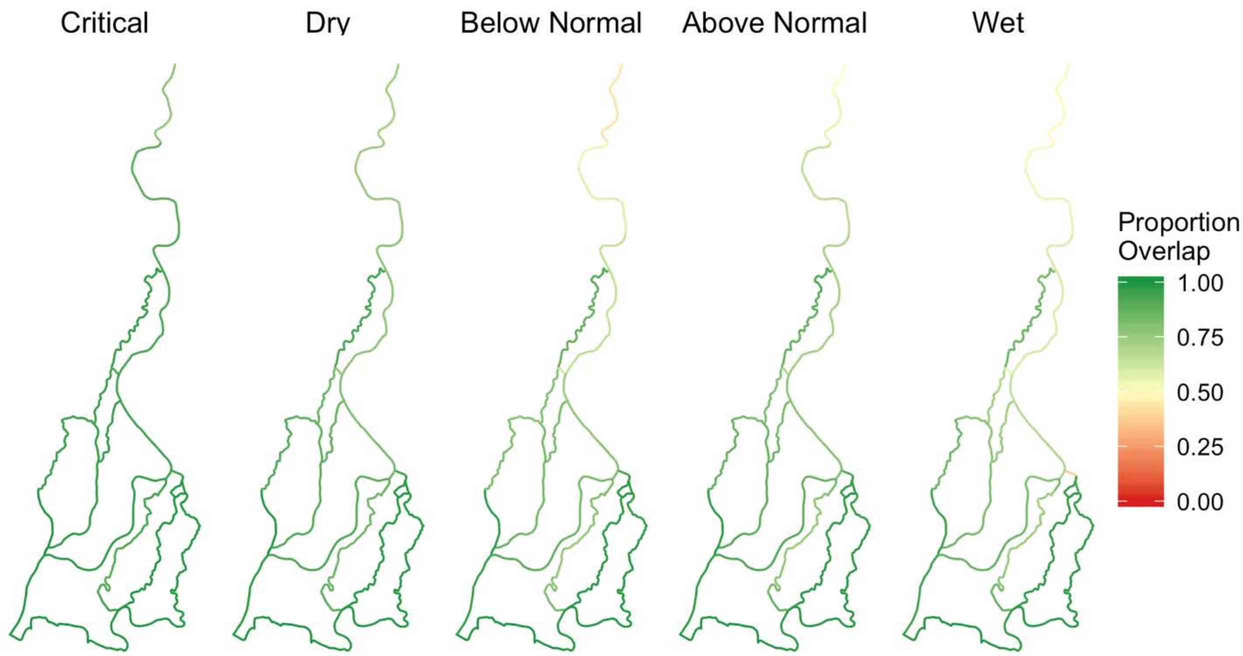

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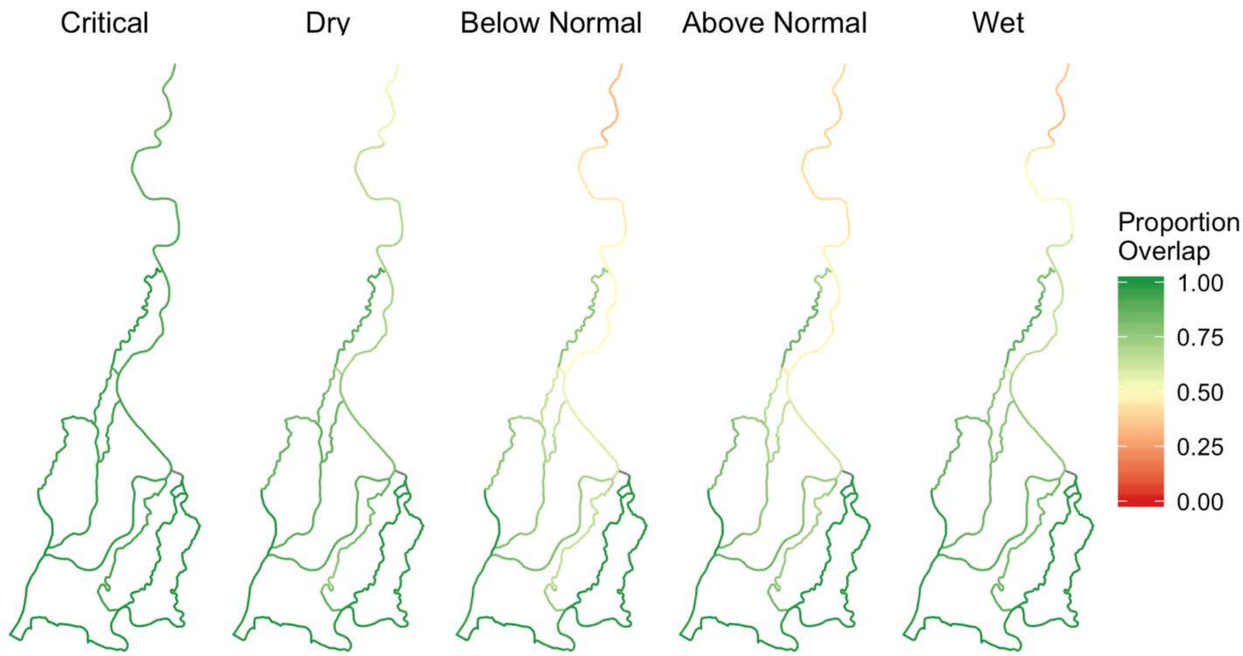

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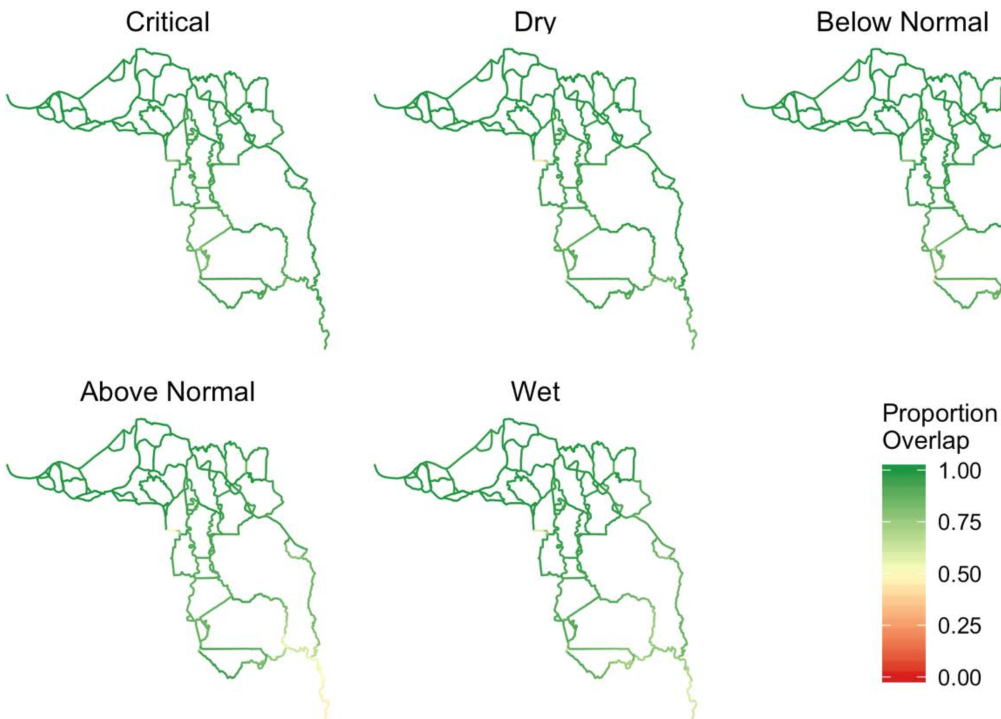

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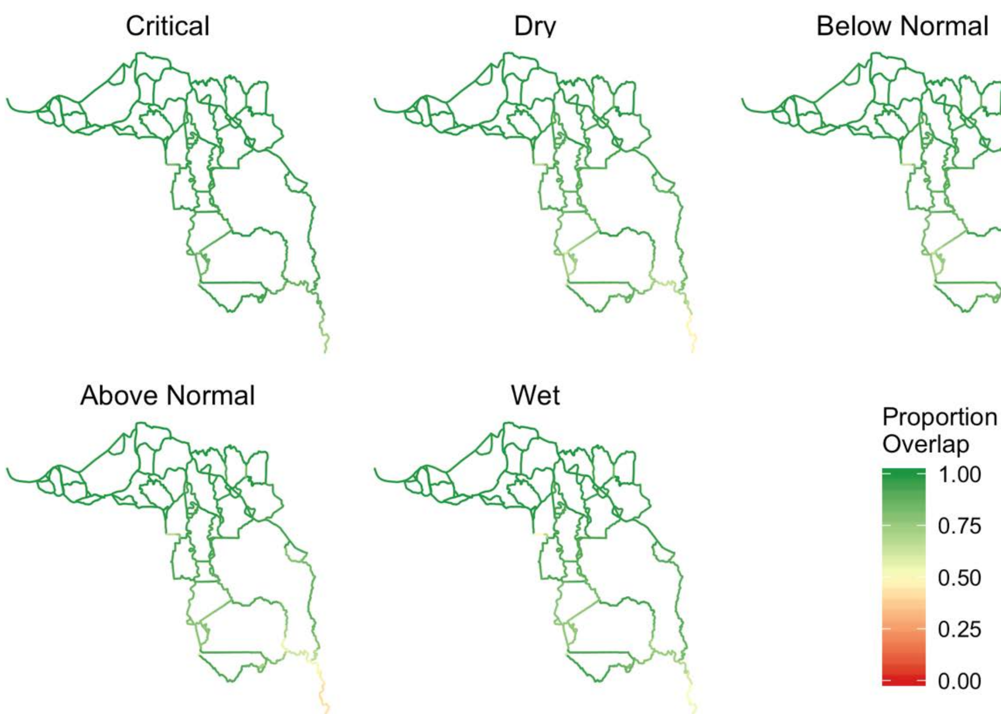

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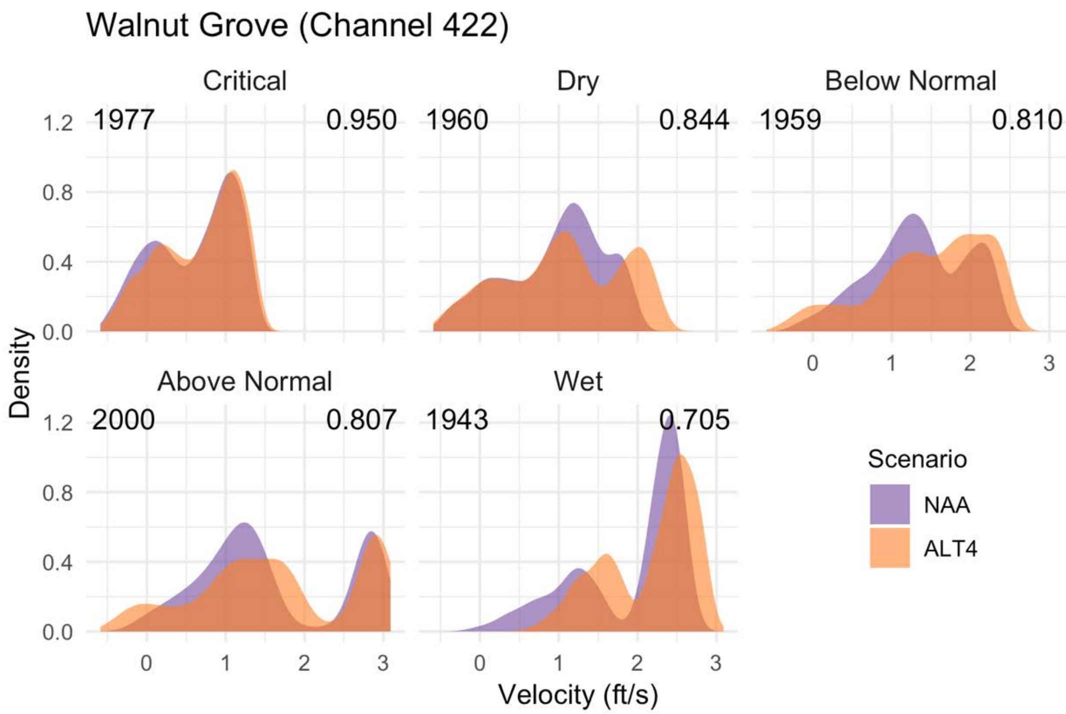

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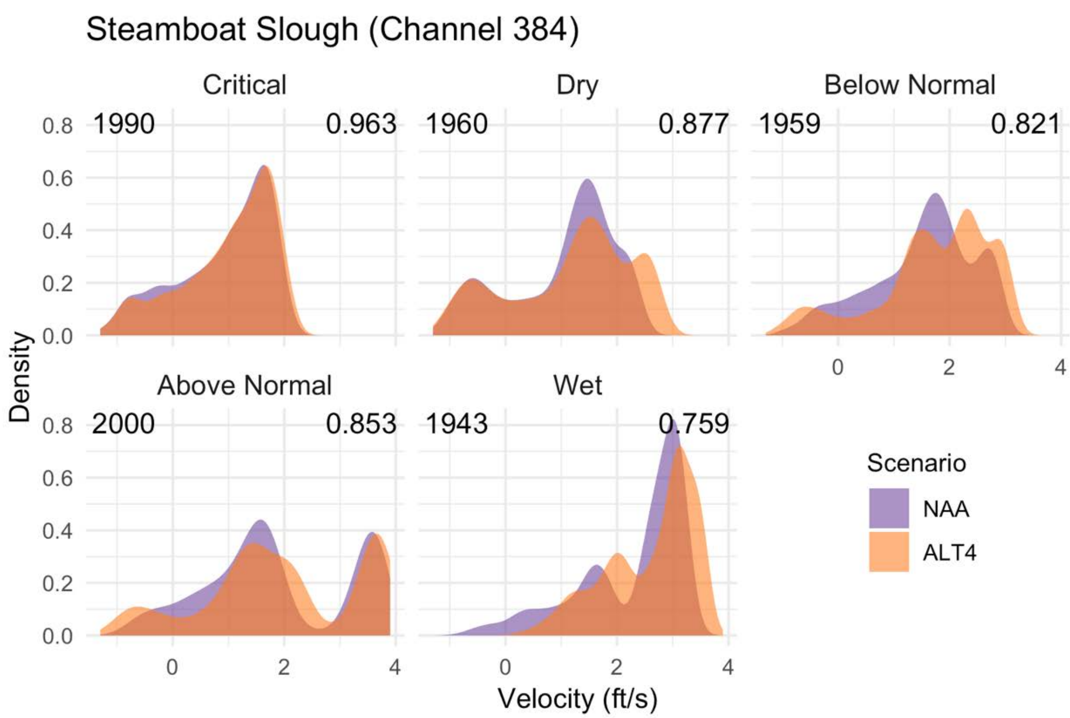

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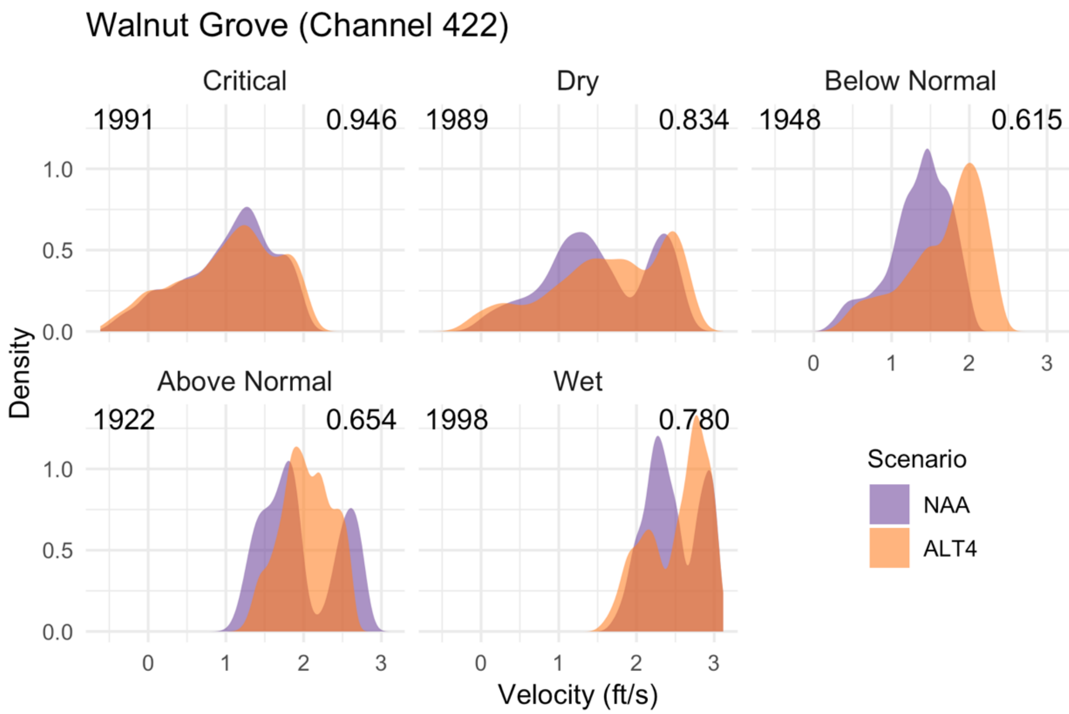

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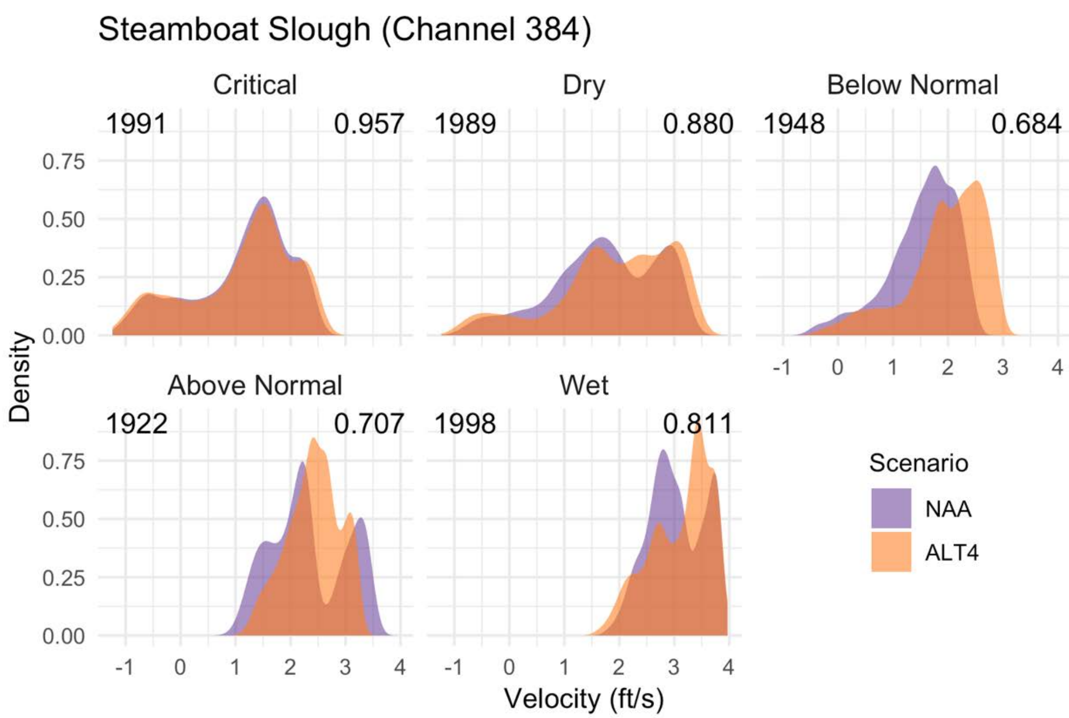

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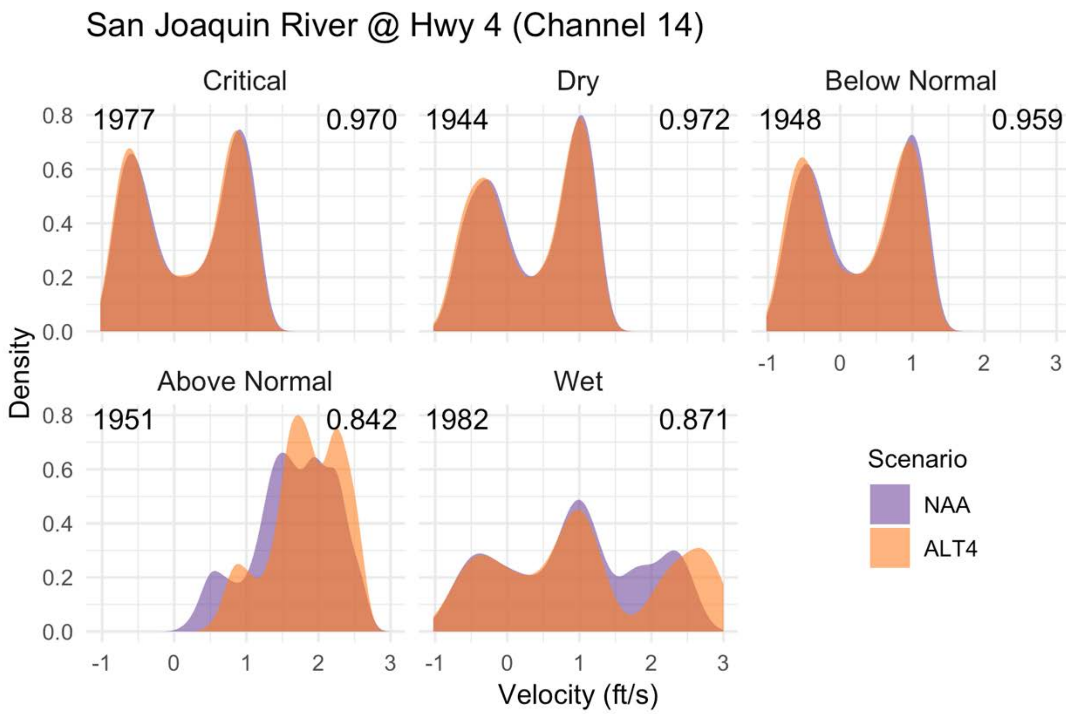

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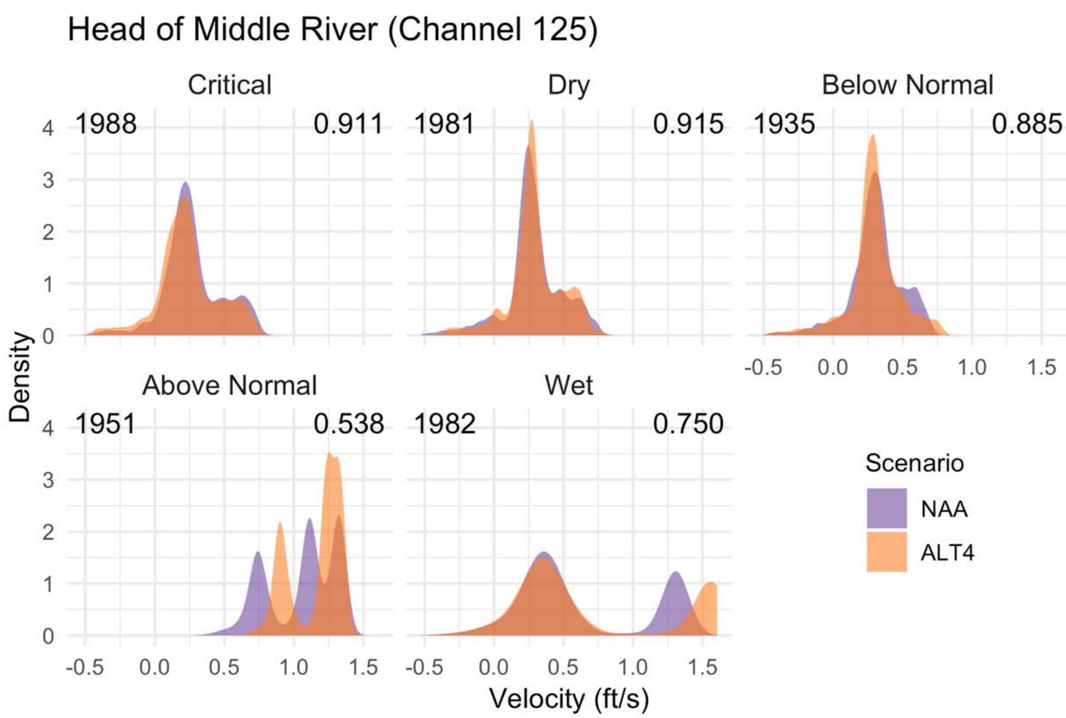

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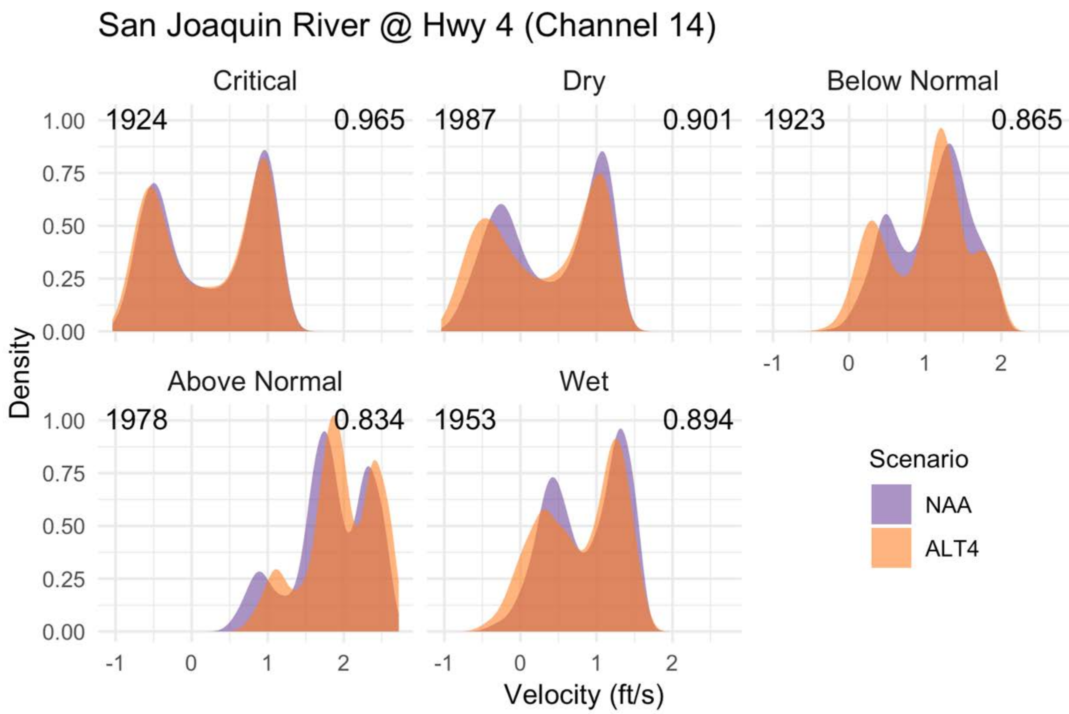

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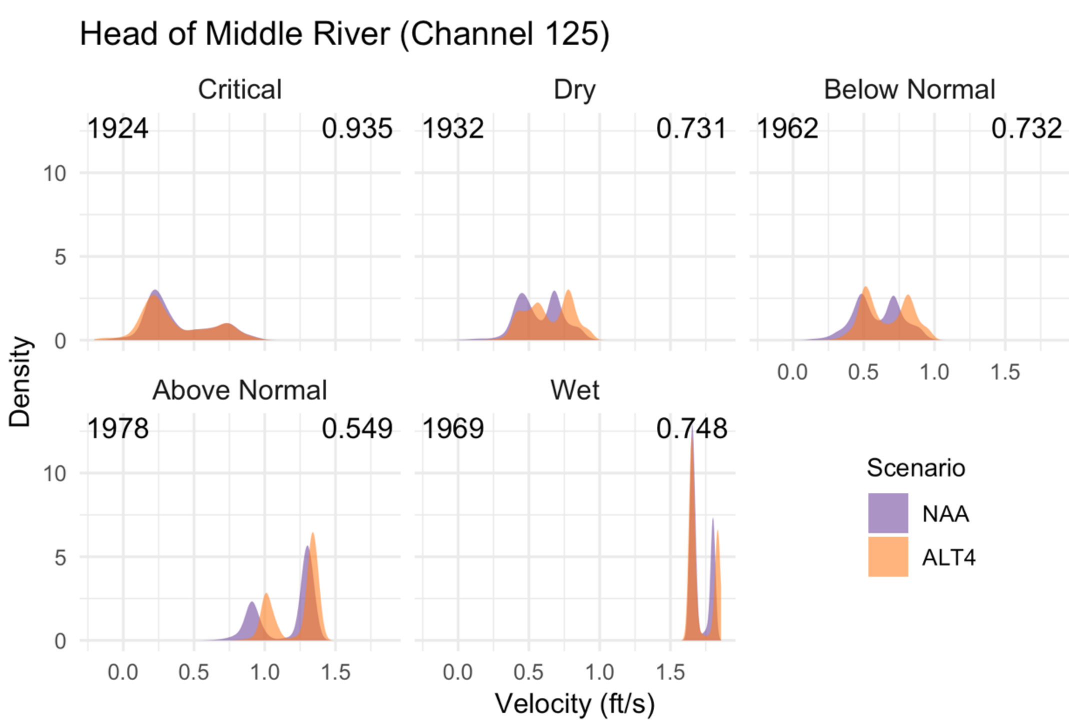

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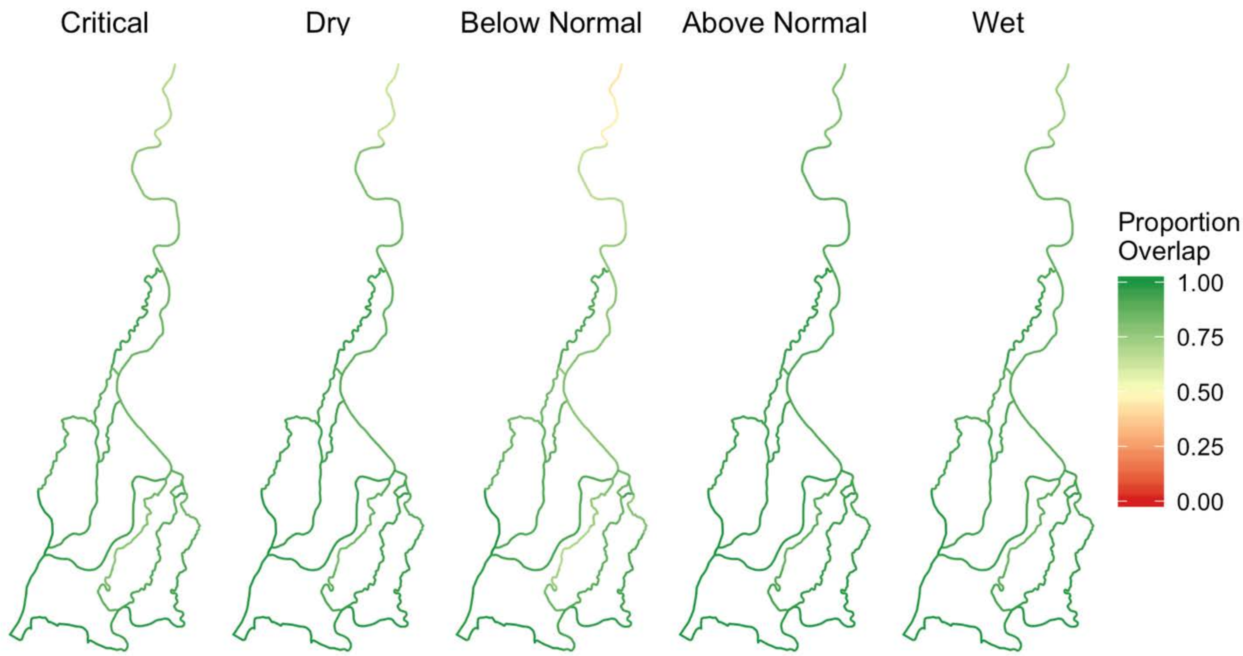
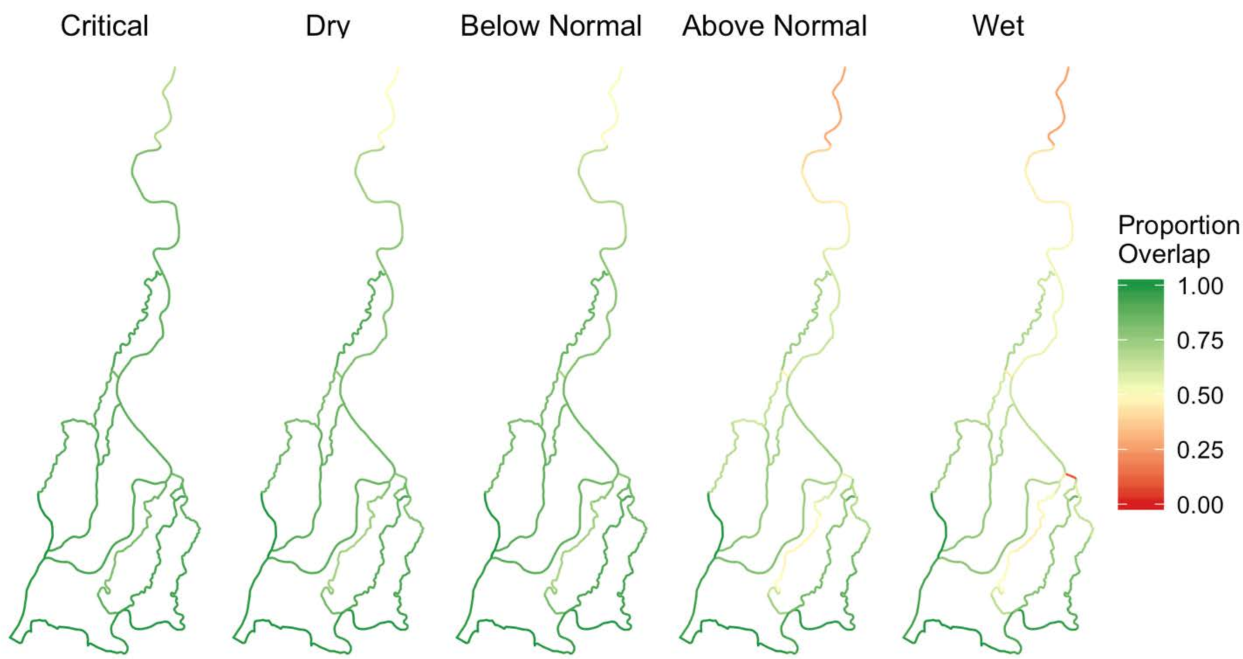


Figure O-65. No Action Alternative vs. Alternative 4, June–August



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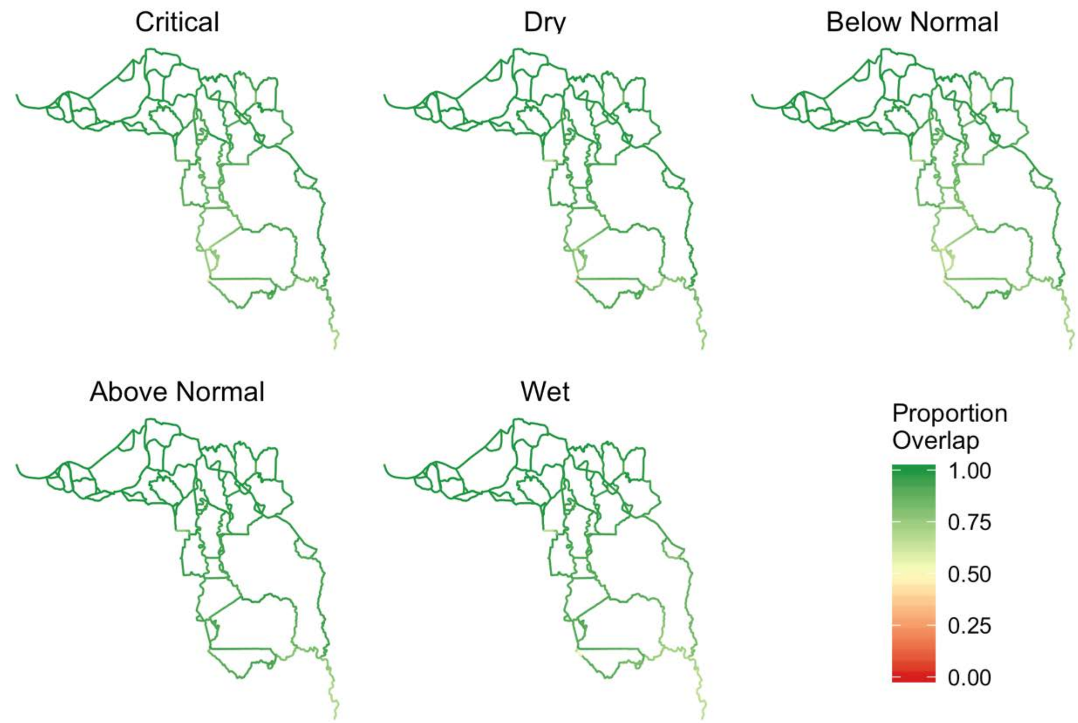

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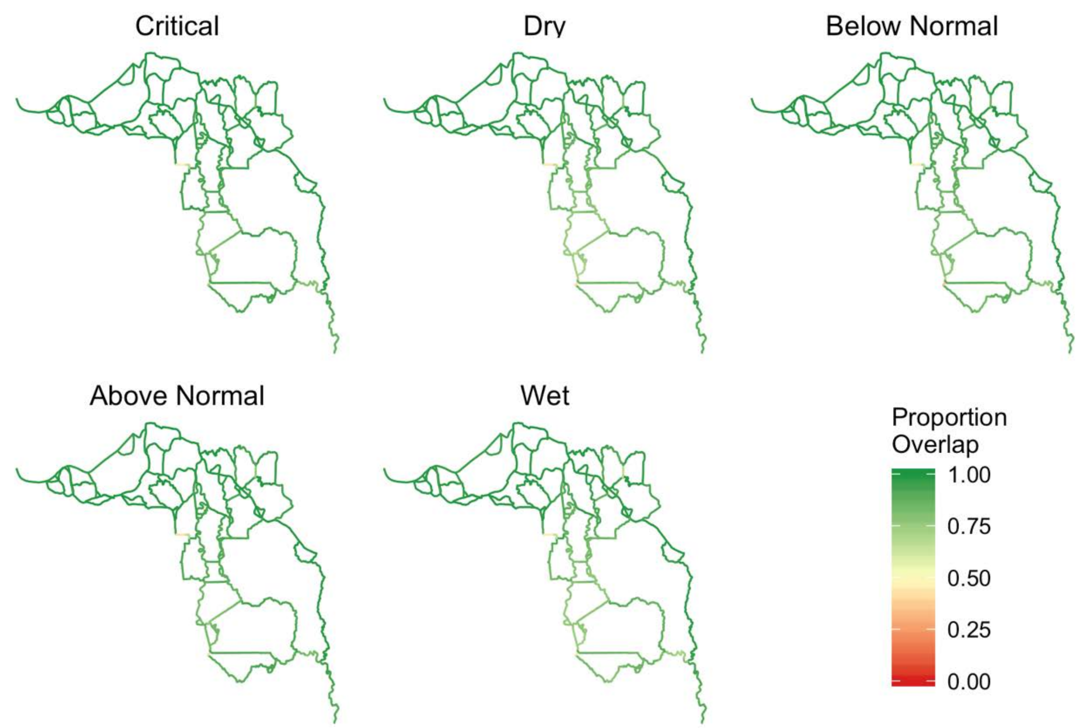

Figure O-68. No Action Alternative vs. Alternative 4, September–November

Appendix P Terrestrial Biological Resources Technical Appendix

This appendix documents the biological resources technical analysis to support the impact analysis in the environmental impact statement (EIS).

P.1 Background Information

P.1.1 Vegetation and Wildlife

P.1.1.1 *Trinity River*

The Trinity River region includes the area along the Trinity River from Trinity Lake to the confluence with the Klamath River; and along the lower Klamath River from the confluence with the Trinity River to the Pacific Ocean. The Trinity River region includes Trinity Lake, Lewiston Reservoir, the Trinity River between Lewiston Reservoir and the confluence with the Klamath River, and along the lower Klamath River. The study area only includes the aquatic areas and associated margins.

P.1.1.1.1 Trinity Lake and Lewiston Reservoir

Along the margins of Trinity Lake and Lewiston Reservoir, vegetation is consistent with species associated with a reservoir environment and standing water, including floating species, rooted aquatic species, and emergent wetland species. Emergent wetland and riparian vegetation is constrained by fluctuating water levels and steep banks (California North Coast Regional Water Quality Control Board [NCRWQCB] and Bureau of Reclamation [Reclamation] 2009; U.S. Fish and Wildlife Service [USFWS] et al. 1999).

The reservoirs attract resting and foraging waterfowl and other species that favor standing or slow-moving water. Impounded water in the reservoirs also provides foraging habitat for eagles and other raptors that prey on fish (e.g., ospreys) and waterfowl.

P.1.1.1.2 Trinity River from Lewiston Reservoir to Klamath River

Between the North Fork and the South Fork, the Trinity River channel is restricted by steep canyon walls that limit riparian vegetation to a narrow band (NCRWQCB and Reclamation 2009; USFWS et al. 1999). Between the South Fork and the confluence with the Klamath River, there are confined reaches with little riparian vegetation, alternating with vegetation similar to the pre-dam conditions in the upper reach below Lewiston dam.

Many wildlife species that inhabited river and riparian habitats prior to dam construction still occur along the Trinity River. Species that prefer early-successional stages or require greater riverine structural diversity are likely to be less abundant under current conditions (NCRWQCB and Reclamation 2009; USFWS et al. 1999). For example, western pond turtle declined since completion of the dams in response to diminishing instream habitat. In contrast, species such as northern goshawk and black salamander that favor mature, late-successional riparian habitats increased with more upland habitat along the riparian corridor.

Current vegetation along the Trinity River includes annual grassland, fresh emergent wetland, montane riparian, valley-foothill riparian, and riverine habitats (NCRWQCB and Reclamation 2009; NCRWQCB et al. 2013). The annual grassland species include grasses (e.g., wild oat, soft brome, ripgut brome, cheatgrass, and barley); forbs (e.g., broadleaf filaree, California poppy, true clover, and bur clover); and native perennial species (e.g., creeping wildrye).

The annual grassland habitat supports mourning dove, savannah sparrow, white-crowned sparrow, American kestrel, red-tailed hawk, coyote, California ground squirrel, Botta's pocket gopher, California kangaroo rat, deer mouse, gopher snake, western fence lizard, western skink, western rattlesnake, and yellow-bellied racer.

The fresh emergent wetland species occur along the backwater areas, depressions, and along the river edges, including American tule, narrow-leaved cattail, dense sedge, perennial ryegrass, Himalayan blackberry, and narrow-leaved willow. Wildlife species along the fresh emergent wetland include western toad, Pacific chorus frog, bullfrog, green heron, mallard, and red-winged blackbird.

The montane riparian habitat adjacent to the river include trees, including bigleaf maple, white alder, Oregon ash, black cottonwood, and Goodding's black willow; and understory species, including mugwort, virgin's bower, American dogwood, Oregon golden-aster, dalmatian toadflax, white sweet clover, musk monkeyflower, straggly gooseberry, California grape, and California blackberry. The valley-foothill riparian habitat occurs along alluvial fans, slightly dissected terraces, and floodplains and includes cottonwood, California sycamore, valley oak, white alder, boxelder, Oregon ash, wild grape, wild rose, California blackberry, blue elderberry, poison oak, buttonbush, willow, sedge, rushes, grasses, and miner's lettuce. Riparian woodlands along the montane riparian habitat support breeding, foraging, and roosting habitat for tree swallow, bushtit, white-breasted nuthatch, Nuttall's woodpecker, downy woodpecker, spotted towhee, and song sparrow; cover for amphibians, including western toad and Pacific chorus frog; and habitat for deer mouse, raccoon, and Virginia opossum. The riverine habitat supports amphibians and reptiles, including western toad, Pacific chorus frog, bullfrog, and western pond turtle; birds, including mallard, great blue heron, osprey, and belted kingfisher; and mammals, including river otter, beaver, big brown bat, and Yuma myotis (bat).

The lands upslope of the Trinity River are characterized by mixed chaparral, montane hardwood-conifer, blue oak-foothill pine, foothill pine, and Klamath mixed conifer (NCRWQCB and Reclamation 2009; NCRWQCB et al. 2013). The trees include Pacific madrone, bigleaf maple, canyon live oak, black oak, blue oak, ponderosa pine, Douglas fir, and incense cedar. Shrubs include greenleaf manzanita, buckbrush, cascara, snowberry, and poison oak. Underlying herbaceous vegetation includes ripgut brome, blue wild rye, silver bush lupine, purple sanicle, and false hedge-parsley. The habitats support numerous birds, including northern flicker, Steller's jay, hairy woodpecker, acorn woodpecker, wrentit, Bewick's wren, California quail, mountain quail, blue grouse, sharp-shinned hawk, red-tailed hawk, and great horned owl; mammals, including black-tailed deer, gray fox, coyote, black-tailed jackrabbit, raccoon, Virginia opossum, spotted skunk, gray squirrel, Allen's chipmunk, deer mouse, and pallid bat; and reptiles and amphibians, including California kingsnake, western rattlesnake, sharp-tailed snake, western fence lizard, southern alligator lizard, and ensatina.

Inundation of lands by Trinity Lake, Lewiston Reservoir, and Whiskeytown Lake removed approximately 20,500 acres of habitat for an estimated 8,500 black-tailed deer (USFWS 1975). The California

Department of Fish and Wildlife (CDFW) established a deer herd management plan for the Critical Winter Range for the Weaverville deer herd. A portion of the winter range is located along the Trinity River (NCRWQCB and Reclamation 2009).

P.1.1.1.3 Lower Klamath River Watershed from Trinity River to the Pacific Ocean

The Klamath River from the confluence with the Trinity River to the Pacific Ocean is characterized by a forested river canyon with riparian vegetation occurring along the channel. There is a greater diversity of riparian vegetation along the lower Klamath River below the mouth of the Trinity River, partly as a result of a more natural hydrograph on the Klamath River than exists on the Trinity River. Plant species composition changes as the Klamath River nears the Pacific Ocean; because the river slows, temperatures increase, and the tides affect salinity.

Grazing, timber harvest, and roads have degraded riparian conditions along the lower Klamath River (Yurok Tribe 2000). Riparian areas are dominated by deciduous trees including red alder. Red alder is a typical hardwood in riparian zones, tanoak is a typical hardwood on mid to upper slopes, and Pacific madrone occurs in small stands on drier sites (Green Diamond Resource Company 2006).

The broad lower Klamath River meanders within the floodplain and supports wetland habitats similar to those that existed pre-dam along the Trinity River. Wetland habitats along the lower Klamath River are dominated by cattails, tules, and a variety of rushes and sedges. As the river nears the ocean, salt-tolerant plants such as cord grass and pickleweed increase in abundance as the salinity increases (USFWS et al. 1999). Wildlife species in the lower Klamath River watershed are similar to those found in the Trinity River watershed.

P.1.1.2 *Sacramento River*

Much of the Sacramento River from Shasta Dam to Redding is deeply entrenched in bedrock, which precludes development of extensive areas of riparian vegetation (Reclamation 2013). The upper banks along these steep-sided, bedrock-constrained segments of the upper Sacramento River are characterized primarily by upland communities, including woodlands and chaparral. Outside the river corridor, other vegetation communities along the upper Sacramento River include riparian scrub, annual grassland, and agricultural lands.

The river corridor between Redding and Red Bluff once supported extensive areas of riparian vegetation (Reclamation 2013). Agricultural and residential development has permanently removed much of the native and natural habitat. Riparian vegetation now occupies only a small portion of floodplains. Willow and blackberry scrub and cottonwood- and willow-dominated riparian communities are still present along active channels and on the lower flood terraces, whereas valley oak-dominated communities occur on higher flood terraces. Although riparian woodlands along the upper Sacramento River typically occur in narrow or discontinuous patches, they provide value for wildlife and support both common and special-status species of birds, mammals, reptiles, amphibians, and invertebrates.

Portions of the adjacent land along the Sacramento River from Red Bluff to Hamilton City include substantial remnants of the pre-European Sacramento Valley historical riparian forest (Reclamation 2013). Along the Sacramento River below Red Bluff, riparian vegetation is characterized by narrow linear stands of trees and shrubs, in single- to multiple-story canopies. These patches of riparian vegetation may be on or at the toe of levees. Riparian communities in this region include woodlands and riparian scrub.

From Red Bluff to Colusa, the Sacramento River contains point bars, islands, high and low terraces, instream woody cover, and early-successional riparian plant growth, reflecting river meander and erosional processes (Reclamation 2013). Major physiographic features include floodplains, basins, terraces, active and remnant channels, and oxbow sloughs. These features sustain a diverse riparian community and support a wide range of wildlife species including raptors, waterfowl, and migratory and resident avian species, plus a variety of mammals, amphibians, and reptiles that inhabit both aquatic and upland habitats.

Downstream of Colusa, the Sacramento River channel changes from a dynamic and active meandering one to a confined, narrow channel (Reclamation 2013). Surrounding agricultural lands encroach directly adjacent to the levees, which have cut the river off from most of its riparian corridor, especially on the eastern side of the river. Most of the levees in this reach are lined with riprap, allowing the river no erodible substrate and limiting the extent of riparian vegetation and riparian wildlife habitat.

P.1.1.3 *Clear Creek*

Riparian communities within the Whiskeytown Unit of the Whiskeytown-Shasta-Trinity National Recreation Area, which includes Whiskeytown Reservoir, include the following species: grey pine, willow, white alder, dogwoods, Oregon ash, bigleaf maple, and Fremont and black cottonwood. Wild grape is also very common; other riparian shrubs include snowberry, California blackberry, toyon, buckeye, and button willow. Flowering herbaceous plants, cattails, sedges, rushes, and ferns make up the riparian understory. The riparian habitats are generally vigorous and well-vegetated, especially in the most favorable locations, such as canyons and stream bottoms (National Park Service [NPS] 1999).

Riparian vegetation is limited to a narrow band along the channel margins in the confined canyon reaches of Clear Creek between Whiskeytown Dam and Clear Creek Bridge, where the alluvial section of the creek begins. Downstream of Clear Creek Bridge, where the valley widens, the channel becomes predominately alluvial, and floodplains and terraces allow riparian vegetation to be more extensive (California Bay-Delta Authority 2004).

Fresh emergent wetlands occur throughout the entire reach of lower Clear Creek from Whiskeytown Dam to the Sacramento River. These wetlands are more prominent in the reach below Clear Creek Road Bridge where soils are deeper and the valley becomes wider and is subject to periodic flooding. Valley-foothill riparian is found primarily in the lower reaches of lower Clear Creek from Clear Creek Road Bridge to the Sacramento River. In addition, smaller linear patches occur scattered throughout the system up to Whiskeytown Dam (U.S. Bureau of Land Management [BLM] and NPS 2008).

Due to the diversity of habitats present within the watershed, the areas adjacent to Whiskeytown Lake and lower Clear Creek support a diverse assemblage of wildlife species. More than 200 vertebrate species are known to occur within the Whiskeytown Unit of the Whiskeytown-Shasta-Trinity National Recreation Area, including at least 35 mammal species, 150 bird species, and 25 reptile and amphibian species (NPS 2014).

P.1.1.4 *Feather River*

P.1.1.4.1 Upper Feather River Lakes

The Upper Feather River lakes, including Antelope Lake, Lake Davis, and Frenchman Lake, are State Water Project (SWP) facilities on the upper Feather River upstream of Lake Oroville. These lakes are part of the Plumas National Forest and provide habitat for raptor nesting and wintering areas, waterfowl nesting area, and deer movement area (California Department of Water Resources [DWR] 2013; Plumas County 2012). Deer movement and fawning areas also occur around Lake Davis.

P.1.1.4.2 Lake Oroville and Thermalito Complex

Lake Oroville is situated in the foothills on the western slope of the Sierra Nevada Mountains, about a mile downstream of the confluence of its major tributaries. Below the dam, a portion of the river flow is diverted at the Thermalito Diversion Dam and routed to the Thermalito Forebay, which is an offstream reservoir with a surface area up to 630 acres (DWR 2007a, 2007b). Downstream of the forebay, water is stored in Thermalito Afterbay (up to 4,300 surface acres), which among other purposes serves as a warming basin for agricultural water.

The majority of vegetation around Lake Oroville consists of a variety of native vegetation associations, including mixed oak woodlands, foothill pine/mixed oak woodlands, and oak/pine woodlands with a mosaic of chaparral (DWR 2004, 2007a). Open areas within the woodlands consist of annual grassland species. Native riparian habitats are restricted to narrow strips along tributaries, consisting mostly of alder, willow, and occasional cottonwood and sycamore. There is minimum wetland vegetation around Lake Oroville, and most is associated with seeps and springs that are a natural part of the landscape above the high-water line. Emergent wetlands are generally absent within the drawdown zone of Lake Oroville.

Lack of vegetative cover within the drawdown zone severely limits wildlife use of this area. Thirty-six wildlife species were detected using habitats within the drawdown zone on at least one occasion during field surveys (DWR 2004). Several of these species may use habitats within the drawdown zone for reproduction including belted kingfisher, Canada goose, canyon wren, American dipper, killdeer, mallard, common merganser, and northern rough-winged swallow.

Riparian vegetation occurs around the north shore of Thermalito Forebay as a thin strip of mixed riparian species (mostly willows), with an understory of emergent wetland vegetation. Cottonwoods and willows occur in scattered areas around the high water surface elevation of Thermalito Afterbay shoreline (Federal Energy Regulatory Commission 2007). Emergent wetlands ranging from thin strips to more extensive areas are found around Thermalito Forebay and Thermalito Afterbay. Waterfowl brood ponds constructed in inlets of Thermalito Afterbay support emergent vegetation along much of their shores.

Species observed within the wetland margin of Thermalito Afterbay include barn swallow, black phoebe, white-tailed kite, black-tailed jackrabbit, brown-headed cowbird, bullfrog, common garter snake, common yellowthroat, gopher snake, northern harrier, Pacific tree frog, raccoon, red-winged blackbird, ring-necked pheasant, short-eared owl, striped skunk, tree swallow, Virginia opossum, and violet-green swallow (DWR 2004).

In contrast to the drawdown area around the margin of Lake Oroville, the drawdown zone of Thermalito Afterbay supports a richer wildlife community and greater habitat diversity. Survey data collected as part of the relicensing process indicate that exposed mudflats seasonally provide habitat for a variety of migratory waterbirds including black-necked stilt, black tern, California gull, Caspian tern, Forster’s tern, greater yellowlegs, least sandpiper, long-billed dowitcher, ring-billed gull, semipalmated sandpiper, spotted sandpiper, and white-faced ibis. Wading birds and other waterfowl have been observed on the mudflats as well as shallow flooded areas (DWR 2004). Potentially suitable giant garter snake habitat is present along portions of the afterbay and forebay margins. The existing waterfowl brood ponds provide a refuge for giant garter snakes during periods of afterbay drawdown.

Several invasive plant species are found around Lake Oroville and downstream in and around the Thermalito Complex. Invasive species associated with riparian and wetland areas include purple loosestrife, giant reed, tree-of-heaven, and red sesbania. About 85 of the roughly 900 acres of wetlands and riparian areas along the margin of Thermalito Afterbay contain varying densities of purple loosestrife (DWR 2007a). Purple loosestrife adversely affects native vegetation.

P.1.1.4.3 <u>Feather River from Oroville Complex to the Sacramento River</u>

The Feather River from Oroville Dam to the confluence with the Sacramento River supports stands of riparian vegetation, which have been restricted over time by flood control levees and land clearing for agriculture and urbanization. As a consequence, the vegetation generally occurs in a narrow zone along much of the river in this reach. However, remnant riparian forest exists in areas where wide meander bends persist, such as at Abbott Lake and O'Connor Lake near the Lake of the Woods State Recreation Area. This area contains mixed riparian forests, including Fremont cottonwood, willow, boxelder, alder, and Oregon ash. The riparian strip along the river is bordered mostly by agricultural fields. Downstream of Yuba City near the confluence with the Sacramento River, valley oak and cottonwood riparian stands becomes more common. Riparian areas provide value for wildlife and support a wide range of species of birds, mammals, reptiles, amphibians, and invertebrates.

P.1.1.5 *American River*

Downstream of Lake Natoma, the lower American River flows to the confluence with the Sacramento River. In the upper reaches of the lower American River, the river channel is controlled by natural bluffs and terraces. Levees have been constructed along the northern and southern banks for approximately 13 miles upstream of the confluence with the Sacramento River (Reclamation et al. 2006).

Most of the lower American River is encompassed by the American River Parkway, which preserves what remains of the historic riparian zone (Reclamation et al. 2006). Vegetation communities along the lower American River downstream of Nimbus Dam include freshwater emergent wetland, riparian forest, and scrub. Oak woodland and annual grassland are present in the upper, drier areas farther away from the river. The current distribution and structure of riparian communities along the river reflects the human-induced changes caused by activities such as gravel extraction, dam construction and operations, and levee construction and maintenance, as well as by both historical and ongoing streamflow and sediment regimes, and channel dynamics.

In general, willow and alder tend to occupy areas within the active channel of the river that are repeatedly disturbed by river flows, with cottonwood-willow thickets occupying the narrow belts along the active river channel (Reclamation et al. 2006). Typical species in these thickets include Fremont cottonwood, willow, poison oak, wild grape, blackberry, northern California black walnut, and white alder.

Cottonwood forest is found on the steep, moist banks along much of the river corridor (Reclamation et al. 2006). Valley oak woodlands occur on upper terraces where fine sediment and adequate soil moisture provide a long growing season. Live oak woodland occurs on the more arid and gravelly terraces that are isolated from the fluvial dynamics and moisture of the river. Annual grassland occurs in areas that have been disturbed by human activity and can be found in many areas within the river corridor.

The cottonwood-dominated riparian forest and areas associated with backwater and off-river ponds are highest in wildlife diversity and species richness relative to other river corridor habitats (Reclamation et al. 2006). More than 220 species of birds have been recorded along the lower American River and more than 60 species are known to nest in the riparian habitats. Typical species that can be found along the river include great blue heron, mallard, red-tailed hawk, American kestrel, California quail, killdeer, belted kingfisher, western scrub jay, swallows, and American robin. Additionally, more than 30 species of mammals reside along the river, including skunk, rabbit, raccoon, squirrel, vole, muskrat, deer, fox, and coyote. Reptiles and amphibians that occupy riparian habitats along the river include western toad, Pacific tree frog, bullfrog, western pond turtle, western fence lizard, common garter snake, and gopher snake (Reclamation 2005a).

Backwater areas and off-river ponds are located throughout the length of the river, but occur predominantly at the Sacramento Bar, Arden Bar, Rossmoor Bar, and between Watt Avenue and Howe Avenue (Reclamation 2005a; Reclamation et al. 2006). Plant species that dominate these backwater areas include various species of willow, sedge, cattail, bulrush, and rush. Riparian vegetation around these ponded areas is composed of mixed-age willow, alder, and cottonwood. These backwater ponds may be connected to the river by surface water during high winter flood flows and by groundwater during other times of the year. Wildlife species typical of these areas include pied-billed grebe, American bittern, green heron, common merganser, white-tailed kite, wood duck, yellow warbler, warbling vireo, dusky-footed woodrat, western gray squirrel, Pacific tree frog, and western toad.

Several non-native weed populations are rapidly expanding in the riparian vegetation of the lower American River (County of Sacramento 2008). In particular, red sesbania is expanding along shorelines of streams and ponds, along with other invasive species such as Chinese tallowtree, giant reed, pampasgrass, Spanish broom, Himalayan blackberry, and tamarisk, which can rapidly colonize exposed bar surfaces and stream banks.

P.1.1.6 *Stanislaus River*

Near the Stanislaus River, vegetation is characterized by riparian woodland with cottonwood, willows, white alder, blue elderberry, and Himalayan berry. Some low-gradient areas along the shoreline of Goodwin Lake, especially in coves, support small patches of emergent aquatic vegetation such as bulrush and cattail (Goodwin Power 2013). Wildlife occurrences are similar to conditions near Tulloch Reservoir.

From Goodwin Dam to Knight’s Ferry, the Stanislaus River flows through a bedrock canyon with nearly vertical walls and rock outcrops (California Department of Fish and Game [CDFG] 1995). The riparian edge includes valley foothill riparian vegetation in a very narrow band for the entire length of this reach. This habitat is characterized by a canopy layer of cottonwood, California sycamore, and valley oak. Subcanopy cover trees are white alder, boxelder, and Oregon ash. Typical understory shrub layer plants include wild grape, wild rose, California blackberry, elderberry, button brush, and willow. The herbaceous layer consists of sedges, rushes, grasses, miner’s lettuce, poison-hemlock, and stinging nettle.

From Knight’s Ferry to the Orange Blossom Bridge, located to the east of the City of Oakdale, the valley foothill riparian habitat continues along the river (CDFG 1995). Further away from the river, vegetation is dominated by blue oak-digger pine woodland and shrub, including California redbud, California buckeye, ceanothus, manzanita, poison oak, and grasslands. Vernal pools and vernal pool complexes are found within adjacent grasslands.

Downstream of the Orange Blossom Bridge, the riparian corridor is virtually nonexistent in some areas with agricultural land uses extending into the riparian corridor (CDFG 1995). In a few areas the riparian corridor is wide, such as within Caswell Memorial State Park. The major habitats include valley foothill riparian along the Stanislaus River with annual grasslands and fresh emergent wetlands among the agricultural and urban developments.

P.1.1.7 *San Joaquin River*

A multilayered riparian forest dominated by cottonwoods occurs on the active low floodplain of the San Joaquin River along with older stands of cottonwood-dominated riparian forest in areas that were formerly active floodplains prior to the completion of Friant Dam and associated diversion channels, and the resulting reduction in river flow (DWR and Reclamation 2002; Reclamation and DWR 2011). Other areas on the low floodplain are dominated by willow, with occasional scattered cottonwood, ash, or white alder. California buttonbush is often present and may even dominate the river bank for stretches.

The intermediate terrace of the floodplain of the San Joaquin River is primarily a mixed-species riparian forest (DWR and Reclamation 2002; Reclamation and DWR 2011). Species dominance in this mixed riparian forest depends on site conditions, such as availability of groundwater and frequency of flooding. Typical dominant trees in the overstory and midstory include Fremont cottonwood, boxelder, Goodding’s black willow, Oregon ash, and California sycamore. Immediately along the water’s edge, white alder occurs in the upper reaches of the San Joaquin River. Typical shrubs include red willow, arroyo willow, and California buttonbush.

Tree-dominated habitats with an open-to-closed canopy are typically found on the higher portions of the floodplain (DWR and Reclamation 2002; Reclamation and DWR 2011). These areas are exposed to less flood-related disturbance than areas lower on the floodplain. Valley oak is the dominant tree species while California sycamore, Oregon ash, and Fremont cottonwood are present in small numbers. Typical understory species include creeping wild rye, California wild rose, Himalayan blackberry, California wild grape, and California blackberry.

Dense stands of willow shrubs frequently occur within the active floodplain of the river in areas subject to more frequent scouring flows and often occupy stable sand and gravel point bars immediately above the active channel (DWR and Reclamation 2002; Reclamation and DWR 2011). Dominant species include sandbar willow, arroyo willow, and red willow. Occasional emergent Fremont cottonwood may also be present.

Other areas have vegetation consisting of woody shrubs and herbaceous species dominated by different species depending on river reach. Some areas are dominated by mugwort, together with stinging nettle and various tall weedy herbs. Other areas are dominated either by blackberry (usually the introduced Himalayan blackberry) or wild rose in dense thickets, with or without scattered small emergent willows.

Areas with fine-textured, rich alluvium located outside the active channels but in areas that are subject to periodic flooding contain a shrub-dominated community characterized by widely spaced blue elderberry shrubs (DWR and Reclamation 2002; Reclamation and DWR 2011). The herbaceous understory is typically dominated by nonnative grasses and forbs that are characteristic of annual grassland communities, including ripgut brome, foxtail fescue, foxtail barley, red-stemmed filaree, and horseweed.

Emergent wetlands typically occur in the river bottom immediately adjacent to the low-flow channel (DWR and Reclamation 2002; Reclamation and DWR 2011). Backwaters and sloughs where water is present through much of the year support emergent marsh vegetation, such as tule and cattails. More ephemeral wetlands, especially along the margins of the river and in swales adjacent to the river, support native and nonnative herbaceous species.

Prevalent invasive species found in this portion of the San Joaquin River corridor include red sesbania, tamarisk, giant reed, Chinese tallow, tree-of-heaven, and perennial pepperweed (Reclamation and DWR 2011). Water hyacinth, water milfoil, parrot's feather, curly-leaf pondweed, and sponge plant occur within the streams, especially in areas with slow or ponded water.

The riparian forest trees and understory provide habitat for raptors, cavity-nesting birds, and songbirds, including red-tailed hawk, red-shouldered hawk, Swainson's hawk, white-tailed kite, downy woodpecker, wood duck, northern flicker, ash-throated flycatcher, Pacific-slope flycatcher, olive sided flycatcher, tree swallow, oak titmouse, white-breasted nuthatch, western wood-pewee, warbling vireo, orange-crowned warbler, yellow warbler, Bullock's oriole, and spotted towhee (DWR and Reclamation 2002; Reclamation and DWR 2011). Western wood-pewee, bushtit, Bewick's wren, lazuli bunting, blue grosbeak, and American goldfinch inhabit the riparian scrub vegetation. Song sparrow, common yellowthroat, marsh wren, and red-winged blackbird inhabit the emergent wetlands. Coyote, river otter, raccoon, desert cottontail, and striped skunk occur in the riparian forest and shrub communities. Killdeer, mallard duck, California vole, common muskrat, Norway rat, Pacific chorus frog, western pond turtle, and western terrestrial garter snake occur near the river.

The reach of the San Joaquin River immediately downstream of the Merced River is more incised than areas further downstream and has a less developed riparian area with less understory vegetation. Between the Merced River and the Delta, agricultural land use has encroached on the riparian areas, leaving only a narrow band of riparian habitat. Near the confluence with tributary rivers, in cutoff oxbows, and in the San Joaquin River National Wildlife Refuge (NWR), there are more extensive riparian habitat areas. Remnant cattail-dominated marshes and tules occur in these areas.

P.1.1.8 *Bay-Delta*

P.1.1.8.1 Delta and Suisun Marsh

The Delta overlies the western portions of the Sacramento River and San Joaquin River watersheds. The Delta is a network of islands, channels, and marshland at the confluence of the Sacramento and San Joaquin Rivers. Major rivers entering the Delta are the Sacramento River flowing from the north, the San Joaquin River flowing from the south, and eastside tributaries (Cosumnes, Mokelumne, and Calaveras Rivers). Suisun Marsh is a tidally influenced brackish marsh located about 35 miles northeast of San Francisco in southern Solano County. It is a critical part of the San Francisco Bay/Sacramento–San Joaquin Delta (Bay-Delta) estuary ecosystem. The Delta, together with Suisun Marsh and greater San Francisco Bay, make up the largest estuary on the west coast of North and South America (DWR 2009).

The Delta was once composed of extensive freshwater and brackish marshes, with tules and cattails, broad riparian thickets of scrub willows, buttonwillow, and native brambles. In addition, there were extensive riparian forests of Fremont cottonwood, valley oak, Oregon ash, boxelder, white alder, and Goodding's black willow. Upland, non-riparian stands of valley oak and coast live oak occurred in a mosaic with seasonally flooded herbaceous vegetation, including vernal pools and alkali wetlands (San Francisco Estuary Institute—Aquatic Science Center [SFEI] 2012).

Substantial areas of the Delta and Suisun Marsh have been modified by agricultural, urban and suburban, and recreational land uses (Reclamation et al. 2011; SFEI 2012). Over the past 150 years, levees were constructed in the Delta and Suisun Marsh to provide lands for agricultural, municipal, industrial, and recreational land uses. The remaining natural vegetation is fragmented, and largely restricted to the edges of waterways, flooded islands, and small protected areas such as parks, wildlife areas, and nature reserves

(Hickson and Keeler-Wolf 2007). A substantial portion of the emergent wetlands exists as thin strips along the margins of constructed levees (SFEI 2012). Current habitat along the Delta waterways includes seasonal wetlands, tidal wetlands, managed wetlands, riparian forests, and riparian scrub.

Seasonal wetlands historically had occurred along the riparian corridor at elevations that were inundated during high flow events. Many of the levees were constructed along the riparian corridor edges; therefore, historic seasonal wetlands were substantially modified (SFEI 2012). Adjacent areas of perennial wetlands on the water-side of the riparian corridor were modified as levees were constructed and channels enlarged. In many of these areas the perennial wetlands were replaced by seasonal wetlands. The vegetation of seasonal wetlands is typically composed of wetland generalist species that occur in frequently disturbed sites such as hyssop loosestrife, cocklebur, dallisgrass, Bermuda grass, barnyard grass, and Italian ryegrass.

Alkali-related habitats occur near salt-influenced seasonal and perennial wetlands. Alkali seasonal wetlands occur on fine-textured soils that contain relatively high concentrations of dissolved salts. These types of soils are typically found at the historical locations of seasonal ponds in the Yolo Basin in and around the CDFW Tule Ranch Preserve, and upland in seasonal drainages that receive salts in runoff from upslope salt-bearing bedrock such as areas near Suisun Marsh and the Clifton Court Forebay. Alkali wetlands include saltgrass, alkali weed, saltbush, alkali heath, and iodine bush. Small stands of alkali sink scrub (also known as valley sink scrub) are characterized by iodine bush.

Tidal wetlands consist of tidal brackish wetlands that occur either as relatively substantial tracts of complex tidal wetlands, or in narrow bands of fringing tidal wetlands (Siegel et al. 2010a). Fringing tidal marsh exists along the outboard side exterior levees and generally has formed since diking for managed wetlands began. Fringing tidal wetlands vary in size and vegetation composition, exhibit less geomorphic complexity, and have a low area-to-edge ratio. Fringing marshes lack connection with the upland transition, are often found in small, discontinuous segments, and can limit movement of terrestrial marsh species.

Plant zones in complex tidal wetlands are influenced by inundation regime and salinity. Tidal wetlands can be divided into three zones: low marsh, middle marsh, and high marsh (Reclamation et al. 2011). The low tidal wetland zone is tidally inundated once or twice per day. At the lowest elevations, vegetation is inhibited by frequent, prolonged, often deep inundation and by disturbance by waves or currents. The dominant plant species are bulrushes. Other species occurring in the low tidal wetland zone are pickleweed, lowclub rush, common reed, and cattails. The low tidal wetland zone provides foraging habitat for waterfowl and shorebirds, California Ridgway's rail, California black rail, and other wading birds.

The middle tidal wetland zone is tidally inundated at least once per day; there is relatively little cover and no refuge from higher tides, which completely flood the vegetation of the middle marsh. The dominant plant species are pickleweed, saltgrass, and bulrush. Other species occurring in the middle tidal marsh are fleshy jaumea, sea milkwort, rushes, salt marsh dodder, alkali heath, cattail, sneezeweed, and marsh gumplant (Siegel et al. 2010b). The middle tidal wetland zone provides foraging habitat for salt marsh harvest mouse and Suisun shrew, as well as common and special-status bird species, including waterfowl and shorebirds, California Ridgway's rail, California black rail, and other wading birds. This zone also provides nesting and foraging habitat for Suisun song sparrow and salt marsh common yellowthroat (Reclamation et al. 2011).

The high tidal wetland zone receives intermittent inundation during the monthly tidal cycle, with the higher elevations being inundated during only the highest tides. Historically, the high marsh was an expansive transitional zone between the tidal wetlands and adjacent uplands. The high marsh and associated upland transition zone have been affected by land use changes (e.g., managed wetlands, agriculture). The dominant plants are native species, such as saltgrass, pickleweed, and Baltic rush, and nonnative species, including perennial pepperweed, poison hemlock, and fennel. Other species occurring in the high tidal marsh are saltmarsh dodder, fleshy jaumea, seaside arrowgrass, alkali heath, brass button, and rabbitsfoot grass.

The high tidal marsh provides habitat for special-status plants, including Suisun marsh aster, soft bird's beak, and Suisun thistle (Siegel et al. 2010b). The high marsh zone provides foraging and nesting habitat for waterfowl, shorebirds, California Ridgway's rail, California black rail, and other birds. It also provides foraging and nesting habitat for special-status species such as salt marsh harvest mouse and Suisun shrew, and provides escape cover for salt marsh harvest mouse and Suisun shrew during periods when the middle and lower portions of the high tidal wetland zone are inundated (Reclamation et al. 2011).

Managed wetlands are primarily located within the Suisun Marsh, Cache Slough, and near the confluence of the Mokelumne and Sacramento Rivers within the historical limits of the high tidal marsh and adjacent uplands that were diked and leveled for agricultural purposes and later managed to enhance habitat values for specific wildlife species (CALFED Bay-Delta Program [CALFED] 2000). Diked managed wetlands and uplands are the most typical land cover type in the Suisun Marsh area. Managed wetlands are considered seasonal wetlands because they may be flooded and drained several times throughout the year. Watergrass and smartweed are typically the dominant species in managed wetlands that use fresher water. Bulrush, cattail, and tule are the dominant species in managed wetlands that employ late drawdown management. Pickleweed, fat hen, and brass buttons are typical in the higher elevations of the managed wetlands. In marshes with higher soil salinity, pickleweed, saltgrass, and other salt-tolerant species are dominant. Managed wetlands are managed specifically as habitat for wintering waterfowl species, including northern pintail, mallard, American wigeon, green-winged teal, northern shoveler, gadwall, cinnamon teal, ruddy duck, canvasback duck, white-fronted goose, and Canada goose. Some wetlands are also managed for breeding waterfowl, especially mallard.

Riparian forest areas are still present in some portions of the Delta along many of the major and minor waterways, oxbows, and levees (CALFED 2000). Riparian forest and woodland communities dominated by tree species are mostly limited to narrow bands along sloughs, channels, rivers, and other freshwater features throughout the Delta. Isolated patches of riparian vegetation are also found on the interior of reclaimed Delta islands, along drainage channels, along pond margins, and in abandoned, low-lying fields. Cottonwoods and willows, Oregon ash, boxelder, and California sycamore, are the most typical riparian trees in central California. Valley oak and black walnut are typical in riparian areas in the Delta. Riparian trees are used for nesting, foraging, and protective cover by many bird species and riparian canopies provide nesting and foraging habitat for a variety of mammals. Understory shrubs provide cover for ground-nesting birds that forage among the vegetation and leaf litter.

Riparian scrub in the Delta and Suisun Marsh consists of woody riparian shrubs in dense thickets (SFEI 2012). Riparian scrub thickets are usually associated with higher, sloping, better drained edges of marshes or topographic high areas, such as levee remnants and elevated flood deposits, and along shorelines of ponds or banks of channels in tidal or non-tidal freshwater habitats. Plant species may include willow, blackberry, buttonbush, mule fat, and other shrub species. Willow-dominated habitat types appear to be increasing in extent in recent years; willows line many miles of artificial levees where waterways historically had flowed into freshwater emergent wetland. Nonnative Himalayan blackberry thickets are a typical element of riparian scrub communities along levees and throughout pastures in the levees. Willow thickets provide habitat for a wide range of wildlife species, including the song sparrow, lazuli bunting, and valley elderberry longhorn beetle.

P.1.1.8.2 Yolo Bypass

The Yolo Bypass is a 59,280-acre floodway through the natural-overflow of the Yolo Basin on the west side of the Sacramento River (DWR 2012). The Yolo Bypass generally extends north to south from Fremont Weir along the Sacramento River (near Verona) to upstream of Rio Vista along the Sacramento River in the Delta. The bypass, part of the Sacramento River Flood Control Project, conveys floodwaters around the Sacramento River near the cities of Sacramento and West Sacramento. The bypass is utilized as a flood bypass approximately once every 3 years, generally during the period from November to April. Land use in the Yolo Bypass is generally restricted to specific agriculture, managed wetlands, and vegetation communities to ensure that floodway function is maintained (CALFED et al. 2001; USFWS 2002). Agricultural crops include corn, tomatoes, melons, safflower, and rice within the northern bypass; and corn, milo, safflower, beans, tomatoes, and Sudan grass in the southern bypass. Waterfowl hunting areas are generally located in the southern bypass, and include rice fields, permanent open water, or a mixture of water and upland habitat. The U.S. Army Corps of Engineers (USACE) has developed criteria for managing emergent vegetation (e.g., cattails and bulrushes) in the Yolo Bypass to maintain flood capacity, including no more than 5% of the vegetation in seasonal wetlands can be emergent wetlands; no more than 50% of the vegetation in permanent wetlands can be emergent wetlands; and riparian vegetation can only occur in specified areas to maintain flood capacity (CDFG and Yolo Basin Foundation 2008).

The Yolo Bypass supports several major terrestrial vegetation types, including riparian woodland, valley oak woodland, open water, and wetland. Historically, riparian woodland and freshwater wetland were the dominant habitat types in the Yolo Basin (CALFED et al. 2001; USFWS 2002). Currently, riparian woodland and associated riparian scrub habitats are primarily found adjacent to Green’s Lake, Putah Creek, and along the East Toe Drain within the Yolo Bypass Wildlife Area. Riparian woodland is a tree-dominated community found adjacent to riparian scrub on older river terraces which have lower flooding frequency and duration. Riparian woodlands include Fremont cottonwood, valley oak, sycamore, willow, eucalyptus, giant reed, and black oak. The understory is typically sparse in this community with limited areas of California grape, blackberry, poison oak, mugwort, grasses, and forbs. The woodland canopy provides habitat for hawks, owls, American crow, great egret, great blue heron, red-tailed kite, yellow-rumped warbler, black phoebe, various woodpecker species, wood duck, bat species, and raccoon. The Yolo Bypass also includes riparian scrub, a shrub-dominated community described above for the Delta/Suisun Marsh area.

Remnants of valley oak woodlands and savanna occur on floodplain terraces in fragmented areas, including downstream of Fremont Weir and along the southern portion of the Toe Drain (CALFED et al. 2001). The habitat also includes sycamore, black walnut, wild grape, poison oak, elderberry, blackberry, grass, and sedge.

Depending on the duration of inundation, local soil factors, site history, and other characteristics, seasonal wetlands typically are dominated by species characteristic of one of three natural wetland communities: freshwater marshes, alkali marshes, or freshwater seasonal (often disturbed) wetlands (CALFED et al. 2001). Freshwater marsh communities are typically found in areas subjected to prolonged flooding during the winter months, and frequently do not dry down until early summer. Permanent open water is found throughout the Yolo Bypass, including Gray's Bend near Fremont Weir, Green's Lake near Interstate 80, ponds in the Yolo Bypass Wildlife Area, along Cache and Prospect sloughs, and within canals and drainage ditches. The wetlands support duck breeding habitat and habitat for many lifestages of grebe, ibis, heron, egret, bittern, coot, rails, raptors, muskrat, raccoon, opossum, beaver, ring-necked pheasant, garter snake, Pacific tree frog, and bullfrog.

Managed wetlands in the Yolo Bypass occur near Fremont Weir, in the 16,770 acre Yolo Bypass Wildlife Area, and within and near Cache Slough. The managed wetlands are generally flooded in the fall, with standing water maintained continuously throughout the winter until drawdown occurs in the following spring (CALFED et al. 2001; CDFG and Yolo Basin Foundation 2008). A primary objective of seasonal wetland management is to provide an abundance and diversity of seeds, aquatic invertebrates, and other foods for wintering waterfowl and other wildlife. The wetlands also are managed to control the extent of tules and cattails, and more recently, water hyacinth. A portion of the managed wetlands occur within rice fields which are flooded in the winter to provide waterfowl feeding and resting habitats. A variety of annual plants germinate on the exposed mudflats of seasonal wetlands during the spring draw down, including swamp timothy, watergrass, smartweed, and cocklebur. These plants are then managed through the timing, duration, or absence of summer irrigation. The mudflats support sandpiper, plover, avocet, stilt, and other shorebirds.

Managed semi-permanent wetlands, commonly referred to as "brood ponds," are flooded during the spring and summer, but may experience a 2- to 6-month dry period each year. These semi-permanent wetlands provide breeding ducks, ducklings, and other wetland wildlife with protection from predators and abundant invertebrate food supplies (CDFG and Yolo Basin Foundation 2008). Permanent wetlands remain flooded throughout the year. Due to year-round flooding, permanent wetlands support a diverse, but usually not abundant, population of invertebrates. Permanent managed wetlands provide deep water habitat for diving ducks, such as ruddy duck, scaup, and goldeneye, and other water birds, including pied-billed grebe, coot, and moorhen. They often have dense emergent cover on their edges that is the preferred breeding habitat for marsh wren and red-winged blackbird, and roosting habitat for black-crowned night heron, white-faced ibis, and egret.

The managed wetlands are operated by private hunting clubs; private conservation entities, including conservation banks; and the federal and state governments (CALFED et al. 2001). Some of the hunting clubs have implemented wetland management agreements with CDFW under the state Presley Program or Wetland Easement Program to coordinate the timing and patterns of flooding, drawdowns, irrigation, soil disturbance, and maintenance of brood habitat. The patterns may be adjusted annually to respond to specific wildlife and hydrologic needs. A similar program focused on providing spring habitat for breeding is provided by the federal Waterbank Program.

Habitat in the Yolo Bypass is affected by periodic flooding (CALFED et al. 2001). Following a flood, roads, canals, and ditches may need to be excavated; debris needs to be removed from habitat; and water delivery facilities may need to be repaired. Flooding also disrupts nesting and resting activities of birds.

P.1.1.8.3 Central Valley Project Reservoirs

The Central Valley Project (CVP) reservoirs in the Bay-Delta include Contra Loma and San Justo reservoirs.

Contra Loma Reservoir

The Contra Loma Reservoir is a CVP facility in Contra Costa County that provides offstream storage along the Contra Costa Canal. The 80-acre reservoir is part of 661-acre Contra Loma Regional Park and Antioch Community Park (Reclamation 2014). The Contra Loma Reservoir area includes open space and recreation facilities. In the open space, vegetative communities include grasslands, blue oak woodland, valley foothill riparian, fresh emergent wetlands, riverine, and open water communities. The annual grasslands include smooth brome, slender wild oats, Italian ryegrass, yellow star thistle, white-stem filaree, and mouse-ear chickweed. Valley foothill riparian occurs along intermittent streams and includes valley oaks, cottonwoods, red willows, Himalayan blackberry, poison oak, and mule fat. The riverine and fresh emergent wetland communities include ryegrass, curly dock, hyssop, loosestrife, Baltic rush, flowering quillwort, cattails, rushes, dallis grass, nutsedge, and cocklebur. Watermilfoil occurs along portions of the shoreline. Recreation areas include urban trees with Oregon ash, black walnut, Fremont cottonwood, blue oak, valley oak, interior live oak, fig, and eucalyptus. East Bay Regional Parks District has initiated restoration actions to improve native grasslands and riparian and provide habitat for quail.

Wildlife in the grasslands areas includes burrowing owl, horned lark, western meadowlark, turkey vulture, northern harrier, American kestrel, white-tailed kite, red-tailed hawk, Brewer’s blackbird, mourning dove, western fence lizard, common garter snake, western rattlesnake, black-tailed jackrabbit, California ground squirrel, Botta’s pocket gopher, western harvest mouse, California vole, American badger, mule deer, and coyote (Reclamation 2014). The valley foothill riparian and blue oak woodland vegetation support a wide range of birds including northern flicker, yellow warbler, acorn woodpeckers, western scrub jay, white-tailed kite, Cooper’s hawk, red-shouldered hawk, American kestrel, great horned owl, song sparrow, black phoebe, European starling, western bluebird, and tree swallow. The valley foothill riparian and blue oak woodland vegetation also support Pacific tree frog, red-legged frog, sharp-tailed snake, California alligator lizard, common garter snake, mule deer, raccoon, coyote, striped skunk, deer mouse, harvest mouse, dusky-footed woodrat, and gray fox. Riverine, wetlands, and open water support Brewer’s blackbird, red-winged blackbird, brown-headed cowbird, great blue heron, great egret, duck species, American coot, common merganser, double-crested cormorant, American wigeon, Canada goose, western grebe, and gull species; Pacific tree frog, red-legged frog, bullfrog, California tiger salamander, western pond turtle, western toad, and garter snakes; deer mouse, California vole, long-tailed weasel, and other mammals that use the adjacent woodlands and grasslands.

San Justo Reservoir

The San Justo Reservoir is a CVP facility in San Benito County that provides offstream storage as part of the San Felipe Division. The reservoir is surrounded by steep hills with recreational facilities on the northeast side reservoir and intermittent streams, wetlands, and open water downslope of the reservoir (San Benito County Water District 2012). Adjacent land uses are dominated by irrigated row crops, orchards, and rangeland. Vegetation and wildlife resources of the reservoir area are consistent with grasslands vegetation on uplands.

P.1.1.8.4 <u>State Water Project Reservoirs</u>

Bethany Reservoir, Patterson Reservoir, and Lake Del Valle are SWP facilities associated with the South Bay Aqueduct in Alameda County.

Vegetative communities around Bethany Reservoir are characterized by nonnative grasses with several areas of woodland habitat (DWR 2014). The grassland habitat includes slender oat, ripgut brome, soft chess, wild barley, Italian ryegrass, black mustard, bull thistle, redstem filaree, dissected geranium, English plantain, tumble mustard, and forbs, including sweet fennel, Great Valley gumweed, Mediterranean linseed, and Ithuriel's spear. The woodland habitat includes white ironbark, casuarina, and Bishop pine. Coyote bush occurs along the water edge. The grasslands provide habitat for mourning dove, western scrub-jay, finch species, sparrow species, owl species, hawk species, California ground squirrel, black-tailed jackrabbit, Audubon's cottontail, Botta's pocket gopher, California vole, mice, and various species of frogs, toads, salamanders, snakes, lizards, and turtles. The woodlands support red-tailed hawk, osprey, owl species, black phoebe, Bullock's oriole, yellow warbler, coyote, and various species of amphibians and reptiles. Emergent vegetation does not occur along the shoreline at Bethany Reservoir (DWR 2005).

Patterson Reservoir is a small, 100-acre-foot, SWP reservoir located along the South Bay Aqueduct between Bethany Reservoir and Lake Del Valle. Vegetation around Patterson Reservoir is characterized by grasslands and upland habitat. Red-legged frog has been observed in the vicinity of Patterson Reservoir (DWR 2014).

Lake Del Valle is a 77,100 acre-foot SWP facility located along the South Bay Aqueduct (DWR 2016). Vegetation around Lake Del Valle includes grasslands, chaparral, shrub, oak woodland, and riparian and freshwater habitats (East Bay Regional Park District [EBRPD] 1996, 2001, 2012, 2013). The grasslands include nonnative grasses and native perennial bunchgrass. The nonnative grasslands include grasses, such as wild oats, bromes, ryegrass, wild barley, silver hairgrass, and dogtail grass; forbs, including filaree, clover, and plantain; and lupine, yarrow, and soap plant. Native grasses include annual and perennial fescues, needlegrass, wild ryes, junegrass, and California bromegrass. The coastal scrub and chaparral vegetation includes coyote brush-scrub, California sagebrush, manzanita, black sage, cream bush, California coffeeberry, yerba santa, blackberry, bush monkeyflower, and poison oak. The oak woodlands and riparian woodlands include coast live oak, black oak, valley oak, scrub oak, California bay, and California buckeye. Mixed deciduous riparian woodlands occur along perennial streams, including white alder, big-leaf maple, western sycamore, willow, and Fremont cottonwood. Along springs and seeps, the vegetation includes rabbitsfoot grass, saltgrass, bentgrasses, rushes, tules, sedges, horsetails, cattail, buttercup, brass-button, mint, duckweed, pondweed, and ferns.

Contra Costa Water District Los Vaqueros Reservoir

Los Vaqueros Reservoir is a Contra Costa Water District offstream storage facility in Contra Costa County. The area around the Los Vaqueros reservoir includes grasslands, upland scrub, valley and foothill woodlands, freshwater wetlands, and open water habitats (Reclamation et al. 2009). The grasslands include perennial and alkali habitats with wild oats, ripgut brome, yellow star thistle, fescue, filaree, mustard, fiddleneck, lupine, popcorn flower, and California poppy. The grasslands support northern harrier, burrowing owl, western meadowlark, California horned lark, turkey vulture, red-tailed hawk, American kestrel, white-tailed kite, western fence lizard, common garter snake, western rattlesnake, California tiger salamander, western harvest mouse, California ground squirrel, black-tailed jackrabbit, and black-tailed deer.

The upland scrub habitat is dominated by evergreen chaparral species and coastal scrub, including chamise, California sagebrush, black sage, poison oak, bush monkeyflower, and California buckwheat underlain by annual grasses and purple needlegrass (Reclamation et al. 2009). This habitat supports California quail, western scrub-jay, bushtit, California thrasher, spotted towhee, sage sparrow, western fence lizard, common garter snake, common king snake, western rattlesnake, deer mouse, and feral pig.

The valley and foothill woodlands and riparian woodlands includes willow, Fremont cottonwood, valley oak, sycamore, black walnut, California buckeye, Mexican elderberry, and Himalayan blackberry, which occurs along much of Kellogg Creek (Reclamation et al. 2009). This habitat supports many birds, reptiles, amphibians, and mammals, including red-legged frog. The freshwater emergent habitat includes meadows with wetland species and stream channels. The vegetation includes tules, bulrushes, and cattail. Wildlife that occurs in this area includes marsh wren, common yellowthroat, red-winged blackbird, red-legged frog, and western pond turtle. The open water habitat of the Los Vaqueros Reservoir provides forage, winter, and brood habitat for Canada goose, American wigeon, gadwall, mallard, northern shoveler, northern pintail, green-winged teal, canvasback, redhead, greater scaup, lesser scaup, bufflehead, common goldeneye, hooded merganser, common merganser, and ruddy ducks; and other habitat values for grebe, sandpiper, pelican, cormorant, egret, heron, and gull.

East Bay Municipal Utility District Reservoirs

The East Bay Municipal Utility District (EBMUD) reservoirs in Alameda and Contra Costa County used to store water within and near the East Bay Municipal Utility District service area include Briones Reservoir, San Pablo Reservoir, Lafayette Reservoir, Upper San Leandro Reservoir, and Lake Chabot. Water stored in these reservoirs includes water from local watersheds, the Mokelumne River watershed, and CVP water supplies.

The Briones Reservoir watershed is characterized by grasslands, chaparral, coastal scrub, oak and bay woodlands, riparian, and freshwater wetlands (EBMUD 1999; EBRPD 1996, 2001, 2013). The San Pablo Reservoir watershed is characterized by grasslands, hardwood forest, coastal scrub, Monterey pine planted along the reservoir shoreline, riparian woodland, and eucalyptus. The Lafayette Reservoir watershed is characterized by grasslands, oak and bay woodland, and coastal scrub. The Upper San Leandro Reservoir watershed includes grasslands, chamise-black sage chaparral, coastal scrub, oak and bay woodland, redwood forest, knobcone forest with a dense manzanita understory, and an 18-acre freshwater marsh. The Lake Chabot watershed includes grasslands, coastal scrub, oak and bay woodland, and riparian and freshwater vegetation.

The grasslands vegetative communities generally include nonnative grasses and native perennial bunchgrass (EBMUD 1999; EBRPD 1996, 2001). The nonnative grasslands include grasses such as wild oat, bromegrass, ryegrass, wild barley, bluegrass, silver hairgrass, and dogtail grass; forbs, including filaree, bur clover, clovers, owl's clover, cat's ear, and English plantain; and brodiaeas, lupine, mariposa lilies, mule's ear, yarrow, farewell to spring, and soap plant. Native grasses include annual and perennial fescues, needlegrass, wild rye, California oatgrass, junegrass, bluegrass, squirreltail, meadow barley, and California bromegrass. Grasslands are used by wildlife similar to those described for other San Francisco Bay Area reservoirs, including hawks, owls, shrikes, swallows, turkey vulture, reptiles, coyote, fox, bobcat, and mice.

The coastal scrub and chaparral vegetation includes coyote brush-scrub, California sagebrush, bitter cherry scrub, manzanita, chamise-black sage, cream bush, California coffeeberry, wild lilac, yerba santa, blackberry, bush monkeyflower, and poison oak (EBMUD 1999; EBRPD 1996, 2001). The woodlands include native and nonnative plants. The native redwood and knobcone pine forests are located at Upper San Leandro Reservoir and provide unique habitat. Nonnative eucalyptus and Monterey pine forests occur at San Pablo Reservoir and Lake Chabot. The eucalyptus trees provide specific habitat for hummingbird, bald eagle, great blue heron, and great egret. The oak and bay woodlands and oak savannas include coast live oak, black oak, valley oak, blue oak, interior live oak, canyon live oak, California bay, California buckeye, and madrone.

Mixed deciduous riparian woodland occurs along perennial streams, including white alder, big-leaf maple, western sycamore, Fremont cottonwood, and black cottonwood that supports frogs, newts, and other amphibians; coast live oak, California bay, and willow woodlands on steep slopes along intermittent streams; and willow riparian scrub along perennial and intermittent streams (EBMUD 1999; EBRPD 1996, 2001). Along springs and seeps, the vegetation includes grasses, including rabbitsfoot grass, saltgrass, bentgrasses, rushes, tules, sedges, horsetails, and cattail; and forbs, including buttercup, watercress, stinging nettle, brass-buttons, mints, duckweed, and pondweed.

P.1.2 Special-Status Species

Species with special status are defined as species that are legally protected or otherwise considered sensitive by federal, state, or local resource agencies. Such species include the following:

- Species listed by the federal government as threatened or endangered.
- Species listed by the state of California as threatened, endangered, or rare (rare status is for plants only).
- Species that are formally proposed for federal listing or are candidates for federal listing as threatened or endangered.
- Species that are candidates for state listing as threatened or endangered.
- Species that meet the definitions of rare, threatened, or endangered under the California Environmental Quality Act.
- Species identified by USFWS as Birds of Conservation Concern.
- Species considered sensitive by BLM or U.S. Forest Service.
- Species identified by CDFW as species of special concern.
- Species designated by California statute as fully protected (e.g., California Fish and Game Code, sections 3511 [birds], 4700 [mammals], and 5050 [reptiles and amphibians] and 5515 [fish]).
- Species, subspecies, and varieties of plants considered by CDFW and California Native Plant Society (CNPS) to be rare, threatened, or endangered in California. The CNPS Inventory of Rare and Endangered Plants of California assigns California Rare Plant Ranks (CRPR) categories for plant species of concern. Only plant species in CRPR categories 1 and 2 are considered special-status plant species in this document.
    - CRPR 1A—Plants presumed to be extinct in California.
    - CRPR 1B—Plants that are rare, threatened, or endangered in California and elsewhere.
    - CRPR 2—Plants that are rare, threatened, or endangered in California but more common elsewhere.

Lists of wildlife and plant species with special status that occur or may occur in portions of the study area are provided in Tables P.1-1 and P.1-2. These resource lists were assembled from resources that include USFWS's IPaC online service, which was used to identify species federally listed as endangered or threatened that occur in or may be affected by projects in the study area. To supplement the IPaC list, the California Natural Diversity Database (CNDDB) was queried (CDFW 2019) for species that are not federally listed.

Table P.1-1 Special-Status Wildlife Species

Common Name	Scientific Name	Status Federal/ State/ CDFW	Habitat/Distribution	Areas with Potential for Occurrence	Potential for Effect	Species Addressed in Reinitiation of Consultation and in EIS (indicated with an X)
Lange's metalmark butterfly	*Apodemia mormo langei*	FE/–/–	Endemic to Antioch Sand Dunes. Restricted to sand dunes along the southern bank of the Sacramento–San Joaquin River and is currently found only at Antioch Dunes NWR. Found in close association with larval host plant, naked-stem buckwheat (*Eriogonum numdum* ssp. *auriculatum*).	Bay-Delta	None. The Antioch sand dunes will not be affected by project activities.	
Conservancy fairy shrimp	*Branchinecta conservatio*	FE/–/–	Large vernal pools and seasonal wetlands, ~ 1 acre in size. Known to occur in suitable habitat on the San Luis NWR Complex, Eastside Bypass, and along the San Joaquin River. Currently found in disjunct and fragmented habitats across the Central Valley of California from Tehama County to Merced County and at two southern California locations on the Los Padres National Forest in Ventura County.	Sacramento River, Feather River, Yolo Bypass, Sutter Bypass San Joaquin River, Bay-Delta	Moderate. Some activities could occur in the vicinity of vernal pools.	
Longhorn fairy shrimp	*Branchinecta longiantenna*	FE/–/–	Vernal pool/seasonal wetlands. Known distribution extends from Contra Costa and Alameda Counties to San Luis Obispo County and also includes Merced County. Within this geographic range, it is extremely rare in vernal pools and swales. Known to occur in suitable habitat on the San Luis NWR Complex.	Bay-Delta, San Joaquin River	Moderate. Some activities could occur in the vicinity of vernal pools.	

Common Name	Scientific Name	Status Federal/ State/ CDFW	Habitat/Distribution	Areas with Potential for Occurrence	Potential for Effect	Species Addressed in Reinitiation of Consultation and in EIS (indicated with an X)
Vernal pool fairy shrimp	*Branchinecta lynchi*	FT/–/–	Typically inhabits vernal pools and seasonal wetlands smaller than 2,153 square feet (200 square meters) and less than 2 inches deep; may also occur in larger, deeper pools. Known to occur in suitable habitat on the San Luis NWR.	Sacramento River, Feather River, Yolo Bypass, Sutter Bypass American River, Bay-Delta, San Joaquin River	Moderate. Some activities could occur in the vicinity of vernal pools.	X
Valley elderberry longhorn beetle	*Desmocerus californicus dimorphus*	FT/–/–	Found only in association with its host plant, blue elderberry (*Sambucus nigra* ssp. *caerulea*). In the Central Valley, the elderberry shrub is found primarily in riparian vegetation. Known to occur in elderberry shrubs present in the riparian woodland and expected to occur in suitable habitat in other locations along the San Joaquin River. Recorded at Caswell Memorial State Park and other locations along the Stanislaus River.	Trinity River, Sacramento River, Feather River, American River, San Joaquin River, Stanislaus River, Bay-Delta, San Luis Reservoir	High. Elderberry shrubs are present along drainages where restoration projects are proposed.	X
Delta green ground beetle	*Elaphrus viridis*	FT/–/–	Associated with vernal pool habitats—seasonally wet pools that accumulate in low areas with poor drainage—that occur throughout the Central Valley. Presently known to occur only in Solano County northeast of the San Francisco Bay Area.	Bay-Delta	None. Highly unlikely for the species to occur where restoration projects are proposed.	
Bay checkerspot butterfly	*Euphydryas editha bayensis*	FT/–/–	Associated with specific host plants that typically grow on serpentine soils.	Bay-Delta	None. Suitable habitat for this species would not be affected.	

Common Name	**Scientific Name**	**Status Federal/ State/ CDFW**	**Habitat/Distribution**	**Areas with Potential for Occurrence**	**Potential for Effect**	**Species Addressed in Reinitiation of Consultation and in EIS (indicated with an X)**
Vernal pool tadpole shrimp	*Lepidurus packardi*	FE/–/–	Vernal pool/seasonal wetlands. Endemic to the Central Valley, with most populations located in the Sacramento Valley. This species has also been reported from the Delta to the east side of San Francisco Bay. Known to occur in suitable habitat on the San Luis NWR Complex and at the Great Valley Grasslands State Park.	Sacramento River, Feather River, Yolo Bypass, Sutter Bypass Bay-Delta, San Joaquin River	Moderate. Some activities could occur in the vicinity of vernal pools.	
Trinity bristle snail	*Monadenia infumata setosa*	–/ST/–	Entire range of the species is within the southern Klamath Mountains and within the Shasta-Trinity National Forest. Occurs along riparian corridors and uplands within Klamath mixed conifer forests with a deciduous hardwood understory. Found in moist, well-drained, well-shaded canyons or streamside benches covered with a layer of leaf mold at least 4 inches deep.	Trinity River, Clear Creek, Shasta Lake	Moderate. Flow changes and restoration activities could occur in areas where this species is present.	
Mission blue butterfly	*Plebejus icarioides missionensis*	FE/–/–	Inhabits coastal chaparral and grasslands of the San Francisco peninsula (Twin Peaks), Marin Headlands, Fort Baker in Marin County, and Sun Bruno Mountain in San Mateo County. Three larval host plants: *Lupinus albifrons*, *L. varicolor*, and *L. formosus*.	Bay-Delta	None. No activities are proposed in habitat for this species.	

Common Name	Scientific Name	Status Federal/ State/ CDFW	Habitat/Distribution	Areas with Potential for Occurrence	Potential for Effect	Species Addressed in Reinitiation of Consultation and in EIS (indicated with an X)
Callippe silverspot butterfly	*Speyeria callippe*	FE/–/–	Limited to these sites in the Bay-Delta region: eastern shore of San Francisco Bay, inner coast range of northwestern Contra Costa County south to Castro Valley, Alameda County, west side of the Bay from San Francisco to La Honda, San Mateo County. Found in native grassland and adjacent habitats where the larval host plant, Johnny jump-up (*Viola pedunculata*), is found.	Bay-Delta	None. No activities are proposed in habitat for this species.	
Myrtle's silverspot butterfly	*Speyeria zerene myrtleae*	FE/–/–	Known from four populations in northwestern Marin County and southwestern Sonoma County. Found in coastal dune or prairie habitat. Known population inhabits coastal terrace prairie, costal bluff scrub, and associated nonnative grasslands. Usually found in wind-sheltered areas below 810 feet (250 meters) and within 3 miles of the coast. Larvae host plant is hookedspur violet (*Viola adunca*).	Bay-Delta	None. No activities are proposed in habitat for this species.	
California tiger salamander	*Ambystoma californiense*	FT/ST/–	Small ponds, lakes, or vernal pools in grasslands and oak woodlands for breeding; rodent burrows, rock crevices, or fallen logs for upland cover during dry season.	Sacramento River, Feather River, American River, San Joaquin River, Stanislaus River, Bay-Delta, San Luis Reservoir	Moderate. Suitable habitat is present in areas proposed for restoration and facility improvements.	X

Common Name	Scientific Name	Status Federal/ State/ CDFW	Habitat/Distribution	Areas with Potential for Occurrence	Potential for Effect	Species Addressed in Reinitiation of Consultation and in EIS (indicated with an X)
Western spadefoot toad	*Spea hammondii*	-/-/SSC	Primarily a species of lowland habitats such as washes, floodplains of rivers, alluvial fans, playas, alkali flats (Stebbins 1985), vernal pools, and vernal swales. However, occurs in the foothills and mountains. Prefers areas of open vegetation and short grasses, where the soil is sandy or gravelly. Found in the valley and foothill grasslands, open chaparral, and pine-oak woodlands (USFWS 2005).	Sacramento River, Feather River, American River, San Joaquin River, Stanislaus River, San Luis Reservoir	Moderate. Suitable habitat is present in areas proposed for restoration and facility improvements.	
Shasta salamander	*Hydromantes shastae*	-/ ST/-	Uncommon in limestone areas in vicinity of Shasta Reservoir in Shasta County. Distribution is discontinuous, with numerous, small isolated populations occurring in limestone areas in valley-foothill hardwood-conifer, ponderosa pine and mixed conifer habitat. Found from 1,100 feet (330 meters) to 2,550 feet (773 meters).	Shasta Lake	None. No activities are proposed in habitat for this species.	
Cascades frog	*Rana cascadae*	–/CE/SSC	In California, found in two locations: Siskiyou County and south near Lassen Peak. Elevational range is 750–8,200 feet (230–2,500 meters). Found in water and surrounding vegetation in mountain lakes, small streams, and ponds in meadows up to timber line. Closely restricted to water.	Trinity River, Shasta Lake, upper reaches of Battle Creek, Paynes Creek, Mill Creek	None. No activities are proposed in habitat for this species.	

Common Name	Scientific Name	Status Federal/ State/ CDFW	Habitat/Distribution	Areas with Potential for Occurrence	Potential for Effect	Species Addressed in Reinitiation of Consultation and in EIS (indicated with an X)
Foothill yellow-legged frog	*Rana boylii*	–/CT/SSC	Streams in woodland, forest, mixed chaparral, and wet meadow habitats with rock and gravel substrate and low overhanging vegetation along the edge; usually found near riffles with rocks and sunny banks nearby.	Trinity River, Shasta Lake, upper reaches of Battle Creek, Paynes Creek, Mill Creek, Stanislaus River, Sacramento River, Bay-Delta	High. Restoration is proposed in areas that support habitat for this species.	
California red-legged frog	*Rana draytonii*	FT/–/SSC	Permanent and semipermanent aquatic habitats such as creeks and cold water ponds, with emergent and submergent vegetation; may aestivate in rodent burrows or cracks during dry periods.	Trinity River, Shasta River/Shasta Lake, Sacramento River, Feather River, American River, San Joaquin River, Stanislaus River, Bay-Delta, San Luis Reservoir	High. Restoration is proposed in areas that support habitat for this species.	X
Western pond turtle	*Emmys marmorata*	–/–/SSC	Inhabits slow-moving streams, sloughs, ponds, irrigation and drainage ditches, and adjacent upland areas. Potentially occurs near New Melones Reservoir. Recorded within Whiskeytown Lake and Clear Creek and near Lewiston Reservoir. Known to occur in suitable habitat on the San Luis NWR Complex, in the Mendota Wildlife Area, and at Mendota Pool; expected to occur in suitable habitat in other locations in the San Joaquin River Restoration Area.	Trinity River, Shasta River/Shasta Lake, Sacramento River, Feather River, American River, San Joaquin River, Stanislaus River, Bay-Delta, San Luis Reservoir	High. Restoration is proposed in areas that support habitat for this species.	

Common Name	Scientific Name	Status Federal/ State/ CDFW	Habitat/Distribution	Areas with Potential for Occurrence	Potential for Effect	Species Addressed in Reinitiation of Consultation and in EIS (indicated with an X)
Blunt-nosed leopard lizard	*Gambelia sila*	FE/SE/FP	Resident of sparsely vegetated grasslands, alkali flats, and washes. Prefers flat areas with open space for running, avoiding densely vegetated areas. Seeks cover in mammal burrows, under shrubs or structures such as fence posts; does not excavate its own burrows. Semiarid grasslands, alkali flats, and washes.	San Joaquin River	None. No activities are proposed in habitat for this species.	
Alameda whipsnake	*Masticophis lateralis euryxanthus*	FT/ST/–	Valleys, foothills, and low mountains associated with northern coastal scrub or chaparral habitat; requires rock outcrops for cover and foraging.	Bay-Delta	None. No activities are proposed in habitat for this species.	
San Francisco garter snake	*Thamnophis sirtalis tetrataenia*	FE/SE/FP	Sloughs, canals, low gradient streams and freshwater marsh habitats where there is a prey base of small fish and amphibians; also found in irrigation ditches and rice fields; requires grassy banks and emergent vegetation for basking and areas of high ground protected from flooding during winter.	Bay-Delta	None. No activities are proposed in habitat for this species.	

Common Name	Scientific Name	Status Federal/ State/ CDFW	Habitat/Distribution	Areas with Potential for Occurrence	Potential for Effect	Species Addressed in Reinitiation of Consultation and in EIS (indicated with an X)
Giant garter snake	*Thamnophis gigas*	FT/ST/–	Marshes, ponds, sloughs, small lakes, low-gradient streams, and other waterways, and in agricultural wetlands, including irrigation and drainage canals, rice fields, and adjacent uplands. Current distribution extends from near Chico in Butte County south to the Mendota Wildlife Area in Fresno County. Known from White Slough/Caldoni Marsh and Yolo Basin/Willow Slough. Known to occur in suitable habitat on the San Luis NWR Complex and in the Mendota Wildlife Area; reported from Mendota Pool.	Sacramento River, Feather River, American River, Yolo Bypass, Sutter Bypass, Bay-Delta, San Joaquin River	Moderate. Suitable habitat is present in areas proposed for restoration and facility improvements.	X
Tricolored blackbird (nesting colony)	*Agelaius tricolor*	–/ST[1]/SSC	Nests colonially in tules, cattails, willows, thistles, blackberries, and other dense vegetation. Forages in grasslands and agricultural fields. Reclamation (2010) concluded this species occurs near New Melones Reservoir. Suitable nesting and foraging habitat is present in the upper Sacramento River area. Known to occur in suitable habitat on the San Luis NWR Complex and other sites in the Yolo Bypass.	Sacramento River, Feather River, Yolo Bypass, Sutter Bypass, American River, Bay-Delta, Stanislaus River	Moderate. Suitable habitat is present in areas proposed for restoration and facility improvements.	

[1] Emergency protection under CESA granted on December 3, 2014, by the California Fish and Game Commission (FGC). FGC voted to list as Threatened on April 19, 2018, official notice pending.

Common Name	Scientific Name	Status Federal/ State/ CDFW	Habitat/Distribution	Areas with Potential for Occurrence	Potential for Effect	Species Addressed in Reinitiation of Consultation and in EIS (indicated with an X)
Tule greater white-fronted goose (wintering)	*Anser albifrons elgasi*	–/–/SSC	Winters in California. Associated with dense tule–cattail marsh habitat. Has been documented near Sherman Island and at various locations in the Suisun Marsh. Winters at Sacramento Valley wildlife refuges and surrounding rice fields, Suisun Marsh, and Grizzly Island Wildlife Area.	Sacramento River, Bay-Delta	Moderate. Suitable habitat is present in areas proposed for restoration.	
Pallid bat	*Antrozous pallidus*	–/–/SSC	Occurs in a variety of habitats from desert to coniferous forest; most closely associated with oak, yellow pine, redwood, and giant sequoia habitats in northern California; relies heavily on trees for cavity roosts, but will use crevices in human-made structures including buildings.	Trinity River, Clear Creek, Shasta River/Shasta Lake, Sacramento River, Feather River, American River, Yolo Bypass, Stanislaus River, San Joaquin River, Bay-Delta, San Luis Reservoir, New Melones Reservoir	Moderate. Suitable habitat is present in areas proposed for restoration.	
Long-eared owl	*Asio otis*	–/–/SSC	Conifer, oak, riparian, pinyon-juniper, and desert woodlands that are either open or are adjacent to grasslands, meadows, or shrublands (Shuford and Gardali 2008).	Sacramento River, Feather River, Yolo Bypass, Bay-Delta, San Joaquin River	Moderate. Suitable habitat is present in areas proposed for restoration.	

Common Name	Scientific Name	Status Federal/ State/ CDFW	Habitat/Distribution	Areas with Potential for Occurrence	Potential for Effect	Species Addressed in Reinitiation of Consultation and in EIS (indicated with an X)
Oak titmouse	*Baeolophus inornatus*	BCC/–/–	Oak woodlands, including scrub oak woodland, from southwest Oregon to northwest Baja California (Cornell Lab of Ornithology 2017).	Trinity River, Clear Creek, Shasta River/Shasta Lake, Sacramento River, Feather River, American River, Yolo Bypass, Stanislaus River, San Joaquin River, Bay-Delta, San Luis Reservoir, New Melones Reservoir	Moderate. Suitable habitat is present in areas proposed for restoration.	
Northern harrier	*Circus cyaneus*	–/–/SSC	Forages in marshes, grasslands, and ruderal habitats; nests in extensive marshes and wet fields.	Sacramento River, Feather River, Yolo Bypass, Bay-Delta, San Joaquin River	High. Suitable habitat is present in areas proposed for restoration.	

Common Name	Scientific Name	Status Federal/ State/ CDFW	Habitat/Distribution	Areas with Potential for Occurrence	Potential for Effect	Species Addressed in Reinitiation of Consultation and in EIS (indicated with an X)
Nuttall's woodpecker	*Picoides nuttalii*	BCC/–/–	Oak woodlands in California. Also uses wooded suburban areas and woodlands near streams farther south in its range where oak trees are scarcer.	Trinity River, Clear Creek, Shasta River/Shasta Lake, Sacramento River, Feather River, American River, Yolo Bypass, Stanislaus River, San Joaquin River, Bay-Delta, San Luis Reservoir, New Melones Reservoir	Moderate. Suitable habitat is present in areas proposed for restoration.	
Short-eared owl (nesting)	*Asio flammeus*	–/–/SSC	Widespread winter migrant, found primarily in the Central Valley, in the western Sierra Nevada foothills, and along the coastline. Usually found in open areas with few trees, such as annual and perennial grasslands, prairies, dunes, meadows, irrigated lands, and saline and fresh emergent wetlands. Occasionally still breeds in northern California. Known to occur in suitable habitat on the San Luis NWR Complex, where it possibly also nests. Breeding range includes coastal areas in Del Norte and Humboldt Counties, the Bay-Delta, northeastern Modoc plateau, the east side of the Sierra from Lake Tahoe south to Inyo County, and the San Joaquin Valley.	Sacramento River, Feather River, Yolo Bypass, Sutter Bypass, Bay-Delta, San Joaquin River	Moderate. Suitable habitat is present in areas proposed for restoration.	

Common Name	Scientific Name	Status Federal/ State/ CDFW	Habitat/Distribution	Areas with Potential for Occurrence	Potential for Effect	Species Addressed in Reinitiation of Consultation and in EIS (indicated with an X)
Burrowing owl (nesting and wintering sites)	*Athene cunicularia*	–/–/SSC	Nests and forages in grasslands, shrub lands, deserts, and agricultural fields, especially where ground squirrel burrows are present. Occurs near New Melones Reservoir. Unlikely to occur along the Sacramento River corridor due to a lack of suitable nesting habitat. Known to occur in suitable habitat in the Yolo Bypass, in the Chowchilla Bypass, on the San Luis NWR Complex, and at Mendota Pool.	Sacramento River, Feather River, American River, Yolo Bypass, Sutter Bypass, Stanislaus River, San Joaquin River, Bay-Delta, San Luis Reservoir	Moderate. Suitable habitat is present in areas proposed for restoration and facility improvements.	
Marbled murrelet	*Brachyramphus marmoratus*	FT/SE/–	Pacific Ocean, but nesting occurs in old growth forest.	Bay-Delta	None. No activities are proposed in suitable habitat for this species.	
Swainson's hawk (nesting)	*Buteo swainsoni*	BCC/ST/–	Nests in riparian woodlands, roadside trees, tree rows, isolated trees, woodlots, and trees in farmyards and rural residences. Forages in grasslands and agricultural fields in Central Valley. Occurs near New Melones Reservoir. Known to nest in suitable habitat on the San Luis NWR Complex and Great Valley Grasslands State Park and other areas along the San Joaquin River. Suitable nesting and foraging habitat is present along Sacramento River.	Sacramento River, Feather River, American River, Yolo Bypass, Sutter Bypass, San Joaquin River, Stanislaus River, Bay-Delta, San Luis Reservoir	Moderate. Suitable habitat is present in areas proposed for restoration and facility improvements.	

Common Name	Scientific Name	Status Federal/ State/ CDFW	Habitat/Distribution	Areas with Potential for Occurrence	Potential for Effect	Species Addressed in Reinitiation of Consultation and in EIS (indicated with an X)
Western snowy plover	*Charadrius alexandrines nivosus*	FT/–/SSC	Coastal beaches above the normal high tide limit in flat, open areas with sandy or saline substrates; vegetation and driftwood are usually sparse or absent.	Bay-Delta	None. No activities are proposed in suitable habitat for this species.	
Black tern	*Childonias niger*	–/–/SSC	Nests in freshwater marsh, forages for fish and insects in open water, rice fields, and marsh. Uncommon visitor in suitable habitat in the area of analysis; expected during the nonbreeding season along the San Joaquin River.	Sacramento River, Feather River, Yolo Bypass, Sutter Bypass, San Joaquin River, Bay-Delta	Moderate. Suitable habitat is present in areas proposed for restoration.	
Western yellow-billed cuckoo (nesting)	*Coccyzus americanus occidentalis*	BCC/FT/SE/–	Densely foliaged, deciduous trees and shrubs, especially willows, required for roosting sites. An uncommon to rare summer resident of valley foothill and desert riparian habitats in scattered locations in California. Breeding pairs known from Sacramento Valley. Reclamation (2010) concluded this species could potentially occur near New Melones Reservoir. Detected by BDCP surveys in 2009 near Walnut Grove. Likely to nest and forage in the upper Sacramento River area.	Trinity River, Clear Creek, Sacramento River, Feather River, Bay-Delta, New Melones Reservoir, San Joaquin Reservoir	Moderate. Suitable habitat is present in areas proposed for restoration.	X

Common Name	Scientific Name	Status Federal/ State/ CDFW	Habitat/Distribution	Areas with Potential for Occurrence	Potential for Effect	Species Addressed in Reinitiation of Consultation and in EIS (indicated with an X)
Townsend's big-eared bat	*Corynorhinus townsendii*	–/–/SSC	Roosts in caves, tunnels, mines, and dark attics of abandoned buildings; very sensitive to disturbances and may abandon a roost after one onsite visit.	Trinity River, Clear Creek, Shasta River/Shasta Lake, Sacramento River, Feather River, American River, Yolo Bypass, Stanislaus River, San Joaquin River, Bay-Delta, San Luis Reservoir, New Melones Reservoir	Low. Suitable foraging habitat is present in areas proposed for restoration.	
Western mastiff bat	*Eumops perotis*	–/–/SSC	Primarily a cliff-dwelling species. Roosts generally under exfoliating rock slabs (e.g., granite, sandstone or columnar basalt). Also been found in similar crevices in large boulders and buildings. Forages in broad open areas, including desert washes, flood plains, chaparral, oak woodland, open ponderosa pine forest, grassland, and agricultural areas (Western Bat Working Group 2017).	Sacramento River, Feather River, American River, Yolo Bypass, Stanislaus River, San Joaquin River, Bay-Delta	Low. Suitable foraging habitat is present in areas	

Common Name	Scientific Name	Status Federal/ State/ CDFW	Habitat/Distribution	Areas with Potential for Occurrence	Potential for Effect	Species Addressed in Reinitiation of Consultation and in EIS (indicated with an X)
Western red bat	*Lasiurus blossevillii*	–/–/SSC	Roosts in the foliage of trees or shrubs. Day roosts are commonly in edge habitats adjacent to streams or open fields, in orchards, and urban areas. May be associated with intact riparian habitat (particularly willows, cottonwoods, and sycamores). This species may also occasionally use caves (Western Bat Working Group 2017).	Trinity River, Clear Creek, Shasta River/Shasta Lake, Sacramento River, Feather River, American River, Yolo Bypass, Stanislaus River, San Joaquin River, Bay-Delta, San Luis Reservoir, New Melones Reservoir	Moderate. Suitable habitat is present in areas proposed for restoration.	
Yellow warbler (nesting)	*Dendroica petechia brewsteri*	BCC/–/SSC	Nests in riparian woodland and riparian scrub habitats. Forages in a variety of wooded and shrub habitats during migration. Reclamation (2010) concluded this species occurs near New Melones Reservoir. No recent nesting records, but potential nesting habitat present; known to occur during migration in suitable habitat on the San Luis NWR. Could nest and forage in the upper Sacramento River area. Likely to use riparian woodlands during migration.	Trinity River, Clear Creek, Shasta River/Shasta Lake, Sacramento River, Feather River, New Melones Reservoir, San Joaquin River	Moderate. Suitable habitat is present in areas proposed for restoration.	

Common Name	Scientific Name	Status Federal/ State/ CDFW	Habitat/Distribution	Areas with Potential for Occurrence	Potential for Effect	Species Addressed in Reinitiation of Consultation and in EIS (indicated with an X)
White-tailed kite (nesting)	*Elanus leucurus*	–/–/FP	Nests in woodlands and isolated trees; forages in grasslands, shrub lands, and agricultural fields. Common to uncommon and a year-round resident in the Central Valley, in other lowland valleys, and along the entire length of the coast. Recent surveys in Yolo and Sacramento Counties have documented active nest sites in riparian habitats in the Yolo Bypass and along Steamboat and Georgiana Sloughs and along the Sacramento River. Suitable nesting and foraging habitat is present along the upper Sacramento River. Expected to occur in suitable habitat along San Joaquin River and in Yolo Bypass.	Shasta River/Shasta Lake, Sacramento River, Feather River, Yolo Bypass, Sutter Bypass, American River, San Joaquin River, Bay-Delta, San Luis Reservoir	Moderate. Suitable habitat is present in areas proposed for restoration.	
Saltmarsh common yellowthroat	*Geothlypis trichas sinuosa*	BCC/–/SSC	Primarily brackish marsh, but also brackish and fresh woody swamps and riparian areas. Ranges generally in the San Francisco Bay Area.	Bay-Delta	Moderate. Suitable habitat is present in areas proposed for restoration.	
Greater sandhill crane (nesting and wintering)	*Grus canadensis tabida*	–/ST/FP	Eight distinct wintering locations in the Central Valley from Chico/Butte Sink on the north to Pixley NWR near Delano on the south, with more than 95% occurring within the Sacramento Valley between Butte Sink and the Delta. Unlikely to breed in the upper Sacramento River area. Known to occur during winter in suitable habitat on the San Luis NWR Complex, along the San Joaquin River, and in the Delta.	Sacramento River, Feather River, Yolo Bypass, Sutter Bypass, San Joaquin River	Moderate. Suitable habitat is present in areas proposed for restoration.	

Common Name	Scientific Name	Status Federal/ State/ CDFW	Habitat/Distribution	Areas with Potential for Occurrence	Potential for Effect	Species Addressed in Reinitiation of Consultation and in EIS (indicated with an X)
Bald eagle (nesting and wintering)	*Haliaeetus leucocephalus*	BCC/FD/SE/FP	Requires large bodies of water or free-flowing rivers with abundant fish and adjacent snags or other perches for foraging. Occurs near New Melones Reservoir, Whiskeytown Lake, Trinity Lake, and Lewiston Reservoir. Known to nest in suitable habitat around Lake Millerton and in the Chowchilla Bypass.	Trinity River, Clear Creek, Shasta River/Shasta Lake, Sacramento River, Feather River, American River, Yolo Bypass, Sutter Bypass, Stanislaus River, San Joaquin River, Bay-Delta, San Luis Reservoir	Moderate. Suitable habitat is present in areas proposed for restoration.	
Least bittern (nesting)	*Ixobrychus exilis*	BCC/–/SSC	Rare to uncommon April to September nester in large, fresh emergent wetlands of cattails and tules in the Sacramento and San Joaquin Valleys. Occurs in fresh water marsh habitats in the Yolo Bypass, east of the Sacramento River, and in the western Delta. Uncommon but regular breeder in suitable habitat in the San Joaquin Valley.	Sacramento River, Feather River, Yolo Bypass, Sutter Bypass, Bay-Delta, San Joaquin River	Moderate. Suitable habitat is present in areas proposed for restoration.	
California black rail	*Laterallus jamaicensis coturniculus*	BCC/ST/FP	Tidal marshes in the northern San Francisco Bay estuary, Tomales Bay, Bolinas Lagoon, the Delta, Morro Bay, the Salton Sea, and the lower Colorado River. Found recently at several inland freshwater sites in the Sierra Nevada foothills in Butte, Yuba, and Nevada Counties, the Cosumnes River Preserve in south Sacramento County, and Bidwell Park in Chico, Butte County.	Bay-Delta	Moderate. Suitable habitat is present in areas proposed for restoration.	

Common Name	Scientific Name	Status Federal/ State/ CDFW	Habitat/Distribution	Areas with Potential for Occurrence	Potential for Effect	Species Addressed in Reinitiation of Consultation and in EIS (indicated with an X)
Least tern	*Sternula antillarum*	FE/SE/FP	Sandy or gravelly areas along bays, estuaries, lagoons, within the Bay-Delta.	Bay-Delta	Low. Suitable habitat is present in areas proposed for restoration.	X
Yellow-breasted Chat	*Icteria virens*	–/–/SSC	Breeds in areas with dense shrubbery, including agricultural areas, forest edges, swamps, and edges of streams and ponds. Breeding habitat is often blackberry bushes (Cornell Lab of Ornithology 2017).	Trinity River, Clear Creek, Shasta River/Shasta Lake, Sacramento River, Feather River, American River, Yolo Bypass, Stanislaus River, San Joaquin River, Bay-Delta, San Luis Reservoir, New Melones Reservoir	Moderate. Suitable habitat is present in areas proposed for restoration.	
Suisun song sparrow	*Melospiza melodia maxillaris*	BCC/–/SSC	Brackish marshes around Suisun Bay.	Bay-Delta	Moderate. Suitable habitat is present in areas proposed for restoration.	

Common Name	Scientific Name	Status Federal/ State/ CDFW	Habitat/Distribution	Areas with Potential for Occurrence	Potential for Effect	Species Addressed in Reinitiation of Consultation and in EIS (indicated with an X)
Osprey (nesting)	*Pandion haliaetus*	–/–/WL	Nests on platform of sticks at the top of large snags, dead-topped trees, on cliffs, or on human-made structures. Requires open, clear waters for foraging. Uses rivers, lakes, reservoirs, bays, estuaries, and surf zones. Reclamation (2010) concluded this species occurs near New Melones Reservoir. Known to nest along the Sacramento River.	Trinity River, Clear Creek, Shasta River/Shasta Lake, Sacramento River, Feather River, Yolo Bypass, Sutter Bypass, American River, New Melones Reservoir	High. Suitable habitat is present in areas proposed for restoration.	
White-faced ibis (nesting colony)	*Plegadis chihi*	–/–/WL	Forages in wetlands and irrigated or flooded croplands and pastures. Breeds colonially in dense freshwater marsh. Known to occur in suitable habitat on the San Luis NWR Complex and other sites in the Restoration Area and Yolo Bypass.	Feather River, Yolo Bypass, Sutter Bypass, American River, San Joaquin River	Moderate. Suitable habitat is present in areas proposed for restoration.	
California Ridgway's rail	*Rallus obsoletus*	FE/SE/FP	Dense marshy areas of the Bay-Delta region.	Bay-Delta	Moderate. Suitable habitat is present in areas proposed for restoration.	X

Common Name	Scientific Name	Status Federal/ State/ CDFW	Habitat/Distribution	Areas with Potential for Occurrence	Potential for Effect	Species Addressed in Reinitiation of Consultation and in EIS (indicated with an X)
Bank swallow (nesting)	*Riparia*	–/ST/–	Neotropical migrant found primarily in riparian and other lowland habitats in California west of the deserts during the spring-fall period. In summer, restricted to riparian, lacustrine, and coastal areas with vertical banks, bluffs, and cliffs with fine-textured or sandy soils, into which it digs nesting holes. Approximately 75% of the current breeding population in California occurs along banks of the Sacramento and Feather Rivers in the northern Central Valley.	Trinity River, Clear Creek, Sacramento River, Feather River, American River, Yolo Bypass, Sutter Bypass, New Melones Reservoir, San Joaquin River, Bay-Delta	Moderate. Suitable habitat may be present in areas proposed for restoration. This species is also vulnerable to changes in flow regimes.	
Least bell's vireo (nesting)	*Vireo bellii pusillus*	FE/SE/–	Nests in dense, low, shrubby vegetation, generally early successional stages in riparian areas, particularly cottonwood-willow forest, but also brushy fields, young second-growth forest or woodland, scrub oak, coastal chaparral, and mesquite brush lands, often near water in arid regions. Observed in Yolo Bypass Wildlife Area. Successfully nested at the San Joaquin River NWR in 2005 and 2006.	Sacramento River, Yolo Bypass, Sutter Bypass, Bay-Delta, San Joaquin River	Moderate. Suitable habitat is present in areas proposed for restoration.	X
Nelson's antelope squirrel	*Ammospermophi lus nelsoni*	–/ST/–	Dry sparsely vegetated loam soils and needs widely scattered shrubs, forbs, and grasses in broken terrain with gullies and washes.	San Joaquin River	None. No activities are proposed in suitable habitat for this species.	

Common Name	**Scientific Name**	**Status Federal/ State/ CDFW**	**Habitat/Distribution**	**Areas with Potential for Occurrence**	**Potential for Effect**	**Species Addressed in Reinitiation of Consultation and in EIS (indicated with an X)**
Ring-tailed cat	*Bassariscus astutus*	–/–/FP	Wooded and brushy areas, especially near water courses. Species distribution not well known. Potentially suitable habitat is present along the Sacramento River corridor.	Shasta River/Shasta Lake, Sacramento River, Feather River, Bay-Delta, San Joaquin River	Moderate. Suitable habitat is present in areas proposed for restoration.	
Fresno kangaroo rat	*Dipodomys nitratoides exilis*	FE/SE/–	Nearly level, light, friable soils in chenopod scrub and grassland communities.	San Joaquin River	None. No activities are proposed in suitable habitat for this species.	
Southern sea otter	*Enhydra lutris nereis*	FT/–/FP	Found in nearshore marine environments with large giant kelp and bull kelp sea beds from Ano Nuevo, San Mateo County to Point Sal, Santa Barbara County. Uses nearshore waters adjacent to rock coasts, near points of land, or large bays for cover, sleeping, foraging. Also rafts in open water off sandy beaches.	Bay-Delta	None. No activities are proposed in suitable habitat for this species.	

Common Name	Scientific Name	Status Federal/ State/ CDFW	Habitat/Distribution	Areas with Potential for Occurrence	Potential for Effect	Species Addressed in Reinitiation of Consultation and in EIS (indicated with an X)
California wolverine	*Gulo gulo*	PT/ST/FP	Scarce resident of North Coast mountains and Sierra Nevada. Ranges from Del Norte and Trinity Counties east through Siskiyou and Shasta Counties, and south through Tulare County. Utilizes Douglas-fir and mixed conifer habitats, red fir, lodgepole, wet meadow, and montane riparian habitats. Elevation in coastal ranges from 1,600 to 4,800 feet (500 to 1,500 meters), and elevation in the Sierra Nevada ranges from 4,300 to 7,300 feet (1,300–2,300 meters).	Trinity River, Shasta River/Shasta Lake, Battle Creek, Paynes Creek, Mill Creek, Butte Creek	None. No activities are proposed in suitable habitat for this species.	
Humboldt marten	*Martes caurina humboldtensis*	–/CE/SSC	Known from coastal northwestern California. Optimal habitats ae mixed evergreen forests with more than 40% crown closure, with large trees and snags. Important habitats include red fir, lodgepole pine, subalpine conifer, mixed conifer, Jeffrey pine, and eastside pine.	Trinity River	None. No activities are proposed in suitable habitat for this species.	
Riparian (= San Joaquin Valley) woodrat	*Neotoma fuscipes riparia*	FE/–/SSC	Historically found in riparian habitat along the San Joaquin, Stanislaus, and Tuolumne Rivers. Now known only from Caswell Memorial State Park on the Stanislaus River near its confluence with the San Joaquin River in very low gradient portion of river. No actions proposed that could affect this species in this area. Last reported at Caswell Memorial State Park in 2002. Likely still extant.	Bay-Delta, Stanislaus River, San Joaquin River	Moderate. Suitable habitat is present in areas proposed for restoration.	X

Common Name	Scientific Name	Status Federal/ State/ CDFW	Habitat/Distribution	Areas with Potential for Occurrence	Potential for Effect	Species Addressed in Reinitiation of Consultation and in EIS (indicated with an X)
Fisher	*Pekania pennanti*	–/ST/SSC	Resident of Sierra Nevada, Cascades, and Klamath Mountains. Also found in a few areas in North Coast Ranges. Occurs in intermediate to large-tree stages of coniferous forests and deciduous-riparian habitats with a high percentage of canopy closure.	Trinity River, tributaries to upper Sacramento, Battle, Paynes, Mill, and Deer Creeks	None. No activities are proposed in suitable habitat for this species.	
Salt marsh harvest mouse	*Reithrodontomys raviventris*	FE/SE/FP	Found only in saline emergent wetlands of San Francisco Bay and its tributaries. Pickleweed saline emergent wetland is preferred habitat, where it may be locally common. Grasslands adjacent to pickleweed marsh are used, but only when new grass growth affords suitable cover in spring and summer. Reported occurrences of the salt marsh harvest mouse from within the Delta are restricted to salt and brackish tidal marshes along the northern edge of the Sacramento River and the southern edge of the San Joaquin River as far east as the vicinity of Collinsville and Antioch, west of Sherman Island.	Bay-Delta	High. Suitable, occupied habitat is present in areas proposed for restoration.	X
Suisun shrew	*Sorex ornatus sinuosus*	–/–/SSC	Historically known from tidal wetlands of Solano, Napa, and eastern Sonoma Counties. Currently limited to the northern borders of San Pablo and Suisun Bays.	Bay-Delta	Moderate. Suitable habitat is present in areas proposed for restoration.	

Common Name	Scientific Name	Status Federal/ State/ CDFW	Habitat/Distribution	Areas with Potential for Occurrence	Potential for Effect	Species Addressed in Reinitiation of Consultation and in EIS (indicated with an X)
Riparian woodrat	*Neotoma fuscipes riparia*	FE/--/SSC	Historically found in riparian habitat along the San Joaquin, Stanislaus, and Tuolumne Rivers. Now known only from Caswell Memorial State Park on the Stanislaus River near its confluence with the San Joaquin River in very low gradient portion of river.	Bay-Delta, Stanislaus, San Joaquin	Moderate. Suitable habitat is present in areas proposed for restoration.	
Riparian brush rabbit	*Sylvilagus bachmani riparius*	FE/SE/–	Historical distribution may have extended along portions of the San Joaquin River and its tributaries on the valley floor from at least Stanislaus County to the Delta. Currently restricted to several populations at Caswell Memorial State Park, near Manteca in San Joaquin County, along the Stanislaus River, along Paradise Cut (a channel of the San Joaquin River in the southern part of the Delta), and a recent reintroduction on private lands adjacent to the San Joaquin River NWR.	Bay-Delta, Stanislaus River, San Joaquin River	Moderate. Suitable habitat is present in areas proposed for restoration.	X
San Joaquin kit fox	*Vulpies macrotis mutica*	FT/ST/–	Saltbush scrub, grassland, oak, savanna, and freshwater scrub.	Bay-Delta, San Joaquin River	None. No activities are proposed in suitable habitat for this species.	

Common Name	Scientific Name	Status Federal/ State/ CDFW	Habitat/Distribution	Areas with Potential for Occurrence	Potential for Effect	Species Addressed in Reinitiation of Consultation and in EIS (indicated with an X)
Sierra Nevada red fox	*Vulpes vulpes necator*	FC/ST/–	Range is throughout high elevations of the Sierra Nevada from Tulare County northward to Sierra County, and from Mount Shasta and Lassen Peak westward to the Trinity Mountains, Trinity County. Seldom seen below 5,000 feet (1,500 meters) and most often observed above 6,889 feet (2,100 meters). Occurs at low densities. Occupied habitat is a composite of high elevation barren, conifer and shrub habitat, montane meadows, subalpine woodlands, and fell-fields. Dens in natural cavities, earthen dens, boulder piles, and vacant space under human-made structures.	Upper reaches of Battle Creek, Paynes Creek, Mills Creek, Dear Creek, Butte Creek	None. No activities are proposed in suitable habitat for this species.	

Abbreviations
Status Codes
BCC = bird species of conservation concern
CE = candidate for state listing as endangered under the California Endangered Species Act
CT = candidate for state listing as threatened under the California Endangered Species Act
FC = candidate for federal listing under the federal Endangered Species Act
FD = federal delisted
FE = federally listed as endangered
FP = California fully protected species
FT = federally listed as threatened
PT = proposed threatened
SE = state-listed as endangered
SSC = California species of special concern
ST = state-listed as threatened
WL = California Department of Fish and Wildlife watch list
Other Abbreviations
BDCP = Bay Delta Conservation Plan
CDFW = California Department of Fish and Wildlife
NWR = National Wildlife Refuge

Table P.1-2. Special-Status Plant Species

Common Name	Scientific Name	Status Federal/State/ CRPR*	Habitat/Distribution	Areas with Potential for Occurrence	Potential for Effect	Species Addressed in Reinitiation of Consultation (indicated with an X)
Adobe sanicle	*Sanicula maritima*	–/SR/1B.1	Clay and serpentine soils in chaparral, coastal prairie, meadow and seeps, and annual grassland.	Bay-Delta	None. No activities are proposed within suitable habitat in the known range of the species.	
Beach layia	*Layia carnosa*	FE/SE/1B.1	Coastal dunes and coastal scrub on sandy soils.	Bay-Delta	None. No activities are proposed within suitable habitat in the known range of the species.	
Bensoniella	*Bensoniella oregona*	–/SR/1B.1	Bogs and fens, meadows and seeps, and mesic areas in lower montane coniferous forest.	Trinity River	None. No activities are proposed within suitable habitat in the known range of the species.	
Bogg's Lake hedge-hyssop	*Gratiola heterosepala*	–/SE/1B.2	Marshy and swampy lake margins, vernal pools. Known from north Delta and from the Sacramento and San Joaquin Valleys. CNDDB documents occurrences at Jepson Prairie, the Rio Linda area, and Mather County Park.	Sacramento River, Yolo Bypass, Sutter Bypass, Bay-Delta, San Joaquin River	None. No activities are proposed within suitable habitat in the known range of the species.	
Bolander's water hemlock	*Cicuta maculata* var. *bolanderi*	–/–/2.1	Coastal fresh or brackish marshes and swamps in Contra Costa, Sacramento, Marin, and Solano Counties. Present at north and central Delta and Suisun Marsh.	Sacramento River, Bay-Delta, Suisun Marsh	High. Restoration activities are proposed within suitable habitat in the known range of the species.	

Common Name	Scientific Name	Status Federal/State/ CRPR*	Habitat/Distribution	Areas with Potential for Occurrence	Potential for Effect	Species Addressed in Reinitiation of Consultation (indicated with an X)
Butte County meadowfoam	*Limnanthes floccosa* ssp.*californica*	FE/SE/1B.1	Vernal pools and swales in annual grassland.	Sacramento River and its tributaries in Butte County	None. No activities are proposed within suitable habitat in the known range of the species.	
Legenere	*Legenere limosa*	–/–/1B.1	Vernal pools and swales in annual grassland.	Sacramento River, Bay-Delta	None. No activities are proposed within suitable habitat in the known range of the species.	
Sandford's arrowhead	*Saggitaria sanfordii*	–/–/1B.2	Freshwater mashes and swamps	Sacramento River, Bay-Delta, San Joaquin River	Low. Some activities could occur near marshes and swamps for this species.	
California jewelflower	*Caulanthus californicus*	FE/SE/1B.1	Sandy soils on chenopod scrub, Pinyon and juniper woodland, and annual grassland.	San Joaquin River	None. No activities are proposed within suitable habitat in the known range of the species.	
California seablite	*Suaeda californica*	FE/–/1B.1	Margins of tidal salt marsh.	Bay-Delta	None. No activities are proposed within suitable habitat in the known range of the species.	
Chinese Camp brodiaea	*Brodiaea pallida*	FT/SE/1B.1	Ephemeral streams, often on serpentine, in cismontane woodland and annual grassland.	Stanislaus and Tuolumne Rivers	None. No activities are proposed within suitable habitat in the known range of the species.	
Colusa grass	*Neostapfia colusana*	FT/SE/1B.1	Adobe soils of vernal pools.	Sacramento River, Yolo Bypass, Sutter Bypass, Stanislaus River, San Joaquin River	None. No activities are proposed within suitable habitat in the known range of the species.	
Coulter's goldfields	*Lasthenia glabrata* ssp. *coulteri*	–/–/1B.1	Coastal salt marshes and swamps, playas, vernal pools	Sacramento River, San Joaquin River	None. No activities are proposed within suitable habitat in the known range of the species.	

Common Name	Scientific Name	Status Federal/State/ CRPR*	Habitat/Distribution	Areas with Potential for Occurrence	Potential for Effect	Species Addressed in Reinitiation of Consultation (indicated with an X)
Contra Costa goldfields	*Lasthenia conjugens*	FE/–/1B.1	Wet areas in cismontane woodland, valley and foothill grassland, vernal pools, alkaline playas, or saline vernal pools and swales.	Sacramento River, Bay-Delta	Low. Some activities could occur near vernal pools where this species occurs.	
Crystal Springs fountain thistle	*Cirsium fontinale* var. *fontinale*	FE/SE/1B.1	Serpentine seeps in chaparral openings and valley and foothill grassland.	Bay-Delta	None. No activities are proposed within suitable habitat in the known range of the species.	
Delta button-celery	*Eryngium racemosum*	–/SE/1B.1	Vernally mesic clay depressions in riparian scrub. Extant occurrences recorded along San Joaquin River in Merced County and in south Delta. Reclamation (2010) concluded this species could potentially occur near New Melones Reservoir.	Bay-Delta, Stanislaus River, New Melones Reservoir, San Joaquin River	Moderate. Potentially affected by floodplain restoration activities.	
Delta tule pea	*Lathyrus jepsonii* var. *jepsonii*	–/–/1B.2	Freshwater and brackish marshes and swamps in the Bay-Delta region. Known from north, central, and west Delta, and Suisun Marsh. CNDDB documents occurrences at Snodgrass, Barker, Lindsey, Hass, and Cache Sloughs; Delta Meadows Park; and Calhoun Cut.	Yolo Bypass, Sutter Bypass, Bay-Delta	High. Restoration activities are proposed within suitable habitat in the known range of the species.	
Franciscan manzanita	*Arctostaphylos hookeri* ssp. *franciscana*	FE/–/1B.1	Coastal scrub on serpentine soils. Known from only a single	Bay-Delta	None. No activities are proposed within suitable habitat in the known range of the species.	

Common Name	Scientific Name	Status Federal/State/ CRPR*	Habitat/Distribution	Areas with Potential for Occurrence	Potential for Effect	Species Addressed in Reinitiation of Consultation (indicated with an X)
			occurrence in the Presidio of San Francisco.			
Greene's tuctoria	*Tuctoria greenei*	FE/SR/1B.1	Dry vernal pools.	Shasta River/Shasta Lake, Feather River, Sacramento River, American River, San Joaquin River	None. No activities are proposed within suitable habitat in the known range of the species.	
Hairy Orcutt grass	*Orcuttia pilosa*	FE/FE/1B.1	Vernal pools.	San Joaquin River, New Melones Reservoir	None. No activities are proposed within suitable habitat in the known range of the species.	
Hartweg's golden sunburst	*Pseudobahia bahiifolia*	FE/FE/1B.1	Predominantly on northern slopes of rocky, bare areas along rolling hills, shady creeks, adjacent to vernal pools and streams, on heavy clay soils in valley and foothill grasslands and cismontane woodland.	Stanislaus River, Tuolumne River, San Joaquin River.	None. No activities are proposed within suitable habitat in the known range of the species.	
Hoover's spurge	*Chamaesyce hooveri*	FT/–/1B.2	Below the high-water mark of large northern hardpan and volcanic vernal pools.	Sacramento River, Feather River, American River, San Joaquin River	None. No activities are proposed within suitable habitat in the known range of the species.	
Keck's checkerbloom	*Sidalcea keckii*	FE/–/1B.1	Serpentine clay soils in cismontane woodland, valley, and foothill grassland.	Sacramento River, Feather River, American River, Bay-Delta, San Joaquin River.	None. No activities are proposed within suitable habitat in the known range of the species.	
Large-flowered fiddleneck	*Amsinckia grandiflora*	FE/SE/1B.1	Cismontane woodland, valley, and foothill grassland slopes.	Bay-Delta	None. No activities are proposed within suitable habitat in the known range of the species.	

Common Name	Scientific Name	Status Federal/State/ CRPR*	Habitat/Distribution	Areas with Potential for Occurrence	Potential for Effect	Species Addressed in Reinitiation of Consultation (indicated with an X)
Livermore tarplant	*Deinandra bacigalupii*	–/SE/1B.2	Alkaline meadows and seeps.	Bay-Delta	None. No activities are proposed within suitable habitat in the known range of the species.	
Marin western flax	*Hesperolinon congestum*	FT/ST/1B.1	Serpentinite chaparral, serpentinite grassland.	Bay-Delta	None. No activities are proposed within suitable habitat in the known range of the species.	
Mason's lilaeopsis	*Lilaeopsis masonii*	–/SR/1B.1	Brackish or freshwater marshes and swamps, riparian scrub in Bay-Delta region. Known and locally common in certain regions of Delta and in Suisun Marsh. CNDDB documents occurrences of this species in Barker, Lindsey, Cache, and Snodgrass Sloughs as well as in Calhoun Cut.	Bay-Delta	High. Restoration activities are proposed within suitable habitat in the known range of the species.	
North Coast semaphore grass	*Pleuropogon hooverianus*	–/ST/1B.1	Open, mesic areas in broadleafed upland forest, meadows and seeps, and North Coast coniferous forest.	Bay-Delta	None. No activities are proposed within suitable habitat in the known range of the species.	
Pacific manzanita	*Arctostaphylos pacifica*	–/SE/1B.1	Chaparral and coastal scrub. Known only from San Bruno Mountain in San Mateo County.	Bay-Delta	None. No activities are proposed within suitable habitat in the known range of the species.	
Pallid manzanita	*Arctostaphylos pallida*	FT/SE/1B.1	Siliceous shale, sandy or gravelly soils in broadleafed upland forest, closed-cone coniferous forest, chaparral, cismontane woodland, and	Bay-Delta	None. No activities are proposed within suitable habitat in the known range of the species.	

Common Name	Scientific Name	Status Federal/State/ CRPR*	Habitat/Distribution	Areas with Potential for Occurrence	Potential for Effect	Species Addressed in Reinitiation of Consultation (indicated with an X)
			coastal scrub habitats. Known only from the East Bay Hills.			
Palmate-bracted bird's-beak	*Cordylanthus palmatus*	FE/SE/1B.1	Alkaline sites in grassland and chenopod scrub.	Bay-Delta	None. No activities are proposed within suitable habitat in the known range of the species.	
Pitkin marsh lily	*Lilium pitkinense*	FE/SE/1B.1	Mesic, sandy soils in cismontane woodland, meadows and seeps, freshwater marshes, and swamps.	Bay-Delta	None. No activities are proposed within suitable habitat in the known range of the species.	
Presidio clarkia	*Clarkia franciscana*	FE/SE/1B.1	Coastal scrub and grassland, typically on serpentine soils. Known only in the cities of San Francisco and Oakland.	Bay-Delta	None. No activities are proposed within suitable habitat in the known range of the species.	
Presidio manzanita	*Arctostaphylos hookeri* ssp. *ravenii*	FE/SE/1B.1	Serpentine outcrops in chaparral, coastal prairie, and coastal scrub. Known only from the Presidio of San Francisco.	Bay-Delta	None. No activities are proposed within suitable habitat in the known range of the species.	
Red hills vervain	*Verbena californica*	FT/ST/1B.1	Mesic areas along serpentine seeps or creeks surrounded by cismontane woodland or grassland. Known only from the Red Hills.	Tuolumne River	None. No activities are proposed within suitable habitat in the known range of the species.	
Robust spineflower	*Chorizanthe robusta* var. *robusta*	FE/–/1B.1	Sandy or gravelly areas in coastal scrub, coastal dunes, and openings in cismontane woodland.	Bay-Delta	None. No activities are proposed within suitable habitat in the known range of the species.	
Sacramento Orcutt grass	*Orcuttia californica* var. *viscida*	FE/SE/1B.1	Vernal pools.	Sacramento River	None. No activities are proposed within suitable habitat in the known range of the species.	

Common Name	Scientific Name	Status Federal/State/ CRPR*	Habitat/Distribution	Areas with Potential for Occurrence	Potential for Effect	Species Addressed in Reinitiation of Consultation (indicated with an X)
San Bruno Mountain manzanita	*Arctostaphylos imbricata*	–/SE/1B.1	Rocky areas in chaparral and coastal scrub habitat.	Bay-Delta	None. No activities are proposed within suitable habitat in the known range of the species.	
San Francisco lessingia	*Lessingia germanorum*	FE/SE/1B.1	Coastal scrub on remnant dunes.	Bay-Delta	None. No activities are proposed within suitable habitat in the known range of the species.	
San Francisco popcornflower	*Plagiobothrys diffusus*	–/SE/1B.1	Coastal prairie and annual grassland.	Bay-Delta	None. No activities are proposed within suitable habitat in the known range of the species.	
San Joaquin Valley Orcutt grass	*Orcuttia inaequalis*	FT/SE/1B.1	Vernal pools.	San Joaquin River	None. No activities are proposed within suitable habitat in the known range of the species.	
San Mateo thorn-mint	*Acanthomintha duttonii*	FE/SE/1B.1	Serpentine soils in valley and foothill grassland, open areas in chaparral and coastal scrub.	Bay-Delta	None. No activities are proposed within suitable habitat in the known range of the species.	
San Mateo woolly sunflower	*Eriophyllum latilobum*	FE/SE/1B.1	Open areas in coast live oak woodland, often on roadsides, sometimes on serpentinite.	Bay-Delta	None. No activities are proposed within suitable habitat in the known range of the species.	
Santa Cruz tarplant	*Holocarpha macradenia*	FT/SE/1B.1	Coastal terrace grasslands, coastal scrub, often on light sandy to sandy clay soils.	Bay-Delta	None. No activities are proposed within suitable habitat in the known range of the species.	
Slender Orcutt grass	*Orcuttia tenuis*	FT/SE/1B.1	Vernal pools.	Sacramento River	None. No activities are proposed within suitable habitat in the known range of the species.	
Soft bird's-beak	*Chloropyron molle* ssp. *molle*	FE/SR/1B.2	Coastal salt marshes and swamps in Contra Costa, Napa, and Solano Counties.	Bay-Delta	High. Restoration activities are proposed within suitable habitat in the known range of the species.	X

Common Name	Scientific Name	Status Federal/State/ CRPR*	Habitat/Distribution	Areas with Potential for Occurrence	Potential for Effect	Species Addressed in Reinitiation of Consultation (indicated with an X)
Suisun marsh aster	*Symphyotrichum lentum*	–/–/1B.2	Endemic to Delta, generally occurs in marshes and swamps, often along sloughs, from 0 to 3 meters in elevation. Brackish and freshwater marshes and swamps in the Bay-Delta region. Known from many areas of Delta and from Suisun Marsh.	Yolo Bypass, Sutter Bypass, Bay-Delta, Suisun Marsh	High. Restoration activities are proposed within suitable habitat in the known range of the species.	
Suisun thistle	*Cirsium hydrophilum* var. *hydrophilum*	FE/–/1B.1	Salt marshes and swamps. Two known occurrences in Grizzly Island Wildlife Area and Peytonia Slough Ecological Reserve. Present at Suisun Marsh.	Bay-Delta	High. Restoration activities are proposed within suitable habitat in the known range of the species.	X
Tiburon jewelflower	*Streptanthus niger*	FE/SE/1B.1	Serpentine grasslands. Known from only two occurrences on the Tiburon Peninsula.	Bay-Delta	None. No activities are proposed within suitable habitat in the known range of the species.	
Tiburon mariposa lily	*Calochortus tiburonensis*	FT/ST/1B.1	Serpentine grasslands. Known only from one occurrence on Ring Mountain Preserve.	Bay-Delta	None. No activities are proposed within suitable habitat in the known range of the species.	
Tiburon paintbrush	*Castilleja affinis* var. *neglecta*	FE/ST/1B.2	Serpentine grasslands.	Bay-Delta	None. No activities are proposed within suitable habitat in the known range of the species.	
Two-fork clover	*Trifolium amoenum*	FE/–/1B.1	Low elevation grasslands, including swales and disturbed areas, sometimes on serpentinite soils.	Bay-Delta	None. No activities are proposed within suitable habitat in the known range of the species.	

Common Name	**Scientific Name**	**Status Federal/State/ CRPR***	**Habitat/Distribution**	**Areas with Potential for Occurrence**	**Potential for Effect**	**Species Addressed in Reinitiation of Consultation (indicated with an X)**
White-rayed pentachaeta	*Pentachaeta bellidiflora*	FE/SE/1B.1	Annual grassland, often on serpentinite.	Bay-Delta	None. No activities are proposed within suitable habitat in the known range of the species.	

Abbreviations
** Status Codes*
FE = federally endangered
SE = state endangered
FT = federally threatened
ST = state threatened
SR = state rare

CRPR Codes
1B = Plants that are rare, threatened, or endangered in California and elsewhere
2 = Plants that are rare, threatened, or endangered in California but more common elsewhere

CRPR Threat Ranks
1 = Seriously threatened in California (over 80% of occurrences threatened / high degree and immediacy of threat)
2 = Fairly threatened in California (20–80% occurrences threatened / moderate degree and immediacy of threat)
3 = Not very threatened in California (<20% of occurrences threatened / low degree and immediacy of threat or no current threats known)

Other Abbreviations
CNDDB= California Natural Diversity Database
CRPR = California Rare Plant Rank

P.1.3 Critical Habitat

Critical habitat refers to areas designated by USFWS for the conservation of species listed as threatened or endangered under the Endangered Species Act (ESA) of 1973, as amended through the 108th Congress. When a species is proposed for listing under the ESA, USFWS considers whether there are certain areas essential to the conservation of the species. Critical habitat is defined in Section 3, Provision 5 of the ESA as follows.

(5)(A) The term "critical habitat" for a threatened or endangered species means -

(i) the specific areas within the geographical area occupied by a species at the time it is listed in accordance with the Act, on which are found those physical or biological features (I) essential to the conservation of the species, and (II) which may require special management considerations or protection; and

(ii) specific areas outside the geographical area occupied by a species at the time it is listed in accordance with the provisions of section 4 of this Act, upon a determination by the Secretary that such areas are essential for the conservation of the species.

Any federal action (permit, license, or funding) in critical habitat requires that federal agency to consult with USFWS where the action has potential to adversely modify the habitat for terrestrial species.

The federally listed wildlife and plant species considered in this EIS that have designated critical habitat areas that could be affected by the project are presented in Table P.1-3.

Table P.1-3. Critical Habitat for Terrestrial Species in the Study Area

Common Name	Scientific Name	Year Designated	Jurisdiction
Soft bird's-beak	*Cordylanthus mollis* ssp. *mollis*	2007	USFWS
Suisun thistle	*Cirsium hydrophilum* var. *hydrophilum*	2007	USFWS
Valley elderberry longhorn beetle	*Desmocerus californicus dimorphus*	1980	USFWS
Western yellow-billed cuckoo	*Coccyzus americanus*	2014 (proposed)	USFWS
California tiger salamander	*Ambystoma californiense*	2011 (Sonoma County DPS), 2005 (Central DPS)	USFWS

P.1.4 Wetlands and Waters of the United States

Wetlands and waters of the United States that occur in the study area are described below.

P.1.4.1 *Lake/Reservoir Communities*

Reservoirs that store CVP and SWP water supplies provide habitat used by some terrestrial species, either within the open water area of the reservoirs or along the margins and in drawdown areas.

P.1.4.1.1 Open Water Areas

Water surface elevations in reservoirs that store CVP and SWP water supplies change seasonally and annually due to hydrologic and operational variables. The open water areas of these reservoirs are used as foraging and resting sites by waterfowl and other birds and by semi-aquatic mammals such as river otter and beaver. Bald eagles and ospreys nest in forests at the margins of these reservoirs and frequently use the reservoirs to forage for fish.

Margins and Drawdown Areas

The CVP and SWP reservoirs in the Central Valley are generally located in canyons where the surrounding slopes are dominated by upland vegetation such as woodland, forest, and chaparral. Within the inundation area, the water surface elevations in these reservoirs fluctuate between maximum allowed storage elevations and minimum elevations defined by the lowest elevation on the intake structure. Along the water surface edge of the inundation area, the soils are usually shallow. Soil is frequently lost to wave action and periodic inundation, followed by severe desiccation when the water elevation declines, generally resulting in a barren drawdown zone around the perimeter of the reservoirs. Natural regeneration of vegetation within the drawdown zone is generally prevented by the timing of seed release when reservoir levels are high in the spring, lack of sediment replenishment necessary for seedling establishment in the spring, and high temperatures combined with low soil moisture levels of exposed soils in the summer.

Lack of vegetative cover within the drawdown zone can limit wildlife use of this area. Rapidly rising reservoir levels can potentially result in direct mortality of some sedentary wildlife species or life stages within the drawdown zone of reservoirs. As reservoir levels drop, energy expenditures can increase for piscivorous (fish-eating) birds foraging in the reservoirs as these species must travel greater distances to forage (DWR 2004).

P.1.4.2 *Riverine Communities*

The rivers and streams influenced by the long-term coordinated operation of the CVP and SWP support habitats for plants and wildlife. The primary components of the riverine environment that support plants and wildlife, including open water areas and adjacent riparian and floodplain communities (including bypasses that are inundated at high flows), are described below.

P.1.4.2.1 Open Water Areas

The riverine environment downstream of reservoirs is managed generally for water supply and flood control purposes. As such, the extent of open water in the rivers varies somewhat predictably, although not substantially, within and among years. In the wetter years when bypasses and floodplains are inundated, vast areas of open water become available during the flood season, generally in the late winter and early spring. Open water portions of riverine systems provide foraging habitat for fish-eating birds and waterfowl. Gulls, terns, ospreys, and bald eagles forage over open water. Near-shore and shoreline areas provide foraging habitat for birds such as waterfowl, herons, egrets, shorebirds, and belted kingfishers. Many species of insectivorous birds such as swallows, swifts, and flycatchers forage over open water areas of lakes and streams. Mammals known to associate with open water and shoreline habitats include river otters, American minks, muskrats, and beavers.

P.1.4.2.2 Riparian and Floodplain Areas

The riparian and floodplain communities that could be affected by CVP and SWP operations entail the vegetation and associated wildlife community supported and influenced by proximity to the waterway, including areas frequently flooded by rising water levels in the rivers (floodplains). The extent of riparian vegetation within the Central Valley has been reduced over time due to a variety of actions, including local, state, and federal construction and operation of flood control facilities on isolated historic floodplains; agricultural and land use development that occurred following development of flood control projects; regulation of flows from dams that has reduced the magnitude and frequency of larger flow events, increased recession rates, and increased summertime flows; and construction and maintenance of active ship channels by USACE (DWR 2012). Currently, levee and bank protection structures associated with the flood protection system are present along more than 2,600 miles of rivers in the Central Valley, including the Delta (DWR 2009).

Characteristic riparian tree species in the Central Valley include willows, cottonwoods, California sycamore, and valley oaks. Typical understory plants include elderberry, blackberries, and poison oak. On the valley floor in the deep alluvial soils, the structure and species composition of the plant communities change with distance from the river, with the denser stands of willow and cottonwood at the water's edge transitioning into stands of valley oaks on the less frequently inundated terraces. In other areas, the riparian zone does not support a canopy of large trees and instead is dominated by shrub species (sometimes referred to as *riparian scrub*).

Riparian and floodplain vegetation supports wildlife habitats because of its high floristic and structural diversity, high biomass and high food abundance, and proximity to water. In addition to providing breeding, foraging, and roosting habitat for an array of animals, riparian and floodplain vegetation also provides movement corridors for some species, connecting a variety of habitats throughout the region. The Sacramento and San Joaquin Valleys lack substantial areas of natural habitat that support native biodiversity or corridors between the areas of natural habitat; therefore, riparian and floodplain corridors play a critical role in connecting wildlife among the few remaining natural areas (California Department of Transportation and CDFG 2010).

River flows and associated hydrologic and geomorphic processes are important for maintaining riparian and floodplain ecosystems. Most aspects of a flow regime (e.g., the magnitude, frequency, timing, duration, and sediment load) affect a variety of riparian and floodplain habitat processes. Two processes that create riparian and floodplain ecosystems are disturbance and plant recruitment. The interaction of these processes across the landscape is primarily responsible for the pattern and distribution of riparian and floodplain habitat structure and condition, and for the composition and abundance of riparian-associated species.

High flow events and associated scour, deposition, and prolonged inundation can create exposed substrate for plant establishment or openings in existing riparian and floodplain communities. Early successional species, like cottonwoods and willows that recruit into these openings, become more abundant in the landscape as vegetation grows within disturbed areas. As a result, structural and species diversity within riparian and floodplain vegetation could increase, as could overall wildlife habitat values. Without disturbance, larger trees and species less tolerant of frequent disturbance begin to dominate riparian woodlands.

The recruitment of cottonwoods and willows especially depends on geomorphic processes that create bare mineral soil through erosion and deposition of sediment along river channels and on floodplains, and on flow events that result in floodplain inundation. Receding flood flows that expose moist mineral soil create ideal conditions for germination of cottonwood and willow seedlings. After germination occurs, the water surface must decline gradually to enable seedling establishment. Riparian and floodplain communities also undergo natural disturbance cycles when flood flows remove streamside vegetation and redistribute sediments and seeds, thereby maintaining habitat diversity for terrestrial species that associate with riparian and floodplain corridors.

Both prolonged drought and prolonged inundation, however, can lead to plant death and loss of riparian plants (Kozlowski and Pallardy 2002). Riparian plants have high moisture requirements during the active growing season (spring through fall), and dry soil conditions can reduce growth and injure or kill plants. On the other hand, prolonged inundation creates anaerobic conditions that, during the active growing season, also can reduce growth, injure, or kill plants.

The continuation of riparian and floodplain communities is anticipated to change along levees within the federally authorized levee systems that have maintenance agreements with the USACE (including Delta levees along the Sacramento and San Joaquin Rivers) and other levees that are eligible for the federal Rehabilitation and Inspection Program (Public Law 84-99). The vegetation management policies of the USACE were changed in 2009 and 2010. Historically, the USACE allowed brush and small trees to be located on the waterside of federal flood management project levees if the vegetation would preserve, protect, and/or enhance natural resources, and/or protect rights of Native Americans, while maintaining the safety, structural integrity, and functionality of the levee (DWR 2011). After Hurricane Katrina in 2005, the USACE issued a policy and draft policy guidance to remove substantial vegetation from these levees throughout the nation. In 2010, the USACE issued a draft policy guidance letter, *Draft Process for Requesting a Variance from Vegetation Standards for Levees and Floodwalls* (75 FR 6364-6368) that included procedures for state and local agencies to request variances on a site-specific basis. DWR has been in negotiations with USACE to remove vegetation on the upper third of the waterside slope, top, and landside of the levees, and continue to allow vegetation on the lower two-thirds of the waterside slope of the levee and along benches above the water surface.The effects of these changes have not become widespread at this time. Future conditions under these requirements are further described under the description of the No Action Alternative in this technical appendix.

P.1.4.3 *Wetlands, Marshes, and Wet Meadows*

Wetlands in the study area can be characterized as perennial or seasonal with perennial wetlands further classified as tidal or non-tidal. Natural, non-tidal perennial wetlands are scattered along the Sacramento and San Joaquin Rivers, typically in areas with slow moving backwaters. Management of wetlands, marshes, and wet meadows can include irrigating open areas to support native herbaceous plants or cultivated species; periodic or continuous flooding to provide feeding and roosting sites for many wetland-associated birds; and either limited tilling or no tilling or disturbance of the managed areas.

Managed seasonal wetlands on the west side of the Sacramento River generally occur between Willows and Dunnigan along the Colusa Basin Drain. Substantial portions of these managed wetland habitats occur at the flood bypasses, including the Yolo Bypass Wildlife Area and Fremont Weir, as a part of the Sacramento National Wildlife Refuge Complex, and around the Thermalito Afterbay. Both tidal and nontidal, perennial wetlands are found in the Delta and Suisun Marsh.

P.1.4.3.1 Perennial Non-Tidal (Freshwater) Wetlands and Marshes

In the Sacramento and San Joaquin Valleys and foothills, perennial non-tidal wetland habitats include freshwater emergent wetlands and wet meadows. Freshwater emergent wetlands, or marshes, are dominated by large, perennial herbaceous plants, particularly tules and cattails, which are generally restricted to shallow water. In marshes, vegetation structure and the number of species are strongly influenced by disturbance, changes in water levels, and the range of elevations present at a site. Wet meadows are similar to perennial freshwater wetlands in many regards; however, they are dominated by a greater variety of perennial plants such as rushes, sedges, and grasses than are found in freshwater wetlands. Perennial freshwater wetlands also provide ecological functions related to water quality and hydrology. These areas generally qualify as jurisdictional wetlands subject to USACE jurisdiction under Sections 401 and 404 of the federal Clean Water Act.

Perennial freshwater wetlands are among the most productive wildlife habitat in California (CDFG 1988). In the Sacramento and San Joaquin Valleys and foothills, these wetlands support several sensitive amphibians, reptiles, birds, and mammals. Perennial freshwater wetlands also provide food, cover, and water for numerous species of wildlife. Wetlands in the Sacramento and San Joaquin Valleys and foothills are especially important to migratory birds and wintering waterfowl.

P.1.4.3.2 Seasonal Wetlands

Natural seasonal wetlands occur in topographic depressions and swales that are seasonally saturated and exhibit hydric soils that support hydrophytic plant species. Natural seasonal wetlands are generally dominated by hydrophytic plants during the winter and spring months. Characteristic plant species in seasonal wetlands consist of both native and nonnative species. Native species include coyote thistle, toad rush, hyssop loosestrife, and foothill meadowfoam. Natural seasonal wetlands provide food, cover, and water for numerous common and special-status species of wildlife that rely on wetlands for all or part of their life cycle. Like perennial wetlands, seasonal wetlands have been substantially reduced from their historical extent.

Numerous managed seasonal wetlands occur within the Sacramento Colusa, Sutter, Tisdale, and Yolo Bypasses and around the Thermalito Afterbay.

Managed marsh areas are intentionally flooded and managed during specific seasonal periods to enhance habitat values for specific wildlife species (CALFED 2000). Managed marsh areas are distributed largely in the northern, central, and western portions of the Delta, as well as in Suisun Marsh and the Yolo Bypass, Stone Lakes NWR, Cosumnes River Preserve, and Suisun Marsh.

P.1.4.3.3 Perennial Tidal Wetlands and Open Water

In the study area tidal wetlands and open water are primarily found in the Delta and Suisun Marsh. Tidal wetlands are influenced by tidal movement of salt water from San Francisco Bay and inflow of freshwater from the Delta and smaller local watersheds. Salinity levels vary throughout the year and are influenced largely by inflow from the Delta (Reclamation et al. 2011). Tidal open water in the Delta is mainly freshwater habitat, with brackish and saline conditions occurring in the western Delta at times of high tides and low flows into the western Delta. It is freshwater in the Yolo Bypass and mainly brackish and saline in Suisun Marsh. Tidal mudflats occur as mostly unvegetated sediment deposits in the intertidal zone between the tidal wetland communities at its upper edge and the tidal perennial aquatic community at its lower edge. Tidal brackish wetlands exist from near Collinsville westward to the Carquinez Strait.

Suisun Marsh is the largest contiguous brackish water marsh remaining on the North America west coast (Reclamation et al. 2011). Tidal freshwater marshes occur at the shallow, slow-moving or stagnant edges of freshwater waterways in the intertidal zone and are subject to frequent, long duration flooding.

P.2 Evaluation of Alternatives

This section describes the technical background for the evaluation of environmental consequences associated with the Project alternatives and the No Action Alternative. This section also describes the results of the impact analysis for each Project alternative and the No Action Alternative. Most of the actions from the project that will affect terrestrial species are programmatic. The only effects from project-specific actions are from flow changes, discussed below. The remainder of the effects are associated with programmatic-level actions.

P.2.1 Technical Background

P.2.1.1 *Land Cover*

Reclamation used existing land cover data to assess effects on terrestrial biological resources. Data sources are listed below:

- Aerial Information Systems, Inc. 2011. Delta Vegetation and Land Use. Available: ftp://ftp.dfg.ca.gov/BDB/GIS/BIOS/Public_Datasets/200_299/ds292.zip. Accessed: December10, 2018.
- U.S. Geological Survey. 2017. NHD Flowline. Available: http://prd-tnm.s3-website-us-west-2.amazonaws.com/?prefix=StagedProducts/Hydrography/NHD/State/HighResolution/GDB. Accessed: May 4, 2017.
- U.S. Geological Survey. 2017. NHD Area. Available: http://prd-tnm.s3-website-us-west-2.amazonaws.com/?prefix=StagedProducts/Hydrography/NHD/State/HighResolution/GDB. Accessed: May 4, 2017.
- Geographic Information Center, Chico Research Foundation. 2016. Vegetation—Great Valley Ecoregion. Available: ftp://ftp.dfg.ca.gov/BDB/GIS/BIOS/Public_Datasets/2600_2699/ds2632.zip. Accessed: November 11, 2017.
- Chico State University and California DWR. 2001. Legal Delta Boundary. Available: ftp://ftp.dfg.ca.gov/BDB/GIS/BIOS/Public_Datasets. Accessed: December 11, 2018. \

P.2.1.2 *Federally Listed Species and Critical Habitat*

To identify federally listed as endangered and threatened species that may occur in the study area, Reclamation used the list generated by the IPaC online service. The species identified by the IPaC list are shown in Tables P.1-1 and P.1-2.

To determine which project components could affect the federally listed terrestrial species identified in Tables P.1-1 and Q-1.2, Reclamation reviewed species range maps to assess which project components overlap the species' ranges. All the range maps originated from the following data sources:

- California Department of Fish and Wildlife California Interagency Wildlife Task Group. 2016. California Tiger Salamander Range. Available: ftp://ftp.dfg.ca.gov/BDB/GIS/BIOS/Public_Datasets. Accessed: January 24, 2019.
- California Department of Fish and Wildlife California Interagency Wildlife Task Group. 2016. Clapper Rail Range. Available: ftp://ftp.dfg.ca.gov/BDB/GIS/BIOS/Public_Datasets. Accessed: January 2, 2019.
- California Department of Fish and Wildlife California Interagency Wildlife Task Group. 2016. Giant Garter Snake Range. Available: ftp://ftp.dfg.ca.gov/BDB/GIS/BIOS/Public_Datasets. Accessed: January 2, 2019.
- California Department of Fish and Wildlife California Interagency Wildlife Task Group. 2016. Least Tern Range. Available: ftp://ftp.dfg.ca.gov/BDB/GIS/BIOS/Public_Datasets. Accessed: January 24, 2019.
- California Department of Fish and Wildlife California Interagency Wildlife Task Group. 2016. Salt-Marsh Harvest Mouse Range. Available: ftp://ftp.dfg.ca.gov/BDB/GIS/BIOS/Public_Datasets. Accessed: January 2, 2019.
- California Department of Fish and Wildlife California Interagency Wildlife Task Group. 2016. Yellow-Billed Cuckoo Range. Available: ftp://ftp.dfg.ca.gov/BDB/GIS/BIOS/Public_Datasets. Accessed: January 2, 2019.
- U.S. Geological Survey Gap Analysis Project. 2018. San Joaquin Valley Wood Rat Range. Available: https://gapanalysis.usgs.gov/species/data/download. Accessed: January 15, 2019.
- Carol W. Witham, Robert F. Holland, and John Vollmar. 2014. Changes in the Distribution of Great Valley Vernal Pool Habitats from 2005 to 2012. Available: https://vernalpools.org/2012CVPIA/2012RemapVernalPoolsFINAL.zip. Accessed: August 27, 2017.
- U.S. Fish and Wildlife. 2005. Vernal Pool Core Areas.

Reclamation used existing species habitat models where available to assess which project components would affect the habitat of federally listed species. Reclamation developed mitigation measures with the first goal being to avoid effects on federally listed species and the second goal being to minimize and compensate for unavoidable effects. Reclamation analyzed each project component to determine whether it could fully avoid effects on federally listed species. If effects were determined to be unavoidable, or potentially unavoidable, Reclamation developed measures to compensate for unavoidable effects. All effects on federally listed species are addressed at a programmatic level and are qualitatively described rather than quantified.

The analyses of potential effects on species' designated critical habitat follow the species analyses. Potential effects on primary constituent elements (PCEs)/physical and biological features (PBFs) of critical habitat are analyzed for western yellow-billed cuckoo and valley elderberry longhorn beetle. These analyses often draw on the foundation provided in the species analyses. Analysis of effects on critical habitat is guided by consideration of recent analyses by USFWS and National Marine Fisheries Service , which included refined interpretation of critical habitat PCEs/PBFs relative to the original descriptions at the time critical habitat was designated.

P.2.1.3 *Special-Status Species That Are Not Federally Listed*

To identify non-federally listed special-status species that may occur in the study area, Reclamation queried the CNDDB (CDFW 2019). These species are listed in Tables P.1-1 and P.1-2. Reclamation then evaluated each of these species based on the species' habitat and the distribution of land cover types in the study area that meet each species' habitat requirements.

For species with potential to be affected as identified in Tables P.1-1 and P.1-2, Reclamation developed mitigation measures with the first goal being to avoid effects on each special-status species, and the second goal being to minimize and compensate for unavoidable effects. Reclamation analyzed each project component to determine whether it could fully avoid effects on the special-status species. If effects were determined to be unavoidable, or potentially unavoidable, Reclamation developed measures to minimize and compensate for unavoidable effects. All effects on special-status species are addressed at a programmatic level and are qualitatively described rather than quantified.

P.2.1.4 *Wetlands and Waters of the United States*

Wetlands and waters of the United States in the study area that could be potentially affected have not been delineated, and the footprints of many of the project components are unknown; therefore, Reclamation addresses effects on wetlands and waters of the United States at a programmatic, qualitative level only. Based on land cover data described in Section P.2.1.1, *Land Cover*, Reclamation evaluated which wetland/waters land cover types may be affected by project components, developed measures for avoiding effects on these wetlands, and developed measures for minimizing and mitigating unavoidable effects.

P.2.2 No Action Alternative

The No Action Alternative for the project means that Reclamation and DWR would continue with current operations of the CVP and SWP. Under the No Action Alternative, no additional habitat restoration activities would occur other than the 8,000 acres of restoration required in the 2009 Biological Opinion. There would be no additional restoration in the Upper Sacramento, American River, Bay-Delta, Stanislaus, or Lower San Joaquin River Watersheds. Other than for 8,000 acres of restoration in the Bay-Delta area, habitat in these watersheds along rivers and tidal channels and in floodplains and marshes currently occupied by or suitable for terrestrial species would remain in the same condition as described in Section P.1.1, *Vegetation and Wildlife*, affected only by normal seasonal and annual variations and future climate change. Under the No Action Alternative, the existing UC Davis Fish Culture and Conservation Laboratory (FCCL) would be used to produce and release up to 50,000 adult Delta Smelt annually into the Bay-Delta to supplement the existing population. The proposed Delta Fish Species Conservation Hatchery (Conservation Hatchery) in Rio Vista would not be built nor constructed in areas that are occupied by or could potentially support terrestrial species such as burrowing owl, California tiger salamander, and vernal pool invertebrates.

P.2.3 Alternative 1

P.2.3.1 Project-Level Effects

Potential changes to wildlife and plant habitat on river banks

Compared to the No Action Alternative, operation of the CVP and SWP under Alternative 1 would change river flows and reservoir levels, which would change existing flow conditions. If river flows or reservoir levels have substantive declines or increases in areas with wildlife or plant habitat, the flows could adversely affect that habitat. Alternative 1, however, would have only minor changes to the water levels in reservoirs and along rivers. The flow changes are relatively small during each year type and would not result in substantive changes to riparian habitat.

For the purposes of the wildlife and plant species analyses, *flow changes* constitute the expected effects of implementing Alternative 1 in comparison with the No Action Alternative. Differences in flow management between Alternative 1 and the No Action Alternative would have the potential to affect a special-status wildlife or plant species if flow changes were to directly affect the species, directly alter habitat availability or quality, or result in vegetation changes that would alter habitat availability or quality. The great majority of stream channels within the study area are linear channels confined by levees or other engineered works that provide negligible habitat for special-status wildlife or plant species. There is, however, potential to affect such species at those sites where habitat has not been removed by channel alteration, or where habitat has been restored, or where habitat is expected to be restored during the proposed term of the proposed action. In the first two of these cases, existing habitat shows evidence of adaptation to anthropogenic modifications to the ecosystem that date back decades and, in many cases, over a century. These modifications include hydrologic changes associated with water manipulation; topographic changes associated with flood control, agriculture, restoration site construction, and other causes; and biological changes associated with the introduction of nonnative species. Implementation of Alternative 1 would generally result in very minor potential changes relative to the No Action Alternative, and these changes are small relative to normal month-to-month and year-to-year variability in the system.

Compared to the No Action Alternative, Alternative 1 is expected to have only minor effects on habitat along the banks of rivers and reservoirs; however, flow changes would have the potential to affect the amount of yellow-billed cuckoo riparian habitat. Alternative 1 may modify flows in a manner that would limit channel-forming flows, which could result in less riparian habitat establishment and expansion over time. If hydrologic modifications lead to too little or too much water during different times of the year, existing riparian habitat could be affected (79 FR 59991 60038); higher flows could result in erosion and potential loss of riparian vegetation while lower flows—especially in spring—could result in drought stress or less riparian vegetation recruitment, such as cottonwood seed dispersal. The hydrologic regime (stream flow pattern) and supply of (and interaction between) surface and subsurface water are driving factors in the long-term maintenance, growth, recycling, and regeneration of western yellow-billed cuckoo habitat (78 FR 61621 61666). Higher flows could also result in higher sedimentation along the channel banks that similarly result in the inability of riparian vegetation to establish or regenerate. Alternatively, lower flows could diminish the water table, leading to reduced groundwater availability and water stress in riparian trees. Physiological stress in native vegetation from prolonged lower flows or groundwater results in reduced growth rate, morphological change, or mortality of plants; altered species composition dominated by more drought-tolerant vegetation; and conversion to habitat dominated by nonnative species (Poff et al. 1997). These effects reduce and degrade habitat for the western yellow-billed cuckoo for foraging, nesting, and cover.

Flow change could adversely affect nesting habitat for bank swallows on the Sacramento and Feather Rivers. One of the primary threats to bank swallows is loss of nesting habitat from the placement of rock revetment for levee stabilization. Because of resulting limited available habitat and the reduction of natural river processes, the species is highly sensitive to 1) reductions in winter flows which are necessary to erode banks for habitat creation, and 2) high flows during the breeding season (generally April 1–August 31). The potential impacts of changes in upstream flows on bank swallows during the breeding season are the flooding of active burrows and destruction of colonies from increased bank sloughing.

Bank swallows arrive in California and begin to excavate their burrows in March, and peak egg-laying occurs between April and May (Bank Swallow Technical Advisory Committee 2013). Therefore, high-flow events on the Sacramento and Feather Rivers that occur after March when the swallows have nested and laid eggs in the burrows could adversely affect bank swallows and result in the loss of nests. On the Sacramento River, breeding season flows between 14,000 and 30,000 cubic feet per second (cfs) have been associated with localized bank collapses that resulted in partial or complete colony failure (Stillwater Sciences 2007).

Additionally, flows above 50,000 cfs on the Sacramento River could lead to multiple colony failures during the breeding season, but they may be beneficial during the non-breeding season because erosion can create new breeding habitat in the form of cut banks (Stillwater Sciences 2007).

Model results illustrate that, relative to the No Action Alternative, flows on the Sacramento River would be higher under Alternative 1 (due to spring pulses) during the bank swallow breeding season. Projected differences between the No Action Alternative and Alternative 1 would occur from mid-April to July; during this time period, average flows on the Sacramento River under Alternative 1 would be slightly greater than under the No Action Alternative but slightly lower than under Alternatives 2 and 3.

Average flows on the Sacramento River downstream of Keswick Reservoir, at Bend Bridge, and below Red Bluff Diversion Dam would increase under Alternative 1 during the bank swallow breeding season, with model results predicting flow staying below 15,000 cfs. Average flows on the Sacramento River at Hamilton City, at Wilkins Slough, and at Freeport under Alternative 1 would generally decrease during the bank swallow breeding season. Monthly flows are highest at Freeport during the bank swallow breeding season, with predicted monthly flows between 15,000 and 19,000 cfs under Alternative 1.

Model results illustrate that, relative to the No Action Alternative, flows on Feather River would be higher under Alternative 1 (due to spring pulses) during the bank swallow breeding season. Projected differences between the No Action Alternative and Alternative 1 would occur from mid-May to July. Average flows on Feather River downstream of Thermalito would increase under Alternative 1 during the bank swallow breeding season, with model results predicting peak flows of 7,000 cfs. However, average flows on the Feather River at the Sacramento River confluence would decrease under Alternative 1 during the bank swallow nesting season.

P.2.3.2 *Program-Level Effects*

Potential changes to existing marshes and associated special-status species in the Bay-Delta region

Alternative 1 would restore tidal wetlands, diked wetlands, and muted marsh habitat in the Bay-Delta region. Several sites including Dutch Slough, Winter Island, Hill Slough, Arnold Slough/Bradmoor Island, Chipps Island, and Lower Yolo Ranch are being restored to tidal habitat as mitigation for adverse impacts on Delta Smelt and its habitat. Tidal habitat restoration at each site would be achieved by conversion of currently leveed, cultivated land through breaching or setback of levees, thereby restoring tidal fluctuation to land parcels currently isolated behind those levees. Where appropriate, portions of restoration sites would be raised to elevations that would support tidal marsh vegetation following levee breaching. Depending on the degree of subsidence and location, lands may be elevated by grading higher elevations to fill subsided areas, importing clean dredged or fill material from other locations, or planting tules or other appropriate vegetation to raise elevations in shallowly subsided areas over time through organic material accumulation. Surface grading would create a shallow elevation gradient from the marsh plain to the upland transition habitat. Based on assessments of local hydrodynamic conditions, sediment transport, and topography, restoration activities may be designed and implemented in a manner that accelerates the development of tidal channels within restored marsh plains. Following reintroduction of tidal exchange, tidal marsh vegetation is expected to establish and maintain itself naturally at suitable elevations relative to the tidal range. Depending on site-specific conditions and monitoring results, patches of native emergent vegetation may be planted to accelerate the establishment of native marsh vegetation on restored marsh plain surfaces.

Habitat restoration activities and restoration of tidal inundation could have deleterious short-term effects on existing tidal, non-tidal, and managed marsh habitats and associated special-status species, including Suisun marsh aster, Mason's lilaeopsis, Bolander's water hemlock, soft bird's-beak, Suisun thistle, delta tule pea, western pond turtle, California black rail, California Ridgway's rail, Suisun song sparrow, saltmarsh common yellowthroat, short eared owl, Suisun shrew, and salt-marsh harvest mouse. The potential effects on tidal marsh habitat would include the conversion of mid- and high-marsh habitat types to low-marsh types; the conversion of low-marsh habitat to subtidal habitat; and the conversion of upland refugia habitat to tidal habitat. While it is expected that the habitat would persist after restoration of tidal action, the extent of mid- and high-marsh is expected to decrease in the near-term. In the longer-term, and with the implementation of remedial measures, the extent of habitat is expected to expand. The extent of habitat may not expand to pre-restoration conditions, although the habitat will be of great extent and more resilient to climate change because tidal habitat has potential to accrete sediment to keep up with sea level rise whereas diked wetlands do not. Furthermore, diked wetlands have the risk of breached dikes that cause excessive flooding of mid- and high-marsh habitats.

Tidal habitat restoration is not expected to occur in areas with occupied habitat for soft bird's-beak or Suisun thistle, and no negative effects would be expected from restoration activities. Over time, the restored and enhanced area is expected to be suitable and of higher long-term value for the species because it would be less vulnerable to sea level rise by including gradual slopes up from the current tidal region, potentially allowing introduction of the species into the restored areas. Thus, Alternative 1 is expected to have a wholly beneficial effect on special-status plant species.

Potential changes to existing riparian areas and associated special-status species

Habitat restoration under Alternative 1 could result in the loss of riparian habitat and associated special-status species. Riparian species potentially affected include valley elderberry longhorn beetle, western yellow-billed cuckoo, foothill yellow-legged frog, least Bell's vireo, yellow warbler, Swainson's hawk, white-tailed kite, yellow-breasted chat, osprey, bald eagle, ring-tailed cat, riparian brush rabbit, and riparian woodrat.

Alternative 1 includes creation of spawning habitat and side channels along rivers, floodplain restoration, or other aquatic habitat restoration in riparian areas. The construction of setback levees to restore seasonally inundated floodplain could permanently remove species habitat and would be expected to transition species habitat from areas that flood frequently (i.e., every 1–2 years) to areas that flood infrequently (i.e., every 10 years or more). Periodic inundation as a result of floodplain restoration is not expected to adversely affect nesting bird species because flooding is unlikely to occur during the breeding season, and the potential effects of inundation on existing riparian vegetation are expected to be minimal. While frequent flooding in the lower elevations of the floodplain may result in scouring of riparian vegetation, this is expected to have a beneficial rather than an adverse long-term effect on most riparian species because periodic scouring increases successional and structural diversity of the habitat.

Floodplain restoration may result in periodic flooding of habitat for riparian brush rabbit and riparian woodrat, which are primarily ground-dwelling species that are adversely affected by flooding if no upland refugia are available during flood events. In addition, the removal of oak trees in floodplains would remove nest building materials for riparian woodrats in floodplains. However, the mitigation measure for riparian brush rabbit and riparian woodrat (MM BIO-21) will avoid and minimize both of these impacts. MM BIO-21 requires floodplain restoration projects to include refugia habitat to provide shelter from flood events and avoidance of mature oak trees in areas identified by a qualified biologist as being occupied by riparian brush rabbit and riparian woodrat. MM BIO-21 also puts limits on the amount of habitat that can be impacted by restoration.

Potential changes to habitat for special-status reptiles

Alternative 1 includes creation of spawning habitat and side channels along rivers, channel margin restoration, floodplain restoration, and other aquatic habitat restoration on the banks of waterbodies that could result in loss of habitat for giant garter snake and western pond turtle. Aquatic habitat and floodplain restoration could result in directly mortality of these species.

Permanent effects on giant garter snake aquatic habitat are likely to occur when agricultural ditches are modified and flooded as part of the tidal habitat restoration process. Permanent effects on both giant garter snake and western pond turtle habitat could occur where channel margin restoration entails levee setback. For giant garter snake, the conversion of rice to tidal habitat would be a permanent loss; however, rice is not common in the areas where tidal restoration and channel margin restoration would likely be sited. Other aquatic features with potential to occur on restoration sites include natural channels and topographic depressions. Tidal aquatic edge habitat where open water meets the levee edge will also be permanently lost in those reaches where the levee is breached. Temporary effects on aquatic edge habitat are also likely to occur during the time of construction, though these effects would not be expected to last more than 2 years. Permanent effects on upland habitat will primarily occur where upland habitat is removed to create tidal connectivity.

Potential to injure or kill special-status species

Construction-related actions associated with habitat restoration and the installation/upgrade of facilities under Alternative 1 could injure or kill special-status species in occupied habitat. The operation of equipment for land clearing and restoration could result in injury or mortality of special-status species. This risk is highest for species with periods of dormancy, like California tiger salamander and giant garter snake. Increased vehicular traffic associated with construction activities could contribute to a higher incidence of road kill. However, construction monitoring and other mitigation measures have been identified to avoid and minimize injury or mortality of special-status species during construction.

In tidal marsh habitat, construction actions such as excavation of levees, construction of tidal control gates, movement and staging of large construction equipment, piling and storage of soils, dredging, and filling and grading of vegetated areas could cause the injury or mortality of special-status species that may be in the vicinity of the construction area. Tidal marsh species are especially vulnerable during periods of higher tides and peak flooding by storms; during these periods, these species move into upland marsh areas for protection. Tidal marsh species could drown or be preyed upon if construction activities or equipment isolate tidal marsh species from their refugia habitat or confuse or disturb them.

Equipment operation for the creation of side channels and levees in riparian habitat during periods of high seasonal activity, such as the nesting bird or bat maternity seasons, could also injure or kill special-status species. Risk is greatest to bird eggs and nestlings or bat pups that could be injured or killed through crushing by heavy equipment, nest abandonment, or increased exposure to the elements or to predators. Injury to adults and fledged juveniles is unlikely, as these individuals are expected to avoid contact with construction equipment.

Night construction could disrupt animal behavior and/or sleep cycles or adversely affect bat foraging activity in all impacted habitat types if special-status species are exposed to night lighting. For example, bird species are attracted to artificial lights, which may disrupt their behavioral patterns or cause collision-related fatalities (Gauthreaux and Belser 2006). Night lighting can also result in circadian/behavior disruptions which can cause bird species to molt and develop their reproductive system earlier than in dark nights. Night lighting can also influence the endocrine system of vertebrates, which can lead to health deterioration (Fonken and Nelson 2014; Ouyang et al. 2018).

Construction-related noise levels could cause additional behavioral modifications if special-status species are present in the general vicinity. Construction activities may create noise up to 60 dBA at no more than 1,200 feet from the edge of the noise generating activity. While 60 dBA is the standard noise threshold for birds (Dooling and Popper 2007), this standard is generally applied during the nesting season, when birds are more vulnerable to behavioral modifications that can cause nest failure. There is evidence, however, that migrating birds will avoid noisy areas during migration (McClure et al. 2013). Noise and visual disturbance outside the project footprint but within 200 feet of construction activities could temporarily affect the use of adjacent habitat by giant garter snake. These effects will be minimized by siting construction 200 feet away from the banks of giant garter snake aquatic habitat, where feasible, as described in MM BIO-5.

Contaminants could be introduced into species' habitats as a result of construction. Exhaust from construction and maintenance vehicles may result in deposition of particulates, heavy metals, and mineral nutrients that could influence the quality and quantity of vegetation and thereby affect presence and abundance of special-status species. The use of mechanical equipment during construction might cause the accidental release of petroleum or other contaminants that will affect occupied, suitable, or adjacent habitat. These accidental spills could also affect special-status species prey, resulting in less food availability. Increased runoff from impervious surfaces into wetland areas carries pollutants that are harmful to reptiles and amphibians, which are particularly sensitive to contaminants and other pollutants in the water.

Potential changes to vernal pools and associated special-status species

Tidal habitat restoration and the construction of the Conservation Hatchery under Alternative 1 could have direct and indirect effects on vernal pools and associated special-status species. Vernal pool species that could be affected include California tiger salamander, Contra Costa goldfields, and vernal pool invertebrates. Direct effects include loss of habitat and individual mortality as a result of construction. Tidal natural community restoration could result in the permanent loss of vernal pool crustacean habitat. It is anticipated that much of the existing vernal pool habitat that would be impacted by the project is already degraded. Vernal pools in the Sacramento and San Joaquin Valleys have already experienced significant disturbance due to agricultural development (e.g., plowing, disking, or leveling), which results in compacted soils, loss of hydrologic connections, and reductions in the size and extent of vernal pools.

Construction of the Conservation Hatchery could result in direct removal of vernal pools if it is constructed in an area that contains vernal pool complexes. Similarly, if these pools are occupied, vernal pool crustaceans could be destroyed. These effects will be avoided through the implementation of the identified/proposed mitigation measures.

Indirect conversion of vernal pool habitat could also occur due to hydrological changes as a result of tidal habitat restoration or construction of the hatchery. Construction restoration activities may result in the modification of hardpan and changes to the perched water table, which could lead to alterations in the rate, extent, and duration of inundation of nearby vernal pool crustacean habitat. USFWS typically considers construction within 250 feet of vernal pool crustacean habitat to constitute a possible conversion of crustacean habitat unless more detailed information is provided to further refine the limits of any such effects. Therefore, MM BIO-1 will ensure a buffer of 250 feet for construction or restoration near vernal pool habitat.

Potential to affect special-status bat species and their habitat

Special-status bat species with potential to occur in the study area employ varied roost strategies, from solitary roosting in foliage of trees to colonial roosting in trees and artificial structures such as tunnels, buildings, and bridges. Various roost strategies could include night roosts, maternity roosts, migration stopover, or hibernation. Special-status bat roosting habitats include riparian habitat, developed lands, and landscaped trees such as eucalyptus, palms, and orchards. Potential foraging habitat includes all riparian habitat types, cultivated lands, developed lands, grasslands, and wetlands.

Four California bat species of special concern could occur in the study area (Table P.1-1) as could several common bat species. Construction and restoration activities associated with Alternative 1 would result in both temporary and permanent losses of foraging and roosting habitat for special-status bat species. Tidal habitat restoration and floodplain restoration would result in permanent and temporary loss of riparian roosting habitat and conversion of foraging habitat from mostly cultivated lands and managed wetlands to tidal and nontidal wetlands. Development of the Conservation Hatchery could also result in the removal of roosting and foraging habitat. Noise and visual disturbances during implementation of riparian habitat restoration and other construction activities could result in temporary disturbances that, if bat roost sites are present, could cause temporary abandonment of roosts. Impacts on special-status bat species that occupy artificial structures are expected to be negligible in comparison to the amount of impacts on natural habitat types, but temporary and permanent impacts on special-status bat species occupying artificial structures could result in local adverse effects.

Despite having potential to result in some adverse effects, implementation of Alternative 1 would result in an overall benefit to special-status bats within the study area through restoration of their foraging and roosting habitats. The majority of affected habitat would be agricultural, and such land would be converted to natural communities with higher value foraging and roosting potential such as riparian land, tidal and nontidal wetlands, and periodically inundated lands. Restored habitats are expected to be of higher value because, compared to agricultural land, pesticide use would be lower and greater numbers of flying insect prey species would be available. In addition, any impact from construction, restoration, or periodic inundation on special-status bats and their habitat would be mitigated through implementation of MM BIO-24, which would ensure there is no significant impact on roosting special-status bats, either directly or through habitat modifications, and no substantial reduction in numbers nor a restriction in the range of special-status bats.

Potential changes to wetlands and waters of the United States

The restoration projects associated with Alternative 1 would likely require some fill of wetlands and waters of the United States. Fill could occur from dredging work, spoils areas, side channel construction, and installation of the Conservation Hatchery. The majority of the impacts on wetlands and waters of the United States are likely on tidal channels, emergent wetlands, and on wetlands and waters found within cultivated lands (agricultural ditches and seasonal wetlands). Reclamation will obtain and implement the conditions and requirements of state and federal permits that may be required prior to the construction of the proposed project.

Unavoidable impacts on waters of the United States would be offset such that the loss of acreage and functions due to construction activities are fully compensated. The restoration projects would ultimately result in a net increase of wetlands and waters of the United States, but restoration could result in short-term losses.

Restoration could also result in conversion from one wetland type to another. Wetland functions are defined as a process or series of processes that take place within a wetland. These include the storage of water, transformation of nutrients, growth of living matter, and diversity of wetland plants, and they have value for the wetland itself, for surrounding ecosystems, and for people. Functions can be grouped broadly as habitat, hydrologic/hydraulic, or water quality. Not all wetlands perform all functions nor do they perform all functions equally well. The location and size of a wetland may determine what functions it will perform. For example, the geographic location may determine its habitat functions, and the location of a wetland within a watershed may determine its hydrologic/hydraulic or water quality functions. Many factors determine how well a wetland will perform these functions: climatic conditions, quantity and quality of water entering the wetland, and disturbances or alteration within the wetland or the surrounding ecosystem. Wetland disturbances may be the result of natural conditions, such as an extended drought, or human activities, such as land clearing, dredging, or the introduction of nonnative species. Wetlands are among the most productive habitats in the world, providing food, water, and shelter for fish, shellfish, birds, and mammals, and serving as a breeding ground and nursery for numerous species. Many endangered plant and animal species are dependent on wetland habitats for their survival. Hydrologic and hydraulic functions are those related to the quantity of water that enters, is stored in, or leaves a wetland. These functions include such factors as the reduction of flow velocity, the role of wetlands as groundwater recharge or discharge areas, and the influence of wetlands on atmospheric processes. Water-quality functions include the trapping of sediment, pollution control, and the biochemical processes that take place as water enters, is stored in, or leaves a wetland.

The functions of the waters of the United States that would be temporarily or permanently impacted by Alternative 1 would vary, depending primarily on existing land uses and historical levels of disturbance. Generally, agricultural ditches and conveyance channels, which are regularly maintained and often devoid of vegetation, support only minimal hydraulic function (water conveyance), with virtually no water quality or habitat function. Some facilities that are regularly maintained can still support some hydrologic, hydraulic, and water quality functions (e.g., reduction of velocity, groundwater recharge, and trapping of sediment). Tidal channels affected by Alternative 1 support functions in all three categories, but the level at which these functions perform vary depending on setting, size, and level of disturbance. Alkaline wetlands and vernal pools exist in nonnative grasslands and have been subjected to some disturbance due to past land uses. Although these features likely support habitat, water quality, and hydrologic/hydraulic functions, the capacity of these features to perform such functions vary depending on the overall ecological setting and level of disturbance. Functions associated with emergent wetland, forest, and scrub-shrub depend primarily on the location of these habitat types. Where they exist as in-stream (in-channel) islands or as the thick band of habitat adjacent to a waterway, these features are expected to function at a high level. However, where these habitats exist as thin bands, or where they are situated in agricultural fields, their habitat functions would be considerably lower. All wetlands classified as seasonal wetlands occur in agricultural fields. As such, their habitat functions have been greatly compromised, but they retain some water quality and hydrologic/hydraulic function. Like seasonal wetlands, most depressions occur within agricultural areas; however, the depressions may support wetland vegetation at their edges.

Potential changes to terrestrial species' critical habitat

The restoration projects under Alternative 1 could result in loss of terrestrial species' critical habitat. Western yellow-billed cuckoo proposed critical habitat is present in Tisdale Bypass and Sutter Bypass. However, Alternative 1 does not propose to modify flows in the Tisdale or Sutter Bypasses. Changes in frequency of inundation in the Sacramento River would be minor, and within the current minimum and maximum flows. Alternative 1 could provide for some different riparian species that require year-round flows, as compared to the No Action Alternative, where low flows in the fall would stress invasive plants and encourage drought-tolerant native species to persist.

Critical habitat for valley elderberry longhorn beetle is present along the American River. However, under the action alternatives Reclamation will avoid valley elderberry longhorn critical habitat.

Critical habitat for vernal pool fairy shrimp and vernal pool tadpole shrimp is present in areas that Reclamation could potentially use for tidal habitat restoration. Reclamation will, however, avoid areas that would affect the primary constituent habitat elements for these species in the critical habitat units.

Critical habitat for California tiger salamander is present in areas that Reclamation could potentially use for tidal habitat restoration. Reclamation will, however, avoid areas that would affect the primary constituent habitat elements for this species in the critical habitat units.

Critical habitat for soft bird's-beak and Suisun thistle is present in areas that Reclamation could potentially use for tidal habitat restoration. Reclamation will, however, avoid areas that would affect the primary constituent habitat elements for these species in the critical habitat units.

P.2.4 Alternative 2

With respect to terrestrial species, Alternative 2 is nearly the same as the No Action Alternative described in Section P.2.2, *No Action Alternative*. Like the No Action Alternative, Alternative 2 proposes no additional restoration activities that would affect terrestrial species, and the existing FCCL would be used to produce and release Delta Smelt instead of constructing and using the new Conservation Hatchery. The only effects on terrestrial species under Alternative 2 would be from river flows, which would be slightly higher than under the No Action Alternative and Alternative 1, and from reservoir levels and inundation in the Yolo and Sutter Bypasses, which are discussed in Section P.2.3, *Alternative 1*, and Section P.2.5, *Alternative 3*.

Based on data indicating bank swallow colonies may be affected at 14,000 to 30,000 cfs, Alternative 2 would not have a significant effect on erosion of bank swallow colonies compared with the No Action Alternative.

P.2.5 Alternative 3

P.2.5.1 *Project-Level Effects*

Potential changes to wildlife and plant habitat on river banks.

Compared to the No Action Alternative, operation of the CVP and SWP under Alternative 3 would change river flows and reservoir levels, which would change existing flow conditions. If river flows or reservoir levels have substantive declines or increases in areas with riparian vegetation, the flows could adversely affect habitat. For example, higher flows could result in erosion and potential loss of riparian vegetation while lower flows, especially during the spring, could result in drought stress or less riparian vegetation recruitment, such as cottonwood seed dispersal. Alternative 3, however, would result in only minor changes to the water levels in reservoirs and along rivers. The flow changes are relatively small during each year type and would not result in substantive changes to riparian habitat.

For the purposes of the wildlife and plant species analyses, *flow changes* constitute the expected effects of implementing Alternative 3 in comparison with the No Action Alternative. Differences in flow management between Alternative 3 and the No Action Alternative would have the potential to affect a special-status wildlife or plant species if flow changes were to directly affect the species, directly alter habitat availability or quality, or result in vegetation changes that would alter habitat availability or quality. The great majority of stream channels within the study area are linear channels confined by levees or other engineered works that provide negligible habitat for special-status wildlife or plant species. There is, however, potential to affect such species at those sites where habitat has not been removed by channel alteration, or where habitat has been restored, or where habitat is expected to be restored during the proposed term of the proposed action. In the first two of these cases, existing habitat shows evidence of adaptation to anthropogenic modifications to the ecosystem that date back decades, and in many cases over a century. These modifications include hydrologic changes associated with water manipulation; topographic changes associated with flood control, agriculture, restoration site construction, and other causes; and biological changes associated with the introduction of nonnative species. Implementation of Alternative 3 would generally result in very minor potential changes relative to the No Action Alternative, and these changes are small relative to normal month-to-month and year-to-year variability in the system.

Compared to the No Action Alternative, Alternative 3 is expected to have only minor effects on habitat along the banks of rivers and reservoirs; however, flow changes would have the potential to affect the amount of yellow-billed cuckoo riparian habitat. Alternative 3 may modify flows in a manner that would limit channel-forming flows, which could result in less riparian habitat establishment and expansion over time. If hydrologic modifications lead to too little or too much water during different times of the year, existing riparian habitat could be affected (79 FR 59991–60038); higher flows could result in erosion and potential loss of riparian vegetation while lower flows—especially during the spring—could result in drought stress or less riparian vegetation recruitment, such as cottonwood seed dispersal. The hydrologic regime (stream flow pattern) and supply of (and interaction between) surface and subsurface water are driving factors in the long-term maintenance, growth, recycling, and regeneration of western yellow-billed cuckoo habitat (78 FR 61621 61666). Higher flows could also result in higher sedimentation along the channel banks that similarly result in the inability of riparian vegetation to establish or regenerate. Alternatively, lower flows could diminish the water table, leading to reduced groundwater availability and water stress in riparian trees. Physiological stress in native vegetation from prolonged lower flows or groundwater results in reduced growth rate, morphological change, or mortality of plants; altered species composition dominated by more drought-tolerant vegetation; and conversion to habitat dominated by nonnative species (Poff et al. 1997). These effects reduce and degrade habitat for the western yellow-billed cuckoo for foraging, nesting, and cover.

Flow changes could adversely affect nesting habitat for bank swallows. One the primary threats to bank swallows is loss of nesting habitat from the placement of rock revetment for levee stabilization. Because of this limited available habitat, and the reduction of natural river processes, the species is highly sensitive to 1) reductions in winter flows which are necessary to erode banks for habitat creation, and 2) high flows during the breeding season. The potential impacts of changes in upstream flows on bank swallows during the breeding season are the flooding of active burrows and destruction of burrows from increased bank sloughing. Bank swallows arrive in California and begin to excavate their burrows in March, and peak egg-laying occurs between April and May (Bank Swallow Technical Advisory Committee 2013). Therefore, increases in flows after March when the swallows have nested and laid eggs in the burrows could result in the loss of nests. On the Sacramento River, breeding season flows between 14,000 and 30,000 cfs have been associated with localized bank collapses which resulted in partial or complete colony failure (Stillwater Sciences 2007).

Additionally, flows above 50,000 cfs on the Sacramento River could lead to multiple colony failures during the breeding season, but they may be beneficial during the non-breeding season because erosion can create new breeding habitat in the form of cut banks (Stillwater Sciences 2007).

Model results illustrate that, relative to the No Action Alternative, flows on the Sacramento River would be higher under Alternative 3 during the bank swallow breeding season. Projected differences between the No Action Alternative and Alternative 3 occur from mid-April to July; during this time period, average flows under Alternative 3 would be slightly greater than under the No Action Alternative and Alternative 1.

Average flows on the Sacramento River downstream of Keswick Reservoir, at Bend Bridge, and below Red Bluff Diversion Dam would increase under Alternative 3 during the bank swallow breeding season, with model results predicting flow staying below 15,000 cfs. Average flows on the Sacramento River at Hamilton City, at Wilkins Slough, and at Freeport under Alternative 3 would generally decrease during the bank swallow breeding season. Monthly flows are highest at Freeport during the bank swallow breeding season, with predicted monthly flows between 15,000 and 19,000 cfs under Alternative 3.

Model results illustrate that, relative to the No Action Alternative, flows on Feather River would be higher under Alternative 3 during the bank swallow breeding season. Projected differences between the No Action Alternative and Alternative 3 would occur from mid-May to July. Average flows on Feather River downstream of Thermalito would increase under Alternative 3 during the bank swallow breeding season, with model results predicting peak flows of 7,000 cfs. However, average flows on the Feather River at the Sacramento River confluence would decrease under Alternative 3 during the bank swallow nesting season.

P.2.5.2 *Program-Level Effects*

Potential changes to existing marshes and associated special-status species in the Bay-Delta region

Alternative 3 would restore tidal wetlands, diked wetlands, and muted marsh habitat in the Bay-Delta region. Several sites including Dutch Slough, Winter Island, Hill Slough, Arnold Slough/Bradmoor Island, Chipps Island, and Lower Yolo Ranch are being restored to tidal habitat as mitigation for adverse impacts on Delta Smelt and its habitat. Tidal habitat restoration at each site would be achieved by conversion of currently leveed, cultivated land through breaching or setback of levees, thereby restoring tidal fluctuation to land parcels currently isolated behind those levees. Where appropriate, portions of restoration sites would be raised to elevations that would support tidal marsh vegetation following levee breaching. Depending on the degree of subsidence and location, lands may be elevated by grading higher elevations to fill subsided areas, importing clean dredged or fill material from other locations, or planting tules or other appropriate vegetation to raise elevations in shallowly subsided areas over time through organic material accumulation. Surface grading would create a shallow elevation gradient from the marsh plain to the upland transition habitat. Based on assessments of local hydrodynamic conditions, sediment transport, and topography, restoration activities may be designed and implemented in a manner that accelerates the development of tidal channels within restored marsh plains. Following reintroduction of tidal exchange, tidal marsh vegetation is expected to establish and maintain itself naturally at suitable elevations relative to the tidal range. Depending on site-specific conditions and monitoring results, patches of native emergent vegetation may be planted to accelerate the establishment of native marsh vegetation on restored marsh plain surfaces.

Habitat restoration activities and restoration of tidal inundation could have deleterious short-term effects on existing tidal, non-tidal, and managed marsh habitats and associated special-status species, including Suisun marsh aster, Mason’s lilaeopsis, Bolander’s water hemlock, soft bird’s-beak, Suisun thistle, delta tule pea, western pond turtle, California black rail, California Ridgway’s rail, Suisun song sparrow, saltmarsh common yellowthroat, short eared owl, Suisun shrew, and salt-marsh harvest mouse. The potential effects on tidal marsh habitat would include the conversion of mid- and high-marsh habitat types to low-marsh types; the conversion of low-marsh habitat to subtidal habitat; and the conversion of upland refugia habitat to tidal habitat. While it is expected that the habitat would persist after restoration of tidal action, the extent of mid- and high-marsh is expected to decrease in the near-term. In the longer-term, and with the implementation of remedial measures and adaptive management, the extent of habitat is expected to expand. The extent of habitat may not expand to pre-restoration conditions, although the habitat will be of great extent and more resilient to climate change because tidal habitat has potential to accrete sediment to keep up with sea level rise whereas diked wetlands do not. Furthermore, diked wetlands have the risk of breached dikes that cause excessive flooding of mid- and high-marsh habitats.

Tidal habitat restoration is not expected to occur in areas with occupied habitat for soft bird’s-beak or Suisun thistle, and no negative effects would be expected from restoration activities. Over time, the restored and enhanced area is expected to be suitable and of higher long-term value for the species because it would be less vulnerable to sea level rise by including gradual slopes up from the current tidal region, potentially allowing introduction of the species into the restored areas. Thus, Alternatives 1 and 3 are expected to have a wholly beneficial effect on special-status plant species.

The effect of tidal marsh restoration on special-status species in the Bay-Delta will be magnified under Alternative 3, as compared to the No Action Alternative and Alternative 1, given that Alternative 3 proposes 25,000 acres of habitat restoration within the Delta— more than triple the amount of habitat restoration under the No Action Alternative and Alternative 1. Although it is unknown at this time how much of the affected habitat is suitable for special-status species, it is likely that additional habitat for special-status species would be affected under Alternative 3. Additional habitat restoration would require a greater extent of permanent and temporary habitat loss, the latter of which would be expected to recover and restore over time. Habitat restoration will ultimately benefit special-status species by increasing the amount of available habitat and enhancing degraded habitat areas.

Potential changes to existing riparian areas and associated special-status species

Habitat restoration under Alternative 3 could result in the loss of riparian habitat and associated special-status species. Riparian species potentially affected include valley elderberry longhorn beetle, western yellow-billed cuckoo, foothill yellow-legged frog, least Bell's vireo, yellow warbler, Swainson's hawk, white-tailed kite, yellow-breasted chat, osprey, bald eagle, ring-tailed cat, riparian brush rabbit, and riparian woodrat.

Alternative 3 includes creation of spawning habitat and side channels along rivers, floodplain restoration, or other aquatic habitat restoration in riparian areas. The construction of setback levees to restore seasonally inundated floodplain could permanently remove species habitat and would be expected to transition species habitat from areas that flood frequently (i.e., every 1–2 years) to areas that flood infrequently (i.e., every 10 years or more). Periodic inundation as a result of floodplain restoration is not expected to adversely affect nesting bird species because flooding is unlikely to occur during the breeding season, and the potential effects of inundation on existing riparian vegetation are expected to be minimal. While frequent flooding in the lower elevations of the floodplain may result in scouring of riparian vegetation, this is expected to have a beneficial rather than an adverse long-term effect on most riparian species because periodic scouring increases successional and structural diversity of the habitat.

Floodplain restoration may result in periodic flooding of habitat for riparian brush rabbit and riparian woodrat, which are primarily ground-dwelling species that are adversely affected by flooding if no upland refugia are available during flood events. In addition, the removal of oak trees in floodplains would remove nest building materials for riparian woodrats in floodplains. However, the mitigation measure for riparian brush rabbit and riparian woodrat (MM BIO-21) will avoid and minimize both of these impacts. MM BIO-21 requires floodplain restoration projects to include refugia habitat to provide shelter from flood events and avoidance of mature oak trees in areas a qualified biologist has identified as being occupied by riparian brush rabbit and riparian woodrat. MM BIO-21 also puts limits on the amount of habitat that can be impacted by restoration.

The effect of aquatic habitat and floodplain restoration on special-status species in riparian areas would be magnified under Alternative 3, as compared to the No Action Alternative and Alternative 1, given that Alternative 3 proposes 25,000 acres of habitat restoration within the Delta. More than triple the amount of habitat will be restored under Alternative 3 than under the No Action Alternative and Alternative 1. Although it is unknown at this time how much of this habitat is suitable for special-status species in riparian areas, it is likely that additional habitat for special-status species would be affected under Alternative 3. Additional habitat restoration would result in a greater extent of permanent and temporary habitat loss, the latter of which would be expected to recover and restore over time. Habitat restoration would ultimately benefit special-status species in riparian areas by increasing the amount of available habitat and enhancing degraded habitat areas.

Potential changes to habitat for special-status reptiles

Alternative 3 includes creation of spawning habitat and side channels along rivers, channel margin restoration, floodplain restoration, and other aquatic habitat restoration on the banks of waterbodies that could result in loss of habitat for giant garter snake and western pond turtle. Aquatic habitat and floodplain restoration could result in directly mortality of these species.

Permanent effects on giant garter snake aquatic habitat are likely to occur when agricultural ditches are modified and flooded as part of the tidal habitat restoration process. Permanent effects on both giant garter snake and western pond turtle habitat could occur where channel margin restoration entail levee setback. For giant garter snake, the conversion of rice to tidal habitat would be a permanent loss, however, rice is not common in the areas where tidal restoration and channel margin restoration would likely be sited. Other aquatic features with potential to occur on restoration sites include natural channels and topographic depressions. Tidal aquatic edge habitat where open water meets the levee edge will also be permanently lost in those reaches where the levee is breached. Temporary effects on aquatic edge habitat are also likely to occur during the time of construction, though these effects would not be expected to last more than 2 years. Permanent effects on upland habitat will primarily occur where upland habitat is removed to create tidal connectivity.

The effect of aquatic habitat and floodplain restoration on special-status reptiles would be magnified under Alternative 3, as compared to the No Action Alternative and Alternative 1, given that Alternative 3 proposes 25,000 acres of habitat restoration within the Delta—more than triple the amount of habitat restored under the No Action Alternative and Alternative 1. Although it is unknown at this time how much of this habitat is suitable for special-status reptiles, it is likely that additional habitat for special-status reptiles will be affected. Additional habitat restoration will occur in a greater extent of permanent and temporary habitat loss, the latter of which would be expected to recover and restore. However, both western pond turtle and giant garter snake occur over a substantial range, which will reduce the magnitude of these effects. The giant garter snake range extends from Chico in Butte County to the Mendota Wildlife Area in Fresno County, and western pond turtle is found throughout Washington, Oregon, and California. Habitat restoration would ultimately benefit special-status reptiles by increasing the amount of available habitat and enhancing degraded habitat areas.

Potential to injure or kill special-status species

Construction-related actions associated with habitat restoration and the installation/upgrade of facilities under Alternative 3 could injure or kill special-status species in occupied habitat. The operation of equipment for land clearing and restoration could result in injury or mortality of special-status species. This risk is highest for species with periods of dormancy, like California tiger salamander and giant garter snake. Increased vehicular traffic associated with construction activities could contribute to a higher incidence of road kill. However, construction monitoring and other mitigation measures have been identified to avoid and minimize injury or mortality of special-status species during construction.

In tidal marsh habitat, construction actions such as excavation of levees, construction of tidal control gates, movement and staging of large construction equipment, piling and storage of soils, dredging, and filling and grading of vegetated areas, could cause the injury or mortality of special-status species that may be in the vicinity of the construction area. Tidal marsh species are especially vulnerable during periods of higher tides and peak flooding by storms; during these periods, these species move into upland marsh areas for protection. Tidal marsh species could drown or be preyed upon if construction activities or equipment isolate tidal marsh species from their refugia habitat or confuse or disturb them.

Equipment operation for the creation of side channels and levees in riparian habitat during periods of high seasonal activity, such as the nesting bird or bat maternity seasons, could also injure or kill special-status species. Risk is greatest to bird eggs and nestlings or bat pups that could be injured or killed through crushing by heavy equipment, nest abandonment, or increased exposure to the elements or to predators. Injury to adults and fledged juveniles is unlikely, as these individuals are expected to avoid contact with construction equipment.

Night construction could disrupt animal behavior and/or sleep cycles or adversely affect bat foraging activity in all impacted habitat types if special-status species are exposed to night lighting. For example, bird species are attracted to artificial lights, which may disrupt their behavioral patterns or cause collision-related fatalities (Gauthreaux and Belser 2006). Night lighting can also result in circadian/behavior disruptions which can cause bird species to molt and develop their reproductive system earlier than in dark nights. Night lighting can also influence the endocrine system of vertebrates, which can lead to health deterioration (Fonken and Nelson 2014; Ouyang et al. 2018).

Construction-related noise levels could cause additional behavioral modifications if special-status species are present in the general vicinity. Construction activities may create noise up to 60 dBA at no more than 1,200 feet from the edge of the noise generating activity. While 60 dBA is the standard noise threshold for birds (Dooling and Popper 2007), this standard is generally applied during the nesting season, when birds are more vulnerable to behavioral modifications that can cause nest failure. There is evidence, however, that migrating birds will avoid noisy areas during migration (McClure et al. 2013). Noise and visual disturbance outside the project footprint but within 200 feet of construction activities could temporarily affect the use of adjacent habitat by giant garter snake. These effects will be minimized by siting construction 200 feet away from the banks of giant garter snake aquatic habitat, where feasible, as described in MM BIO-5.

Contaminants could be introduced into species' habitats as a result of construction. Exhaust from construction and maintenance vehicles may result in deposition of particulates, heavy metals, and mineral nutrients that could influence the quality and quantity of vegetation and thereby affect presence and abundance of special-status species. The use of mechanical equipment during construction might cause the accidental release of petroleum or other contaminants that will affect occupied, suitable, or adjacent habitat. These accidental spills could also affect special-status species prey, resulting in less food availability. Increased runoff from impervious surfaces into wetland areas carries pollutants that are harmful to reptiles and amphibians, which are particularly sensitive to contaminants and other pollutants in the water.

Construction-related effects would be magnified under Alternative 3, as compared to the No Action Alternative and Alternative 1, given that Alternative 3 proposes 25,000 acres of habitat restoration within the Delta. Although the construction activities would be the same across Alternatives 1 and 3 (e.g., noise, lighting, equipment), Alternative 3 has a greater potential to occur in special-status species habitat and directly affect (i.e., injure or kill) a special-status species. Given that construction under Alternative 3 would occur in more than double the area that it will occur under Alternative 1, Alternative 3 has a greater potential to impact entire populations in the vicinity of the construction area or even an entire species, especially if that species has restrictive habitat requirements and a narrow range distribution. For example, Suisun shrew is only found in the northern borders of San Pablo and Suisun Bay, and Suisun thistle is known from only two occurrences and is present in Suisun March. However, if construction is properly cited and mitigation measures are in place, impacts on species with restrictive habitat requirements and range distribution can be avoided.

Potential changes to vernal pools and associated special-status species

Tidal habitat restoration and the construction of the Conservation Hatchery under the Alternative 3 could have direct and indirect effects on vernal pools and associated special-status species. Vernal pool species that could be affected include California tiger salamander, Contra Costa goldfields, and vernal pool invertebrates. Direct effects include loss of habitat and individual mortality as a result of construction. Tidal natural community restoration could result in the permanent loss of vernal pool crustacean habitat. It is anticipated that much of the existing vernal pool habitat that would be impacted by the project is already degraded. Vernal pools in the Sacramento and San Joaquin Valleys have already experienced significant disturbance due to agricultural development (e.g., plowing, disking, or leveling) which results in compacted soils, loss of hydrologic connections, and reductions in the size and extent of vernal pools.

Construction of the Conservation Hatchery could result in direct removal of vernal pools if it is constructed in an area that contains vernal pool complexes. Similarly, if these pools are occupied, vernal pool crustaceans could be destroyed. These effects will be avoided through the implementation of the identified/proposed mitigation measures.

Indirect conversion of vernal pool habitat could also occur due to hydrological changes as a result of tidal habitat restoration or construction of the hatchery. Construction restoration activities may result in the modification of hardpan and changes to the perched water table, which could lead to alterations in the rate, extent, and duration of inundation of nearby vernal pool crustacean habitat. USFWS typically considers construction within 250 feet of vernal pool crustacean habitat to constitute and a possible conversion of crustacean habitat unless more detailed information is provided to further refine the limits of any such effects. Therefore, MM BIO-1 will ensure a buffer of 250 feet for construction or restoration near vernal pool habitat.

The effect of the project on vernal pools and special-status species will be magnified under Alternative 3, as compared to Alternative 1, given that Alternative 3 proposes an additional 25,000 acres of habitat restoration. Although it is unknown at this time how much occupied and suitable vernal pool habitat will be impacted by each Action Alternative, additional habitat restoration is likely to impact a greater amount of vernal pool habitat. However, as stated above, MM1 requires full avoidance of vernal pools.

Potential to affect special-status bat species and their habitat

Special-status bat species with potential to occur in the study area employ varied roost strategies, from solitary roosting in foliage of trees to colonial roosting in trees and artificial structures, such as tunnels, buildings, and bridges. Various roost strategies could include night roosts, maternity roosts, migration stopover, or hibernation. Special-status bat roosting habitats include riparian habitat, developed lands, and landscaped trees such as eucalyptus, palms and orchards. Potential foraging habitat includes all riparian habitat types, cultivated lands, developed lands, grasslands, and wetlands.

Four California bat species of special concern could occur in the study area (Table P.1-1), as well as a number of common bat species. Construction and restoration activities associated with Alternative 3 would result in both temporary and permanent losses of foraging and roosting habitat for special-status bat species. Tidal habitat restoration and floodplain restoration would result in permanent and temporary loss of riparian roosting habitat and conversion of foraging habitat from mostly cultivated lands and managed wetlands to tidal and nontidal wetlands. Development of the Conservation Hatchery could also result in the removal of roosting and foraging habitat. Noise and visual disturbances during implementation of riparian habitat restoration and other construction activities could result in temporary disturbances that, if bat roost sites are present, could cause temporary abandonment of roosts. Impacts on special-status bat species that occupy artificial structures are expected to be negligible in comparison to the amount of impacts on natural habitat types, but temporary and permanent impacts on special-status bat species occupying artificial structures could result in local adverse effects.

Despite having potential to result in some adverse effects, implementation of Alternative 3 would result in an overall benefit to special-status bats within the study area through restoration of their foraging and roosting habitats. The majority of affected habitat would be agricultural, and such land would be converted to natural communities with higher value foraging and roosting potential such as riparian land, tidal and nontidal wetlands, and periodically inundated lands. Restored habitats are expected to be of higher value because, compared to agricultural land, pesticide use would be lower and greater numbers of flying insect prey species would be available. In addition, any impact from construction, restoration, or periodic inundation on special-status bats and their habitat would be mitigated through implementation of MM BIO-24, which would ensure there is no significant impact on roosting special-status bats, either directly or through habitat modifications, and no substantial reduction in numbers nor a restriction in the range of special-status bats.

Potential changes to wetlands and waters of the United States

The restoration projects associated with Alternative 3 would likely require some fill of wetlands and waters of the United States. Fill could occur from dredging work, spoils areas, side channel construction, and installation of the Conservation Hatchery. The majority of the impacts on wetlands and Waters of the United States are likely on tidal channels, emergent wetlands, and on wetlands and waters found within cultivated lands (agricultural ditches and seasonal wetlands). Reclamation will obtain and implement the conditions and requirements of state and federal permits that may be required prior to the construction of the proposed project.

Unavoidable impacts on waters of the United States would be the same as previously described for this impact under Section P.2.3, *Alternative 1*.

The functions of the Waters of the United States that would be temporarily or permanently impacted by Alternative 1 and Alternative 3 would vary, given that Alternative 3 proposes to restore 25,000 acres while Alternative 1 would restore 8,000 acres. The significance of the impact would depend primarily on existing land uses and historical levels of disturbance. Generally, agricultural ditches and conveyance channels, which are regularly maintained and often devoid of vegetation, support only minimal hydraulic function (water conveyance), with virtually no water quality or habitat function. Some facilities that are regularly maintained can still support some hydrologic, hydraulic, and water quality functions (e.g., reduction of velocity, groundwater recharge, and trapping of sediment). Tidal channels affected by this alternative support functions in all three categories, but the level at which these functions perform vary depending on setting, size, and level of disturbance. Alkaline wetlands and vernal pools exist in nonnative grasslands and have been subjected to some disturbance due to past land uses. Although these features likely support habitat, water quality, and hydrologic/hydraulic functions, the capacity of these features to perform such functions vary depending on the overall ecological setting and level of disturbance. Functions associated with emergent wetland, forest, and scrub-shrub depend primarily on the location of these habitat types. Where they exist as in-stream (in-channel islands) or as the thick band of habitat adjacent to a waterway, these features are expected to function at a high level. However, where these habitats exist as thin bands, or where they are situated in agricultural fields, their habitat functions would be considerably lower. All wetlands classified as seasonal wetlands occur in agricultural fields. As such, their habitat functions have been greatly compromised, but they retain some water quality and hydrologic/hydraulic function. Like seasonal wetlands, most depressions occur within agricultural areas; however the depressions may support wetland vegetation at their edges

Potential changes to terrestrial species' critical habitat

The restoration projects under Alternative 3 could result in loss of terrestrial species' critical habitat.

Western yellow-billed cuckoo proposed critical habitat is present in Tisdale Bypass and Sutter Bypass. However, Alternative 3 does not propose to modify flows in the Tisdale or Sutter Bypasses. Changes in frequency of inundation in the Sacramento River would be minor, and within the current minimum and maximum flows. The action alternatives could provide for some different riparian species that require year-round flows, as compared to the No Action Alternative, where low flows in the fall would stress invasive plants and encourage drought tolerant native species to persist.

Critical habitat for valley elderberry longhorn beetle is present along the American River. However, Reclamation will avoid valley elderberry longhorn critical habitat.

Critical habitat for vernal pool fairy shrimp and vernal pool tadpole shrimp is present in areas that Reclamation could potentially use for tidal habitat restoration. Reclamation will, however, avoid areas that would affect the primary constituent habitat elements for these species in the critical habitat units.

Critical habitat for California tiger salamander is present in areas that Reclamation could potentially use for tidal habitat restoration. Reclamation will, however, avoid areas that would affect the primary constituent habitat elements for this species in the critical habitat units.

Critical habitat for soft bird’s-beak and Suisun thistle is present in areas that Reclamation could potentially use for tidal habitat restoration. Reclamation will, however, avoid areas that would affect the primary constituent habitat elements for these species in the critical habitat units.

Therefore, Alternative 3 would have no effect on critical habitat for these species.

P.2.6 Alternative 4

P.2.6.1 *Project-Level Effects*

Potential changes to wildlife and plant habitat on river banks

Compared to the No Action Alternative, operation of the CVP and SWP under Alternative 4 would change river flows and reservoir levels, which would change existing flow conditions. Increases in peak flows are expected in the affected stream reaches for the Sacramento River, Clear Creek, Feather River, American River and Yolo Bypass under Alternative 4 compared to the No Action Alternative. If peak river flows or reservoir levels have substantive increases beyond the No Action Alternative, it could kill or injure special-status species and remove their habitat along rivers and reservoirs. However, evaluation of changes in peak flow indicates that increases would maintain higher flows generally from the months of February through June, where it is common for seasonal discharge to increase naturally. These flows are not expected to result in river bank overtopping/flooding or increased inundation in the Yolo Bypass, therefore flow increases under Alternative 4 would not result in any change to wildlife and plant habitat on river banks in comparison to the No Action Alternative.

P.2.6.2 *Program-Level Effects*

Potential changes to habitat for special-status reptiles

Alternative 4 components to increase water use efficiencies in agricultural areas may result in loss of habitat for giant garter snake . Permanent effects on giant garter snake aquatic habitat are likely to occur when agricultural ditches and canals are replaced with pipes to reduce water loss.. In addition, the conversion of rice to dryland farming or land uses would be a permanent loss of habitat for giant garter snake. Temporary effects on aquatic habitat for giant garter snake may also occur during the time of construction, though these effects would not be expected to last more than 2 years. Permanent effects on upland habitat would primarily occur where upland habitat is removed during construction of new on-farm irrigation or distribution systems or during alteration of existing on-farm distribution systems.

Potential to injure or kill special-status species

Construction-related actions associated with construction of new agricultural water use efficiency facilities under Alternative 4 could injure or kill giant garter snake and elderberry longhorn beetle in occupied habitat. The operation of equipment for land clearing could result in injury or mortality of special-status species. This risk is highest during the giant garter snake period of dormancy in the winter, where these snakes estivate in burrows adjacent to aquatic habitat, and when elderberry shrubs are removed along canals and ditches. Increased vehicular traffic associated with construction activities could contribute to a higher incidence of vehicle strikes. However, construction monitoring and other mitigation measures have been identified to avoid and minimize injury or mortality of giant garter snake and valley elderberry longhorn beetle during construction.

Construction-related noise levels could cause additional behavioral modifications if special-status species are present in the general vicinity. Construction activities may create noise up to 60 dBA at no more than 1,200 feet from the edge of the noise generating activity. While 60 dBA is the standard noise threshold for birds (Dooling and Popper 2007), this standard is generally applied during the nesting season, when birds are more vulnerable to behavioral modifications that can cause nest failure. There is evidence, however, that migrating birds will avoid noisy areas during migration (McClure et al. 2013). Noise and visual disturbance outside the project footprint but within 200 feet of construction activities could temporarily affect the use of adjacent habitat by giant garter snake. These effects will be minimized by siting construction 200 feet away from the banks of giant garter snake aquatic habitat, where feasible, as described in MM BIO-5.

Contaminants could be introduced into species' habitats as a result of construction. Exhaust from construction and maintenance vehicles may result in deposition of particulates, heavy metals, and mineral nutrients that could influence the quality and quantity of vegetation and thereby affect presence and abundance of special-status species. The use of mechanical equipment during construction might cause the accidental release of petroleum or other contaminants that will affect occupied, suitable, or adjacent habitat. These accidental spills could also affect special-status species prey, resulting in less food availability. Increased runoff from impervious surfaces into wetland areas carries pollutants that could contaminant the water.

Potential changes to wetlands and waters of the United States

The agricultural water use efficiency facilities associated with Alternative 4 would likely require some fill of wetlands and waters of the United States. The impacts on wetlands and waters of the United States. are waters found within cultivated lands (e.g., agricultural ditches, canals, seasonal wetlands). Reclamation will obtain and implement the conditions and requirements of state and federal permits that may be required prior to the construction of the proposed project.

Unavoidable impacts on waters of the United States would be offset such that the loss of acreage and functions due to construction activities are fully compensated. Unlike the alternatives described above which include restoration, construction would likely not result in a net increase of wetlands and waters of the United States. These losses may be short-term if construction results in conversion from one wetland type to another.

P.2.7 Mitigation Measures

Mitigation measures are included in this document to avoid, minimize, or compensate for adverse environmental effects of alternatives as compared to the No Action Alternative. The first set of mitigation measures described below are measures to avoid or minimize effects on special-status species, and to compensate for unavoidable effects (Section P.2.8, *Summary of Impacts*). A summary of how each of the measures will mitigate effects for each alternative is provided below.

P.2.7.1 *Species-Specific Mitigation Measures*

Reclamation will implement the following mitigation measures to avoid or minimize effects on special-status species and their habitat. Species-specific measures described below have been developed to avoid and minimize effects that could result from the proposed action on listed and nonlisted species addressed in this appendix. Table P.2-1 below briefly summarizes the species-specific measures.

Table P.2-1. Mitigation Measures for Terrestrial Species in the Study Area

Number	Title	Summary
BIO-1	Vernal Pool Fairy Shrimp, Vernal Pool Tadpole Shrimp, Conservancy Fairy Shrimp, Longhorn Fairy Shrimp	Avoidance of vernal pool habitat and critical habitat, regardless of occupancy, and maintain 250-foot nondisturbance buffer; conduct protocol-level surveys or assume presence.
BIO-2	Valley Elderberry Longhorn Beetle	Habitat avoidance where possible, preconstruction surveys, fencing, monitoring. Mitigate unavoidable impacts consistent with *Framework for Assessing Impacts to the Valley Elderberry Longhorn Beetle* (USFWS 2017).
BIO-3	California Tiger Salamander and Western Spadefoot Toad	Habitat avoidance (including critical habitat).
BIO-4	Foothill Yellow-Legged Frog	Preconstruction survey, timing, compensate for unavoidable effects
BIO-5	Giant Garter Snake	Habitat avoidance where possible, preconstruction survey, and biological monitoring. Unavoidable habitat loss will be offset through habitat protection and/or restoration at a 3:1 ratio.
BIO-6	Western Pond Turtle	Habitat assessment, preconstruction survey, and relocation.
BIO-7	California Black Rail	Protocol-level surveys, habitat avoidance, nondisturbance buffer, and timing of project activity.
BIO-8	California Ridgway’s Rail	Preconstruction protocol-level survey, timing, habitat avoidance.
BIO-9	Greater and Lesser Sandhill Crane	Timing of construction, habitat avoidance where possible. Preconstruction survey, avoid roosts where possible, directional lighting.
BIO-10	Least Bell’s Vireo	Habitat assessment, preconstruction survey, nondisturbance buffer, noise analysis, limit construction activity near nests. Mitigate unavoidable impacts through habitat creation at a 2:1 ratio.
BIO-11	Suisun Song Sparrow, Saltmarsh Common Yellowthroat, Yellow-Breasted Chat, Yellow Warbler	Preconstruction survey, nondisturbance buffer, biological monitoring of active nests, noise reduction, minimize construction traffic, directional lighting.
BIO-12	Swainson’s Hawk	Preconstruction survey, habitat avoidance where possible, nondisturbance buffer. Mitigate unavoidable loss of foraging

Number	Title	Summary
		habitat through foraging habitat protection at a 1:1 ratio and unavoidable loss of nesting habitat through riparian restoration at a 2:1 ratio.
BIO-13	Tricolored Blackbird	Preconstruction survey, habitat avoidance, biological monitoring. Mitigate unavoidable loss of foraging habitat at a 1:1 ratio and unavoidable loss of nesting habitat through restoration at a 2:1 ratio.
BIO-14	Western Burrowing Owl	Protocol-level survey, preconstruction survey, habitat avoidance, relocation during nonbreeding season, nondisturbance buffer, biological monitoring. Mitigate unavoidable loss of nesting, wintering, and satellite burrows, and burrowing owl habitat in comparable habitat at an approved mitigation ratio in consultation with the California Department of Fish and Wildlife.
BIO-15	Western Yellow-Billed Cuckoo	Habitat avoidance (including critical habitat), preconstruction surveys.
BIO-16	White-Tailed Kite	Preconstruction survey, nondisturbance buffer, work window restriction, biological monitoring. Mitigate unavoidable loss of foraging habitat through foraging habitat protection at a 1:1 ratio and unavoidable loss of nesting habitat through riparian restoration at a 2:1 ratio.
BIO-17	Bald Eagle	Nesting habitat avoidance, nondisturbance buffer, monitoring.
BIO-18	Bank Swallow	Preconstruction survey, nondisturbance buffer, monitoring, project design to avoid impacts.
BIO-19	California Least Tern	Habitat avoidance.
BIO-20	Migratory Nesting Birds	Preconstruction survey, nondisturbance buffer, monitoring.
BIO-21	Riparian Woodrat and Riparian Brush Rabbit	Habitat suitability assessment, protocol-level survey, habitat avoidance where possible. 3:1 compensation for unavoidable impacts.
BIO-22	Salt Marsh Harvest Mouse and Suisun Shrew	Preconstruction survey, biological monitoring, exclusion fence.
BIO-23	Ring-Tailed Cat	Avoid denning period, preconstruction survey, nondisturbance buffer, biological monitoring.
BIO-24	Special-Status Bats	Preconstruction surveys, monitoring, exclusion, timing, buffers.
BIO-25	Suisun Thistle and Soft Bird’s-Beak	Botanical survey, habitat avoidance (including critical habitat), minimize introduction of invasive plants. 1:1 compensation for unavoidable impacts.
BIO-26	Other Special-Status Plant Species	Botanical survey, habitat avoidance, prevent spread of invasive plant species. 1:1 compensation for unavoidable impacts.
BIO-27	Wetlands and Waters of the United States	Avoid fill of wetlands and waters of the United States. To the extent feasible, offset unavoidable effects through wetland creation, restoration, or enhancement.

Mitigation Measure BIO-1: Vernal Pool Fairy Shrimp, Vernal Pool Tadpole Shrimp, Conservancy Fairy Shrimp, Longhorn Fairy Shrimp

Reclamation will avoid vernal pool crustacean habitat, including habitat for vernal pool fairy shrimp, vernal pool tadpole shrimp, conservancy fairy shrimp, and longhorn fairy shrimp with a minimum

250-foot nondisturbance buffer. Reclamation will either conduct protocol-level surveys to assess whether habitat is occupied or will assume presence of the species.

Reclamation will avoid affecting any of the primary constituent elements of critical habitat for vernal pool fairy shrimp or vernal pool tadpole shrimp within designated critical habitat units.

Mitigation Measure BIO-2: Valley Elderberry Longhorn Beetle

Suitable Habitat

Valley elderberry longhorn beetle habitat is defined as elderberry shrubs within the study area. Elderberry shrubs in the study area could be found in riparian areas, along levee banks, grasslands, and in agricultural settings where vegetation is not being maintained (e.g., fence rows, fallow fields).

Avoidance and Minimization

Activities will be located to avoid or minimize disturbance of valley elderberry longhorn beetle suitable habitat within the species' range to the greatest extent practicable.

Reclamation will avoid valley elderberry longhorn beetle critical habitat during implementation of the project components.

Complete avoidance (i.e., no adverse effects) may be assumed when elderberry shrubs are not present or within a 165-foot buffer of the activity. USFWS will be consulted before any disturbances, including construction, within the 165-foot buffer area if it contains elderberry shrubs and/or riparian habitat.

Preconstruction surveys for elderberry shrubs will be conducted within all project construction footprints and areas within 165 feet by a biologist familiar with the appearance of valley elderberry longhorn beetle exit holes in elderberry shrubs. When possible, preconstruction surveys will be conducted in the calendar year prior to disturbance and will follow the guidance of USFWS's *Framework for Assessing Impacts to the Valley Elderberry Longhorn Beetle* (USFWS 2017), herein referred to as the 2017 VELB Framework.

For elderberry shrubs not directly affected by construction but that occur between 20 feet and 165 feet from ground-disturbing activities, the following measures will be implemented.

- All areas to be avoided during construction activities will be fenced and/or flagged as close to construction limits as feasible.
- Activities that may damage or kill an elderberry shrub (e.g., trenching, paving, etc.) may need an avoidance area of at least 20 feet (6 meters) from the drip-line, depending on the type of activity.
- A qualified biologist will provide training for all contractors, work crews, and any onsite personnel on the status of the valley elderberry longhorn beetle, its host plant and habitat, the need to avoid damaging the elderberry shrubs, and the possible penalties for noncompliance.
- A qualified biologist will monitor the work area at project-appropriate intervals to assure that all avoidance and minimization measures are implemented. The amount and duration of monitoring will depend on the project specifics and should be discussed with the USFWS biologist.
- As much as feasible, all activities that could occur within 165 feet (50 meters) of an elderberry shrub will be conducted outside of the flight season of the valley elderberry longhorn beetle (March to July).

- Trimming may remove or destroy valley elderberry longhorn beetle eggs and/or larvae and may reduce the health and vigor of the elderberry shrub. To avoid and minimize adverse effects to valley elderberry longhorn beetle, trimming will occur between November and February and will avoid the removal of any branches or stems that are greater than or equal to 1 inch in diameter. Measures to address regular and/or large-scale maintenance (trimming) should be established in consultation with the USFWS.
- Herbicides will not be used within the drip-line of the shrub. Insecticides will not be used within 98 feet (30 meters) of an elderberry shrub. All chemicals will be applied using a backpack sprayer or similar direct application method.
- Mechanical weed removal within the drip-line of the shrub will be limited to the season when adults are not active (August to February) and will avoid damaging the elderberry.
- Erosion control will be implemented, and the affected area will be revegetated with appropriate native plants.
- The potential effects of dust on valley elderberry longhorn beetle will be minimized by applying water during construction activities or by presoaking work areas that will occur within 100 feet of any potential elderberry shrub habitat. Elderberry shrubs with stems greater than 1 inch that are directly affected by construction should be transplanted under the following conditions:
  - If the elderberry shrub cannot be avoided.
  - If indirect effects will result in the death of stems or the entire shrub.

The removal of the elderberry shrub may either include the roots or just the removal of the aboveground portion of the plant. When possible, the entire root ball will be retained and the elderberry shrub will be transplanted as close as possible to its original location. Elderberry shrubs will be relocated adjacent to the project footprint if (1) the planting location is suitable for elderberry growth and reproduction; and (2) the project proponent is able to protect the shrub and ensure that the shrub becomes reestablished. If these criteria cannot be met, the shrub may be transplanted to an appropriate USFWS-approved mitigation site. Any elderberry shrub that is unlikely to survive transplanting because of poor condition or location, or a shrub that would be extremely difficult to move because of access problems, may not be appropriate for transplanting. The following transplanting guidelines may be used by agencies/applicants in developing their valley elderberry longhorn beetle conservation measures:

- A qualified biologist will be onsite for the duration of transplanting activities to ensure compliance with avoidance and minimization measures and other conservation measures.
- Exit-hole surveys will be completed immediately before transplanting. The number of exit holes found, GPS location of the plant to be relocated, and the GPS location of where the plant is transplanted will be reported to the USFWS and to the CNDDB.
- Elderberry shrubs will be transplanted when the shrubs are dormant (November through the first 2 weeks in February) and after they have lost their leaves. Transplanting during the nongrowing season will reduce shock to the shrub and increase transplantation success.
- Transplanting will follow the most current version of the ANSI A300 (Part 6) guidelines for transplanting (http://www.tcia.org/).

- Trimming will occur between November and February and should minimize the removal of branches or stems that exceed 1 inch in diameter.

Compensation for Unavoidable Effects

Reclamation will coordinate with the USFWS to offset unavoidable impacts on elderberry shrubs by either creating valley elderberry longhorn beetle habitat or by purchasing the equivalent credits at a USFWS-approved conservation bank with a service area that overlaps with the study area. Compensatory mitigation will be coordinated with the USFWS to determine the appropriate type and amount of compensatory mitigation and follow criteria in the 2017 VELB Framework. These guidelines recommend that the permanent loss of valley elderberry longhorn beetle habitat be replaced with habitat that is commensurate with the type (riparian or nonriparian) and amount of habitat lost. For plants in riparian areas, compensation may be appropriate for any impacts to valley elderberry longhorn beetle habitat. In nonriparian areas, compensation may be appropriate for occupied shrubs. Suitable riparian habitat may be replaced at a minimum ratio of 3:1 for all acres that will be permanently affected by the project. Suitable nonriparian habitat may be replaced at a minimum ratio of 1:1 for all acres that will be permanently affected by the project. Impacts on individual shrubs in riparian areas may be replaced by the purchase of two credits (one credit = 1,800 square feet) at a USFWS-approved bank for each shrub that will be trimmed regardless of the presence of exit holes. If the shrub will be completely removed by the activity, the entire shrub may be transplanted to a USFWS-approved location in addition to the credit purchase. Impacts on individual shrubs in nonriparian areas be replaced through a purchase of 1 credit at a USFWS-approved bank for each shrub that will be trimmed if exit holes have been found in any shrub on or within 165 feet of the project. If the shrub will be completely removed by the activity, the entire shrub will be transplanted to a USFWS-approved location in addition to a credit purchase. These ratios may apply if compensation occurs prior to or concurrent with the impacts. If compensation occurs after the impacts, a higher ratio may be required by USFWS. Appropriate compensatory mitigation may include purchasing credits at a USFWS-approved conservation bank, providing onsite mitigation, or establishing and/or protecting habitat for valley elderberry longhorn beetle.

Mitigation Measure BIO-3: California Tiger Salamander and Western Spadefoot Toad

For restoration projects and construction of the Conservation Hatchery, Reclamation will avoid California tiger salamander and western spadefoot toad upland and aquatic habitat. Reclamation will avoid affecting any of the primary constituent elements of critical habitat for California tiger salamander within designated critical habitat units.

Mitigation Measure BIO-4: Foothill Yellow-Legged Frog

Species-specific mitigation for foothill yellow-legged frog will only be required for projects occurring within or adjacent to suitable habitat as identified by assessments conducted during the project component planning phase. A qualified biologist will conduct a field evaluation for foothill yellow-legged frog for all project activities that occur within suitable habitat.

Prior to any ground-disturbing activity scheduled to occur during the dry season (June 1–October 15), a qualified biologist will survey potential breeding habitat for the presence of foothill yellow-legged frogs using methods from the *Draft Visual Encounter Survey Protocol for* Rana boylii *in Lotic Environments* (Peek et al. 2017) or other more recent guidelines, if available. Surveys will be conducted no more than 30 days before the start of ground-disturbing activities and will be spatially phased to precede construction activities. Avoidance and minimization measures, including moving individuals to nearby ponds or other appropriate measures, will be implemented with authorizations issued under the California Endangered Species Act (CESA).

Compensation for Unavoidable Effects

Reclamation will provide compensatory mitigation for unavoidable permanent impacts on habitat for foothill yellow-legged frog. Impacts on occupied or presumed occupied aquatic habitat will be compensated for at a ratio of 3:1 for breeding and foraging habitat.

Mitigation Measure BIO-5: Giant Garter Snake

Avoidance and Minimization Measures

Species-specific mitigation for giant garter snake will be required only for projects occurring within or adjacent to suitable habitat, as identified by assessments conducted during the project component planning phase. A qualified biologist will conduct a field evaluation of suitable upland or aquatic habitat for giant garter snake for all covered activities that occur within suitable giant garter snake habitat.

If the project does not fully avoid effects on suitable habitat, the following measures will be required:

- Initiate construction between May 1 and October 1 within suitable giant garter snake upland habitat, which corresponds with the snake’s active period. Work in giant garter snake upland habitat may also occur between October 2 and November 1 or between April 1 and May 1 if ambient temperatures exceed 75 degrees Fahrenheit (°F) during construction activities and maximum daily temperatures have exceeded 75°F for a least 3 consecutive days immediately preceding work. During these periods, giant garter snakes are more likely to be active in aquatic habitats and less likely to be found in upland habitats. To the extent practicable, conduct all activities within paved roads, farm roads, road shoulders, and similarly disturbed and compacted areas; confine ground disturbance and habitat removal to the minimum area necessary to facilitate construction activities. For construction activities and any conveyance facility maintenance involving heavy equipment, giant garter snake aquatic and upland habitat that can be avoided will be clearly delineated on the work site, with high-visibility fencing and signage identifying these areas as sensitive. The fencing will be installed before equipment is moved onsite and before any ground-disturbing activities begin. The purpose of the fencing is to prevent construction activities from encroaching into sensitive habitat areas and not intended to exclude animals. To minimize the potential for snakes and other ground-dwelling animals to be caught in the construction fencing, the fencing will be placed with at least a 6-inch gap between the ground and the bottom of the fencing to allow animals to pass under.
- All construction personnel and personnel involved in operations and maintenance in or near giant garter snake habitat will attend worker environmental awareness training (as described in Appendix O, *Aquatic Resources Technical Appendix*). This training will include instructions to workers on how to recognize giant garter snakes, their habitat(s), and the nature and purpose of protection measures.
- Within 24 hours prior to construction activities or maintenance activities requiring heavy equipment within giant garter snake habitat, a USFWS-approved biologist will survey all areas planned for disturbance and at least 50 feet outside the disturbance area where giant garter snake

could be present. The surveyor will inspect all burrows, soil cracks, and crevices that could be used by giant garter snake. To the extent that these habitat features can be avoided within the work area, they will be flagged, and the locations will be provided to the biological monitor. This survey of the work area will be repeated if a lapse in construction activity of 2 weeks or greater occurs during the giant garter snake inactive period (October 1 to May 1) or if the lapse in construction activity is more than 12 hours during the active period (May 1 to October 1). If a giant garter snake is encountered during surveys or construction, activities will cease until appropriate corrective measures have been completed, it has been determined that the giant garter snake will not be harmed, or the giant garter snake has left the work area.

- For all construction activities that occur in giant garter snake habitat that could result in injury or mortality of snakes (e.g., movement of heavy equipment; excavation of soil, rock, or existing structures; grading; vegetation removal), a USFWS-approved biologist will be present to monitor these activities. As work is performed, the biologist will visually scan work areas, under equipment, and excavated materials for giant garter snakes. The biologist will also help guide access and construction work around wetlands, active rice fields, and other sensitive habitats capable of supporting giant garter snake to minimize habitat disturbance and risk of injuring or killing giant garter snakes.
- Report all observations of giant garter snakes to the USFWS-approved biological monitor. If a giant garter snake is observed in the work area, the monitor will have the authority to stop work in the immediate vicinity of the snake. If possible, the snake will be allowed to leave the work area on its own volition and the monitor will remain in the area until the snake is safely out of harm's way. A giant garter snake may be captured and relocated out of the work area with prior authorization from USFWS and by an individual with the appropriate handling permit. The snake will be relocated to suitable habitat at least 200 feet from the work area.
- Maintain all construction and operations and maintenance equipment to prevent leaks of fuel, lubricants, and other fluids and use extreme caution when handling and or storing chemicals (such as fuel and hydraulic fluid) near waterways, and abide by all applicable laws and regulations. Follow all applicable hazardous waste BMPs and keep appropriate materials onsite to contain, manage, and clean up any spills.
- Conduct service and refueling procedures in uplands in staging areas and at least 200 feet away from waterways when practicable.
- During construction and operation and maintenance activities in and near giant garter snake habitat, employ erosion (non-monofilament silt fence), sediment, material stockpile, and dust control BMPs. Avoid using fill or allowing runoff into wetland areas or waterways to the extent practicable.
- Return temporary work areas to pre-existing contours and conditions upon completion of work. Where revegetation and soil stabilization are necessary in nonagricultural habitats, revegetate with appropriate noninvasive native plants at a density and structure similar to that of preconstruction conditions. Restoration of aquatic vegetation in giant garter snake aquatic habitat and annual grassland within giant garter snake upland habitat will be detailed in a mitigation and monitoring plan that will be reviewed and approved by USFWS prior to the start of construction. Habitat will be restored within one season (defined as May 1 to October 1).

- Properly contain and remove from the worksite all trash and waste items generated by construction and crew activities to prevent the encouragement of predators such as raccoons and coyotes from occupying the site.
- Permit no pets, campfires, or firearms at the worksite.
- Store equipment in designated staging area areas at least 200 feet away from giant garter snake aquatic habitat to the extent practicable.
- Confine any vegetation clearing to the minimum area necessary to facilitate construction activities.
- Limit vehicle speed to 10 miles per hour (mph) on access routes (except for public roads and highways) and within work areas that are within 200 feet of giant garter snake aquatic habitat but not protected by exclusion fencing to avoid running over giant garter snakes.
- Visually check for giant garter snake under vehicles and equipment prior to moving them. Cap all onsite materials (conduits, pipe, etc.), precluding wildlife from becoming entrapped. Check any crevices or cavities in the work area where individuals may be present including stockpiles that have been left for more than 24 hours where cracks or crevices may have formed.
- For proposed activities that will occur within suitable aquatic giant garter snake habitat during the active giant garter snake season (May 1 through October 1), prior to proposed construction activities that will commence during the inactive period, and when unavoidable, all aquatic giant garter snake habitat will be dewatered for at least 14 days prior to excavating or filling the dewatered habitat. Dewatering is necessary because aquatic habitat provides prey and cover for giant garter snake; dewatering serves to remove the attractant and increase the likelihood that giant garter snake will move to other available habitat. Any deviation from this measure will be done in coordination with, and with approval of, the USFWS.
- Following dewatering of aquatic habitat, all potential affected areas that provide suitable aquatic or upland giant garter snake habitat will be surveyed for giant garter snake by the USFWS-approved biologist. If giant garter snakes are observed, they will be passively allowed to leave the area, or the USFWS will be consulted to determine the appropriate course of action for removing giant garter snake from the area.

Maintenance activities such as vegetation and rodent control, embankment repair, and channel maintenance will occur at conveyance facilities with permanent structures and at conveyance facility and restoration sites with flexible locations (e.g., transmission line right of ways, restoration locations, etc.). The following avoidance and minimization measures will be applied to maintenance activities in suitable aquatic habitat and uplands within 200 feet of suitable aquatic habitat, to minimize effects on the giant garter snake:

- Vegetation control will take place during the active period (May 1 through October 1) when snakes are able to move out of areas of activity.
- Trapping or hunting methods will be used for rodent control rather than poison bait. All rodent control methods will be approved by USFWS. If trapping or other nonpoison methods are ineffective, the USFWS will be consulted to determine the best course of action.

- Movement of heavy equipment will be confined to outside 200 feet of the banks of giant garter snake aquatic habitat to minimize habitat disturbance.
- All construction personnel and personnel involved in operations and maintenance in or near giant garter snake habitat will attend worker awareness training (as described in Appendix O, *Aquatic Resources Technical Appendix*). This training will include instructions to workers on how to recognize giant garter snakes, their habitat, and the nature and purpose of protection measures.

Compensation for Unavoidable Effects

Where giant garter snake habitat cannot be avoided, compensation for the permanent loss of the habitat will occur at a rate of 3:1 for aquatic and upland habitat.

Mitigation Measure BIO-6: Western Pond Turtle

Species-specific mitigation for western pond turtle will only be required for projects occurring within or adjacent to suitable habitat as identified by assessments conducted during the project component planning phase. A qualified biologist will conduct a field evaluation of suitable upland or aquatic habitat for western pond turtles for all covered activities that occur within suitable pond turtle habitat.

If the project does not fully avoid effects on suitable habitat, the following measures will be required.

- The project proponent will retain a qualified wildlife biologist to conduct a preconstruction survey within 48 hours of disturbance in aquatic and riparian habitats to determine presence or absence of pond turtles in the construction work area.
- If possible, the surveys will be timed to coincide with the time of day and year when turtles are most likely to be basking and visible (during the cooler part of the day, 8:00 a.m. to 12:00 p.m., during spring, summer, and late summer). Prior to conducting presence/absence surveys the biologist will locate the microhabitats for turtle basking (logs, rocks, brush thickets) and determine a location to quietly observe turtles.
- Each survey will include a 30-minute wait time after arriving at the site to allow startled turtles to return to open basking areas. The survey will consist of a minimum 15-minute observation time per area where turtles could be observed.
- If turtles are observed during a survey, they will be relocated outside of the construction area to appropriate aquatic habitat by a biologist.

Mitigation Measure BIO-7: California Black Rail

Preconstruction surveys for California black rail will be conducted where potentially suitable habitat for this species occurs within 500 feet of work areas where access is available. Potentially suitable habitat includes tidal and nontidal seasonal or perennial wetlands at least 2 acres in size with any kind of vegetation types consistent with black rail use in the Delta, as determined by field evaluations conducted by a qualified biologist with experience surveying for black rail, over 10 inches high, whether or not the patch in question was mapped as modeled habitat. Surveys will be initiated sometime between January 15 and February 1. A minimum of four surveys will be conducted. The survey dates will be spaced at least 2 to 3 weeks apart and will be scheduled so that the last survey is conducted no more than 2 weeks before April 15. This will allow the surveys to encompass the time period when the highest frequency of calls is likely to occur. These surveys will involve the following protocols (based on Evens et al. 1991), or other approved survey methodologies that may be developed using new information and best-available science, and will be conducted by biologists with the qualifications stipulated in the approved methodologies.

- Listening stations will be established at 300-foot intervals throughout potential black rail habitat that will be affected by covered activities. Listening stations will be placed along roads, trails, and levees to avoid trampling.
- California black rail vocalization recordings will be played at each station, and playing will cease immediately once a response is detected.
- Each listening station will be occupied for 6 minutes, including 1 minute of passive listening, 1 minute of "grr" calls followed by 30 seconds of "ki-ki-krrr" calls, then followed by another 3.5 minutes of passive listening.
- Each survey will include a survey at sunrise and a survey at sunset.
- Sunrise surveys will begin 60 minutes before sunrise and conclude 75 minutes after sunrise (or until presence is detected).
- Sunset surveys will begin 75 minutes before sunset and conclude 60 minutes after sunset (or until presence is detected).
- Surveys will not be conducted when tides are greater than National Geodetic Vertical Datum or when sloughs and marshes are more than bank-full.
- California black rail vocalizations will be recorded on a data sheet. A GPS receiver and compass will be used to identify surveys stations, angles to call locations, and call locations and distances. The call type, location, distance from listening station, and time will be recorded on a data sheet.

The project will be implemented in a manner that will not result in take of California black rail, as defined by Section 86 of the California Fish and Game Code. If California black rail is present in the immediate construction area, the following measures will apply during construction activities:

- To avoid the loss of individual California black rails, activities within 500 feet of potential habitat will not occur within 2 hours before or after extreme high tides (6.5 feet or above, as measured at the Golden Gate Bridge). During high tide, protective cover for California black rail is sometimes limited, and activities could prevent them from reaching available cover.
- To avoid the loss of individual California black rails, activities within 500 feet of tidal marsh areas and managed wetlands will be avoided during the rail breeding season (February 1 to August 31), unless surveys are conducted to determine that no rails are present within the 500-foot buffer.
- If breeding California black rail is determined to be present, activities will not occur within 500 feet of an identified calling center (unless a qualified biologist determines that a smaller distance will not result in the take of the state-listed species). If the intervening distance between the rail calling center and any activity area is greater than 200 feet and across a major slough channel or substantial barrier (e.g., constructed noise barrier) it may proceed at that location within the breeding season.
- If California black rail are determined to be present in habitat that must be disturbed, vegetation will be removed during the nonbreeding season (September 1 to January 31) to encourage them to

leave the area. Vegetation removal will be completed carefully using hand tools or vegetation removal equipment that is approved by a biologist. The biologist will search vegetation immediately in front of the removal equipment, and will stop removal if rails are detected. Vegetation removal will resume when the black rail leaves the area.

- If construction activities require removal of potential California black rail habitat, whether or not black rails have been detected there, vegetation will be removed during the nonbreeding season (September 1 to January 31). Vegetation removal will be completed carefully using hand tools or vegetation removal equipment that is approved by an biologist. The biologist will search vegetation immediately in front of the removal equipment, and will stop removal if rails are detected. Vegetation removal will resume when the rail leaves the area.
- Exception: Inspection, maintenance, or nonconstruction monitoring activities may be performed during the California black rail breeding season (February 1 to August 31) in areas within or adjacent to breeding habitat (within 500 feet) with CDFW approval and under the supervision of a permitted, approved biologist.
- If the construction footprint is within 500 feet of a known calling center, noise reduction structures such as temporary noise reducing walls, will be installed at the edge of construction footprint, as determined by an onsite biologist. Noise-causing construction will begin during the nonbreeding season (September 1 to January 31) so that rails can acclimate to noise and activity prior to initiating nests.

Mitigation Measure BIO-8: California Ridgway's Rail

If construction or restoration activities are necessary during the breeding season, preconstruction surveys for California Ridgway's rail will be conducted where suitable habitat for these species occurs within or adjacent to work areas. Surveys will be initiated sometime between January 15 and February 1. A minimum of four surveys will be conducted. The survey dates will be spaced at least 2 to 3 weeks apart and will cover the time period from the date of the first survey through the end of March and mid-April. This will allow the surveys to encompass the time period when the highest frequency of calls is likely to occur. These surveys will involve the following protocols (based on USFWS 2015 and Evens et al. 1991), or other approved survey methodologies that may be developed based on new information and evolving science, and will be conducted by biologists with the qualifications stipulated in the approved methodologies.

- Listening stations will be established at 200-meter intervals along roads, trails, and levees that will be affected by covered activities.
- California Ridgway's rail vocalization recordings will be played at each station, and playing will cease immediately once a response is detected.
- For California Ridgway's rail, each listening station will be occupied for a period of 10 minutes, followed by 1 minute of playing California Ridgway's rail vocalization recordings, then followed by an additional minute of listening.
- Sunrise surveys will begin 60 minutes before sunrise and conclude 75 minutes after sunrise (or until presence is detected).
- Sunset surveys will begin 75 minutes before sunset and conclude 60 minutes after sunset (or until presence is detected).

- Surveys will not be conducted when tides are greater than 4.5 National Geodetic Vertical Datum or when sloughs and marshes are more than bank-full.
- California Ridgway's rail vocalizations will be recorded on a data sheet. A GPS receiver and compass will be used to identify surveys stations, angles to call locations, and call locations and distances. The call type, location, distance, and time will be recorded on a data sheet.

If California Ridgway's rail is present in the immediate construction area, the following measures will apply during construction activities.

- To avoid the loss of individual California Ridgway's rails, activities within or adjacent to the species' habitat will not occur within 2 hours before or after extreme high tides (6.5 feet or above, as measured at the Golden Gate Bridge), when the marsh plain is inundated. During high tide, protective cover for California Ridgway's rail is sometimes limited, and activities could prevent them from reaching available cover.
- To avoid the loss of individual California Ridgway's rails, activities within or adjacent to tidal marsh areas will be avoided during the rail breeding season (February 1 through August 31), unless surveys are conducted to determine rail locations and territories can be avoided.
- If breeding California Ridgway's rail are determined to be present, activities will not occur within 500 feet of an identified calling center (unless a qualified biologist determines that a smaller distance will not result in the take of the state-listed species). If the intervening distance is across a major slough channel or across a substantial barrier between the rail calling center and any activity area is greater than 200 feet, it may proceed at that location within the breeding season.
- Exception: Inspection, maintenance, or nonconstruction monitoring activities may be performed during the California Ridgway's breeding season in areas within or adjacent to breeding habitat (within 500 or 200 feet, as specified above) as long as a qualified biologist determines the action will not result in take. These activities will be conducted under the supervision of a qualified, permitted biologist.

Mitigation Measure BIO-9: Greater and Lesser Sandhill Crane

If construction and restoration activities are to occur during sandhill crane wintering season (September 15 through March 15) in a greater sandhill crane winter use area or within suitable lesser sandhill crane wintering habitat, the following avoidance and minimization measures will be implemented.

- Construction will be minimized during the sandhill crane wintering season to the extent practicable in light of project schedule and cost and logistical considerations.
- To the extent feasible, construction that cannot be completed prior to commencement of the wintering season will be started before September 15 or after March 15, such that no new sources of noise or other major disturbance that could affect cranes will be introduced after the cranes arrive at their wintering grounds.
- Preconstruction surveys will be conducted for sandhill crane temporary and permanent roost sites within 0.75 mile of the construction area boundary where access is available. Surveys will be conducted during the winter prior to project implementation, over multiple days within the survey area by a qualified biologist with experience observing the species. Alternatively, roost sites

within 0.75 mile of the construction area boundary can be identified by a qualified sandhill crane biologist familiar with roost sites. If a sandhill crane roost site is located within 0.75 mile of the construction area boundary, then to the extent practicable, nighttime (1 hour before sunset to 1 hour after sunrise) project activities will be relocated to maintain a 0.75-mile nondisturbance buffer.

- Route truck traffic to reduce headlight impacts in roosting habitat.
- Install light barriers to block the line-of-sight between the nearest roosting areas and the primary nighttime construction light source areas.
- Operate portable lights near roosting habitat at the lowest allowable wattage and height, while in accordance with the National Cooperative Highway Research Program's (NCHRP's) *Report 498: Illumination Guidelines for Nighttime Highway Work*.
- Screen all lights and direct them down toward work activities and away from the night sky and nearby roost sites. A biological construction monitor will ensure that lights are properly directed at all times.
- Limit the number of nighttime lights used to the greatest extent practicable in light of worker safety requirements.
- If restoration takes place near Stone Lake NWR, install a vegetation screen or other noise and visual barrier along the south side of Hood Franklin Road along the length of Stone Lake NWR's property to reduce disturbance to sandhill cranes. The noise and visual barrier will be a minimum of 5 feet high (above the adjacent elevated road, if applicable) and will provide a continuous surface impenetrable by light. This height may be obtained by installing a temporary structure, such as fencing (e.g., chain link with privacy slats) or a semipermanent structure, such as a concrete barrier (e.g., a roadway median barrier or architectural concrete wall system) retrofitted with an approved visual screen, if necessary, to meet the required height. This barrier will not be installed immediately adjacent to crane foraging habitat, and placement will be coordinated with a qualified crane biologist.

Mitigation Measure BIO-10: Least Bell's Vireo

Species-specific mitigation measures for least Bell's vireo will be required for activities occurring within suitable habitat within the species' range. Prior to disturbing an area potentially supporting habitat for the species, a USFWS approved biologist will evaluate the area to identify suitable habitat.

Activities will be located to avoid or minimize disturbance of least Bell's vireo suitable habitat within the species' range. The following measures will be required for project components unable to avoid least Bell's vireo habitat:

- Prior to construction, all suitable least Bell's vireo habitat within the species' range in the construction area will be surveyed.
- At least five surveys will be conducted in suitable habitats within 30 days of the onset of construction, with the last survey conducted within 3 days of the onset of construction, by a qualified biologist with experience surveying and observing these species and familiar with their vocalizations.

- If an active nest site is present, a 500-foot nondisturbance buffer will be established around nest sites during the breeding season (generally, late February through late August).
- Disturbance to previous least Bell's vireo nesting sites (for up to 3 years since known nest activity) will also be avoided during the breeding season unless the disturbance is to maintain public safety. Least Bell's vireo uses previous nesting sites, and disturbance during the breeding season may preclude birds from using existing unoccupied nest sites.
- The required buffer may be reduced in areas where barriers or topographic relief are sufficient to protect the nest from excessive noise or other disturbance, as determeined by a the qualified biologist on a case-by-case basis.
- If occupied nests are identified, a qualified biologist will monitor construction activities in the vicinity of all active least Bell's vireo nests to ensure that covered activities do not affect nest success.
- If surveys find least Bell's vireos in the area where vegetation will be removed, vegetation removal will be done when the birds are not present.
- If an activity is to occur within 1,200 feet of least Bell's vireo habitat (or within 2,000 feet if pile driving will occur) during the breeding period for least Bell's vireos, the following measures will be implemented to avoid noise effects on least Bell's vireo.
    - Prior to the construction, a noise expert will create a noise contour map showing the 60 A-weighted decibel noise contour specific to the type and location of construction to occur in the area.
    - During the breeding period for least Bell's vireo, a USFWS-approved biologist will survey any suitable habitat for least Bell's vireo within the 60 dBA noise contour daily during a 2-week period prior to construction. While construction is occurring within this work window, the USFWS-approved biologist will conduct daily surveys in any suitable habitat where construction related noise levels could exceed 60 dBA L_{eq} (1 hour). If a least Bell's vireo is found, sound will be limited to 60 dBA in the habitat being used until the USFWS-approved biologist has confirmed that the bird has left the area.
    - Limit pile driving to daytime hours (7:00 a.m. to 7:00 p.m.).
    - Locate, store, and maintain portable and stationary equipment as far as possible from suitable least Bell's vireo habitat.
    - Employ preventive maintenance including practicable methods and devices to control, prevent, and minimize noise.
    - Route truck traffic to reduce construction noise impacts and traffic noise levels within 1,200 feet of suitable least Bell's vireo habitat during migration periods.
    - Limit trucking activities (e.g., deliveries, export of materials) to the hours of 7:00 a.m. to 10:00 p.m.
    - Screen all lights and direct them down toward work activities away from migratory habitat. A biological construction monitor will ensure that lights are properly directed at all times.
    - Operate portable lights at the lowest allowable wattage and height, while in accordance with NCHRP's *Report 498: Illumination Guidelines for Nighttime Highway Work* (Transportation Research Board 2003).

Compensation to Offset Effects

Reclamation will offset the loss of least Bell's vireo habitat through habitat creation or restoration at a 2:1 ratio. Reclamation will develop a riparian restoration plan that will identify the location and methods for riparian creation or restoration, and this plan will be subject to USFWS approval.

Mitigation Measure BIO-11: Suisun Song Sparrow, Saltmarsh Common Yellowthroat, Yellow-Breasted Chat, Yellow Warbler

Preconstruction surveys of potential breeding habitat for the Suisun song sparrow, saltmarsh common yellowthroat, yellow-breasted chat, and yellow warbler will be conducted within 500 feet project activities where access is available. At least five surveys will be conducted in suitable habitats within 30 days of the onset of construction, with the last survey conducted within 3 days of the onset of construction, by a qualified biologist with experience surveying and observing these species and familiar with their vocalizations.

If an active nest site is present, a 250-foot nondisturbance buffer will be established around nest sites during the breeding season (generally, late February through late August for yellow-breasted chat, early April through mid-July for saltmarsh common yellowthroat and yellow warbler, and early April through late August for Suisun song sparrow).

The required buffer may be reduced in areas where barriers or topographic relief are sufficient to protect the nest from excessive noise or other disturbance, as determined by a qualified biologist on a case-by-case basis.

If occupied nests are identified, a qualified biologist will monitor construction activities in the vicinity of all active nests to ensure that covered activities do not affect nest success.

To the extent feasible, the contractor will employ the following best practices to reduce construction noise during daytime and evening hours (7:00 a.m. to 10:00 p.m.) such that construction noise levels do not exceed 60 dBA Leq (1 hour) during migration periods:

- Limit construction during nighttime hours (10:00 p.m. to 7:00 a.m.) such that construction noise levels do not exceed 50 dBA L_{max} (1 hour) at the nearest residential land uses.
- Limit construction activities to daytime hours (7:00 a.m. to 7:00 p.m.), where feasible.
- Locate, store, and maintain portable and stationary equipment 300 feet away from suitable nesting habitat during migration periods, and 300 feet from active breeding sites.
- Employ preventive maintenance including practicable methods and devices to control, prevent, and minimize noise.
- Except where equipment must cross through riparian zones, route truck traffic to at least 300 feet from suitable avian migratory habitat during migration periods.
- Limit trucking activities (e.g., deliveries, export of materials) to the hours of 7:00 a.m. to 10:00 p.m. within 300 feet of migration habitat during migration periods.
- Screen all lights and direct them down toward work activities away from migratory habitat. A biological construction monitor will ensure that lights are properly directed at all times.
- Operate portable lights at the lowest allowable wattage and height, while in accordance with the NCHRP *Report 498: Illumination Guidelines for Nighttime Highway Work* (Transportation Research Board 2003).

Mitigation Measure BIO-12: Swainson's Hawk

Preconstruction surveys will be conducted to identify the presence of active nest sites of tree-nesting raptors within 0.25 mile of project sites, staging and storage areas, construction access roads, work areas, and soil stockpile areas where accessible by a qualified biologist with experience identifying Swainson's hawk. Transportation routes along public roads (roads leading to and from work areas) are considered disturbed, and no surveys or monitoring are required for nests along those roadways unless they are within 0.25 mile of work areas. Surveys for nesting Swainson's hawks will be conducted to ensure nesting activity is documented prior to the onset of construction activity. Swainson's hawks nest in the study area between approximately March 15 and September 15. While many nest sites are traditionally used for multiple years, new nest sites can be established in any year. Therefore, construction activity that is planned after March 15 of any year will require surveys during the year of the construction. If construction is planned before March 15 of any year, surveys will be conducted the year immediately prior to the year of construction. If construction is planned before March 15 of any year and subject to prior-year surveys, but is later postponed to after March 15, surveys will also be conducted during the year of construction.

The survey protocol shown in Table P.2-2 is modified from the recommended timing and methodology for Swainson's hawk nesting surveys in the Central Valley (Swainson's Hawk Technical Advisory Committee 2000). This protocol will be used to detect active nests for Swainson's hawk. If active nests are found, appropriate avoidance and minimization measures will be implemented as described. If no activity is found, then construction can proceed with no restrictions until the following breeding season. Survey results will be documented in a memo no less than 5 days prior to commencement of construction activities, and provided to the Program Environmental Manager and Construction Supervisor. The designated biologist will include the location of any known nest trees (occupied within 1 or more of the last 5 years) present within 0.25 mile of the construction footprint.

Removal of known nest trees (defined as a tree that has been used for nesting at least once in the last 3 years) will be avoided to the maximum extent feasible. No trees with occupied nests will be removed until the nest is vacated.

The designated biologist will survey potential Swainson's hawk nest trees and monitor occupied Swainson's hawk nests as described below. When proposed construction will occur within 0.25 mile of known nest trees, construction activities will be limited to outside the breeding season if feasible, or until the tree site is determined to be inactive.

Where construction activities cannot be restricted to more than 0.25 mile of an occupied nest site, activities will be restricted during the period of egg-laying to post-hatching to the extent feasible. If construction activities must occur in that time frame, construction will be initiated prior to egg-laying to the extent feasible. This will allow time for Swainson's hawks to acclimate to disturbance before eggs are laid, reducing the potential for abandonment. If construction activities must begin after egg-laying is initiated, a 650-foot-radius nondisturbance buffer will be established at least until eggs have hatched.

When construction activities will occur within 0.25 mile of an occupied Swainson's hawk nest, a 650-foot-radius nondisturbance buffer will be established around each occupied hawk nest tree. To the greatest extent feasible, no construction activity will be allowed to occur within the buffer while a Swainson's hawk nest is occupied. A nest is considered occupied from the time the nest is being constructed until the young leave the nest, or until the nesting attempt fails and the nest is abandoned. Occupied nests will be monitored to track progress of nesting activities. The buffer will be clearly delineated with fencing or other conspicuous marking.

Where construction will occur within 0.25 mile of an occupied Swainson's hawk nest tree, the following monitoring plan will be implemented. If a project nesting bird monitoring and management plan is prepared by a designated biologist, it will prevail where it differs from the measures below.

- A designated biologist will observe any nest site that is within 0.25 mile of construction activities for at least 1 hour and until normal nesting behavior can be determined 5 days and 3 days prior to the initiation of construction. The biologist will determine nest status and document normal nesting behaviors, which may be used to compare to the hawks' activities once construction begins. The results of preconstruction monitoring will be reported in a memo and provided to the Program Environmental Manager and Construction Supervisor.
- Where a Swainson's hawk occupied nest occurs less than 325 feet from construction activities, the designated biologist will observe the nest periodically throughout the day where covered activities occur to ensure the hawks are engaged in normal nesting behavior.
- Where a Swainson's hawk occupied nest occurs between 325 and 650 feet from construction, the designated biologist will observe the nest for at least 2 hours per construction day where covered activities occur to ensure the hawks are engaged in normal nesting behavior.
- Where a Swainson's hawk occupied nest occurs between 650 and 1,300 feet from construction, the designated biologist will observe the nest for at least 3 days per construction week to ensure the hawks are engaged in normal nesting behavior and to check the status of the nest.

Physical contact with an active nest tree will be prohibited from the time of egg laying to fledging. Construction personnel outside of vehicles must remain at least 650 feet, unless the biologist determines that a smaller buffer will not result in take of this state-listed species, from the nest tree unless construction activities require them to be closer.

All personnel will be out of the line of sight of an occupied nest during breaks if within 650 feet of the nest (as stated above, activities will only occur within 650 feet of a nest with approval by the designated biologist).

If during construction the designated biologist determines that a nesting Swainson's hawk within 0.25 mile of the project is disturbed by project activities, to the point where their reproductive failure could occur, the designated biologist will immediately notify the Construction Supervisor and Program Environmental Manager. The Program Environmental Manager will contact CDFW, and it will be determined by the parties whether additional protection measures can be implemented.

Potential nest abandonment and failure may be indicated if Swainson's hawk exhibits distress and/or abnormal nesting behavior such as swooping/stooping at construction equipment or personnel, excessive vocalization (distress calls) or agitation directed at construction equipment or personnel, failure to remain on nest, or failure to deliver prey items for an extended time period. Additional protection measures will remain in place until the Swainson's hawk behavior has normalized. The designated biologist will notify CDFW if nests or nestlings are abandoned and if the nestlings are still alive to determine appropriate actions for salvaging the eggs or returning nestlings to the wild.

In addition to the measures described above, the following measures will also be implemented for activities for which the extent and location of the activity have not yet been fully planned.

- Restoration exploration activities will fully avoid Swainson's hawk nesting habitat.
- Restoration exploration will not be conducted within 0.25 mile of an occupied Swainson's hawk nest.

Table P.2-2. Timing and Methodology for Swainson's Hawk Nesting Surveys

Survey Dates	Survey Time	Number of Surveys	Methodology
First week of April	Sunrise to 12:00 p.m.; 4:00 p.m. to sunset	1	Position the surveyor at 50 to 200 feet from suitable nesting habitat with a clear view of trees and surrounding area. Scan all trees for a minimum of 2 hours within 0.25 mile of the project boundary. Observe perching, nest building, mating, courtship, and other prenesting behaviors to identify a nest or nesting activity area.
Second week of April	Sunrise to 12:00 p.m.; 4:00 p.m. to sunset	1	Repeat the above survey in areas not determined to be occupied during the first survey. Attempt to confirm nest locations within nesting activity areas.
Third week of April	Sunrise to 12:00 p.m.; 4:00 p.m. to sunset	1	Repeat the above survey in areas not determined to be occupied during the first and second survey. In cases where a nest site was not identified within a nesting activity area during the first two surveys, approach the nesting activity area carefully to locate nests. If a nest is not found where there is reasonable certainty of nesting activity, rely on observations of courtship, mating, nest building, and other behaviors to define a nesting area and establish a buffer.
June 10 through July 15	Sunrise to 12:00 p.m.; 4:00 p.m. to sunset	3 surveys spaced at least 3 days apart	Inspect all previously identified nests for activity status. Walk and scan all other suitable nest trees within 0.25 mile of the project boundary for nests not found during the initial survey.

Mitigation Measure BIO-13: Tricolored Blackbird

Prior to implementation of project activities, a qualified biologist with experience surveying for and observing tricolored blackbird will conduct a preconstruction survey to establish use of suitable habitat by tricolored blackbird colonies. Surveys will be conducted in suitable habitat within 1,300 feet of proposed construction areas, where access allows, during the nesting season (generally March 15 to July 31) 1 year prior to, and then again the year of, construction. During each year, surveys will be conducted monthly in March, April, May, June, and July. If construction is initiated at a site during the nesting season, three surveys will be conducted within 15 days of construction with one of the surveys within 5 days of the start of construction. The CDFW Suisun Marsh Unit tracks tricolored blackbird colonies yearly in Suisun Marsh as part of the University of California, Davis/USFWS tricolored blackbird portal project; these records will also be searched and staff at the portal project consulted for recent colony information. If active tricolored blackbird nesting colonies are identified, minimization requirements and construction monitoring will be required.

- Project activities will avoid active tricolored blackbird nesting colonies and associated habitat during the breeding season (generally March 15 to July 31). Avoidance measures will include relocating covered activities away from the nesting colonies and associated habitat to the maximum extent practicable.
- Projects (construction and restoration) will be designed to avoid construction activity to the maximum extent practicable up to 1,300 feet, but not less than a minimum of 300 feet, from an active tricolored blackbird nesting colony. This minimum buffer may be reduced in areas with

dense forest, buildings, or other habitat features between the construction activities and the active nest colony, or where there is sufficient topographic relief to protect the colony from excessive noise or visual disturbance as determined by a biologist experienced with tricolored blackbird.

- Project activities potentially affecting a nesting colony will be monitored by a qualified biologist to verify that the activity is not disrupting the colony. If it is, the activity will be modified, as practicable, by either delaying construction until the colony abandons the site or until the end of the breeding season, whichever occurs first; temporarily relocating staging areas; or temporarily rerouting access to the construction site. Reclamation technical staff will consult with the fish and wildlife agencies and evaluate exceptions to the minimum nondisturbance buffer distance on a case-by-case basis.
- Prior to initiation of construction within 300 feet of suitable roosting habitat, a biologist with experience surveying for and observing tricolored blackbirds will conduct preconstruction surveys to establish use of roosting habitat by tricolored blackbird colonies. Surveys will be conducted in suitable habitat where access is available within 300 feet of proposed construction areas during the nonbreeding season (generally August 1 to March 14) 1 year prior to, and then again the year of, construction. If construction is initiated at a site during the nonbreeding season, three surveys will be conducted within 15 days prior to construction with one of the surveys within 5 days prior to the start of construction.
- Construction and restoration projects will also be designed to avoid construction activity within at least 300 feet from occupied active tricolored blackbird roosting habitat. This minimum buffer may be reduced in areas with dense forest, buildings, or other habitat features between the construction activities and the active roosting site, or where there is sufficient topographic relief to protect the roosting site from excessive noise or visual disturbance, or where sound curtains are used, as determined by a biologist experienced with tricolored blackbird.
- Construction activities that are within 300 feet of occupied roosting habitat will be monitored by a biologist familiar with tricolored blackbird behavior patterns to verify that the activity is not disrupting the roosting birds. If it is, the activity will be modified, as practicable, by delaying construction until the blackbirds are no longer using the roosting site, temporarily relocating staging areas, temporarily rerouting access to the construction site, or use of sound curtains. The biologist will evaluate the nondisturbance buffer distance on a case-by-case basis.

Unavoidable loss of foraging habitat will be mitigated through foraging habitat protection at a 1:1 ratio, and unavoidable loss of nesting habitat through riparian restoration at a 2:1 ratio.

Mitigation Measure BIO-14: Western Burrowing Owl

Species-specific measures for western burrowing owl will only be required for water conveyance construction, restoration, and operations and maintenance activities occurring within suitable habitat as identified from habitat assessments conducted in advance of initiating ground-disturbing and staging activities. This measure incorporates survey, avoidance, and minimization guidelines taken primarily from the *Staff Report on Burrowing Owl Mitigation* (CDFG 2012).

Preconstruction Surveys

Western burrowing owl surveys will be required within and adjacent to (within 500 feet) water conveyance work areas and restoration sites where suitable habitat has been identified during habitat assessment surveys where access is available. Surveys will be conducted during the breeding season that precedes construction.

Four survey visits will be conducted with at least one site visit between February 15 and April 15 and a minimum of three survey visits, at least 3 weeks apart, between April 15 and July 15, with at least one visit after June 15. Surveys will be conducted between 10:00 a.m. and 2 hours before sunset. A qualified biologist will survey the study area and record and map all burrowing owl observations and burrows that may be occupied (as indicated by tracks, feathers, egg shell fragments, pellets, prey remains, cast pellets, whitewash, or decoration) on the project site. The surveys will be conducted while walking transects throughout the entire project footprint, plus all accessible areas within a 500-foot radius of the project footprint. The centerlines of these transects will be spaced 15 to 60 feet apart and will vary in width to account for changes in terrain and vegetation that can preclude complete visual coverage of the area. For example, in hilly terrain with patches of tall grass, transects will be closer together, while in open areas with little vegetation they can be 60 feet apart. Surveyors will stop at least every 300 feet along each transect to scan the entire visible area for presence of burrowing owls. Adjacent parcels under different land ownership will be surveyed only if access is granted or if the parcels are visible from authorized areas.

In addition, preconstruction surveys will be conducted with one occurring 14 days prior to ground breaking and/or staging activities and another within 24 hours of these activities. These surveys will confirm whether owls identified during the breeding season surveys are still present or whether the site has since become occupied by burrowing owls.

Avoidance and Minimization

To the extent feasible, burrowing owls will be avoided by relocating work areas with flexible locations, such as geotechnical exploration sites and restoration sites. Within the construction footprint where ground disturbance cannot avoid burrowing owls, owls will be relocated during the nonbreeding season and burrows will be excavated.

If an active burrow is identified near a work area and work cannot be conducted outside of the nesting season (February 1 to August 31), a qualified biologist will establish a nondisturbance buffer that extends a minimum of 250 feet around the burrow. If burrowing owls are present at the site during the nonbreeding season (September 1 through January 31), a qualified biologist will establish a nondisturbance buffer that extends a minimum of 150 feet around the burrow.

If the appropriate nondisturbance buffer for breeding or nonbreeding burrowing owls cannot be established, a wildlife biologist experienced in burrowing owl behavior will evaluate site-specific conditions and recommend a smaller buffer that still minimizes the potential to disturb the owls (and still allows reproductive success during the breeding season), if possible. The site-specific buffer will be established by taking into consideration the type and extent of the proposed activity occurring near the occupied burrow, the duration and timing of the activity, the sensitivity and habituation of the owls to existing conditions, and the dissimilarity of the proposed activity to background activities. If an appropriate buffer cannot be established around the active owl burrows, actions will be taken to exclude the owls from the site per the requirements below.

A biological monitor will be present during all construction activities occurring within any reduced buffers. If during the breeding season there is any change in owl nesting and foraging behavior as a result of construction activities, the biological monitor will work with construction personnel and the Environmental Manager to provide additional protections to reduce disturbance, such as adding visual and sound curtains; any modifications to the standard protections will be approved by a qualified biologist.

If monitoring indicates that the nest is abandoned prior to the end of nesting season and the burrow is no longer in use by owls, the nondisturbance buffer may be removed. If necessary because the burrow cannot be avoided by construction activity, the biologist will excavate and collapse the burrow to prevent reoccupation.

Relocation

No exclusion of burrowing owls will occur during the breeding season. If burrowing owls are present within the construction footprint and cannot be avoided during the nonbreeding season (generally September 1 through January 31), they will be relocated through passive relocation, with or without burrow exclusion. Passive relocation will be used when (1) there is a sufficient amount of suitable habitat adjacent to the work area to support nesting and foraging, (2) there are compatible land use practices in the area and 3) the area is preferably currently under or proposed for conservation.

Passive relocation will be conducted during the nonbreeding season; however passive relocation techniques may be used during the breeding season (February 1 through August 30) if a qualified biologist determines through site surveillance that the burrow is not occupied by a breeding pair, young, or eggs. To the extent feasible, passive relocation will first be considered without the use of exclusion devices to avoid and minimize harassment of owls.

Passive Relocation without Exclusion

Prior to relocating owls, all potential burrowing owl burrows in suitable nesting habitat and within the project footprint and 75 feet around the footprint, will be surveyed for owl use, and excavated if no owls are found. If occupied burrows are found, two natural or artificial burrows will be provided for each occupied burrow in the above defined survey area, at least 250 feet from the construction footprint. Artificial burrows will be installed following the methods in Barclay (2008) and Johnson et al. (2010). Sites used for artificial burrows will either be properties currently used for or proposed for conservation. After constructing the artificial burrows, the owls will be given 60 days to relocate on their own. The study area will be monitored weekly for up to 60 days to determine whether the owls have left the burrow and to attempting to confirm occupancy at the artificial or other nearby burrows. The formerly occupied burrows will then be excavated. Whenever possible, burrows will be excavated using hand tools and refilled to prevent reoccupation. Sections of flexible plastic pipe (at least 3 inches in diameter) will be inserted into burrows during excavation to maintain an escape route for any animals inside the burrow.

Passive Relocation with Exclusion

If the burrowing owls found in the above survey area do not relocate on their own through the above methodology, passive relocation will be accomplished by installing one-way doors (e.g., modified dryer vents). The one-way doors will be left in place for a minimum of 48 hours and be monitored twice daily to ensure that the owls have left the burrow. The burrow will be excavated using hand tools, and a section of flexible plastic pipe (at least 3 inches in diameter) will be inserted into the burrow tunnel during excavation to maintain an escape route for any animals that may be inside the burrow.

Compensation for Unavoidable Effects

Mitigate unavoidable loss of nesting, wintering, and satellite burrows, and burrowing owl habitat in comparable habitat at an approved mitigation ratio in consultation with CDFW. The mitigation strategy will be consistent with the mitigation guidance in the *Staff Report on Burrowing Owl Mitigation* (CDFG 2012).

Mitigation Measure BIO-15: Western Yellow-Billed Cuckoo

This measure for western yellow-billed cuckoo will be required for activities occurring within suitable habitat, or in the vicinity of suitable habitat. Prior to disturbing an area potentially supporting habitat for the species, a USFWS-approved biologist will evaluate the area to identify suitable habitat.

Project activities will be located to avoid or minimize disturbance of western yellow-billed cuckoo suitable habitat within the species' range. The following measures will be required for project components unable to avoid western yellow-billed cuckoo habitat.

- Permanent or temporary loss of all suitable migratory habitat will be minimized by all activities associated with the proposed action through project design.
- Prior to construction, all suitable western yellow-billed cuckoo habitat in the construction area will be surveyed.
- At least five surveys will be conducted in suitable habitats within 30 days of the onset of construction, with the last within 3 days of the onset of construction, by a qualified biologist with experience surveying and observing this species and familiar with its vocalizations.
- If an active nest site is present, a 500-foot nondisturbance buffer will be established around nest sites during the breeding season (generally, late February through late August).
- The required buffer may be reduced in areas where barriers or topographic relief are sufficient protect the nest from excessive noise or other disturbance, as determined by a qualified biologist on a case-by-case basis.
- If occupied nests are identified, a qualified biologist will monitor construction activities in the vicinity of all active western yellow-billed cuckoo nests to ensure that covered activities do not affect nest success.
- If surveys find western yellow-billed cuckoos in the area where vegetation will be removed, vegetation removal will be done when cuckoos are not present.
- If an activity is to occur within 1,200 feet of western yellow-billed cuckoo habitat (or within 2,000 feet if pile driving will occur) during the period of from June 15 through September 1 (the period in which yellow-billed cuckoos have been observed in the legal Delta) the following measures will be implemented to avoid noise effects on migrating western yellow- billed cuckoos.
    - Prior to the construction, a noise expert will create a noise contour map showing the 60 dBA noise contour specific to the type and location of construction to occur in the area.
    - During the period between June 15 and September 1, a qualified biologist will survey any suitable migratory habitat for yellow-billed cuckoos within the 60 dBA noise contour on a daily basis during a two-week period prior to construction. While construction is occurring within this work window, the USFWS-approved biologist will conduct daily surveys in any suitable habitat where construction related noise levels could exceed 60 dBA L_{eq} (1 hour). If a yellow-billed cuckoo is found, sound will be limited to 60 dBA in the habitat being used until the USFWS-approved biologist has confirmed that the bird has left the area.
    - Locate, store, and maintain portable and stationary equipment as far as possible from suitable western yellow-billed cuckoo habitat.

- Employ preventive maintenance including practicable methods and devices to control, prevent, and minimize noise.
- Route truck traffic to reduce construction noise impacts and traffic noise levels within 1,200 feet of suitable western yellow-billed cuckoo migratory habitat during migration periods.
- Limit trucking activities (e.g., deliveries, export of materials) to the hours of 7:00 a.m. to 10:00 p.m.
- Screen all lights and direct them down toward work activities away from migratory habitat. A biological construction monitor will ensure that lights are properly directed at all times.
- Operate portable lights at the lowest allowable wattage and height, while in accordance with the NCHRP *Report 498: Illumination Guidelines for Nighttime Highway Work* (Transportation Research Board 2003).

Compensation to Offset Effects

Reclamation will offset the loss of western yellow-billed cuckoo migratory habitat through the creation or restoration at a 3:1 ratio, for a total of [to be determined] acres of migratory riparian habitat creation or restoration in USFWS-approved location. For restoration, Reclamation will develop a riparian restoration plan that will identify the location and methods for riparian creation or restoration, and this plan will be subject to USFWS approval.

Mitigation Measure BIO-16: White-Tailed Kite

Preconstruction surveys will be conducted to identify the presence of active nest sites of tree nesting raptors within 0.25 mile of project sites, staging and storage areas, construction access roads, work areas, and soil stockpile areas where accessible, by a qualified biologist with experience identifying white-tailed kite nests. Transportation routes along public roads (roads leading to and from work areas) are considered disturbed, and no surveys or monitoring are required for nests along those roadways unless they are within ¼ mile of work areas. Surveys for nesting white-tailed kites will be conducted within 30 days prior to construction to ensure nesting activity is documented prior to the onset of construction activity during the nesting season. White-tailed kites nest in the study area between approximately March 15 and September 15. While many nest sites are traditionally used for multiple years, new nest sites can be established in any year. Therefore, construction activity that is planned after March 15 of any year will require surveys during the year of the construction. If construction is planned before March 15 of any year, surveys will be conducted the year immediately prior to the year of construction. If construction is planned before March 15 of any year and subject to prior-year surveys, but is later postposed to after March 15, surveys will also be conducted during the year of construction.

Construction will be restricted to the greatest extent possible during the nesting season where nest sites occur within 0.25 mile of construction activities, unless an already existing suitable buffer between the construction activity and the nest site is identified by a biologist. Surveys for white-tailed kite nests and nesting activity will occur in conjunction with the surveys for bald eagles under MM BIO-17 and follow the same protocol. If active nests are found or nesting activity is identified within 0.25 mile of construction activities appropriate avoidance and minimization measures will be implemented as described. Results of the surveys will be summarized in a memo(s) and provided to the Program Environmental Manager and Construction Supervisor prior to the commencement of construction.

Removal of known nest trees will be avoided to the maximum extent feasible. No trees with occupied nests will be removed until the nest is vacated.

The biologist will conduct a second survey of potential nesting trees and active nests, and monitor white-tailed kite nests no more than 72 hours prior to construction. If no nesting activity is found, then construction can proceed with no restrictions.

Where construction activities within 0.25 mile of an active nest cannot feasibly be avoided, construction will be initiated prior to egg-laying to the extent possible. If eggs and or young are present in the nest, work will be restricted until a biologist determines that white-tailed kites have acclimated to disturbance and exhibit normal nesting behavior.

A 650-foot-radius nondisturbance buffer will be established around each active white-tailed kite nest site. No construction activity will be allowed to occur in the buffer while a nest site is occupied by white-tailed kite during the breeding season. The buffer size may be modified based on the field examination and determination by the biologist of conditions that may minimize disturbance effects, including line-of-sight, topography, land use, type of disturbance, existing ambient noise and disturbance levels, and other relevant factors. The buffer will be clearly delineated with fencing or other conspicuous marking. Active nests will be monitored to track progress of nesting activities. Entry into the buffer will be granted when the biologist determines that the young have fledged and are capable of independent survival or the nest has failed and the nest site is no longer active.

Where it is infeasible to avoid construction within 0.25 mile of an active white-tailed kite nest identified in preconstruction surveys, at a minimum the following measures will be implemented as part of a nesting bird monitoring and management plan. The final plan may include additional measures that are specific to site conditions.

- A designated biologist will observe any nest site that is within 0.25 mile of construction activities for at least 1 hour and until normal nesting behavior can be determined 5 days and 3 days prior to the initiation of construction. The biologist will determine nest status and observe normal nesting behaviors, which may be used to compare to the nesting activities once construction begins. The results of preconstruction monitoring will be reported in a memo and provided to the Program Environmental Manager and Construction Supervisor.
- Where pre-project surveys have identified an occupied white-tailed kite nest less than 325 feet from construction, the designated biologist will observe the nest periodically throughout the day where covered activities occur to ensure the white-tailed kites demonstrate normal nesting behavior.
- Where pre-project surveys have identified an occupied white-tailed kite nest between 325 to 650 feet from construction, the designated biologist will observe the nest for at least 2 hours per construction day where covered activities occur to ensure the white-tailed kites are engaged in normal nesting behavior.
- Where pre-project surveys have identified an occupied white-tailed kite nest between 650 to 1,300 feet from construction, the Biological Monitor will observe the nest for at least 3 days per construction week to ensure the white-tailed kites are engaged in normal nesting behavior and to check the status of the nest.

During construction or ongoing operation and maintenance activities, physical contact with an active nest tree is prohibited from the time of egg laying to fledging, unless approved by CDFW. Construction personnel outside of vehicles must remain at least 650 feet, or the length of a buffer approved by a qualified biologist which will not result in take, from the nest tree unless construction activities require them to be closer.

All personnel will remain out of the line of sight of an occupied white-tailed kite nest during breaks if within 650 feet of the nest (as stated above, activities will only occur within 650 feet of a nest with approval by the designated biologist).

The project will be implemented in a manner that will not result in take of white-tailed kite as defined by Section 86 of the California Fish and Game Code. If during construction monitoring, the designated biologist determines that a nesting white-tailed kite within 650 feet of construction is disturbed by construction activities, to the point where reproductive failure could occur, the designated biologist will immediately notify the Construction Supervisor and Program Environmental Manager. The Program Environmental Manager will contact CDFW, and it will be determined by the parties whether additional protection measures can be implemented.

Potential nest abandonment and failure may be indicated if white-tailed kite exhibits distress and/or abnormal nesting behavior such as swooping/stooping at construction equipment or personnel, excessive vocalization (distress calls) or agitation directed at construction equipment or personnel, failure to remain on nest or failure to deliver prey items for an extended time period. Additional protection measures will remain in place until the white-tailed kite behavior has normalized.

Mitigate unavoidable loss of foraging habitat through foraging habitat protection at a 1:1 ratio, and unavoidable loss of nesting habitat through riparian restoration at a 2:1 ratio.

Mitigation Measure BIO-17: Bald Eagle

The following measures will be implemented to avoid and minimize impacts on bald eagle during Reclamation project activities.

- If restoration activities, including helicopter flights, need to take place during the nesting season and within 0.5 mile of potential bald eagle nesting habitat, qualified agency-approved biologists will conduct a preconstruction survey for occupied bald eagle nest in and within 0.5 mile of the work areas. An *occupied nest* is a “nest used for breeding in the current year by a [bald or golden eagle] pair” (Pagel et al. 2010). Survey procedures, including required surveyor qualifications, will follow the USFWS’ *Interim Golden Eagle Inventory and Monitoring Protocols; and Other Recommendations* (Pagel et al. 2010) or other more recent guidelines, if available.
- Reclamation will implement, at a minimum, the following measures to avoid disturbance of active eagle nests (i.e., “a golden eagle [or bald eagle] nest characterized by the presence of any adult, egg, or dependent young at the nest in the past 10 consecutive days immediately prior to, and including, at present” [Pagel et al. 2010]):
    - No activities involving loud noise (>90 decibels) or helicopter flight paths will be permitted within 0.5 mile of any active eagle nest found during preconstruction surveys. This restriction will be in effect from January to August 31 unless nest monitoring by a qualified agency-approved biologist reveals that the nest is no longer active (e.g., adults did not nest that year, nest failure from natural causes, young fledged).
    - Activities that do not involve loud noise will maintain an exclusion zone of 0.25 mile around all active eagle nests found during preconstruction surveys. This restriction will be in effect from January to August 31 unless nest monitoring by a qualified agency-approved biologist reveals that the nest is no longer active.

- Eagle nest exclusion zones may be removed if monitoring reveals the nest to be inactive, and considered to be an "alternate nest" under current regulations under the Bald and Golden Eagle Protection Act. An alternate nest is "one of potentially several nests within a nesting territory that is not an in-use nest at the current time" (USFWS 2016). Monitoring to demonstrate that nests are not in-use will follow observational procedures described by Pagel et al. (2010).

Mitigation Measure BIO-18: Bank Swallow

The following measures will be implemented to avoid and minimize impacts on bank swallow individuals, colonies, current and potential habitat (i.e., natural banks), and, if feasible, to river processes. This applies to activities year-round, whether bank swallows are present or not.

Preconstruction Surveys

Prior to beginning project activities within 500 feet of the Sacramento River, Feather River, and lower American River during the bank swallow nesting season (April 1 through August 31), a preconstruction survey for bank swallow colonies will be conducted where bank swallow habitat is present within 500 feet of work areas. If no active nesting colonies are present, no further measures are required.

If an active colony is found and work must occur during the nesting season (April 1 through August 31), Reclamation will establish a nondisturbance buffer (in consultation with a biologist) around the colony during the breeding season. In addition, the biologist will monitor any active colony within 500 feet of work areas to ensure that activities do not affect nest success. No project activities will take place within the disturbance buffer.

Avoidance and Minimization

Prevent Impacts on Individuals, Colonies, and Habitat

To the extent feasible, where proposed water management or land-use projects (i.e., restoration activities) projects would impact bank swallows or river processes, alternatives such as setback levees can be used to avoid those impacts.

Consult with a biologist when planning projects within the floodplain of the Sacramento River and its tributaries to ensure projects do not affect colonies or current or potential habitat.

Develop flow criteria that avoid impacts of high water flows by limiting frequency and duration of peak flows over 14,000 cfs (Sacramento River) or rapid draw-downs to nesting bank swallow habitat during the breeding season (April 1 through August 31); this includes downstream tributary flows when timing water releases (Bank Swallow Technical Advisory Committee 2013).

Prevent Impacts on River Processes

To the extent feasible, where restoration activities would impact river processes, alternatives to bank stabilization, such as setback and adjacent levees, should be used to preserve dynamic river processes.

Maintain flow regimes during the nonbreeding season (September 1 through March 31) that promote natural river processes and create bank swallow habitat by providing annual flows that cause local bank erosion and a minimum of one bankfull flood event every 3 years to promote bank erosion, meander migration, and channel cutoff. (Bank Swallow Technical Advisory Committee 2013).

Mitigation Measure BIO-19: California Least Tern

For restoration projects, Reclamation will avoid California least tern nesting colony sites.

Mitigation Measure BIO-20: Migratory Birds (Osprey, Short-Eared Owl, Tule Greater White-fronted Goose, Black Tern, Least Bittern, White-Faced Ibis)

The following measures will be implemented to avoid and minimize impacts on nesting migratory birds, including special-status birds, during Reclamation restoration activities.

- A qualified wildlife biologist with experience with nesting birds will conduct nesting surveys before the start of restoration activities. A minimum of three separate surveys will be conducted within 30 days prior to the initiation of work, with the last survey within 3 days prior to work beginning in a given work area. Surveys will include a search of all suitable nesting habitat in the work area. In addition, a 500-foot radius around the work area, where accessible, will be surveyed for nesting raptors, and an area within 50 feet of the work area will be surveyed for other nesting birds protected by the MBTA. If no active nests are detected during these surveys, no additional measures are required.

If active nests are found in the survey area, nondisturbance buffers will be established around the nest sites to avoid disturbance or destruction of the nest site until the end of the breeding season (approximately September 1) or until a qualified wildlife biologist determines that the young have fledged and moved out of the study area. The end of the breeding season varies by species and the stage of the nesting effort (i.e., nest building, egg laying, incubation, feeding nestling, feathered young, fledged young, etc.) as determined by the qualified wildlife biologist. A qualified wildlife biologist will monitor activities in the vicinity of the nests to ensure that activities do not affect nest success. The extent of the buffers will be determined by the biologist and will depend on the level of noise or disturbance, line-of-sight between the nest and the disturbance, ambient levels of noise and other disturbances, and other topographical or artificial barriers. Suitable buffer distances may vary between species.

Mitigation Measure BIO-21: Riparian Woodrat and Riparian Brush Rabbit

The measures for riparian woodrat and riparian brush rabbit will be implemented for projects occurring within suitable habitat. Within the study area, based on the known distribution of the species, suitable habitat is defined to include the areas within the legal Delta along San Joaquin and Stanislaus Rivers south of State Route 4 and Old River Pipeline. Within this area, suitable riparian habitat includes the vegetation types that make up a dense, brushy understory shrub layer with a minimum patch size of 0.05 acres. Riparian brush rabbit grassland habitat includes grasslands with a minimum patch size of 0.05 acres that are adjacent to riparian brush rabbit riparian habitat.

A qualified biologist will conduct a field evaluation of suitable habitat for both species for all covered activities that occur within the defined area for these species' habitat as described above. If the project cannot fully avoid effects on suitable habitat, the following measures will be required.

- A qualified biologist will assess habitat suitability for both species. If the qualified biologist determines the habitat to be suitable for the species, then Reclamation will avoid disturbing suitable habitat while accessing restoration sites (i.e., access to enhancement sites for in-stream activities such as gravel placement).

- If a habitat or floodplain restoration component would disturb suitable habitat, Reclamation will assume presence or conduct protocol-level surveys according to the USFWS *Draft Habitat*

Assessment Guidelines and Survey Protocol for the Riparian Brush Rabbit and the Riparian Woodrat (USFWS n.d.).

- If occupied riparian woodrat or riparian brush rabbit habitat is present, or the habitat is assumed to be occupied, Reclamation will redesign the project to avoid occupied habitat. Avoidance requires the following buffers and avoidance measures:
  - Establish minimum 250-foot nondisturbance buffers between project activities and suitable riparian habitat that is occupied or assumed to be occupied. The nondisturbance buffer is not necessary for access to restoration sites provided existing access roads are used.
  - Establish a 1,400-foot buffer between any lighting and suitable riparian habitat that is occupied or assumed to be occupied.
  - Screen all lights and direct them down toward work activities away from riparian habitat that is occupied or assumed to be occupied. A biological construction monitor will ensure that lights are properly directed at all times.
  - Operate portable lights at the lowest allowable wattage and height, while in accordance with the NCHRP *Report 498: Illumination Guidelines for Nighttime Highway Work* (Transportation Research Board 2003).
- If the suitable habitat is determined through surveys to be unoccupied, Reclamation will implement the following measures to minimize long-term effects on the habitat so that it may provide for the recovery of the species. No more than 45 acres of suitable, unoccupied riparian habitat and 30 acres of adjacent grasslands may be permanently removed by levee construction in the San Joaquin River watershed. No more than 35 acres of suitable riparian habitat and 20 acres of adjacent grassland habitat may be temporarily removed for levee construction in the San Joaquin watershed. No more than 10 acres of suitable, unoccupied riparian habitat may be affected in the Stanislaus River watershed.
  - Floodplain restoration projects will be designed to minimize the removal of mature oaks in areas providing suitable habitat for the riparian woodrat.
  - Include refugia within the restored floodplains to provide shelter from flood events for any individuals of these species that may come to occupy the area.
- Reclamation will additionally implement the following measures to avoid and minimize noise and lighting-related effects on riparian brush rabbit:
  - Establish a 1,200-foot nondisturbance buffer between any project activities and suitable riparian habitat.
- Offset any unavoidable loss of suitable riparian habitat through restoration at a 3:1 ratio, using the following restoration design measures:
- Restoration must meet specific ecological requirements for the species.
- Restoration is adjacent to, or facilitates connectivity with, existing occupied or potentially occupied habitat.

Mitigation Measure BIO-22: Salt Marsh Harvest Mouse and Suisun Shrew

Where suitable salt marsh harvest mouse and Suisun shrew habitat has been identified within a tidal restoration work area or within 100 feet of a tidal restoration work area where ground-disturbing activities will occur (e.g., at a levee breach or grading location) a biologist will conduct preconstruction surveys for the mouse or shrew prior to ground disturbance. If a mouse or shrew is discovered, tidal restoration activities near the mouse or shrew will cease until wildlife staff can be contacted and a relocation plan can be developed. Prior to tidal restoration ground-disturbing activities, vegetation will first be removed with nonmechanized hand tools (e.g., goat or sheep grazing, or, in limited cases where the biological monitor can confirm that there is no risk of harming salt marsh harvest mouse or Suisun shrew, hoes, rakes, and shovels may be used) to allow salt marsh harvest mouse and Suisun shrew to passively move out of the location. Vegetation must be cleared to bare ground and removed from the work area, including roads. The upper 6 inches of soil excavated within salt marsh harvest mouse and Suisun shrew habitat will be stockpiled and replaced on top of backfilled material. Vegetation will be removed under supervision of a biological monitor familiar with salt marsh harvest mouse and Suisun shrew. Vegetation removal will start at the edge farthest from the salt marsh and work its way toward the salt marsh. This method of removal provides cover for salt marsh harvest mouse and Suisun shrew and allows them to move toward the salt marsh as vegetation is being removed.

Temporary exclusion fencing will be placed around a defined tidal restoration work area before construction activities start and immediately after vegetation removal. The fence should be made of material that does not allow a salt marsh harvest mouse or Suisun shrew to pass through and should be buried to a depth of 2 inches so that mice cannot crawl under the fence. Supports for the fence must be placed on the inside of the exclusion area. Prior to the start of daily activities during initial ground disturbance, the biologist will inspect the salt marsh harvest mouse-proof boundary for holes or rips. The work area will also be inspected to ensure no mice are trapped inside. Any mice or shrews found along or outside the fence will be closely monitored until they move away from the construction site. Tidal restoration work will be scheduled to avoid extreme high tides (6.5 feet or above, as measured at the Golden Gate Bridge) to allow for salt marsh harvest mouse to more easily move to higher grounds.

The biologist with previous salt marsh harvest mouse and Suisun shrew experience will be onsite during construction activities related to tidal restoration in suitable habitat. The biologist will document compliance with the project permit conditions and avoidance and conservation measures. The approved biologist will have the authority to stop tidal restoration activities if any of the requirements associated with these measures are not being fulfilled. If the biologist requests work stoppage because of take of any listed species, CDFW and USFWS staff will be notified within 1 day by email or telephone.

Mitigation Measure BIO-23: Ring-Tailed Cat

Because ring-tailed cats maintain multiple dens, the loss of one den would be a negligible impact. However, the loss of a natal or maternity den would be significant. Reclamation will implement the following measure for ring-tailed cat:

- A qualified biologist familiar with ring-tailed cat biology will conduct a habitat assessment of the proposed construction area. If highly suitable denning habitat is present, the area will be designated as an Environmental Sensitive Area and marked on project maps.
- When possible, the removal of vegetation and construction activities will be conducted outside of the breeding season for ring-tailed cat (February 1 through May 1).

- If the denning season cannot be completely avoided, a qualified biologist will conduct a preconstruction survey within 2 weeks prior to commencement of construction for potential natal or maternity den trees. If an active den is found, a qualified biologist, will determine a construction-free buffer zone to be establish around the den until the young have left the den.
- A biological monitor will be present when construction activities take place when active ring-tailed cat dens are identified within the construction work area and work takes place within 150 feet of the den.

Mitigation Measure BIO-24: Special-Status Bats

The following measure was designed to avoid and minimize adverse direct and indirect effects on special-status bats. Baseline data are not available or are limited on how bats use the study area and on individual numbers of bats and how they vary seasonally. Accordingly, it is difficult to determine if there would be a substantial reduction in species numbers. Bat species with potential to occur in the study area employ varied roost strategies, from solitary roosting in foliage of trees to colonial roosting in trees and artificial structures, such as buildings and bridges. Daily and seasonal variations in habitat use are common. To obtain the highest likelihood of detection, preconstruction bat surveys will be conducted by Reclamation and will include these components:

- Identification of potential roosting habitat within project footprint.
- Daytime search for bats and bat sign in and around identified habitat.
- Evening emergence surveys at potential day-roost sites, using night-vision goggles and/or active full-spectrum acoustic monitoring where species identification is sought.
- Passive full-spectrum acoustic monitoring and analysis to detect bat use of the area from dusk to dawn over multiple nights.
- Additional onsite night surveys as needed following passive acoustic detection of special-status bats to determine nature of bat use of the structure in question (e.g., use of structure as night roost between foraging bouts).
- Qualified biologists will have knowledge of the natural history of the species that could occur in the study area and experience using full-spectrum acoustic equipment. During surveys, biologists will avoid unnecessary disturbance of occupied roosts.

Preconstruction Bridge and Other Structure Surveys

Before work begins on the bridge/structure, qualified biologists will conduct a daytime search for bat sign and evening emergence surveys to determine if the bridge/structure is being used as a roost. Biologists conducting daytime surveys would listen for audible bat calls and would use naked eye, binoculars, and a high-powered spotlight to inspect expansion joints, weep holes, and other bridge features that could house bats. Bridge surfaces and the ground around the bridge/structure would be surveyed for bat sign, such as guano, staining, and prey remains.

Evening emergence surveys will consist of at least one biologist stationed on each side of the bridge/structure watching for emerging bats from a half hour before sunset to 1–2 hours after sunset for a minimum of 2 nights within the season that construction would be taking place. Night-vision goggles and/or full-spectrum acoustic detectors shall be used during emergence surveys to assist in species identification. All emergence surveys would be conducted during favorable weather conditions (calm nights with temperatures conducive to bat activity and no precipitation predicted).

Additionally, passive monitoring with full-spectrum bat detectors will be used to assist in determining species present. A minimum of 4 nights of acoustic monitoring surveys will be conducted within the season that the construction would be taking place. If site security allows, detectors should be set to record bat calls for the duration of each night. To the extent possible, all monitoring will be conducted during favorable weather conditions (calm nights with temperatures conducive to bat activity and no precipitation predicted). The biologists will analyze the bat call data using appropriate software and prepare a report with the results of the surveys. If acoustic data suggest that bats may be using the bridge/structure as a night roost, biologists will conduct a night survey from 1 to 2 hours past sunset up to 6 hours past sunset to determine if the bridge is serving as a colonial night roost.

If suitable roost structures will be removed, additional surveys may be required to determine how the structure is used by bats, whether it is as a night roost, maternity roosts, migration stopover, or for hibernation.

Preconstruction Tree Surveys

If tree removal or trimming is necessary, qualified biologists will examine trees to be removed or trimmed for suitable bat roosting habitat. High-value habitat features (large tree cavities, basal hollows, loose or peeling bark, larger snags, palm trees with intact thatch, etc.) will be identified and the area around these features searched for bats and bat sign (guano, culled insect parts, staining, etc.). Riparian woodland, orchards, and stands of mature broadleaf trees should be considered potential habitat for solitary foliage roosting bat species.

If bat sign is detected, biologists will conduct evening visual emergence surveys of the source habitat feature from a half hour before sunset to 1–2 hours after sunset for a minimum of 2 nights within the season that construction would be taking place. Methodology should follow that described above for the bridge emergence survey.

Additionally, if suitable tree roosting habitat is present, acoustic monitoring with a bat detector will be used to assist in determining species present. These surveys would be conducted in coordination with the acoustic monitoring conducted for the bridge structure.

Protective Measures for Bats using Bridges/Structures and Trees

Avoidance and minimization measures shall be necessary if it is determined that bats are using the bridge/structure or trees as roost sites and/or sensitive bats species are detected during acoustic monitoring. Appropriate measures shall include, as applicable, the measures listed below.

- Ensure that bats are protected from noise, vibrations, and light that result from construction activities associated with water conveyance facilities, conservation components, and ongoing habitat enhancement, as well as operations and maintenance of above-ground water conveyance facilities, including the transmission facilities. This would be accomplished by either directing noise barriers and lights inward from the disturbance or ensuring that the disturbances do not extend more than 300 feet from the point source.
- Disturbance of the bridge will be avoided between March 1 and October 31 (the maternity period) to avoid impacts on reproductively active females and dependent young.

- Installation of exclusion devices from March 1 through October 31 to preclude bats from occupying the bridge during construction. Exclusionary devices will only be installed by or under the supervision of an experienced bat biologist.
- Tree removal will be avoided between April 15 and September 15 (the maternity period for bat species that use trees) to avoid impacts on pregnant females and active maternity roosts (whether colonial or solitary).
- Tree removal will be conducted between September 15 and October 31 to the maximum extent feasible, which corresponds to a time period when bats would not likely have entered winter hibernation and would not be caring for flightless young.
- Trees will be removed in pieces, rather than felling the entire tree.
- If a maternity roost is located, whether solitary or colonial, that roost will remain undisturbed with a buffer as determined in by a qualified biologist until September 15 or until the qualified biologist has determined the roost is no longer active.
- If a non-maternity roost is found, that roost will be avoided to the maximum extent feasible and an appropriate buffer established in consultation with a qualified biologist. Every effort would be made to avoid the roost to the maximum extent feasible, as methods to evict bats from trees are largely untested. However, if the roost cannot be avoided, eviction will be attempted and procedures designed in consultation with the qualified biologist will be employed to reduce the likelihood of mortality of evicted bats. In all cases:
  - Eviction would not occur before September 15.
  - Qualified biologists would carry out or oversee the eviction tasks and would monitor the tree trimming/removal.
  - Eviction would take place late in the day or in the evening to reduce the likelihood of evicted bats falling prey to diurnal predators.
  - Eviction would take place during weather and temperature conditions conducive to bat activity.
  - Special-status bat roosts would not be disturbed.
- Eviction procedures shall include but are not limited to the following:
  - Pre-eviction surveys to obtain data to inform the eviction approach and subsequent mitigation requirements. Relevant data may include the species, sex, reproductive status and/or number of bats using the roost, and roost conditions themselves such as temperature and dimensions. Surveys may include visual emergence, night vision, acoustic, and/or capture.
  - If needed, structural changes to the roost, performed without harming bats, such that the conditions in the roost are undesirable to roosting bats and the bats leave on their own (e.g., open additional portals so that temperature, wind, light and precipitation regime in the roost change).
  - Non-injurious harassment at the roost site to encourage bats to leave on their own, such as ultrasound deterrents or other sensory irritants.
- Prior to removal/trimming, after other eviction efforts have been attempted, any confirmed roost tree would be shaken, repeatedly struck with a heavy implement such as an axe and several

minutes should pass before felling trees or trimming limbs to allow bats time to arouse and leave the tree. The biologists should search downed vegetation for dead and injured bats. The presence of dead or injured bats would be reported to CDFW.

Compensatory mitigation for the loss of roosting habitat will include the construction and installation of suitable replacement habitat onsite. Depending on the species and type of roost lost, various roost replacement habitats have met with some success (e.g., bat houses, “bat bark,” planting cottonwood trees, leaving palm thatch in place rather than trimming). Creating natural habitat onsite is generally preferable to artificial habitat.

Artificial roosts are often unsuccessful, and care must be taken to determine as closely as possible the conditions in the natural roost to be replaced. Even with such care, artificial habitat may fail. Several artificial roosts have been highly successful in replacing bridge roost habitat when incorporated into new bridge designs. “Bat bark” has been successfully used by the Arizona Department of Game and Fish to create artificial crevice-roosting bat habitat mounted on pine trees (Mering and Chambers 2012:765). Bat houses have at best an inconsistent track record but information is mounting on how to create successful houses. There is no single protocol or recipe for bat-house success. Careful study of the roost requirements of the species in question; the particular conditions at the lost roost site including temperature, orientation of the openings, airflow, internal dimensions and structures (cavity vs. crevice, etc.) should increase the chances of designing a successful replacement.

Restoring riparian woodland with plantings shows signs of success in Colorado. Western red bat activity has been positively correlated with increased vegetation and tree growth, canopy complexity and restoration acreage at cottonwood-willow restoration sites along the Lower Colorado River (Broderick 2010). These complex woodland areas would ultimately provide a wider range of bat species with preferred roost types, including both foliage-roosting and crevice-/cavity-roosting bats.

Mitigation Measure BIO-25: Suisun Thistle and Soft Bird’s-Beak

A complete botanical survey of project sites will be completed using *Guidelines for Conducting and Reporting Botanical Inventories for Federally Listed, Proposed and Candidate Plants* (USFWS 1996) and *Protocols for Surveying and Evaluating Impacts to Special Status Native Plant Populations and Sensitive Natural Communities* (CDFW 2018). The surveys will be floristic in nature and conducted in a manner that maximizes the likelihood of locating Suisun thistle and soft bird’s-beak (i.e., during the appropriate season and at an appropriate level of ground coverage).

Special-status plant surveys required for project-specific permit compliance will be conducted early in the planning process to allow design of the individual restoration projects to avoid adverse modification of habitat for specified covered plants. The purpose of these surveys will be to verify that the locations of Suisun thistle and soft bird’s-beak identified in previous record searches or surveys are extant, identify any new occurrences, and cover any portions of the study area not previously identified. The extent of compensation for direct loss of or indirect effects on Suisun thistle and soft bird’s-beak will be based on these survey results. Locations of the plants in proposed construction areas will be recorded using a GPS unit and flagged.

The following measures will be implemented:

- Design restoration projects to avoid the direct, temporary loss of occupied habitat from construction activities for Suisun thistle. In tidal restoration areas, Suisun thistle occurrences may experience the indirect effect of tidal damping. This effect will be monitored and adaptively managed to ensure the occurrence is protected from loss.

- If a soft bird's-beak occurrence has more than 10 individuals, no more than 5% of the total number of individuals in the occurrence will be removed. If an occurrence has 10 or fewer individuals, all individuals may be removed. Loss of individuals for all occurrences will be offset through replacement of occupied habitat at a ratio of at least 1:1, to achieve no net loss of occupied habitat.
- To minimize the spread of nonnative, invasive plant species from restoration sites, Reclamation will retain a qualified botanist or weed scientist prior to clearing operations to determine if affected areas contain invasive plants. If areas to be cleared contain invasive plants, then chipped vegetation material from those areas will not be used for erosion control; in these cases, the material will be disposed of to minimize the spread of invasive plant propagules (e.g., by burning, composting). All revegetation materials (such as mulches and seed mixtures used during restoration) shall be certified weed-free and come from locally adapted native plant materials.
- To minimize the introduction of invasive plant species, construction vehicles and construction machinery will be cleaned prior to entering construction sites that are in or adjacent to natural communities other than cultivated lands and prior to entering any restoration sites or conservation lands other than cultivated lands. Vehicles travelling off paved roads in areas with infestations of invasive plant species will be cleaned before travelling to other parts of the study area. Cleaning stations will be established at the perimeter of covered activities along construction routes as well as at the entrance to reserve system lands. Biological monitoring will include locating and mapping locations of invasive plant species within the construction areas during the construction phase and the restoration phase. Infestations of invasive plant species will be targeted for control or eradication as part of the restoration and revegetation of temporarily disturbed construction areas.
- Reclamation will ensure that covered activities in designated critical habitat areas for Suisun thistle or soft bird's-beak, if any, will not result in the adverse modification of any of the primary constituent elements for Suisun thistle or soft bird's-beak critical habitat. The CDFW Suisun Marsh Unit tracks both of these species (GIS-mapped) in Suisun Marsh. No covered activities will take place within designated Suisun thistle or soft bird's-beak critical habitat areas without prior written concurrence from USFWS that such activities will not adversely modify any primary constituent elements of Suisun thistle or soft bird's-beak critical habitat. Primary constituent elements for Suisun thistle are defined as follows.
  - Persistent emergent, intertidal, estuarine wetland at or above the mean high water mark as extended directly across any intersecting channels).
  - Open channels that periodically contain moving water with ocean-derived salts in excess of 0.5%.
  - Gaps in surrounding vegetation to allow for seed germination and growth.
- Primary constituent elements for soft bird's-beak are defined as follows.
  - Persistent emergent, intertidal, estuarine wetland at or above the mean high water mark (as extended directly across any intersecting channels).
  - Rarity or absence of plants that naturally die in late spring (winter annuals).

- Partially open spring canopy cover at ground level, with many small openings to facilitate seedling germination.

Mitigation Measure BIO-26: Other Special-Status Plant Species (Contra Costa Goldfields, Delta Button-Celery, Delta Tule Pea, Mason's Lilaeopsis, Suisun Marsh Aster, Bolander's Water Hemlock, Sanford's Arrowhead)

A complete botanical survey of project sites in areas of suitable habitat for special-status plants will be completed using *Protocols for Surveying and Evaluating Impacts to Special Status Native Plant Populations and Sensitive Natural Communities* (CDFW 2018). The surveys will be floristic in nature and conducted in a manner that maximizes the likelihood of locating special-status plant species or special-status natural communities that may be present (i.e., during the appropriate season and at an appropriate level of ground coverage).

Special-status plant surveys required for project-specific permit compliance will be conducted during the planning phase to allow design of the individual project activities to avoid or minimize adverse impacts to habitat for specified covered plants. The purpose of these surveys will be to verify that the locations of special-status plants identified in previous record searches or surveys are extant, identify any new special-status plant occurrences, and cover any portions of the study area not previously identified. The extent of mitigation of direct loss of or indirect effects on special-status plants will be based on these survey results. Locations of special-status plants in proposed construction areas will be recorded using a GPS unit and flagged.

The following measures will be implemented.

- Design restoration projects to avoid the direct, temporary loss of occupied habitat from construction activities for other special-status plant species. If other special-status plant species occur in a floodplain restoration area, restoration projects may be designed to include occupied habitat in the restored floodplain provided ground disturbance is avoided in the occupied habitat and the restoration is designed such that the anticipated level of flooding and scouring is compatible with the life-history needs of the covered plant species. In tidal restoration areas, occurrences may experience the indirect effect of tidal damping. This effect will be monitored and adaptively managed to ensure the occurrence is protected from loss.
- Avoid modeled habitat for vernal pool plants to the maximum extent practicable. Where practicable, no ground-disturbing activities or alterations to hydrology will occur within 250 feet of vernal pools. Reclamation will ensure that there will be no adverse modification of critical habitat for vernal pool plants.
- Avoid the loss of extant occurrences of all other special-status plant species.
- If an occurrence has more than 10 individuals, no more than 5% of the total number of individuals in the occurrence will be removed. If an occurrence has 10 or fewer individuals, all individuals may be removed. Loss of individuals for all occurrences will be offset through replacement of occupied habitat at a ratio of at least 1:1, to achieve no net loss of occupied habitat.
- To minimize the spread of nonnative, invasive plant species from restoration sites, Reclamation will retain a qualified botanist or weed scientist prior to clearing operations to determine if affected areas contain invasive plants. If areas to be cleared contain invasive plants, then chipped vegetation material from those areas will not be used for erosion control; in these cases, the

material will be disposed of to minimize the spread of invasive plant propagules (e.g., by burning, composting). All revegetation materials (such as mulches and seed mixtures used during restoration) shall be certified weed-free and come from locally adapted native plant materials.

- To minimize the introduction of invasive plant species, construction vehicles and construction machinery will be cleaned prior to entering construction sites that are in or adjacent to natural communities other than cultivated lands, and prior to entering any project restoration sites or conservation lands other than cultivated lands. Vehicles travelling off paved roads in areas with infestations of invasive plant species will be cleaned before travelling to other parts of the project. Cleaning stations will be established at the perimeter of covered activities along construction routes as well as at the entrance to conservation lands. Biological monitoring will include locating and mapping locations of invasive plant species within the construction areas during the construction phase and the restoration phase. Infestations of invasive plant species will be targeted for control or eradication as part of the restoration and revegetation of temporarily disturbed construction areas.
- This mitigation measure does not apply to the routine management and maintenance activities of Reclamation. Reclamation will determine during implementation the most effective and cost-efficient means to minimize the unintentional spread of invasive plants through vehicle travel.

P.2.7.2 *Mitigation Measures for Wetlands and Waters of the United States*

Mitigation Measure BIO-27: Wetlands and Waters of the United States

Reclamation will avoid fill of wetlands and waters of the United States to the extent feasible, and will offset unavoidable effects through wetland creation, restoration, or enhancement with the goal of achieving no net loss of wetland acres and functions.

P.2.8 Summary of Impacts

Table P.2-3 includes a summary of impacts, the magnitude and direction of those impacts, and potential mitigation measures for consideration.

Table P.2-3. Impact Summary

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
Potential changes to wildlife and plant habitat on river banks (Project-Level)	No Action	No effect	–
	1	Changes in flows compared with the No Action Alternative are expected to result in very minor effects on plants and wildlife along stream and reservoir banks but could result in substantial adverse effects on bank swallow colonies.	MM BIO-18 Bank Swallow

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
	2	Changes in flows compared with the No Action Alternative are expected to result in very minor effects on plants and wildlife along stream and reservoir banks but could result in substantial adverse effects on bank swallow colonies.	MM BIO-18 Bank Swallow
	3	Changes in flows compared with the No Action Alternative are expected to result in very minor effects on plants and wildlife along stream and reservoir banks, but could result in substantial adverse effects on bank swallow colonies.	MM BIO-18 Bank Swallow
	4	Changes in flows compared with the No Action Alternative are expected to result in very minor effects on plants and wildlife along stream and reservoir banks, but could result in substantial adverse effects on bank swallow colonies.	MM BIO-18 Bank Swallow
Potential changes to existing marshes and associated special-status species in the Bay-Delta region (Program-Level)	No Action	No effect	–
	1	Habitat restoration may result in short-term loss of tidal marsh habitat.	MM BIO-7 California Black Rail, MM BIO-8 California Ridgway's Rail, MM BIO-22, Salt Marsh Harvest Mouse and Suisun Shrew, MM BIO-25 Suisun Thistle and Soft Bird's-Beak, MM BIO-26 Other Special-Status Plant Species
	2	No effect	–
	3	Habitat restoration may result in short-term loss of tidal marsh habitat.	MM BIO-7 California Black Rail, MM BIO-8 California Ridgway's Rail, MM BIO-22, Salt Marsh Harvest Mouse and Suisun Shrew, MM BIO-25 Suisun Thistle and Soft Bird's-Beak, MM BIO-26 Other Special-Status Plant Species

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
	4	No effect	–
Potential changes to existing riparian areas and associated special-status species (Program-Level)	No Action	No effect	–
	1	Habitat restoration may result in the loss of riparian habitat.	MM BIO-2 Valley Elderberry Longhorn Beetle, MM BIO-4 Foothill Yellow-Legged Frog, MM BIO-15 Western Yellow-Billed Cuckoo, MM BIO-10 Least Bell's Vireo, MM BIO-12 Swainson's Hawk, MM BIO-16 White-Tailed Kite, MM BIO-11 Suisun Song Sparrow, Saltmarsh Common Yellowthroat, Yellow-Breasted Chat, Yellow Warbler, MM BIO-20 Migratory Nesting Birds, MM BIO-17 Bald Eagle, MM BIO-23 Ring-Tailed Cat, MM BIO-21 Riparian Woodrat and Riparian Brush Rabbit
	2	No effect	–
	3	Habitat restoration may result in the loss of riparian habitat.	MM BIO-2 Valley Elderberry Longhorn Beetle, MM BIO-4 Foothill Yellow-Legged Frog, MM BIO-15 Western Yellow-Billed Cuckoo, MM BIO-10 Least Bell's Vireo, MM BIO-12 Swainson's Hawk, MM BIO-16 White-Tailed Kite, MM BIO-11 Suisun Song Sparrow, Saltmarsh Common Yellowthroat, Yellow-Breasted Chat, Yellow Warbler,, MM BIO-20 Migratory Nesting Birds, MM BIO-17 Bald Eagle, MM BIO-23 Ring-Tailed Cat, MM BIO-21 Riparian Woodrat and Riparian Brush Rabbit
	4	No effect	–
Potential changes to habitat for special-status reptiles (Program-Level)	No Action	No effect	–
	1	Habitat restoration could result in the loss of giant garter snake and western pond turtle habitat.	MM BIO-5 Giant Garter Snake
	2	No effect	–

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
	3	Habitat restoration could result in the loss of giant garter snake and western pond turtle habitat.	MM BIO-5 Giant Garter Snake
	4	Components to increase water use efficiencies in agricultural areas may result in loss of habitat for giant garter snake.	MM BIO-5 Giant Garter Snake
Potential to injure or kill special-status species (Program-Level)	No Action	No effect	–
	1	Construction activities associated with restoration and installation of facilities could kill or injure special-status species in occupied habitat.	All mitigation measures
	2	No effect	–
	3	Construction activities associated with restoration and installation of facilities could kill or injure special-status species in occupied habitat.	All mitigation measures
	4	Components to increase water use efficiencies in agricultural areas may result in loss of habitat for giant garter snake and valley elderberry longhorn beetle.	MM BIO-2 Valley Elderberry Longhorn Beetle, MM BIO-5 Giant Garter Snake
Potential changes to vernal pools and associated special-status species (Program-Level)	No Action	No effect	–
	1	Occupied vernal pools could be removed or impacted by restoration or fish hatchery construction.	MM BIO-1 Vernal Pool Fairy Shrimp, Vernal Pool Tadpole Shrimp, Conservancy Fairy Shrimp, Longhorn Fairy Shrimp, MM BIO-3, California Tiger Salamander and Western Spadefoot Toad, MM BIO-26 Other Special-Status Plant Species
	2	No effect	–
	3	Occupied vernal pools could be removed or impacted by restoration or fish hatchery construction.	MM BIO-1 Vernal Pool Fairy Shrimp, Vernal Pool Tadpole Shrimp, Conservancy Fairy Shrimp, Longhorn Fairy Shrimp, MM BIO-3, California Tiger

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
			Salamander and Western Spadefoot Toad, MM BIO-26 Other Special-Status Plant Species
	4	No effect	-
Potential to affect special-status bat species and their habitat (Program-Level)	No Action	No effect	--
	1	Habitat restoration and construction and could injure or kill bat species and remove their habitat.	MM BIO-24 Special-Status Bats
	2	No effect	-
	3	Habitat restoration and construction and could injure or kill bat species and remove their habitat.	MM BIO-24 Special-Status Bats
	4	No effect	-
Potential changes to wetlands and waters of the United States (Program-Level)	No Action	None	–
	1	Potential short-term decrease or long-term conversion of wetland types and waters of the United States.	MM BIO-27 Wetlands and Waters of the United States
	2	None	–
	3	Potential short-term decrease or long-term conversion of wetland types and waters of the United States.	MM BIO-27 Wetlands and Waters of the United States
	4	Potential short term decrease or long-term conversion of wetland types and waters of the United States.	MM BIO-27 Wetlands and Waters of the United States

P.2.9 Cumulative Effects

The cumulative effects analysis for terrestrial biological resources addresses the potential for the project alternatives to act in combination with other past, present, and reasonably foreseeable future projects, programs, or conditions to create a cumulatively adverse impact. The analysis also considers whether any incremental effect of the alternative is cumulatively considerable.

The projects and programs that have been considered as part of the cumulative analysis have been compiled in Appendix Y, *Cumulative Methodology*. The list of past, present, and reasonably foreseeable future projects and programs has been evaluated to determine which of these activities may have effects on terrestrial habitats and terrestrial species that are known to occur within the study area.

In addition, the effects of climate change have been considered in addressing the cumulative effects of alternatives on terrestrial biological resources. Changes that might occur within the study area related to climate change are considered reasonably foreseeable and part of the cumulative condition that might combine with the effects of the implementation of project alternatives.

To assess whether implementation of the alternatives would contribute to an adverse cumulative effect on the terrestrial biological resources of the study area, a judgment must first be made regarding potential adverse effects of the alternatives. Where adverse effects are anticipated, a determination must be made as to whether these effects would contribute to a cumulative adverse effect on a terrestrial biological resource. If there is a contribution to a cumulative adverse effect, a final judgment must be made as to whether the effect of the alternative represents a considerable contribution to the cumulative effect.

P.2.9.1 *Cumulative Effects of the No Action Alternative*

P.2.9.1.1 Effects of Past, Present, and Reasonably Foreseeable Projects and Programs

The current conditions of study area biological resources are the byproduct of past and ongoing human activity, including declining acreages of natural habitat due to agricultural, urban development, and flood control and water management activities. The various projects and programs listed in Appendix Y will have cumulative effects on the existing biological resources of the study area through the early long-term (year 15) and over the next 50 years. The most relevant elements of these projects and programs are their abilities to modify land use patterns, modify land management practices, and change the patterns of hydrology and vegetation in the study area. Most of the local, state, and federal land use and land management programs that are affecting or will affect the study area are designed to preserve open space and agricultural lands, and to manage the resources of the area for multiple uses, including agriculture, recreation, fish and wildlife habitat, flood protection, and water management. The restoration programs would increase primarily wetland and riparian natural communities by converting agricultural land or managed wetland. The special-status and common plants and wildlife that rely on wetland and riparian habitats for some stage of their life would benefit from these changes over time. Other species that rely on agricultural land and managed wetland but do not benefit from wetland and riparian expansion may decline in the study area. On the upland fringes of the Bay-Delta, plans exist for small expansions of urban development that would remove primarily agricultural land uses. The management of state- and federally owned wildlife areas, including Grizzly Island, Sherman Island, and Yolo Bypass State Wildlife Areas and Stone Lakes NWR, would continue to focus on multiple uses, including wildlife habitat improvement, public access for wildlife viewing, wildlife friendly agricultural production, and hunting opportunities. Natural habitat would be improved and expanded. The principal changes that are likely to result from the various habitat conservation plans that overlap with the study area would be expected to include the restoration and protection of the habitats that support the same special-status species in the study area. These changes would be expected to result in increases of wetland, grassland, and riparian habitats and a decrease in agricultural lands, and possibly managed wetlands in the study area.

Implementation of the water management strategies associated with the programs listed in Appendix Y would not modify the principal species habitat in the study area. These management strategies are designed, in part, to improve aquatic habitat conditions in the study area for the benefit of special-status fish species. Periodic levee and channel maintenance activities associated with the flood management programs identified in Appendix Y would result in localized disturbances to valley/foothill riparian, grassland, and tidal perennial aquatic natural communities, and to a lesser extent to tidal brackish and tidal freshwater emergent wetlands. To the extent that ongoing levee repair and replacement involves use of reinforcing rock and discouragement of replanting streamside vegetation, there could be a gradual decline in the extent and value of valley/foothill riparian habitat and grassland along minor and major waterways. Several of the water management and transportation projects listed in Appendix Y require localized removal of natural communities and agricultural land for expanding infrastructure.

The overall direction of these existing and ongoing programs and policies that influence land conversion and land management in the study area would continue to be toward maintaining the mix of agricultural, recreational, water management, and wildlife uses in the study area. However, given that the No Action Alternative would not change CVP and SWP operations and would not change flow rates or increase land conversion or land management activities, the No Action Alternative would have no effect on terrestrial biological resources.

P.2.9.1.2 Effects of Climate Change

Climate change is expected to result in many physical changes to the study area. From a terrestrial biology perspective, the most significant changes would include a gradual rise in sea level, increasing water and air temperatures, more frequent drought and extreme rainfall events, and changes in the hydrologic patterns of the rivers and the Bay-Delta channels that influence the terrestrial and aquatic habitats used by terrestrial plant and wildlife. Climate change includes sea level and air temperature increases, as well as changes in the frequency of drought and extreme rainfall events has not been predicted, but these events are expected to be part of future California conditions with climate change. Hydrologic conditions in the rivers and Bay-Delta channels are expected to be altered by changes in precipitation patterns, with a portion of precipitation shifting from snow to rainfall in the winter months. This would increase river flows in winter and early spring, and decrease flows in the remainder of the year as snowmelt runoff decreases. The changes in river flows would generate subsequent changes in west Bay-Delta and Suisun Marsh salinity levels.

The physical changes in conditions in the study area related to the climate change described above, especially the sea level rise, could change the distribution and value of study area habitats. The sea level rise is expected to gradually inundate existing habitats on the periphery of the Bay-Delta, in the lower Yolo Bypass, and the northern and southern edges of Suisun Marsh. Tidal brackish and freshwater marsh could be gradually inundated and converted to more subtidal habitat. In areas where there is no upland barrier (e.g., levees, roads, residential development, agricultural fields), some portion of the tidal marsh may re-establish upslope with the higher water levels if there is sufficient sediment available to provide an appropriate substrate. However, decreases in sediment availability that have occurred in the Bay-Delta and Suisun Marsh over time and that may continue may not keep pace if the higher estimated rates of sea level rise occur (Barnard et al. 2013). The result could be a gradual loss of these tidal marshes. Where barriers exist upslope of existing marsh, the tidal marsh habitat could be gradually inundated and subtidal areas would remain. Subtidal habitat is less valuable to the special-status and common terrestrial plants and wildlife of the study area. Low-lying upland grassland and riparian areas that border the study area waterways could also be gradually converted to tidal marsh, but would be expected to re-establish upslope where open ground exists and there are no physical barriers. Where these deeper water incursions bisect existing wildlife corridors, the ability of certain species to move and interact with adjacent populations would decrease. Population numbers of riparian, grassland, and tidal marsh species would be likely to decrease and population distribution would be altered. The habitats adjacent to study area waterways would also be exposed to more frequent inundation and desiccation as precipitation levels show greater fluctuation.

Land subsidence, sea level rise, gradual or catastrophic levee failure, or a combination of these conditions, should they occur, would result in flooding and inundation that could significantly damage existing facilities and infrastructure, uproot and kill vegetation to an unknown extent, permanently flood Bay-Delta islands, and drastically alter the salinity of Bay-Delta waterways and wetlands. Depending on the extent and duration of flooding, significant short- and long-term changes could occur in the availability of shallow tidal wetlands, riparian and grassland habitats and managed lands useful to certain special-status and common species (e.g., cultivated lands, managed wetland). Depending on the amount of human intervention to drain islands and rebuild levees, there may be a gradual succession of habitats less valuable to the plant and animal species currently relying on the Delta for growth and seed production, cover, breeding, nesting, resting, movement corridors and foraging.

While similar risks would occur under implementation of the action alternatives, these risks may be reduced by project-related levee improvements, along with implementation of those project elements identified for the purposes of flood protection in Appendix Y. The negative elements of climate change described above would be a contributing factor to any cumulative effects of implementing the projects and programs that are part of the No Action Alternative (Appendix Y). Any negative effects on terrestrial biological resources associated with the action alternatives (see below), when considered with all of the above effects of the No Action Alternative, could create adverse cumulative effects on these terrestrial biological resources.

P.2.9.2 *Cumulative Effects of the Action Alternatives*

This cumulative analysis discusses Alternatives 1, 2, 3, and 4, all of which would result in slight increases in flows throughout the study area. Alternatives 1 and 3 also include restoration and other construction-related activities that could result in impacts on terrestrial biological resources. However, based on the analyses presented in earlier parts of this appendix, these changes would have little or no negative effect on the terrestrial biological resources of concern in the study area and would be expected to improve the long-term viability of special-status species and their habitats. The positive effects of implementing Alternatives 1 and 3 are similar, while Alternatives 2 and 4 include no additional restoration activities but would change flow regimes in the study area. There would be relatively small variations in the acres affected by flow regime changes across the alternatives but larger variations in the acres affected by restoration; thus restoration has the greatest potential to modify natural communities and affect special-status plants and wildlife.

The past, present, and reasonably foreseeable projects, described in Appendix Y, *Cumulative Methodology,* may have effects on terrestrial biological resources. The cumulative projects include actions across California to develop new water storage capacity, new water conveyance infrastructure, new water recycling capacity, and the reoperation of existing water supply infrastructure, including surface water reservoirs and conveyance infrastructure. The cumulative projects also include ecosystem improvement and habitat restoration actions to improve conditions for special status species whose special status in many cases constrains water supply delivery operations.

Collectively, these cumulative projects would have short-term effects but would benefit terrestrial biological resources over the long-term. While flow changes, construction activities, and restoration activities in the short-term period of cumulative projects could temporarily or permanently remove natural communities and modeled habitat for special-status plant and wildlife species, the short-, mid- and long-term result of construction and restoration activities would replace, enhance, and in most cases expand habitat acres and value for these species; therefore the action alternatives' contributions would not be substantial.

In addition, for Alternatives 1, 2, 3, and 4, the avoidance and minimization measures presented are sufficient to avoid cumulative effects from the combined losses due to flow changes, construction, and restoration

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