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 action alternatives evaluated in this 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 action 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 action alternatives considered in this EIS. Changes in aquatic resources resulting from 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 from 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 appendix 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 Coordinated Long-Term Operation of the Central Valley Project and State Water Project (ROC LTO BA).

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 *Northern DPS*	Threatened	Species of Special Concern	Yes	Trinity River
Spring-Run Chinook Salmon *Upper Klamath-Trinity River ESU*	None	Candidate Endangered; Species of Special Concern	Yes	Trinity River
Fall-Run Chinook Salmon *Upper Klamath-Trinity River ESU*	None	Candidate Endangered; 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

Species or *Population*	**Federal Status**	**State Status[2]**	**Tribal, Commercial, or Recreational Importance**	**Occurrence within Study Area**
White Sturgeon	None	Species of Special Concern	Yes	Trinity River
Black Bass (Largemouth, Smallmouth, Spotted)	None	None	Yes	Trinity Lake
Brown Trout	None	None	Yes	Trinity River, Klamath River, and Trinity Lake
Rainbow Trout	None	None	Yes	Trinity Lake
Kokanee Salmon (landlocked Sockeye Salmon)	None	None	Yes	Trinity Lake
Eulachon *Southern DPS*	Threatened	None	Yes	Lower Klamath River
Winter-Run Chinook Salmon *Sacramento River ESU*	Endangered	Endangered	Yes	Sacramento River, Delta, and Suisun Marsh
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

Species or *Population*	Federal Status	State Status[2]	Tribal, Commercial, or Recreational Importance	Occurrence within Study Area
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
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 ROC LTO BA. 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:

[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*.

  - 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.
  - 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 (*Oncorhynchus tshawytscha*) 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, which is operated by USFWS (70 FR 37160–37204). 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 DPS Steelhead*

The California Central Valley distinct population segment (DPS) Steelhead (*O. mykiss*) 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 National Fish Hatchery 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 DPS Steelhead*

The Central California Coast DPS Steelhead 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 (2009) 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 (64 FR 24049–24062).

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" (Title 33 Code of Federal Regulations [CFR] Part 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 (74 FR 52300–52351).

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.
- 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) (59 FR 65256–65278).

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; 76 FR 65324).

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. 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.2.3.1.1 <u>Fish in Trinity Lake</u>

Recreational Fish

Trinity Lake supports several fish species, including native and nonnative fish. No special-status fish species occur in Trinity Lake. The predominant sportfish in Trinity Lake include both cold water species and warm water species. Cold water species include Rainbow Trout, Brown Trout, Kokanee (landlocked Sockeye Salmon), Chinook Salmon (landlocked). Warm water species include Black Bass (Smallmouth Bass, Spotted Bass, Largemouth Bass) and catfish (White Catfish and bullhead).

Cold water fish species in the lake generally migrate into tributaries to spawn either during the spring (Rainbow Trout) or fall (Kokanee and Brown Trout). Populations of Rainbow Trout, Brown Trout, and Kokanee are sustained through a combination of natural reproduction and fish hatchery stocking practices. Landlocked Chinook Salmon do not typically reproduce (Perales et al. 2015) and are supported by annual stocking practices.

Warm water fish species typically rely on habitat in the lake during all life stages. In general, Black Bass spawn during the late spring and early summer in shallow water (1.5 feet to 6.0 feet deep) along the lake margins at water temperatures ranging from 55 degrees Fahrenheit (°F) to 75°F (Moyle 2002). Catfish spawning typically occurs during June and July when water temperatures exceed 68°F, but spawning can sometimes extend into September; spawning occurs in sandy substrate adjacent to cover (rocks, wood, or aquatic vegetation) (Moyle 2002). Warm water fish species in Trinity Lake are currently self-sustaining through natural reproduction.

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 fresh water 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 from August to 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 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 2017a; 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 the Trinity River Salmon and Steelhead Hatchery, while the remaining 15,275 fish were estimated to have spawned in the river (CDFW 2014b). 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 from October to 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 fresh water, 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 fresh water for up to 3 years. The majority of Steelhead (86%) that return to the Klamath River basin are estimated to spend 2 years in fresh water before out-migrating 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 millimeters (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 adults 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 from 1980 to 2017. Run-size estimates during this period 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

Northern DPS Green Sturgeon occurs in the Trinity River Region; however, data from the Trinity River are limited, so most information on life history characteristics for Green Sturgeon in the Trinity

River are 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 years 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; Israel and Klimley 2008).

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 out-migrating 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 fresh water. American Shad spawn shortly after entering fresh water. 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 Salmon and Steelhead Hatchery was established immediately downstream of Lewiston Dam to mitigate for the loss of salmonid production upstream of the Lewiston and Trinity Dams (Reclamation 2008a). 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[2] 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 *Disease*

Several endemic salmonid-specific pathogens occur in the Klamath River watershed: *Ceratomyxa shasta* (*C. shasta*), *Parvicapsula minibicornis* (*P. minibicornis*), *Ichthyophthirius multifis* (Ich), and *Flavobacterium columnare* (columnaris). The parasites *C. shasta* and *P. minibicornis* regularly result in substantial mortality of Klamath River salmon (Fujiwara et al. 2011; True et al. 2013), while Steelhead are generally resistant to *C. shasta*. These parasites occur throughout the watershed, however, *C. shasta* and *P. minibicornis* are not found at significant levels in the Trinity River (Stocking et al. 2006). Within the Klamath River, *C. shasta*, Ich, and columnaris has been observed to result in high rates of mortality in salmon.

Both *C. shasta* and *P. minibicornis* spend part of their life cycle in an invertebrate host and another part in a fish host which limits transmission of these parasites to areas where the invertebrate host is present. In the Klamath River, their invertebrate host is the annelid polychaete worm *Manayunkia speciosa* (Bartholomew et al. 1997, 2007). Once the polychaetes are infected, they release *C. shasta* and *P. minibicornis* actinospores into the water column. Actinospores are generally released when temperatures rise above 50°F and remain viable from 3 days to 7 days at temperatures from 51.8°F to 64.4°F, with temperatures outside that range resulting in a shorter period of viability (Foott et al. 2007). Studies found that increasing parasite concentrations and water temperatures were positively associated with the proportion of juvenile fish that experienced infection and mortality (Ray et al. 2014). Despite potential resistance to *C. shasta* and *P. minibicornis* in native populations, salmon

[2] In 2014 and 2015, under *Environmental Protection Information Center v. Lehr et al* (2014), Steelhead and Coho Salmon production at the Trinity River Fish Hatchery was temporarily reduced from 800,000 to no more than 448,000 Steelhead and from 500,000 to 300,000 Coho Salmon until a hatchery genetics management plan can be adopted.

exposed to high levels of the parasite may be more susceptible to disease—particularly juvenile salmon, and more so at higher (>59ºF [>15 degrees Centigrade [ºC]) water temperatures.

Ich, a protozoan parasite that spreads horizontally from fish to fish, and columnaris have occasionally had a substantial impact on adult salmon, particularly when habitat conditions include exceptionally low flows, high water temperatures, and high densities of fish. For adult salmon the effects of Ich and columnaris are generally not as harmful as the observed effects of the myxozoan parasites on juveniles, although under some conditions substantial fish mortality can occur as a result. The 2002 fish kill in the Lower Klamath River provided dramatic evidence of the ability of Ich and columnaris to cause adult salmon mortality, with more than 33,000 adult salmon and Steelhead lost during a disease outbreak (CDFG 2004). Most of the fish affected by the 2002 fish die-off were Fall-Run Chinook Salmon in the lower 36 miles of the Klamath River (CDFG 2004). Environmental conditions in the River at the time of the 2002 Fall-Run Chinook Salmon run were characterized by low flow rates and volume, warm water temperatures, and an apparent lack of migration cues to proceed upriver.

O.2.3.6 *Lower Klamath River from Trinity River*

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.2.3.6.1 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.

Although 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 to 2014, with abundance peaking during 2013 to 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 months 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, 1998).

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 Battle Creek Salmon and

Steelhead Restoration Project 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 from January to 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 AB, Attachment A, *Components for the Reinitiation of Consultation on Long-Term Operations)* (Reclamation 2019). 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 2017b, Martin et al. 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 cubic feet per second (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 2009). 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 fish to 23,000 fish during the 1980s, 100 fish to 4,100 fish during the 1990s, and 0 fish to 600 fish from 2000 to 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 2009). 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 young-of-year or as yearlings. The emigration period for Spring-Run Chinook Salmon extends from November to early May, with up to 69% of the young-of-year 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 2009). 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 month 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 from July to 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 2009; 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 River 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 from August to March, primarily from August through October; they migrate upstream past RBDD during all months of the year, but primarily during September and October (NMFS 2009). 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 fresh water streams for 2 to 4 years before out-migrating 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 2009).

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 (74 FR 52300–52351), 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 (2002a) 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, 2017; NMFS 2018b). Green Sturgeon eggs are believed generally to hatch about a week after fertilization (Heublein et al. 2017).

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.

From 2010-2015, the estimates of annual run size ranged from 334-1,236 individuals and averaged 571, with a 95% condifence interval (CI) of 529-613 (Mora et al. 2018). Mora et al. (2018) also estimated the number of adults in the Southern DPS to be 2,106 (95% CI = 1,246-2,966), the number of juveniles to be 4,387 (95% CI = 2,595-6,179) and the number of subatults to be 11,055 (95% CI = 6,540-15,571). The total population estimate of all Green Sturgeon in the Southern DPS was 17,548, with a 95% CI of 12,614-22,482 individuals (Mora et al. 2018).

A genetic analysis of Green Sturgeon larvae captured in the Sacramento River resulted in an estimate of 32 to 124 adult spawning pairs upstream of RBDD from 2002 to 2006 (Israel 2006). NMFS 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 (74 FR 52300–52351). 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). Young-of-year 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 young-of-year 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 Pacific Lamprey

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 from early January to 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 Striped Bass

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 2009). 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 State Water Resources Control Board (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 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 (Martin et al. 2017), 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 cold water 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 AB, Attachment A,*Components for the Reinitiation of Consultation on Long-Term Operations*) (Reclamation 2019). 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 during 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 2017c). 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 2005a).

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 2009; 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 2009), 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 2009).

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 National Fish Hatchery, 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 National Fish Hatchery 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 National Fish Hatchery 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 National Fish Hatchery are adipose fin-clipped and coded wire-tagged (CHSRG 2012). As previously noted, 200,000 juvenile Winter-Run Chinook Salmon from Livingston Stone National Fish Hatchery 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 2009). 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 National Fish Hatchery, 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 National Fish Hatchery. As noted above, 200,000 juvenile Winter-Run Chinook Salmon from Livingston Stone National Fish Hatchery 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 and California Central Valley (Central Valley) Steelhead. 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 on 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. From 2000 to 2017, adult returns ranged from 0 in 2001 to 659 in 2013 (Figure O.2-1).

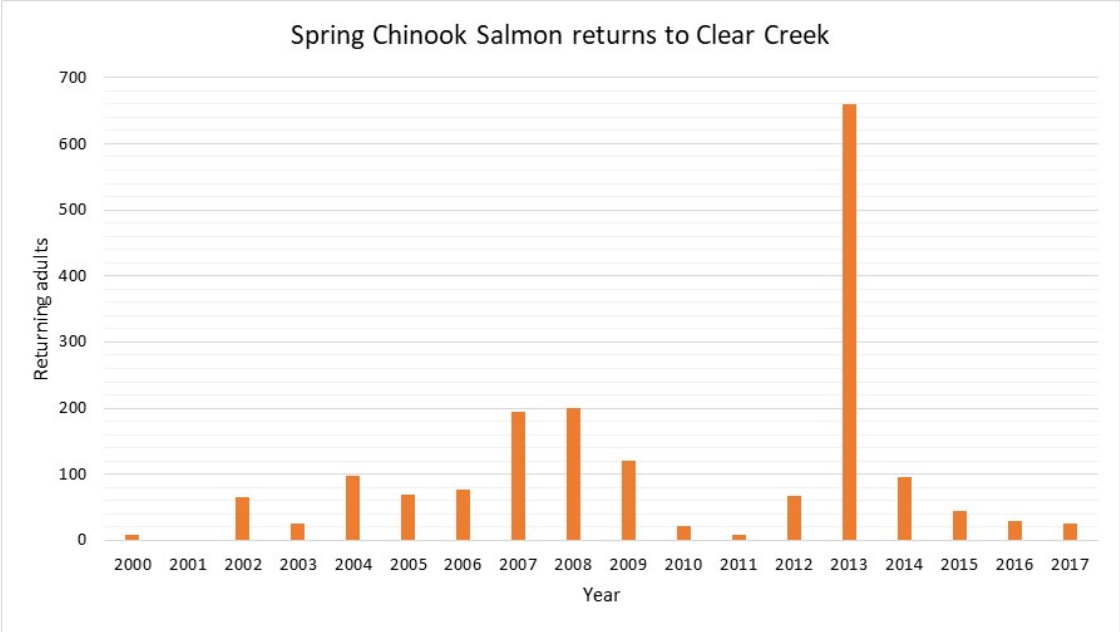

Figure O.2-1. Spring-Run Chinook Salmon Returns 2000 to 2017

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 cold water 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).

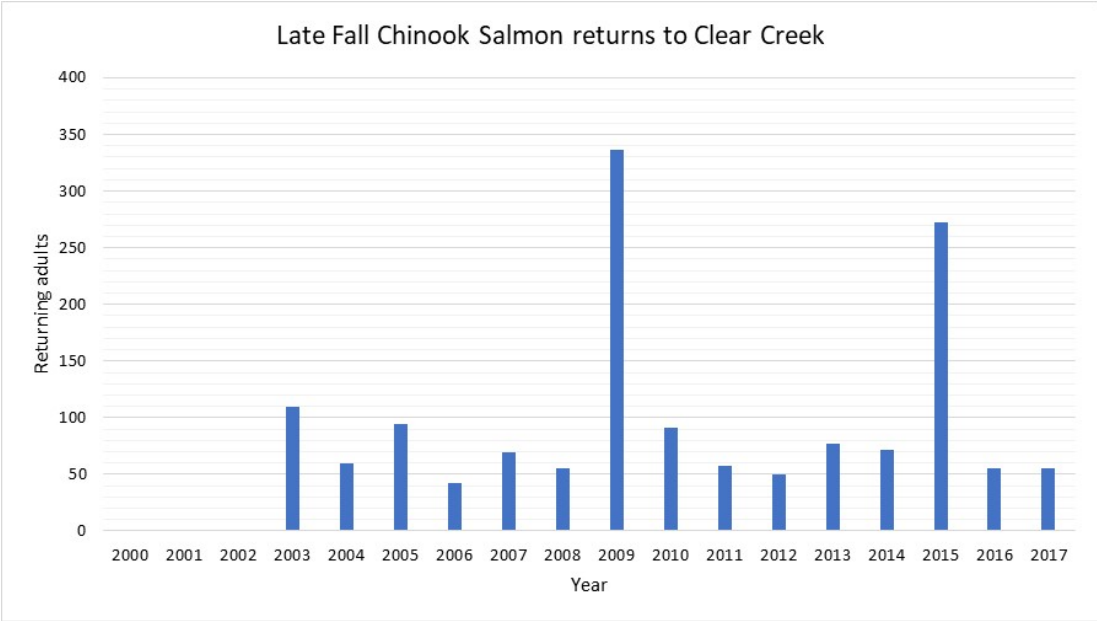

Figure O.2-2. Late Fall–Run Chinook Salmon Returns 2000 to 2017

(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.)

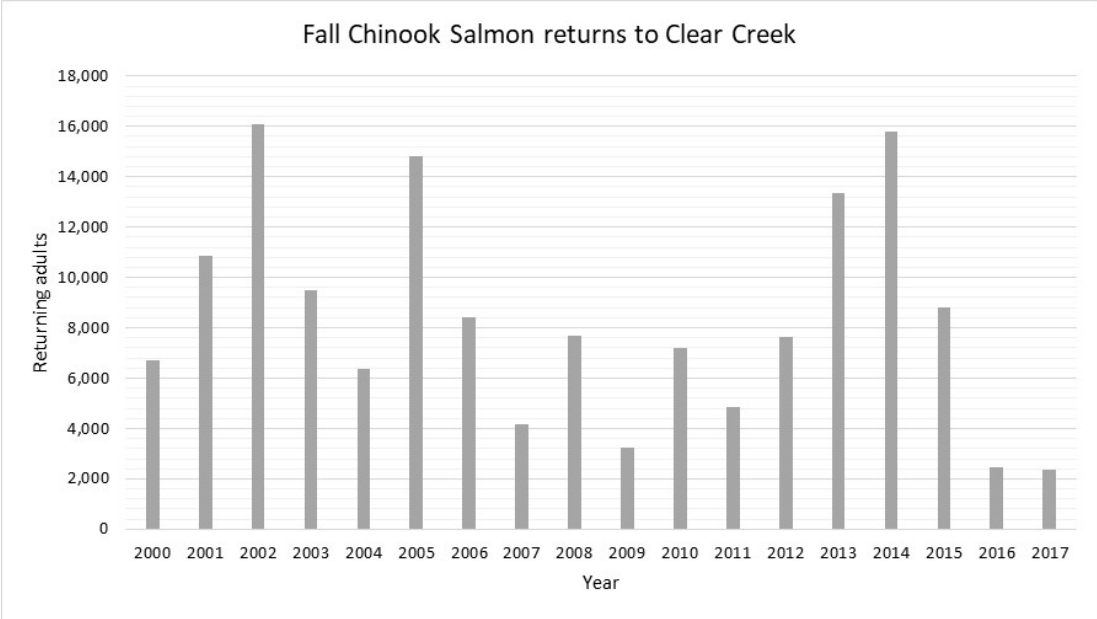

Figure O.2-3. Fall-Run Chinook Salmon Returns 2000 to 2017

(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 month to 7 months (Moyle et al. 2015).

Based on carcass surveys and juvenile out-migration trapping, Fall-Run 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 from 2003 to 2011, with redd counts ranging from 42 to 409, with an average of 176 (Giovanetti et al. 2013; Provins and Chamberlain 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 to RM 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 and Chamberlain 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 2018). (

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 from 50 cfs to 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 5 to 9 months before fish enter 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 from 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 fresh water 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 from November to 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 DPS Steelhead immigrate into the Feather River from July to 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 from March to 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. 2017). 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. 2017).

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. Stream flow 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).

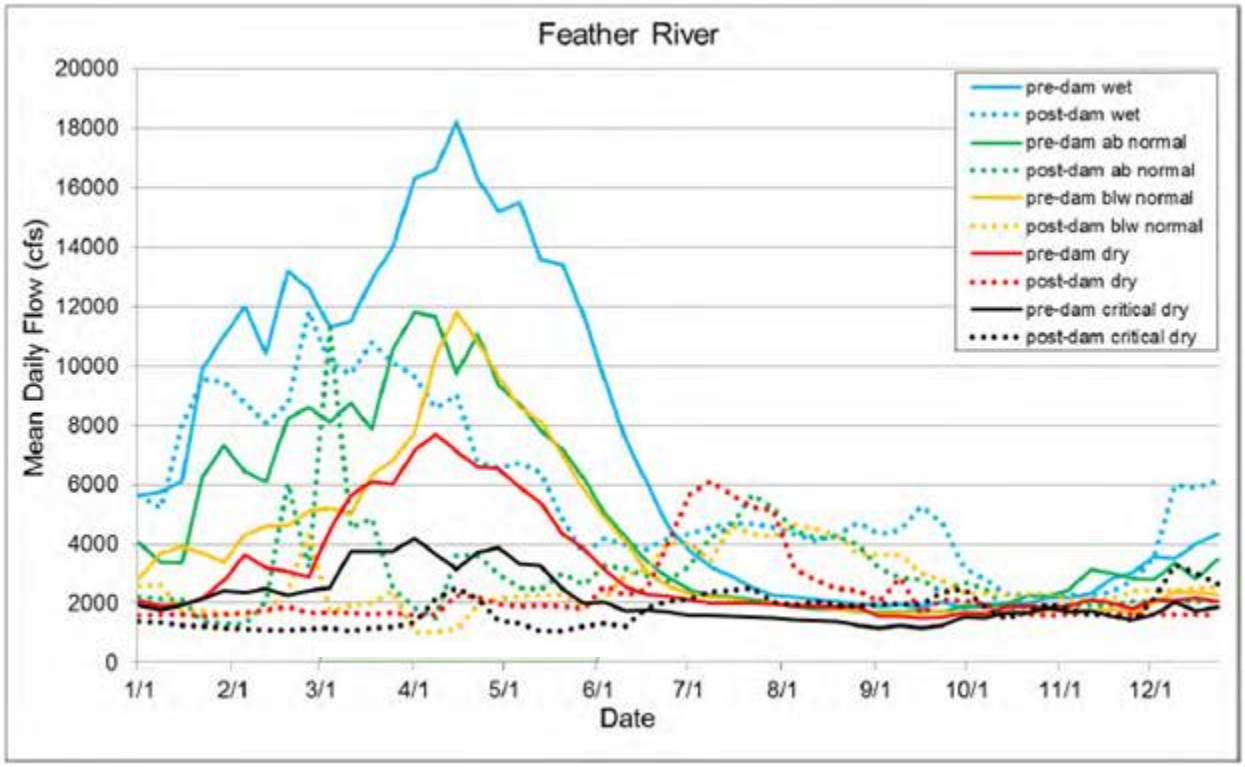

Figure O.2-4. Mean Daily Flow During all Water Year Types in the Feather River During Pre-Dam Years (Oroville Gage 1906–1965) and Post-Dam Years (Gridley gage 1969–2012; NMFS 2016a)

Modeling and surveys have been conducted to inform management decisions by identifying optimum water flow for native salmonids. According to DWR (2003) 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, Central 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 4 feet to 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 does not address the more recent 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 achieved. 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 Palmer-Zwahlen et al. (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 from December to July; out-migration peaks in February and 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 2009).

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 Nielsen 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 2009).

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 out-migrating 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 young-of-year 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 from early January to 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). Because upstream migration is more directed and fish tend to swim farther upstream during wet years (Moyle 2002), 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 young-of-year 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 2009). 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 from 1895 to 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 DPS Steelhead. 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 from 65°F to 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 2011b), 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, which has now been replaced with the more current BO (NMFS 2019), 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		

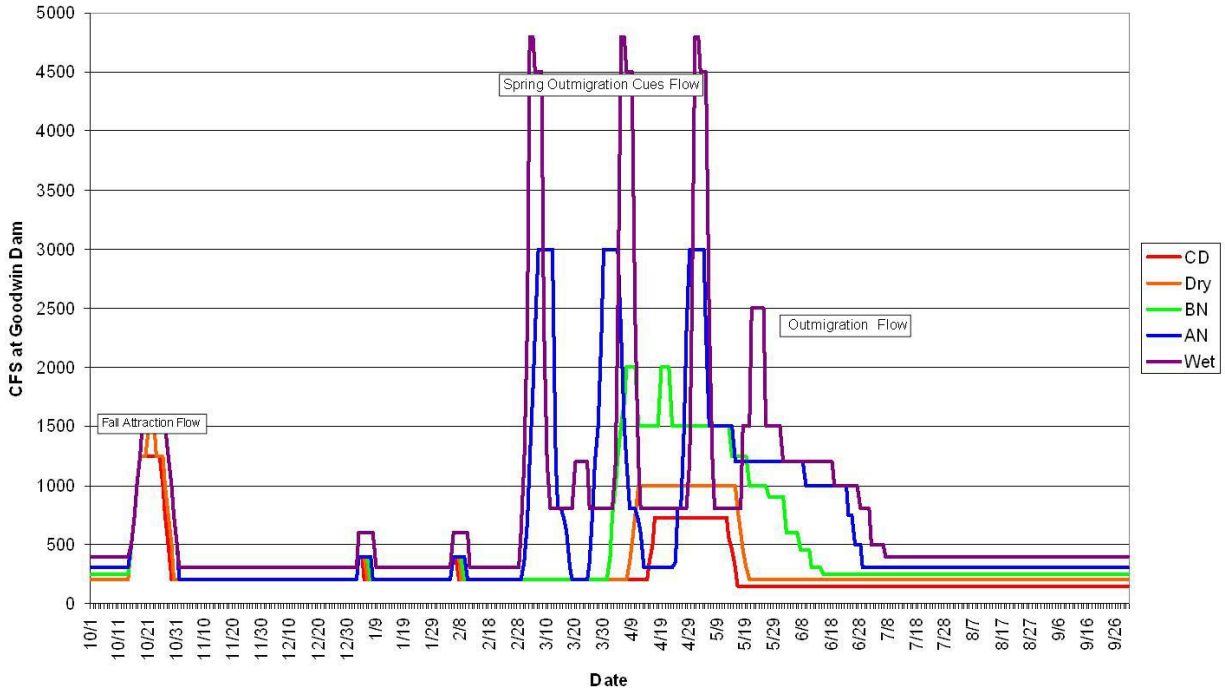

Figure O.2-5. Depicts Minimum Stanislaus River In-Stream Flow Schedule for Central Valley Steelhead as Measured at Goodwin Dam

O.2.8.1.2 <u>Temperature</u>

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 (NMFS 2009).

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, which has now been replaced with the more current BO (NMFS 2019), 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 (NMFS 2011b).

Based on the flow schedule depicted in Appendix 2-E of the 2011 NMFS RPA, 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 salmonids 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 from 11% to 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 2009). 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 from January 1 to 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, from September to 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 from December to 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 early January to 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. It has been shown that low dissolved oxygen conditions in the San Joaquin River during the fall can be ameliorated somewhat through installation of the Head of the Old River Barrier, which increases San Joaquin River flows during the fall (SJTA 2012). The Port of Stockton has operated an aeration facility to achieve SWRCB dissolved oxygen water quality objectives since 2012 reducing the need for the fall Head of Old River Barrier to achieve this purpose.

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 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 from 1940 to 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 (2009) 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 stream flows 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 Defense 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. Although specific temperatures 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 from late September to 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 2008, 2009b, 2010, 2011, 2012b; CDFW 2013, 2014a) documented that anglers upstream of

State Route 140 caught from 8 to 25 mature White Sturgeon annually during 2007 through 2013. Below State Route 140 downstream to Stockton, anglers caught 2 to 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. From 2007 to 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
- 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)), with such factors potentially including geographic location (Manly et al. 2015).

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 2009). 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 2009).

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 (Skinner fish facility) and the CVP Tracy Fish Collection Facility (TFCF or Tracy fish facility) in the south Delta (NMFS 2009).

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 2009). Habitat degradation in the Delta caused by factors such as channelization and changes in water quality can present challenges for out-migrating juveniles. Additionally, out-migrating juveniles are subjected to predation and entrainment in the project export facilities and smaller diversions (NMFS 2009). 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: out-migrating to the Delta and ocean during their first year of life as young-of-year, or holding over in their natal streams and out-migrating 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 from November to the end of May (Snider and Titus 1998, 2000b, 2000c, 2000d; Vincik et al. 2006; Roberts 2007).

Young-of-year 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 young-of-year 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 out-migrating 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 2009). 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 out-migrating 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, out-migrating 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 out-migrating 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 out-migrating juvenile Chinook Salmon from these watersheds.

Although not directly comparable to these previous CWT studies in the San Joaquin River, Buchanan et al. (2013, 2018) 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 and Skalski 2019). 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 conditions 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 2009). 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 2009). 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 2009). 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).

Out-migrating 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 (from April 15 to 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 from April to 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 2009; 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 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 (70 FR 17386-17401). 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 2009).

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, young-of-year 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 2008). 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 population 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 2019a). 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 2019a). 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).

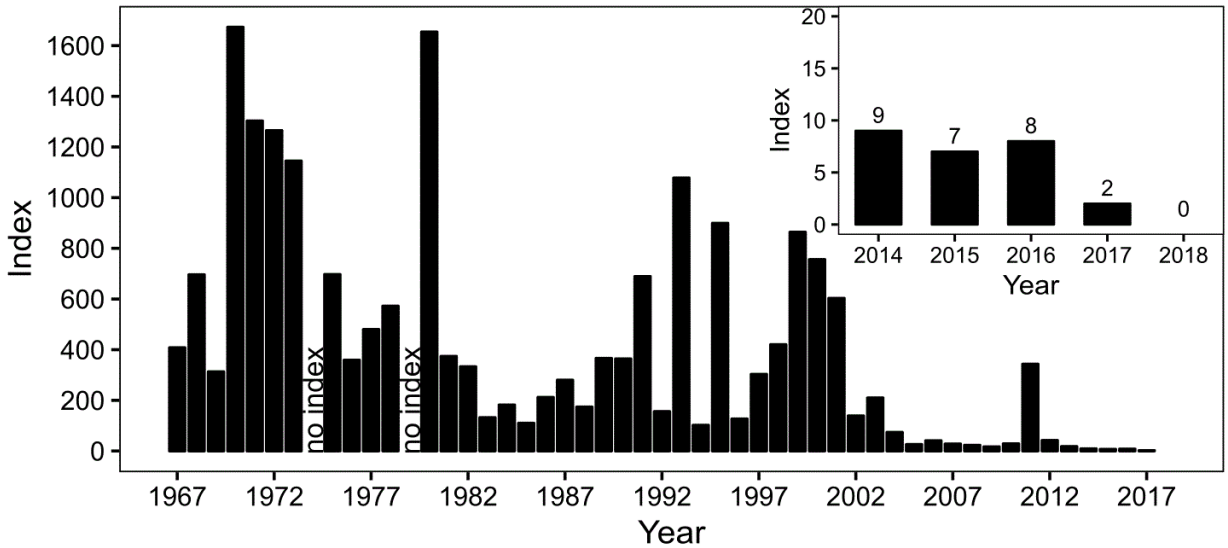

Figure O.2-6 Fall Midwater Trawl Abundance Indices for Delta Smelt from 1967 to 2018

Source: CDFW 2019a.

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 correlated with 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 MAST 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 2010:

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. 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.

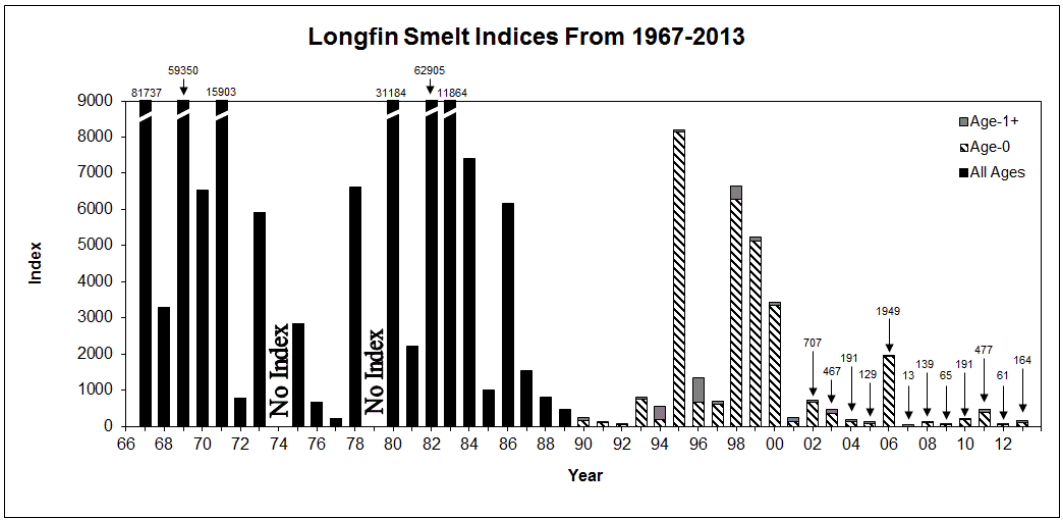

Figure O.2-7 Fall Midwater Trawl Abundance Indices for Longfin Smelt from 1967 to 2013

Source: CDFW 2014c.

Habitat for Longfin Smelt is open water, largely away from shorelines and vegetated inshore areas except perhaps during spawning (Grimaldo et al. 2017). 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 Sacramento 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 American 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 American Shad may rear in the Delta for up to a year before out-migrating 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 2002a).

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.

Young-of-year Striped Bass distribute themselves in accordance with the estuarine salinity gradient (Kimmerer 2002a; 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 young-of-year, 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 young-of-year 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 young-of-year 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., 20ºC to 25°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 abundances correlated with current Delta hydrology include Delta Smelt, Longfin Smelt, Sacramento Splittail, White Sturgeon, juvenile Chinook Salmon, and Striped Bass (Jassby et al. 1995; Kimmerer 2002a; 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 life stage. 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 2008). 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 2008, 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 2002b).

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. 2001b), 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 (USGS) 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 2008).

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 (Deng et al. 2010; Acuña et al. 2012; Lehman et al. 2010).

There are longstanding concerns related to mercury and selenium in the Sacramento and San Joaquin watersheds, the Delta, and San Francisco Bay (see Appendix G, Water Quality Technical Appendix, 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. 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 out-migrating 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).

Out-migrating 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, 2013). 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 out-migrating 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 out-migrating 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 2009).

However, analysis by Perry et al. (2015) and Perry et al. (2018) suggest 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 DCC 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 (CCWD) intakes; and agricultural intakes. CCWD 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 tidally averaged 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); though recent investigations have determined that altered channel velocities and flow direction are more likely to influence juvenile salmonids than tidally averaged net flow conditions (Anderson et al. 2012;, Monismith et al. 2014; SST 2017) 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). Analyses have identified regions of mortality hot spots for juvenile salmon in the South and Central Delta (SST 2017; Grossman 2016) which may relate to one or more of these mechanisms.

Cunningham et al. (2015) conducted a statistical analysis of adult Chinook spawning escapement from 1967 to 2010 and found a negative correlation of the export/inflow ratio on the survival of Fall-Run Chinook Salmon populations and a negative correlation of increased total Delta exports on the survival of Spring-Run Chinook populations. According to the Cunningham et al. results, 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). However, these results are based on correlations between indices of export operations and spawning escapement observed over more than 40 years, and thus may reflect changes through time in factors not included in the statistical analysis. The magnitude of export effects predicted by Cunningham et al. (2015) are inconsistent with direct empirical evaluations of Delta juvenile salmon survival relative

to export rates that have shown smaller magnitude and more uncertain effects (Newman 2003; Newman and Brandes 2010; Newman 2008; Zeug and Cavallo 2012; SST 2017). Although a mechanistic explanation for the large predicted export-survival effect remains elusive, Cunningham et al. (2015) state, "*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*". However, hydrodynamic analysis suggest exports have minimal potential to influence routing at junctions of the North and Central Delta (Cavallo et al. 2015) and are therefore unlikely to provide a plausible mechanism for the effect.

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 Old and Middle Rivers (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 (2009) 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 may 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.

Two recent publications are available that provide an overview of general findings relevant to tidal Delta. Perry et al. (2018) utilized nearly 3,000 acoustically tagged fish released into the North Delta. Among other important findings, he reported survival in tidal reaches of the Delta were not related to river inflows (exports effects were not evaluated). Buchanan et al. (2018) reports on 6 years of studies including 8,000 acoustically tagged juvenile Chinook Salmon released into the San Joaquin River Delta. In all years, through-Delta survival was extremely low, ranging from 0 to 5%. Very high San Joaquin River inflows improved survival in riverine reaches, but survival in tidal areas of the Delta remained low despite ostensibly favorable tidally averaged flow conditions. In 2010 and 2011, relatively wet years when no Head of Old River Barrier was installed, acoustically tagged salmon having passed through the Old River and Granite Line Canal corridor and continuing to head north in the OMR corridor experienced extremely low survival despite positive tidally averaged flow conditions. Importantly, juvenile salmon entrained into the CVP export facilities during these studies experienced higher survival to Delta exit than fish migrating volitionally northward in the OMR corridor. In 2010 and 2011, an average of 64% of the tagged juvenile salmon surviving to exit the Delta were fish entrained, salvaged and trucked from the CVP export facilities. The remaining 34% that survived to Delta exit appear to have migrated volitionally through the San Joaquin River portion of the Delta (i.e., not through the OMR route). Were it not for the placement of the Head of Old River barrier in 2012 through 2016, more observations would be available to understand the apparently positive contribution of CVP export salvage to through-Delta survival.

The SST (2017) reported juvenile Chinook Salmon survival relative to the 10-day average of total exports and San Joaquin River inflows. No negative association with exports was apparent, though relatively few observations were available at high export rates. A similar 6-year study utilizing Steelhead smolts (rather than juvenile Chinook Salmon) has been completed, but is not yet fully reported. Results available indicate higher survival rates for Steelhead smolts relative to juvenile Chinook Salmon, but a similar absence of negative response to exports.

Analysis of 14 years of CWT Chinook Salmon releases (representing more than 28 million coded wire tagged juvenile salmon) in the Sacramento and San Joaquin Rivers were performed by Zeug and Cavallo (2014) to estimate proportional entrainment losses and to elucidate conditions that result in salvage of migrating fish. They compared the capability of an export to inflow ratio (E:I) relative to separate flow and export values to explain the data and found the ratio was not an effective predictor. Further, the authors reported weak and inconsistent effects of flow on salvage whereas export effects were relatively strong. Their findings suggest that flow and exports are not interchangeable components as is sometimes assumed. Zeug and Cavallo (2014) also found entrainment loss (salvage of fish expanded for subsampling and pre-screen mortality) was very low (mean 0.1% across all races and releases) and contributed little to through-Delta migration mortality.

To evaluate the hypothesized effect of export operations pulling migrating juvenile salmon into the South Delta, Cavallo et al. (2015) analyzed 41 independent estimates of junction routing probabilities derived from several different juvenile salmon acoustic telemetry studies. The analysis found that routing at the Head of Old River junction was influenced by exports, but only with lowest levels of San Joaquin River inflow. South Delta exports exhibited no substantive influence on fish routing at any other analyzed junction in the Delta.

A study of salmonid behavior and Tracy Fish Collection Facility efficiency at the CVP was performed in 2013 using acoustic telemetry (Karp et al. 2017). Findings indicate salmon are more likely to enter the CVP export facility at high-pumping rates. Lower pumping rates resulted in salmon spending more time in areas where they are exposed to predators. This suggests that reducing pumping levels when fish are detected at the export facility may reduce salvage, but fish already near the facilities may be preyed upon rather than entering the facility and then being salvaged. The Karp et al. (2017) findings provide an explanatory mechanism for patterns revealed by CWT survival studies (Newman 2008) by more recent acoustic tagging studies Buchanan et al. (2018) where salvage at the CVP appears to provide higher probability of through-Delta survival than natural migration.

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 OMR reverse flows (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; 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

[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."

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). Analyses have identified regions of mortality hot spots for juvenile salmon in the South and Central Delta (Grossman et al. 2013; Grossman 2016). 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 out-migrating 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 out-migrating 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 young-of-year 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. 2001a; CALFED Bay-Delta Program 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. 2001a, 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. 2001a, 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 2009; 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. Ongoing 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 2009).

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 2009; 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 (RRDS), Morrow Island Distribution System (MIDS), 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 RRDS 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 MIDS 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 two 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 CCWD 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 Bass), 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 CCWD 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. Gamefish at the reservoir include Rainbow Trout, Kokanee Salmon, Largemouth Black Bass, Brown Bullhead, Catfish, Striped Bass, Sunfish, White Crappie, and Sacramento Perch(CCWD 2019b).

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 and Trinity River region entering the Pacific Ocean, and the Central Valley salmon stocks may 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. 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 and Klamath River region streams produce Chinook Salmon that contribute to the diet of Southern Resident Killer Whales. The number of 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 Central Valley 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 action alternatives and the No Action Alternative. This section also describes the results of the impact analysis for each action 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 action 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
- HEC-5Q
- 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*

The 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 (Reclamation 2015).

O.3.1.2 *HEC-5Q*

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 HEC-5Q model) (Reclamation 2008a). Recently, these models were compiled and updated into a single modeling package called in here as the HEC-5Q model. Further updates were performed under the EIS modeling that included improved meteorological data and subsequent validation of the Sacramento River 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 (Reclamation 2015).

O.3.1.3 *Reclamation Temperature Model*

The 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 (Reclamation 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 (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 (Anderson 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 Salmon 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 HEC-5Q 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 from 1996 to 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 on aquatic species' life stage transitions that are based on available species-specific conceptual models consistent with the analysis conducted in the associated 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 action 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 on 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 3, *Alternatives*. 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 Trinity River ROD provides variable annual instream flows for the Trinity River from the Trinity River Division based on forecasted hydrology for the Trinity River Basin as of

April 1 of each year, ranging from 369,000 acre-feet in critically dry years to 815,000 acre-feet in extremely wet years, to meet legal and trust mandates for the restoration and protection of the Trinity River fishery. 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 intended to restore and maintain fishery resources in the Trinity River and 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. The variable flow releases also include high springtime releases to lower water temperatures and improve rearing, juvenile, and emigration conditions throughout the Trinity and lower Klamath River basins (USDOI 2000: 12, 18; also see Section O.3.2.1.4, *Trinity River Record of Decision*).

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.

Under the No Action Alternative, disease affecting salmon, such as *C. shasta* (Ich) and *columnaris*, could continue to have substantial impact on adult salmon, particularly when habitat conditions include exceptionally low flows, high water temperatures, and high densities of fish. However, the No Action Alternative evaluates conditions through 2030 and therefore considers 10 years of additional TRRP projects. Under the No Action Alternative, habitat conditions would be expected to reduce the threat of disease outbreaks. Nonetheless, disease pressures could change and there is uncertainty in how disease prevalence will affect future 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 to 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 373 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 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. In addition, peak flow releases are expected to interact with existing and new restoration actions to promote continuing geomorphic change resulting in increased habitat complexity and the spatial and temporal diversity of stream temperatures. Habitat improvements would be expected to reduce the threat of disease outbreaks for Coho Salmon, although there is uncertainty in how disease prevalence will affect future conditions.

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 provide 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. These habitat improvements would be expected to reduce the threat of disease outbreaks for Spring- and Fall-Run Chinook Salmon, although there is uncertainty in how disease prevalence will affect future conditions.

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. These habitat improvements would be expected to reduce the threat of disease outbreaks for Steelhead (although somewhat resistant to these strains of disease), although there is uncertainty in how disease prevalence will affect future conditions.

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 provide 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 Trinity Lake

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).

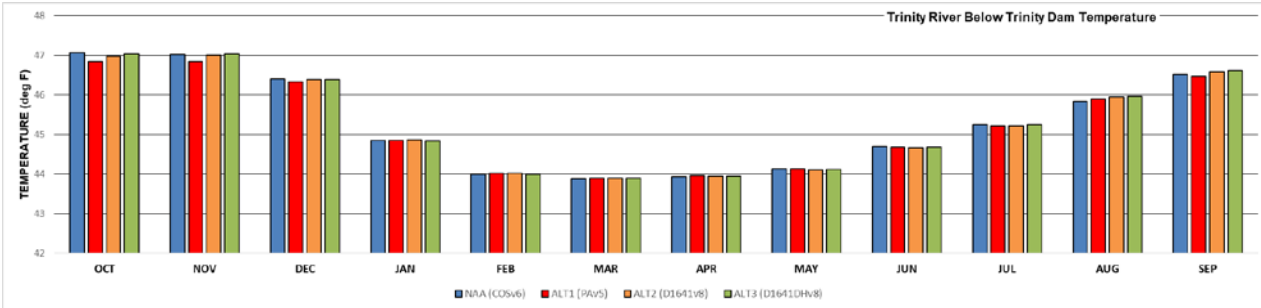

Figure O.3-1. Average Trinity River Water Temperatures below Trinity Dam for the Period October to September, Average of All Water Year Types

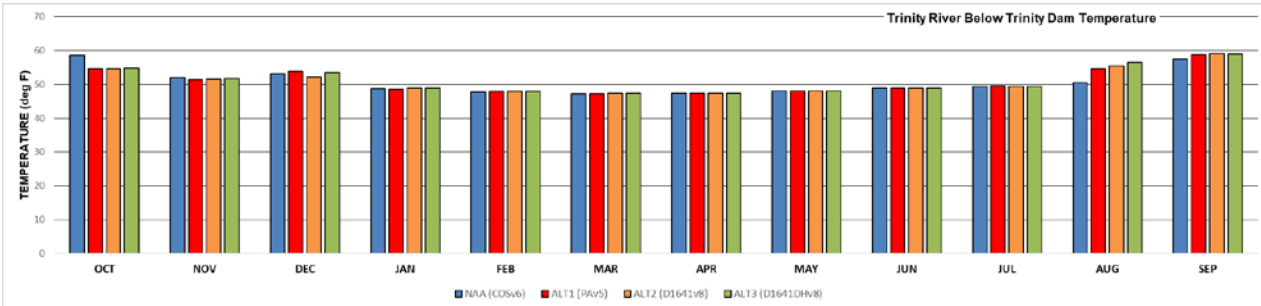

Figure O.3-2. Maximum Trinity River Water Temperatures below Trinity Dam for the Period October to September, Average of All Water Year Types

As discussed in Section O.2.3.1, *Trinity Lake and Lewiston Reservoir*, Trinity Lake supports a recreational fishery that provides substantial angling opportunities, including trophy Smallmouth Bass, Largemouth Bass, Rainbow and Brown Trout, Kokanee Salmon (landlocked Sockeye Salmon), landlocked Chinook Salmon, and White Catfish. Current reservoir operations have supported sustained year-after-year recreational harvests, and these populations are anticipated to support continued recreational harvests under the No Action Alternative through 2030. 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

[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

Trinity River (Table O.3-1); 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) recommendations 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.

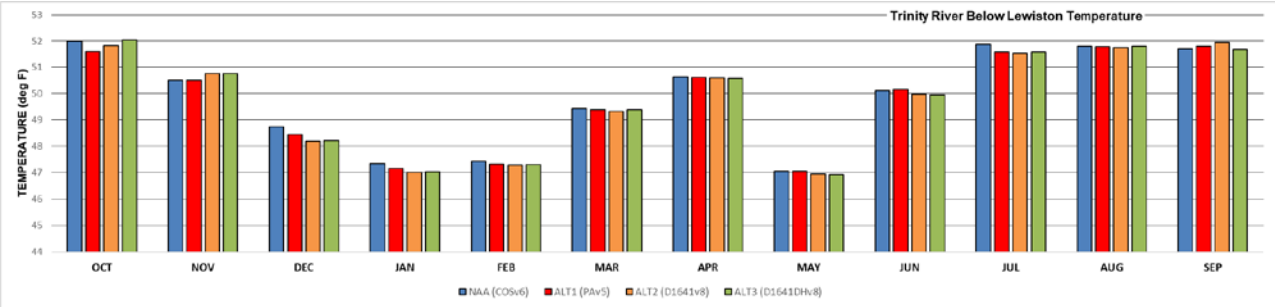

Figure O.3-3. Average Trinity River Water Temperatures below Lewiston Dam for the Period October to September, Average of All Water Year Types

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.

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.

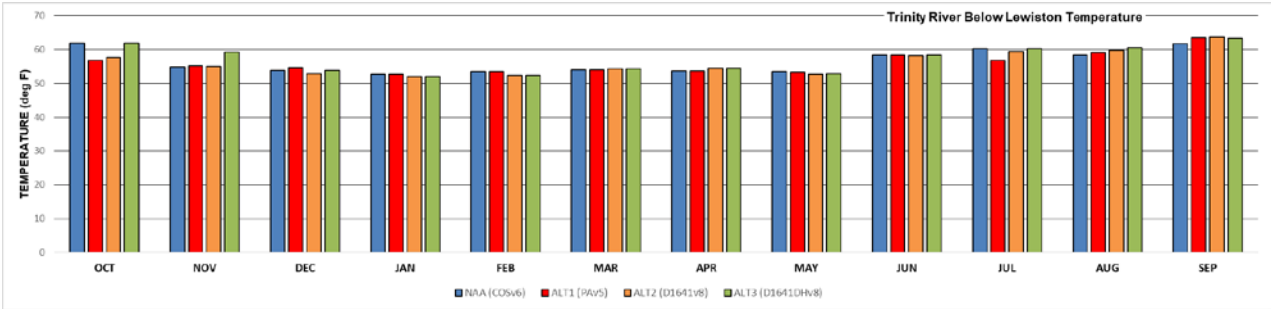

Figure O.3-4. Maximum Trinity River Water Temperatures below Lewiston Dam for the Period October to September, Average of All Water Year Types

Table O.3-2. Maximum Trinity River Water Temperatures below Lewiston 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 (Figure O.3-3 and Table O.3-1). The modeling uses maximum water temperature, which has a greater exceedance probability compared to the maximum 7-day average of the daily maximum used by USEPA or the daily average temperature used by NCRWQCB. Full modeling results showing probabilities of exceedance are provided in Appendix F. For the Trinity River (Table O.3-1); however, modeled maximum monthly 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 monthly 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 are not expected to affect the majority of juvenile Chinook Salmon (Spring-Run and Fall-Run), which typically spend only a few months rearing in the Trinity River before they out-migrate; however, they may affect a small component of the juvenile Chinook population that over-summer in the Trinity River before out-migrating in the fall. 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 monthly 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, there are other potential cumulative factors that could influence future trends in anadromous fish populations in the Trinity River. Cumulative effects are discussed here, in part, but the associated conclusions of the analysis are presented in Section O.3.13. Potential cumulative effects are 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 on 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 cumulative effects that could influence future Trinity River Chinook Salmon populations include land use, climate change, restoration actions, invasive species, and population trends. Cumulative effects are discussed here, in part, but the associated conclusions of the analysis are presented in Section O.3.13. 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 cumulative effects that could influence future Trinity River Steelhead populations include land use, climate change, restoration actions, invasive species, and population trends. Cumulative effects are discussed here, in part, but the associated conclusions of the analysis are presented in Section O.3.13. 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 Trinity River ROD is directed at restoring fish populations in the Trinity River that experienced significant declines after construction of the Trinity River Diversion 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 Trinity River Diversion 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 Trinity River Diversion 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 under the ROD 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 also expected to improve spawning and rearing habitat for anadromous fish in the mainstem Trinity River. Flow releases included under the ROD would help restore and maintain fishery resources in the Trinity River by improving physical habitat for fish, specifically, appropriate depths, velocities, and temperature regimes for anadromous salmonids. The ROD also includes high springtime flow releases, which range from 1,500 cfs during critically dry years to 11,000 cfs during extremely wet years (USDOI 2000: 12). The timing and duration of these high flows correspond to the juvenile anadromous salmonid smolt out-migration period, and are intended to lower water temperatures and improve rearing, juvenile, and emigration conditions throughout the Trinity and lower Klamath River basins (USDOI 2000: 18). 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 (e.g., channel rehabilitation designs evolved during Phase 1 to further improve the performance of projects in achieving ROD restoration objectives, including increasing the number of side channels, incorporating large wood, encouraging lateral channel migration, creating a more sinuous channel pattern, and promoting floodplain connectivity and diversity [Hoopa Valley Tribe et al. 2011: 4]).

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 on

track 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 to 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 (acre-feet), 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 fresh water 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

The Trinity River ROD identified that mechanical channel rehabilitation would include 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. From 2005 to 2017, approximately 25 restoration sites were constructed (TRRP 2019). As of 2014, more than half of the 44 original channel rehabilitation sites (nearly 15 miles of the 40-mile upper Trinity River Restoration reach) have had channel rehabilitation treatments (Buffington et al. 2014; TRRP 2014). Initially restoration focused on the removal of riparian berms, but the degree of mechanical manipulation and project complexity increased over time to promote more rapid geomorphic change (Buffington et al. 2014). During Phase 1, channel rehabilitation designs evolved to improve the performance of projects in achieving ROD restoration objectives, including: increasing the number of side channels, incorporating large wood, encouraging lateral channel migration, creating a more sinuous channel pattern, and promoting floodplain connectivity and diversity (Hoopa Valley Tribe et al. 2011: 4).

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 (USDOI 2000: 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, there are other potential cumulative factors that may influence future trends in anadromous fish populations in the Trinity River. Cumulative effects are discussed here, in part, but the associated conclusions of the analysis are presented in Section O.3.13. Potential cumulative effects are 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 cumulative factors that may influence future Coho Salmon populations in the Trinity River include land use, climate change, restoration actions, invasive species, and population trends. Cumulative effects are discussed here, in part, but the associated conclusions of the analysis are presented in Section O.3.13. 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 DEIS for 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 2009d: 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). Increased late-summer flow releases associated with the Klamath LTP that occur in some years have the potential to affect the level of hybridization between Spring-Run and Fall-Run Chinook Salmon due to potential effects on migration and spawning timing of the two runs. 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 fresh water after only 2 to 4 months at sea, overwinter in fresh water, 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 from the ocean into fresh water during 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

Cumulative effects are discussed here, in part, but the associated conclusions of the analysis are presented in Section O.3.13. As a result of cumulative effects, fish habitat conditions in 2030 have the potential to differ from current conditions in Grass Valley Creek 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 Grass Valley Creek 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 Grass Valley Creek due to restoration efforts have the potential to improve spawning habitat conditions and increase egg-to-emergence survival of salmonids not only in Grass Valley Creek 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 Grass Valley Creek 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 Grass Valley Creek.

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 Grass Valley Creek.

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 Grass Valley Creek.

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 Grass Valley Creek.

Potential changes to aquatic resources due to past and ongoing restoration in Grass Valley Creek

Coho Salmon

Cumulative effects are discussed here, in part, but the associated conclusions of the analysis are presented in Section O.3.13. 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 Grass Valley Creek 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 Grass Valley Creek, 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 Grass Valley Creek.

Chinook Salmon (Spring-Run and Fall-Run)

Cumulative effects are discussed here, in part, but the associated conclusions of the analysis are presented in Section O.3.13. 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 Grass Valley Creek 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 Grass Valley Creek 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 Grass Valley Creek.

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 Grass Valley Creek 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 Grass Valley Creek, 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 Grass Valley Creek.

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 Grass Valley Creek 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 Grass Valley Creek, 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 Grass Valley Creek.

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 39th year of a predicted lifespan of 40 to 50 years. Increased water temperatures due to decreased storage capacity and climate change may negatively affect Coho Salmon in Grass Valley Creek. However, water temperature increases will produce a minimal net negative effect on Coho Salmon in Grass Valley Creek. No to minimal negative effect on water temperature in the Trinity River is expected due to the relatively small influence Grass Valley Creek has on flow in the Trinity River during the summer.

Chinook Salmon (Spring-Run and Fall-Run)

In 2030 Buckhorn Reservoir will be entering its 39th year of a predicted lifespan of 40 to 50 years. Increased water temperatures due to decreased storage capacity and climate change may negatively affect Chinook Salmon in Grass Valley Creek. However, water temperature increases will produce a minimal net negative effect on Chinook Salmon in Grass Valley Creek. No to minimal negative effect on water temperature in the Trinity River is expected due to the relatively small influence Grass Valley Creek has on flow in the Trinity during the summer.

Steelhead (Winter-Run and Summer-Run)

In 2030 Buckhorn Reservoir will be entering its 39th year of a predicted lifespan of 40 to 50 years. Increased water temperatures due to decreased storage capacity and climate change may negatively affect juvenile Steelhead in Grass Valley Creek. However, water temperature increases will produce a minimal net negative effect on juvenile Steelhead in Grass Valley Creek. No to minimal negative effect on water temperature in the Trinity River is expected due to the relatively small influence Grass Valley Creek has on flow in the Trinity during the summer.

Pacific Lamprey

In 2030 Buckhorn Reservoir will be entering its 39th year of a predicted lifespan of 40 to 50 years. Increased water temperatures due to decreased storage capacity and climate change may negatively affect Pacific Lamprey in Grass Valley Creek. However, water temperature increases will produce a minimal net negative effect on Pacific Lamprey in Grass Valley Creek. No to minimal negative effect on water temperature in the Trinity River is expected due to the relatively small influence Grass Valley Creek has on flow in the Trinity during the summer.

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 River Winter-Run Chinook Salmon, Central Valley Fall-Run and 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 <u>Winter-Run Chinook Salmon</u>

Sacramento River 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 3-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 Keswick Dam and RBDD.

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 Salmon 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 2018a).

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 (71 FR17757–17766). 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 (71 FR17757–17766).

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 River 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 3-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 Keswick Dam and RBDD.

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 Salmon 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 2018a).

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 (71 FR 17757–17766). 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 (71 FR 17757–17766).

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 from November to 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.

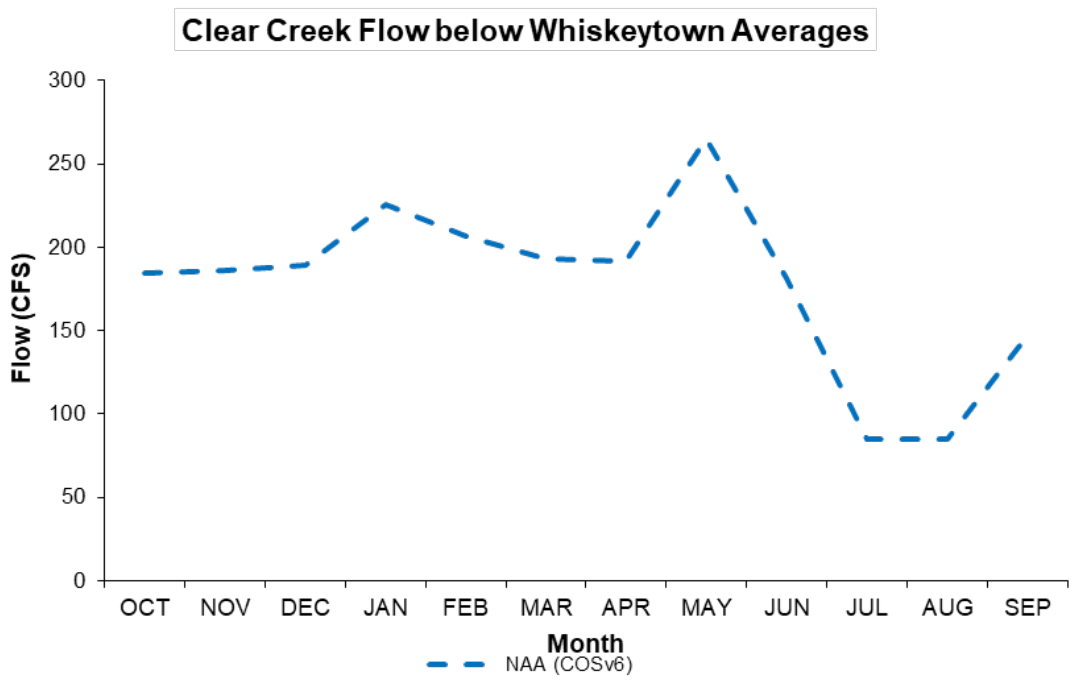

Figure O.3-5. Modeled average monthly flows in Clear Creek downstream of Whiskeytown Reservoir under the No Action Alternative.

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 out-migrating 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 out-migrating 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 out-migrating 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 (USEPA 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 from 1986 to 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 (USEPA 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 5-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. From 2012 to 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.

Cumulative effects are discussed here, in part, but the associated conclusions of the analysis are presented in Section O.3.13. Cumulative effects of 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 consistent with separate authorizations 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).

From a cumulative perspective, 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 from 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). From a cumulative perspective, 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 consistent with separate authorizations 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 from 1967 to 1991 to an average of approximately 1,300 from

1992 to 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 from 2012 to 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).

From a cumulative perspective, 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 Salmon 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 2-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) pursuant to DWR and the California Department of Fish and Wildlife's (CDFW's) *Agreement Concerning the Operation of the Oroville Division of the State Water Project for Management of Fish and Wildlife* (1983 DWR-CDFW 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.

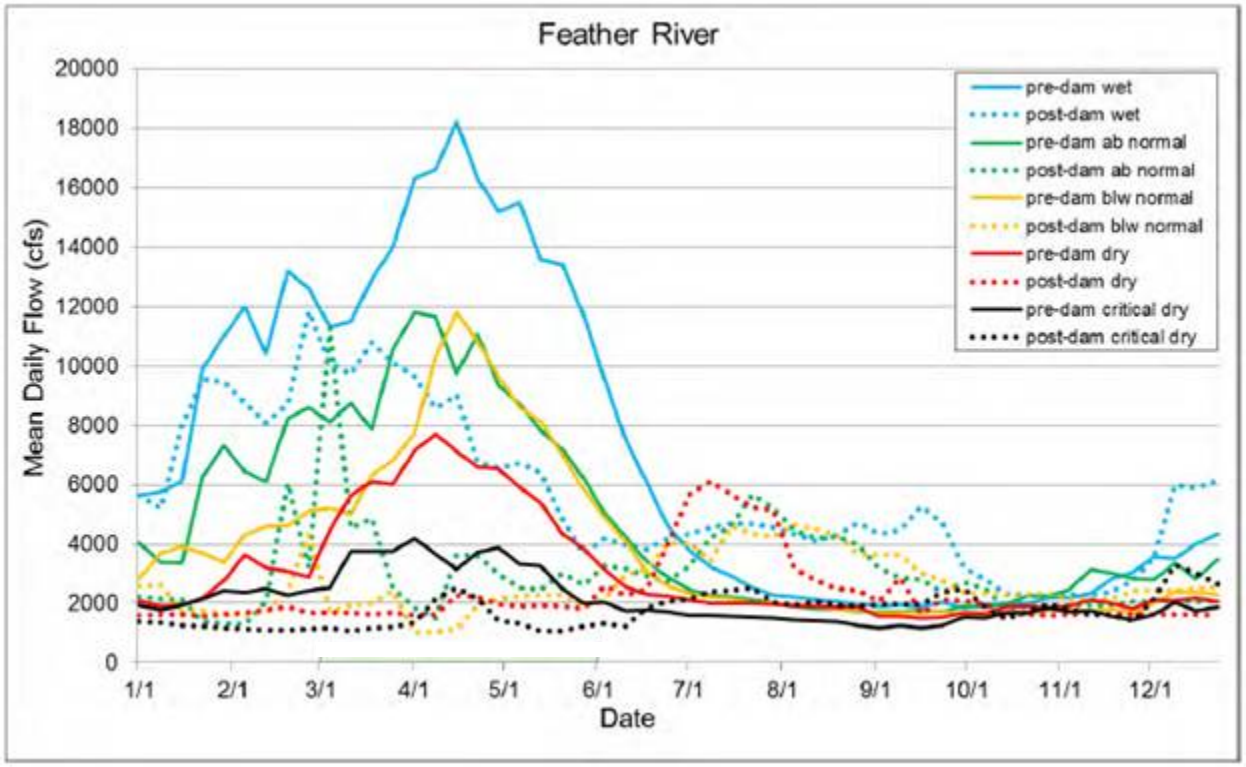

Figure O.3-6. Mean Daily Flow during All Water Year Types in the Feather River during Pre-Dam Years (Oroville Gage 1906–1965) and Post-Dam Years (Gridley Gage 1969–2012; NMFS 2016a)

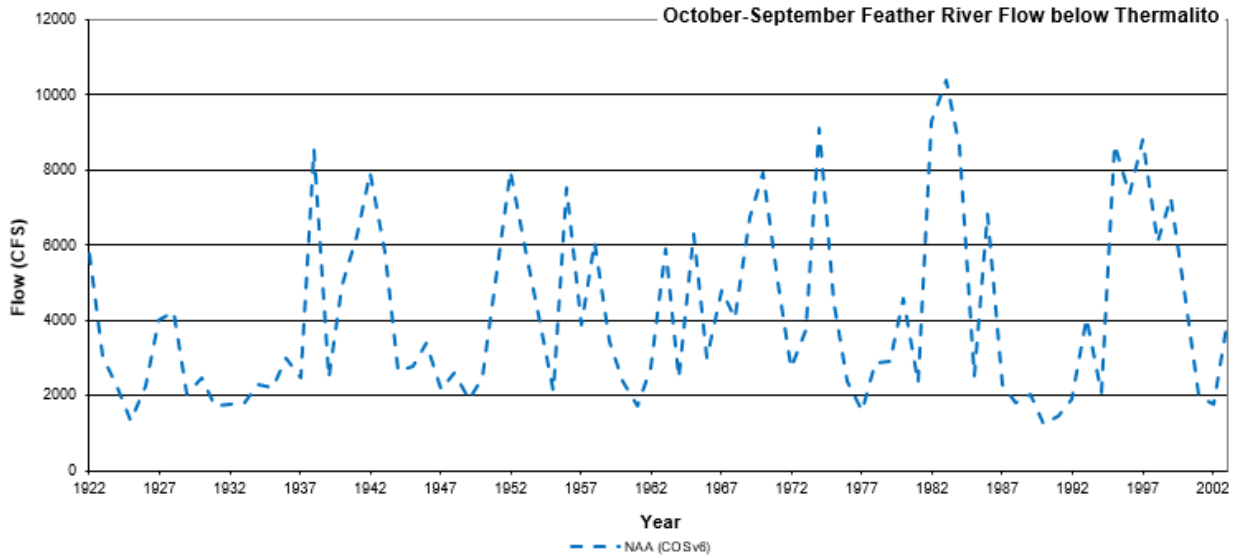

Figure O.3-7. CalSim Average Estimated Feather River Flow below Thermalito under the No Action Alternative.

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 at 2,908 fish in 1964 to 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 from October to 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 occur during 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

Stream flow, 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).

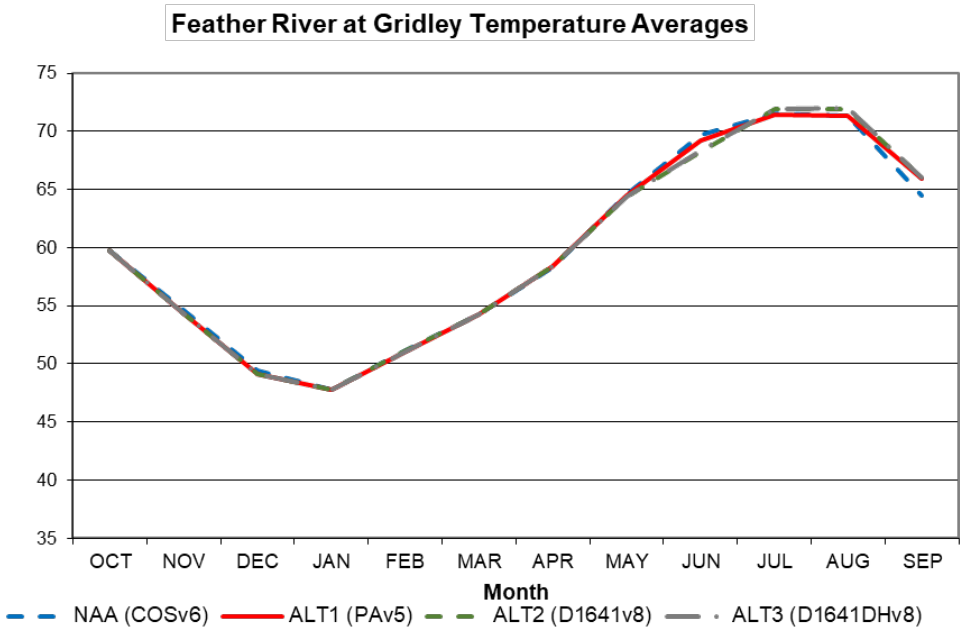

Figure O.3-8. RecTemp Average Feather River Water Temperatures at Gridley Bridge under the No Action Alternative, Alternative 1, Alternative 2, and Alternative 3 Scenarios.

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 and 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.3-9 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 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 fresh water (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. 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, 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.

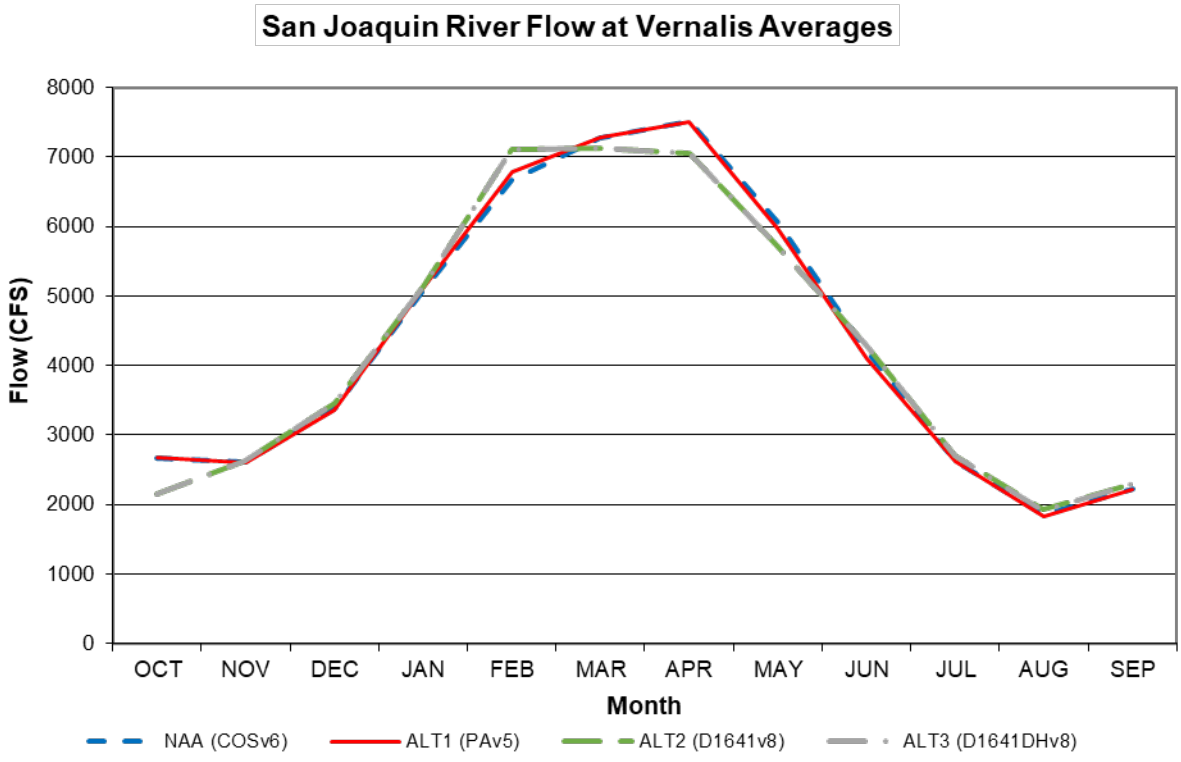

Figure O.3-10. Average Flow by Month at Vernalis on the San Joaquin River

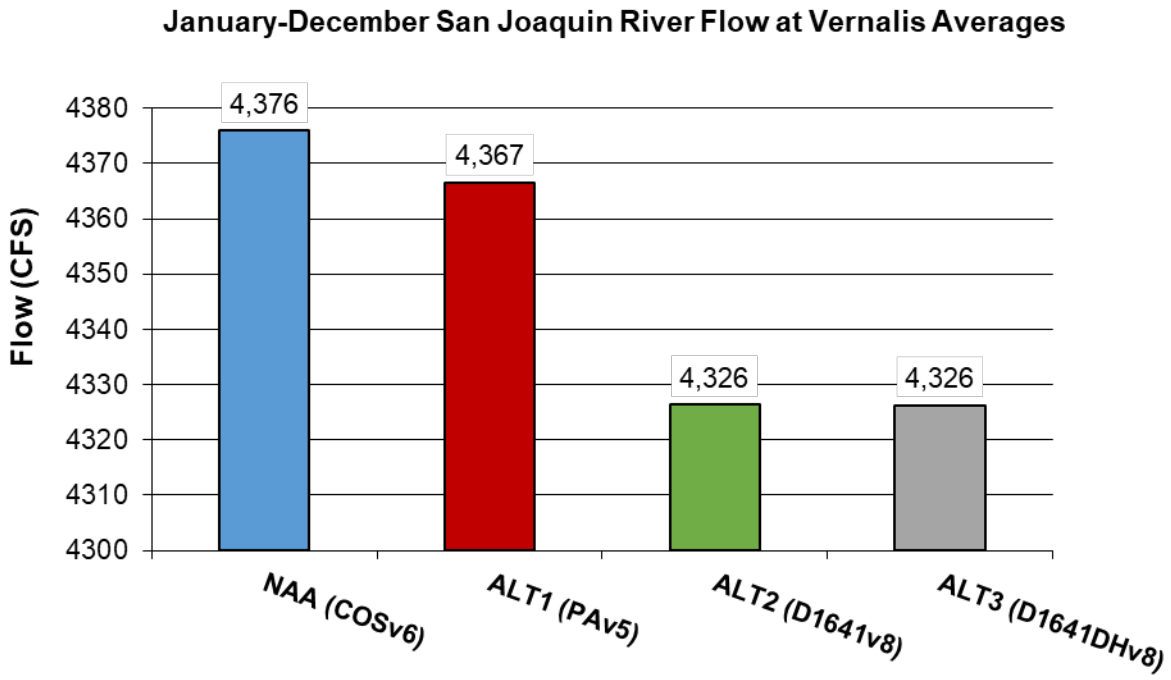

Figure O.3-11. Average Annual Flow Occurring at Vernalis on the San Joaquin River

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.

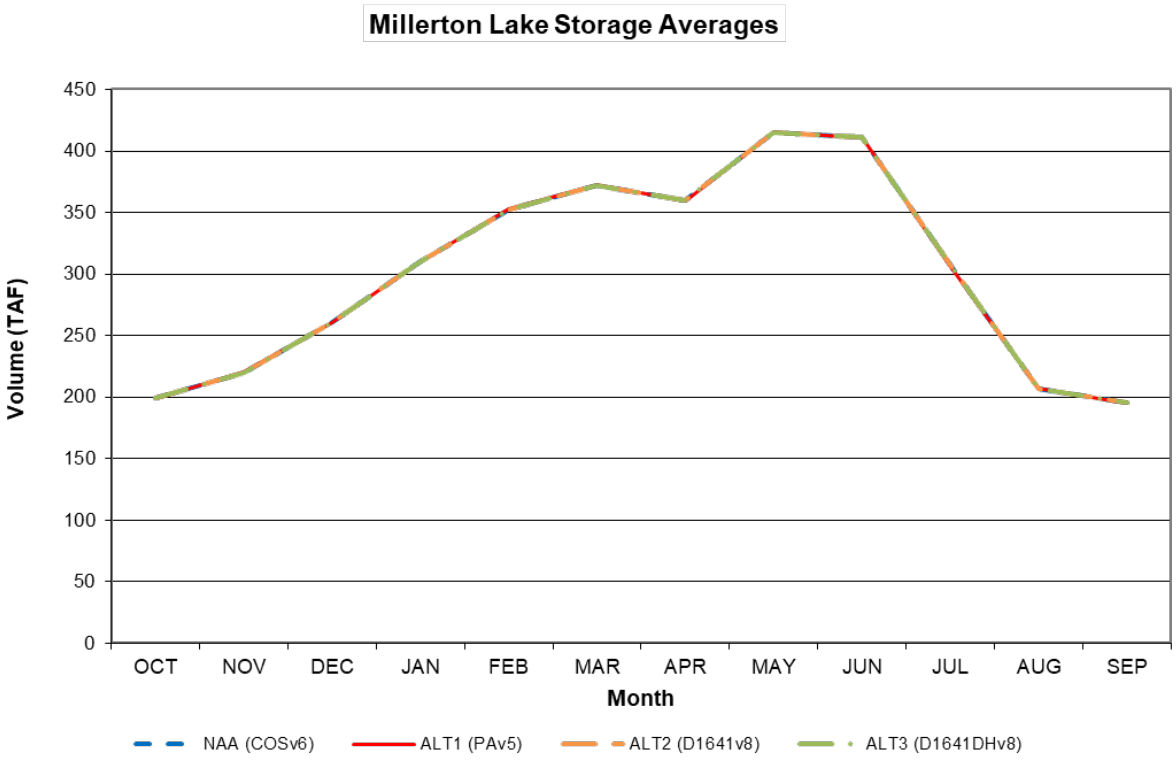

Figure O.3-12. Average Monthly Reservoir Volume at Millerton Lake on the San Joaquin River

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 action alternatives. Based on these results there does not appear to be any notable effect on water temperature.

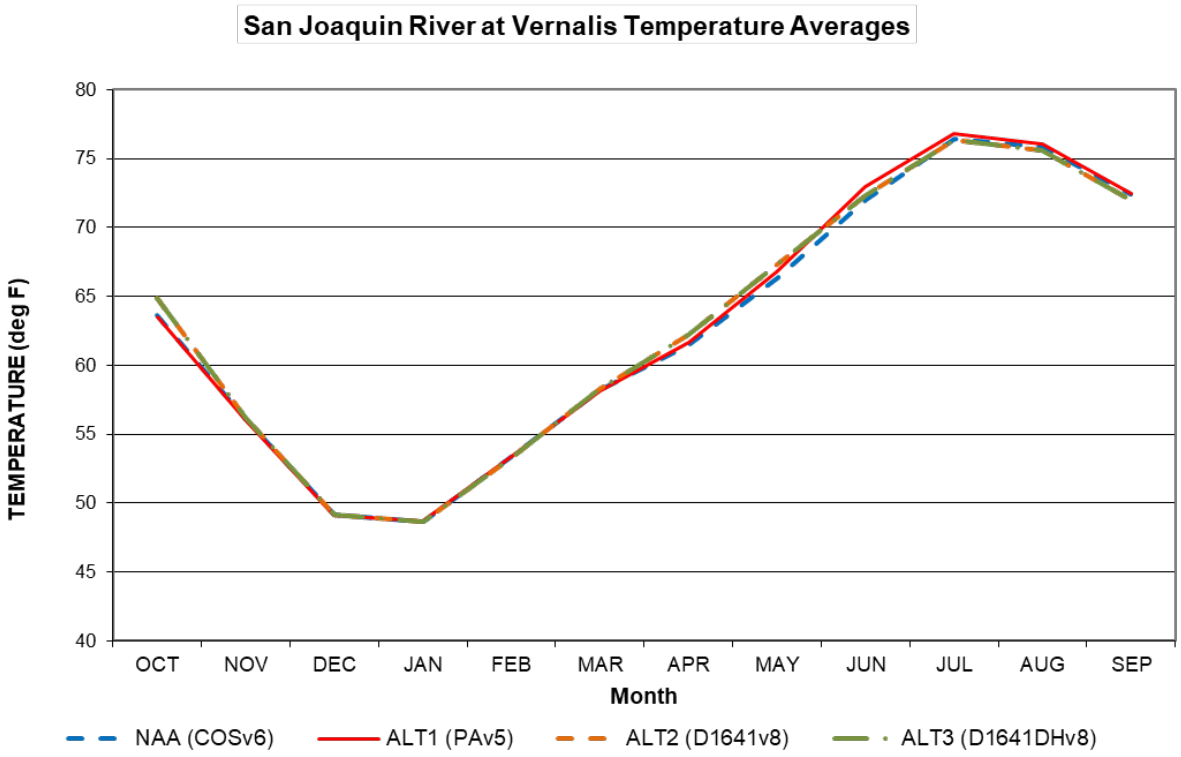

Figure O.3-13. Average Monthly Water Temperature at Vernalis by Project Alternative

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 on 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 on 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 on 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 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 on 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 (TBP) 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

CCWD operations under the No Action Alternative would not change from current conditions and therefore would be expected to have similar effects on 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 on 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 Forebay 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 on 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 on 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 on 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 TBP on Longfin Smelt would be expected to be similar in nature but less than the effects on Delta Smelt under current conditions (i.e., near-field predation for smelts occurring in the vicinity; see also ROC LTO BA), with less effect on 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

CCWD operations under the No Action Alternative would not change from current conditions and therefore would be expected to have similar effects on 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 on 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 (2009c) 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 Forebay 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 Longfin 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 (2009c) 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 on 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 on 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 on 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 DCC if they are present when the gates are open. Individuals entrained into the DCC 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 TBP during the period when the barriers 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

CCWD 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 on Winter-Run Chinook Salmon 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 Forebay 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 Chinook Salmon 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 on 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 on 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 DCC if they are present when the gates are open. Individuals entrained into the DCC 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 TBP during the period when the barriers 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

CCWD 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 on 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 Forebay 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 on 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 on Fall-Run Chinook Salmon 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 DCC if they are present when the gates are open. Individuals entrained into the DCC 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 TBP during the period when the barriers are installed. A greater fraction of San Joaquin River-origin Fall-Run Chinook Salmon 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

CCWD 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 on Fall-Run Chinook Salmon 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 Chinook Salmon 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 Forebay 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 on 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 on California Central Valley 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 California Central Valley Steelhead are vulnerable to entrainment into the DCC if they are present when the gates are open. Individuals entrained into the DCC 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 California Central Valley Steelhead would be expected to occur in the region of the TBP during the period when the barriers are installed. A greater fraction of San Joaquin River-origin California Central Valley 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

CCWD operations under the No Action Alternative would not change from current conditions and therefore would be expected to have similar effects on California Central Valley 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 on California Central Valley 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 California Central Valley Steelhead d 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 California Central Valley Steelhead in the Delta.

Potential changes to aquatic resources from Clifton Court Forebay 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 California Central Valley 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 on California Central Valley 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 California Central Valley 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 on 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 DCC if they are present when the gates are open. Individuals entrained into the DCC 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 TBP during the period when the barriers 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

CCWD 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 on 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 Forebay 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 on Southern Resident Killer Whale as a result of SWP/CVP operations could occur as a result of effects on 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 BO that are not likely to result in local depletion of Southern Resident Killer Whale prey (NMFS 2009: 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 (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.

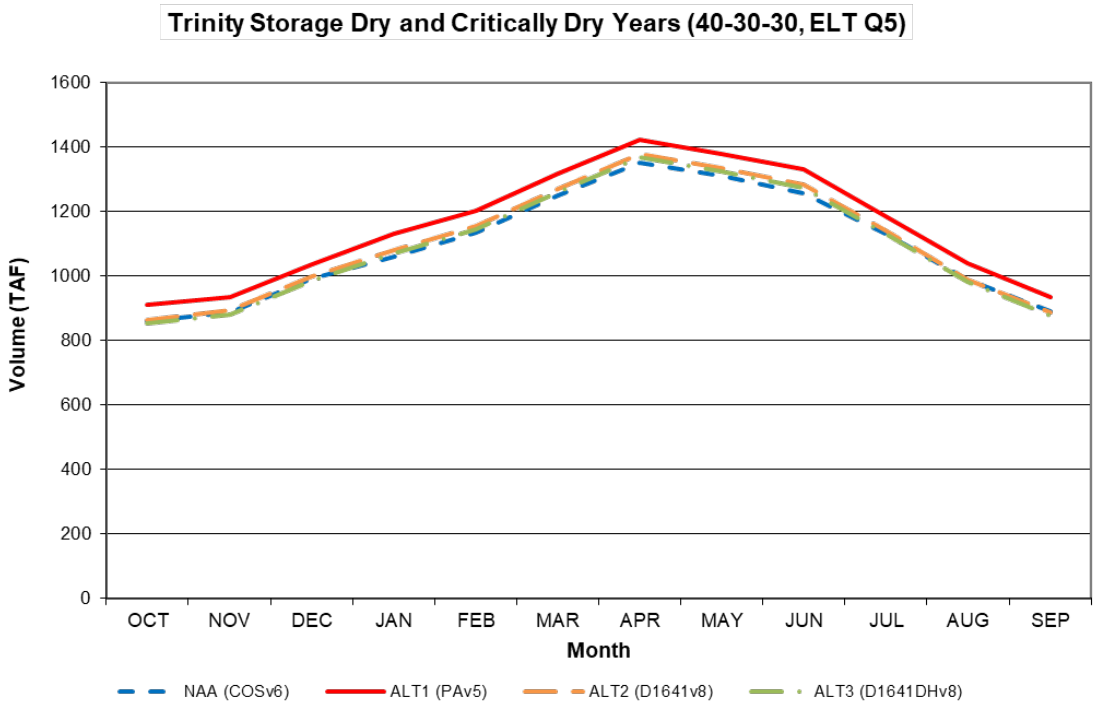

Figure O.3-14. Average Monthly Storage in Trinity Lake for the No Action Alternative and Alternatives 1, 2, and 3 in Dry and Critically Dry Water Year Types (40-30-30 Index)

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.

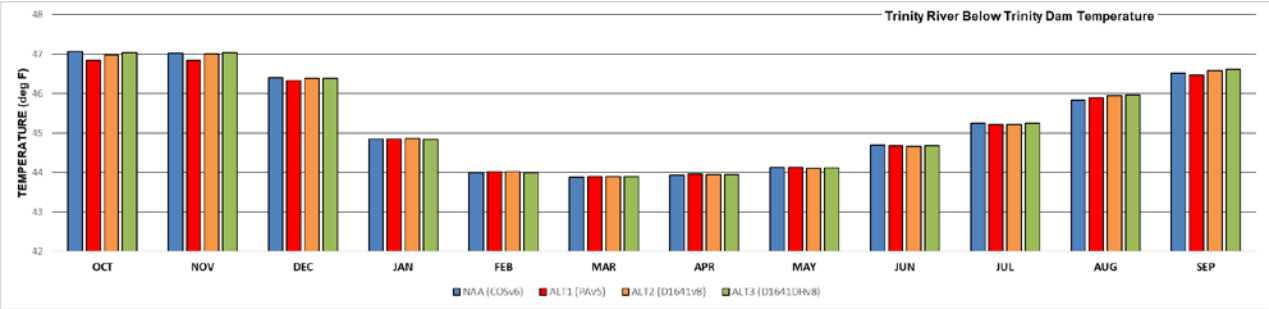

Figure O.3-15. Average Trinity River Water Temperatures below Trinity Dam for the period October to September, Average of All Water Year Types

Reservoir Fish Species

Increased storage under Alternative 1 compared to the No Action Alternative would increase fish habitat, particularly for species that utilize margins, such as Black Bass. Conversely, reservoir drawdown during June of some years may cause nest dewatering for basses and sunfish, which spawn in relatively shallow lake areas where water warms to at least 50°F in late spring or summer (Figure O.3-15b). However, these species have rapid reproductive rates that can enable them to recover from episodic recruitment failures. Rainbow Trout, Brown Trout, and Kokanee Salmon typically spawn in tributary streams, but they are capable of spawning in lakes if they are unable to access moving water. Increased stoarge during November may improve access to spawning areas for the fall-spawning Brown Trout and Kokanee Salmon. Effects of Trinity Reservoir storage on fish in the Trinity River downstream of Lewiston Dam are described below.

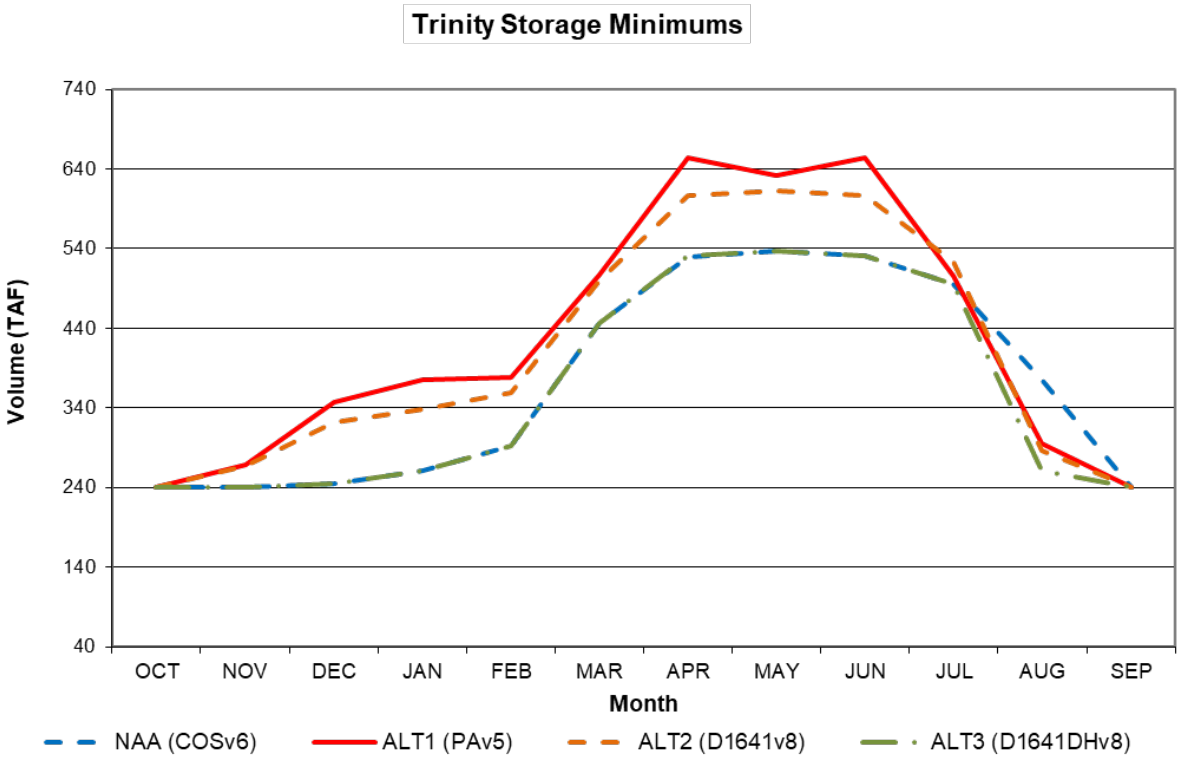

Figure O.3-15b. Modeled Trinity Lake Monthly Minimum Storage Volume under the No Action Alternative, Alternative 1, Alternative 2, and Alternative 3 during All Water Year Types

Table O.3-3b. Modeled Monthly Differences in Trinity Lake Monthly Minimum Storage Volumes during All Water Year Types under Alternative 1 relative to the No Action Alternative

Month	Change in Volume from No Action Alternative (TAF)
October	1
November	28
December	102
January	114
February	85
March	61
April	124
May	96
June	123
July	11
August	-80
September	0

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 is not expected to result in redd scour based on previous studies in the Trinity River which reported sand and gravel substrate became mobile at flows of around 2,700 cfs or greater (McBain & Trush 1997). The flow increase could decrease available Coho fry and rearing habitat by approximately 20% to 25% during February based on weighted usable area (WUA) reported in USFWS et al. 1999. Habitat improvements under Alternative 1 would also be expected to reduce the threat of disease outbreaks for Coho Salmon, although there is uncertainty in how disease prevalence will affect future conditions.

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 is not expected to result in redd scour based on previous studies in the Trinity River which reported sand and gravel substrates became mobile at flows of around 2,700 cfs or greater (McBain and Trush 1997). The flow increase could decrease available Spring-Run Chinook Salmon fry and juvenile rearing habitat by approximately 20% to 25% during February based on WUA reported in USFWS et al. 1999. Habitat improvements under Alternative 1 would also be expected to reduce the threat of disease outbreaks for Spring-Run Chinook Salmon, although there is uncertainty in how disease prevalence will affect future conditions.

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 is not expected to result in redd scour based on previous studies in the Trinity River which reported sand and gravel substrates became mobile at flows of around 2,700 cfs or greater (McBain and Trush 1997). The flow increase could decrease available Fall-Run Chinook Salmon fry and juvenile rearing habitat by approximately 20% to 25% during February based on WUA reported in USFWS et al. 1999. Habitat improvements under Alternative 1 would also be expected to reduce the threat of disease outbreaks for Fall-Run Chinook Salmon, although there is uncertainty in how disease prevalence will affect future conditions.

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. Habitat improvements under Alternative 1 would be expected to reduce the threat of disease outbreaks for Steelhead, although Steelhead are somewhat resistant to these diseases and there is uncertainty in how disease prevalence will affect future conditions.

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.

Eulachon

Eulachon are only found in the lower Klamath River. Water temperature and habitat conditions within the Lower Klamath River downstream of the confluence with the Trinity River are heavily influenced by several large tributaries that enter the Trinity River as well the Klamath River itselft. 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 Eulachon.

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).

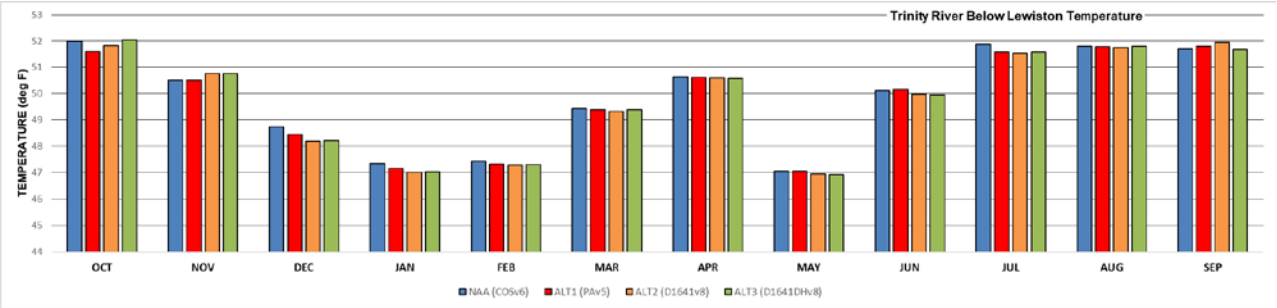

Figure O.3-16. Average Trinity River Water Temperatures below Lewiston Dam for the Period October to September, Average of All Water Year Types

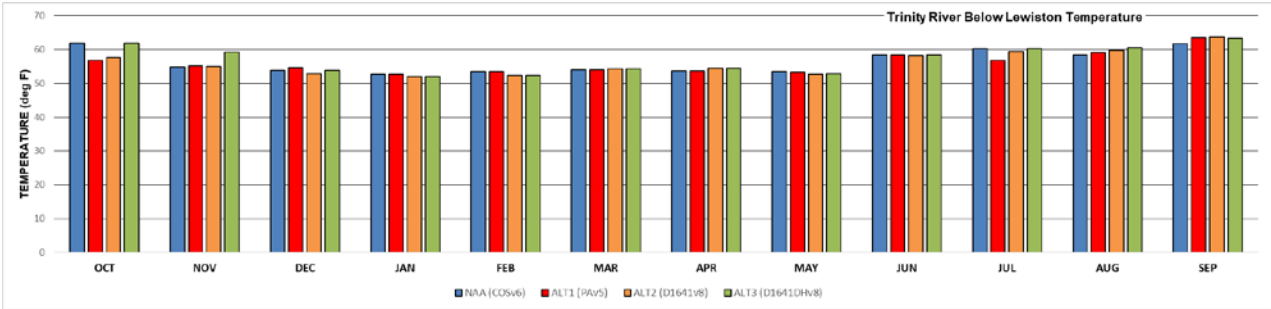

Figure O.3-17. Maximum Trinity River Water Temperatures below Lewiston Dam for the Period October to September, Average of All Water Year Types

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 from October to 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.

Eulachon

Eulachon are only found in the lower Klamath River. Water temperature and habitat conditions within the Lower Klamath River downstream of the confluence with the Trinity River are heavily influenced by several large tributaries that enter the Trinity River as well the Klamath River itselft. 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 Eulachon.

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 action 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 action 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 cold water 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 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 cold water 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 temperature control device 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 temperature control device side gates are opened to utilize the remaining cold water 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 2011b).

The main changes in water temperature management between the No Action Alternative and Alternative 1 would be in how the temperature control device would be operated to preserve sufficient cold water 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 2017b, 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 cold water pool storage on May 1, combined with summer and fall predictions from water temperature modeling. In years with high May 1 cold water 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 cold water 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 cold water pool on May 1. In years with low May 1 cold water 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 cold water 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 3, *Alternatives*.

Reclamation would regularly evaluate the performance of the cold water 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 Sacramento River Temperature Task Group 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 3, *Alternatives*.

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 (temperature control device) 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 temperature control device (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 recommendations (e.g., 53.5°F water temperature at CCR), 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 action 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 action 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	Monthly Temperature (°F)											
Water Year Type4	**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 parentheses.
[6] Bold green font indicates greater than 1°F reduction in temperature, bold red font indicates greater than 1°F increase in temperature.

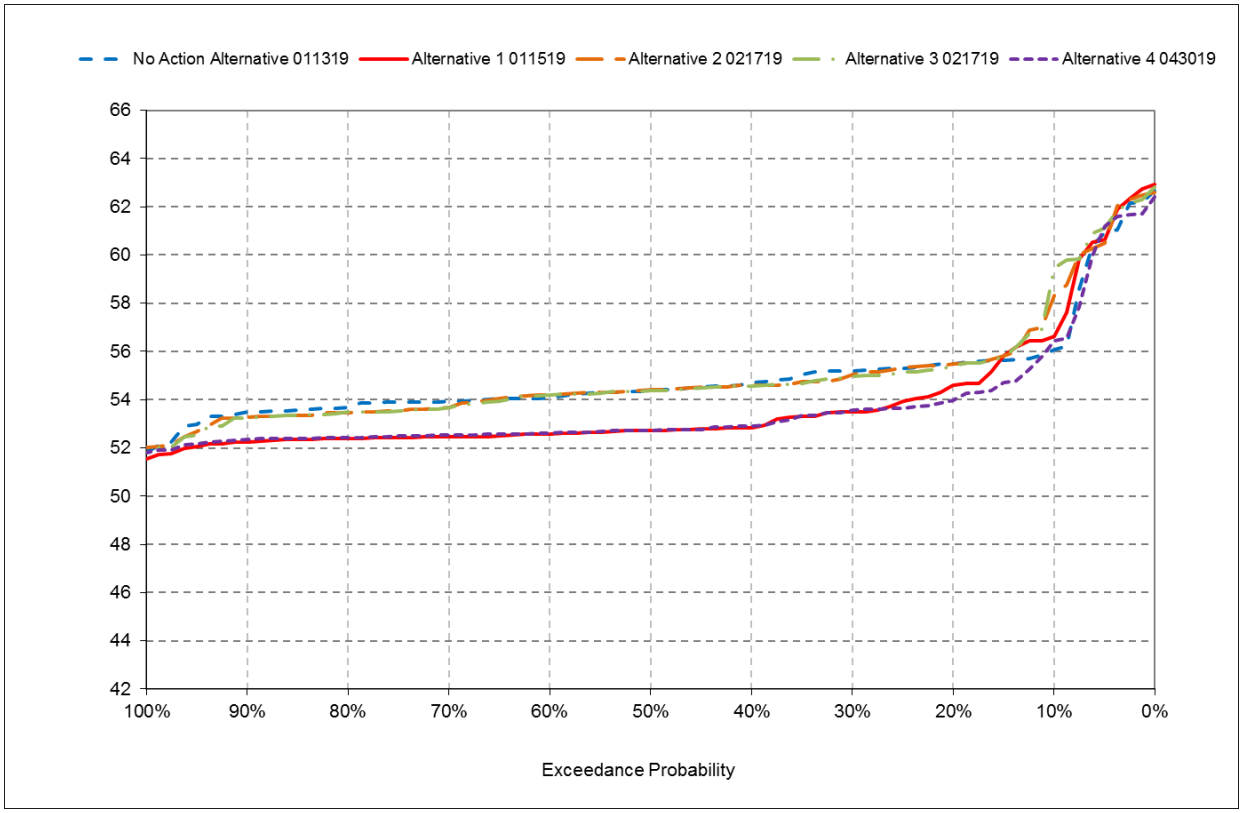

Figure O.3-18. HEC-5Q Sacramento River Water Temperatures at Keswick Dam under the No Action Alternative, Alternative 1, Alternative 2, Alternative 3 and Alternative 4; October

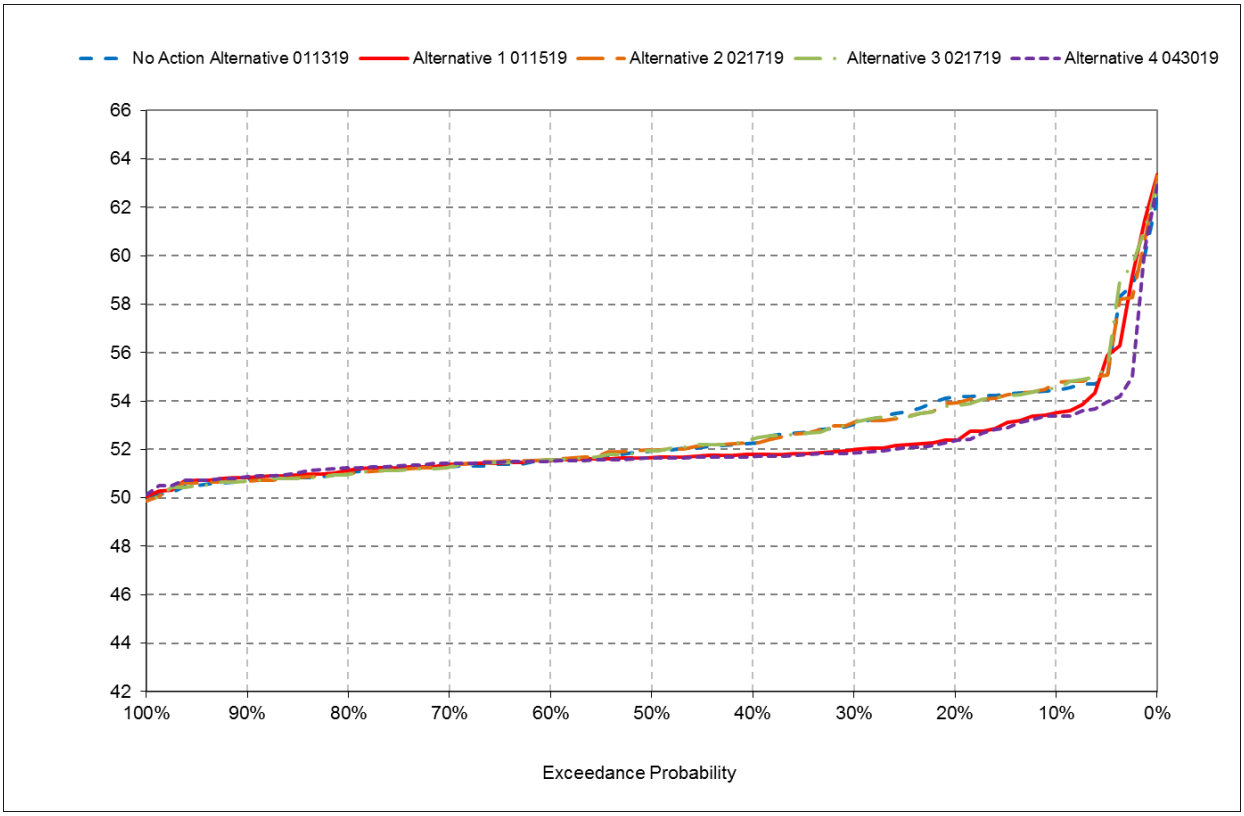

Figure O.3-19. HEC-5Q Sacramento River Water Temperatures at Keswick Dam under the No Action Alternative, Alternative 1, Alternative 2, Alternative 3 and Alternative 4; August

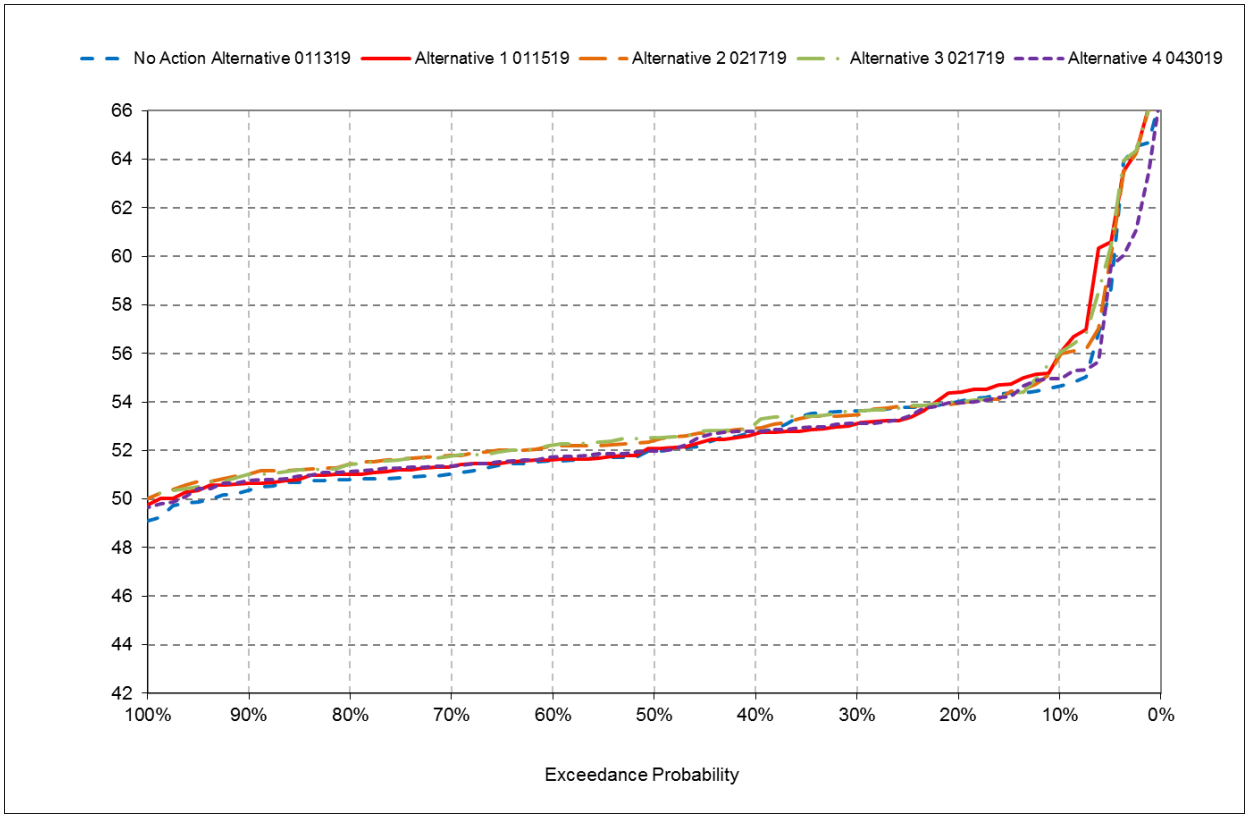

Figure O.3-20. HEC-5Q Sacramento River Water Temperatures at Keswick Dam under the No Action Alternative, Alternative 1, Alternative 2, Alternative 3 and Alternative 4; September

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]	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]	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 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.3-8. 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]	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	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 parentheses.
[6] Bold green font indicates greater than 1°F reduction in temperature, bold red font indicates greater than 1°F increase in temperature.

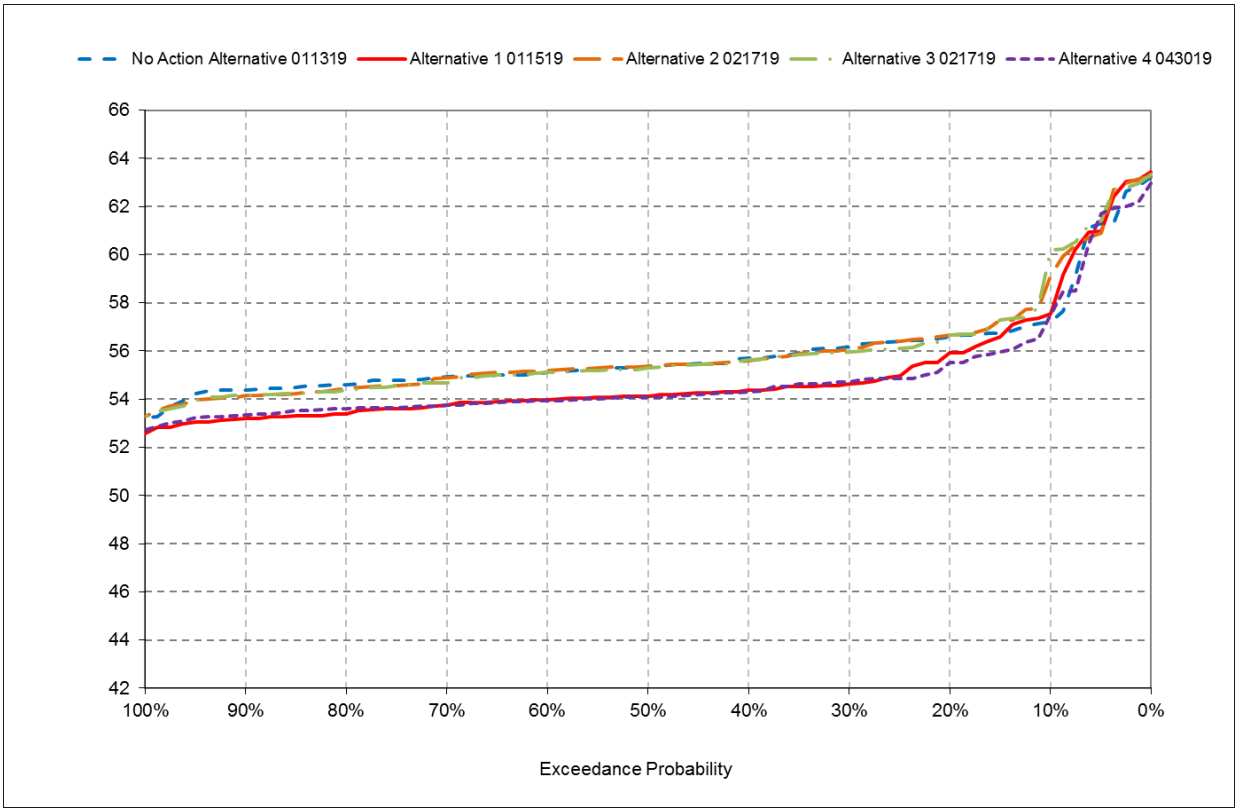

Figure O.3-21. HEC-5Q Sacramento River Water Temperatures at Balls Ferry under the No Action Alternative, Alternative 1, Alternative 2, Alternative 3 and Alternative 4; October

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]	**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 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 parentheses.
[6] Bold green font indicates greater than 1°F reduction in temperature, bold red font indicates greater than 1°F increase in temperature.

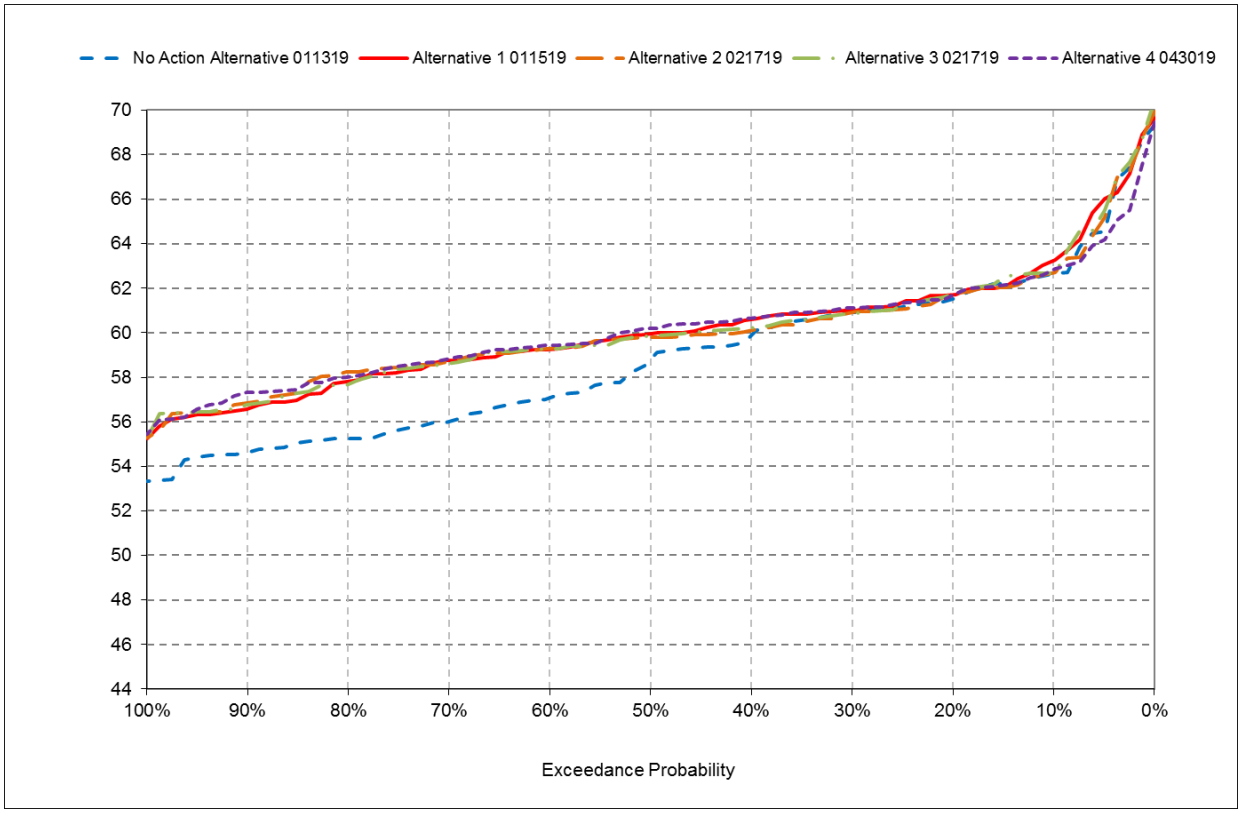

Figure O.3-22. HEC-5Q Sacramento River Water Temperatures at Red Bluff Diversion Dam under the No Action Alternative, Alternative 1, Alternative 2, Alternative 3 and Alternative 4; September

Table O.3-10. HEC-5Q Monthly Average Water Temperatures (degrees Fahrenheit) by Water Year Type and Month below Hamilton City for No Action Alternative, Alternative 1 and Differences between Them

Alternative[1,2,3]	Monthly Temperature (°F)											
Water Year Type4	**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 parentheses.
[6] Bold green font indicates greater than 1°F reduction in temperature, bold red font indicates greater than 1°F increase in temperature.

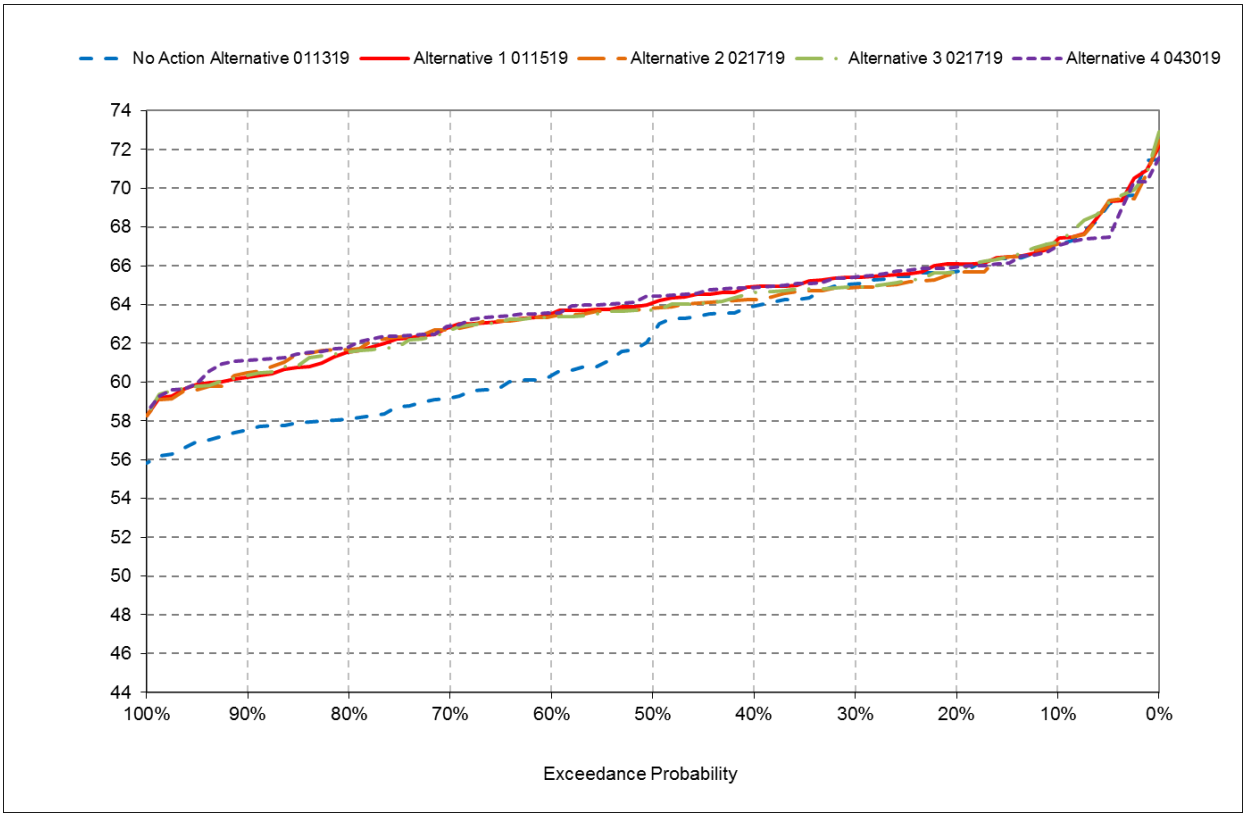

Figure O.3-23. HEC-5Q Sacramento River Water Temperatures below Hamilton City under the No Action Alternative, Alternative 1, Alternative 2, Alternative 3 and Alternative 4; September

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

Alternative[1,2,3]	Monthly Temperature (°F)											
Water Year Type4	**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)
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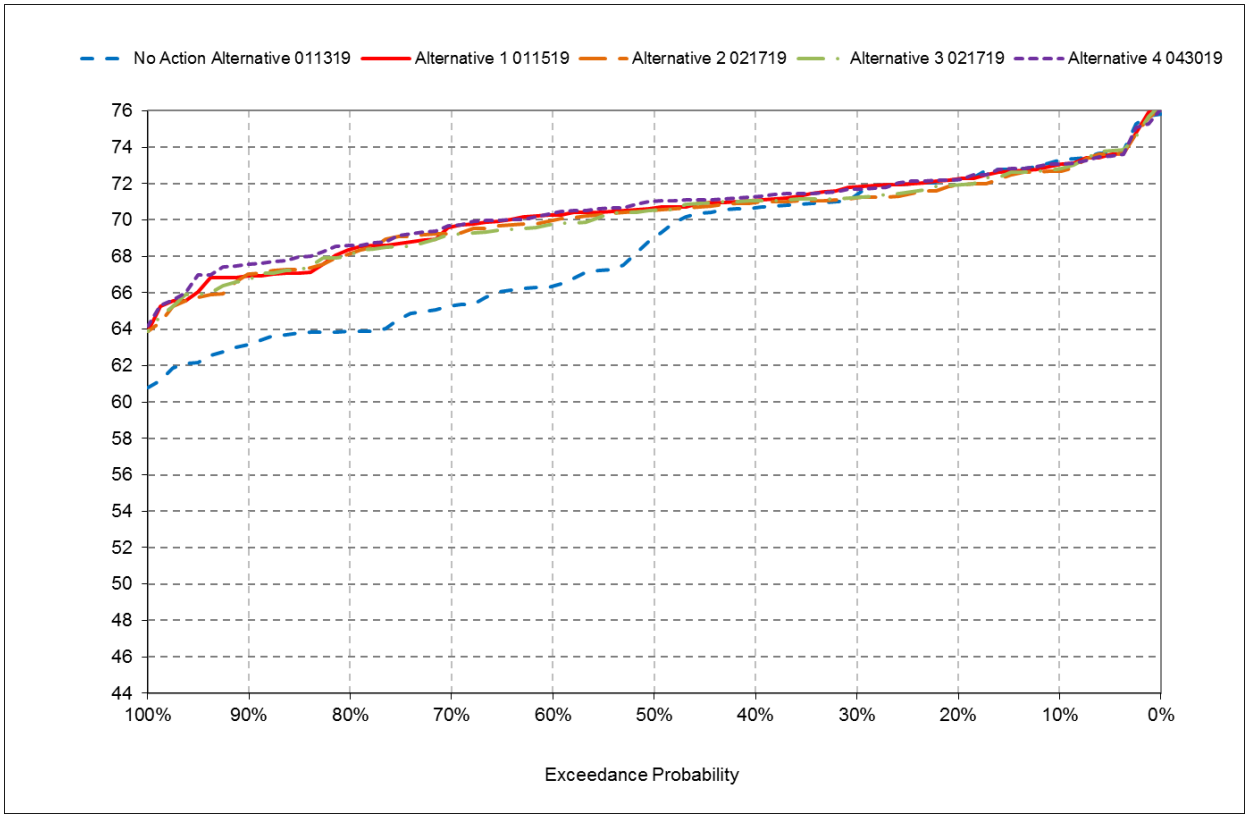


Figure O.3-24. HEC-5Q Sacramento River Water Temperatures at Knights Landing under the No Action Alternative, Alternative 1, Alternative 2, Alternative 3 and Alternative 4; September

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 cold water 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]	**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 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 parentheses.
[6] Bold green font indicates greater than 5% increase in flow; bold red font indicates greater than 5% reduction in flow.

Table O.3-13. 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]	**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
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]	**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
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

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.

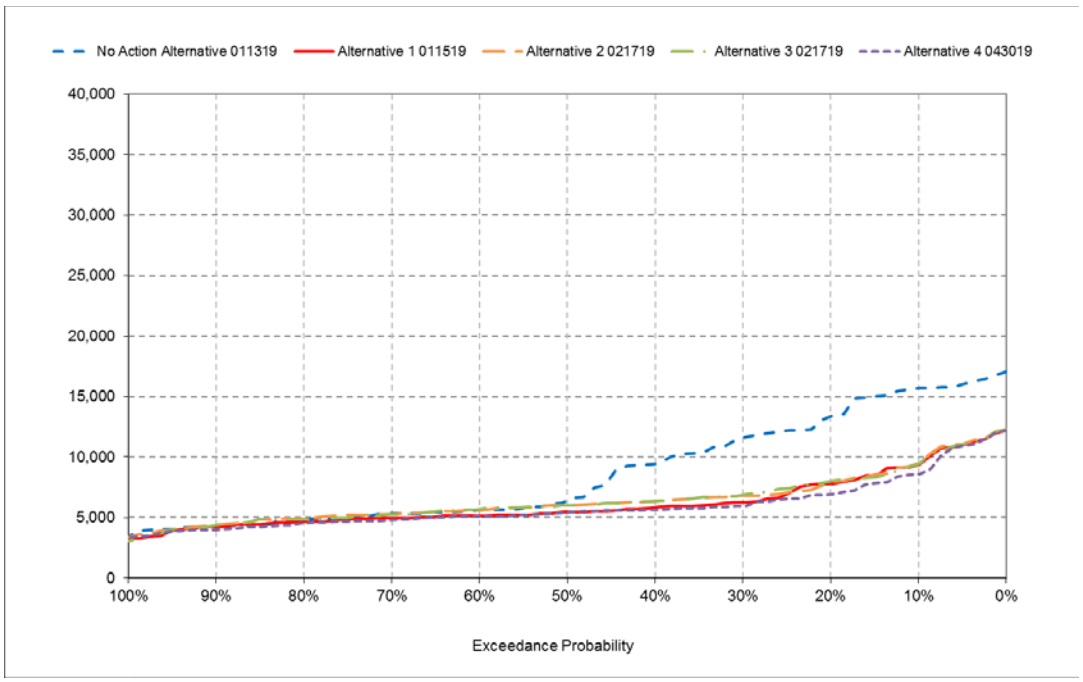


Figure O.3-25. CalSim II Sacramento River Flow at Keswick Dam under the No Action Alternative, Alternative 1, Alternative 2, Alternative 3 and Alternative 4; September

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 Martin 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.

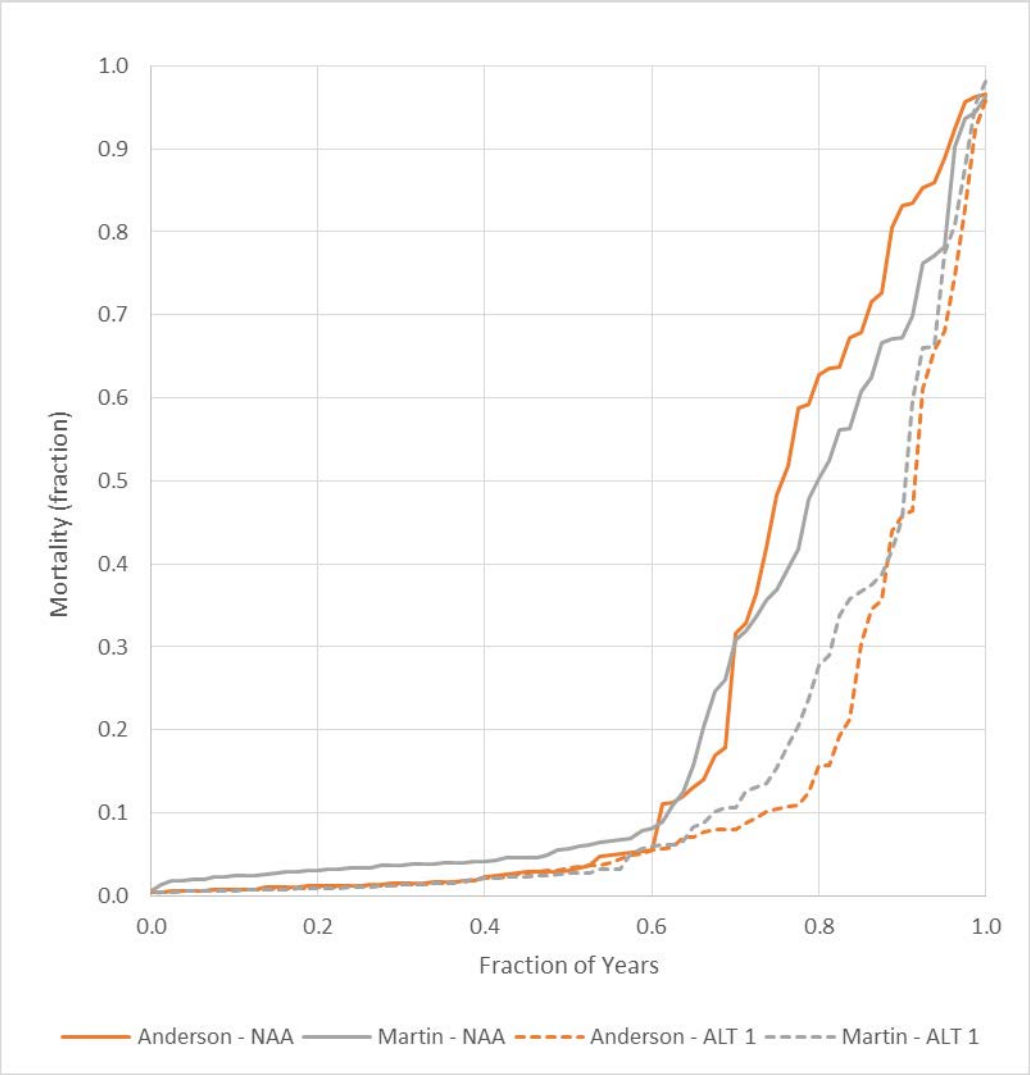


Figure O.3-26. Exceedances of Winter-Run Chinook Salmon Temperature-Dependent Egg Mortality, Alternative 1 vs. No Action Alternative; All Water Year Types

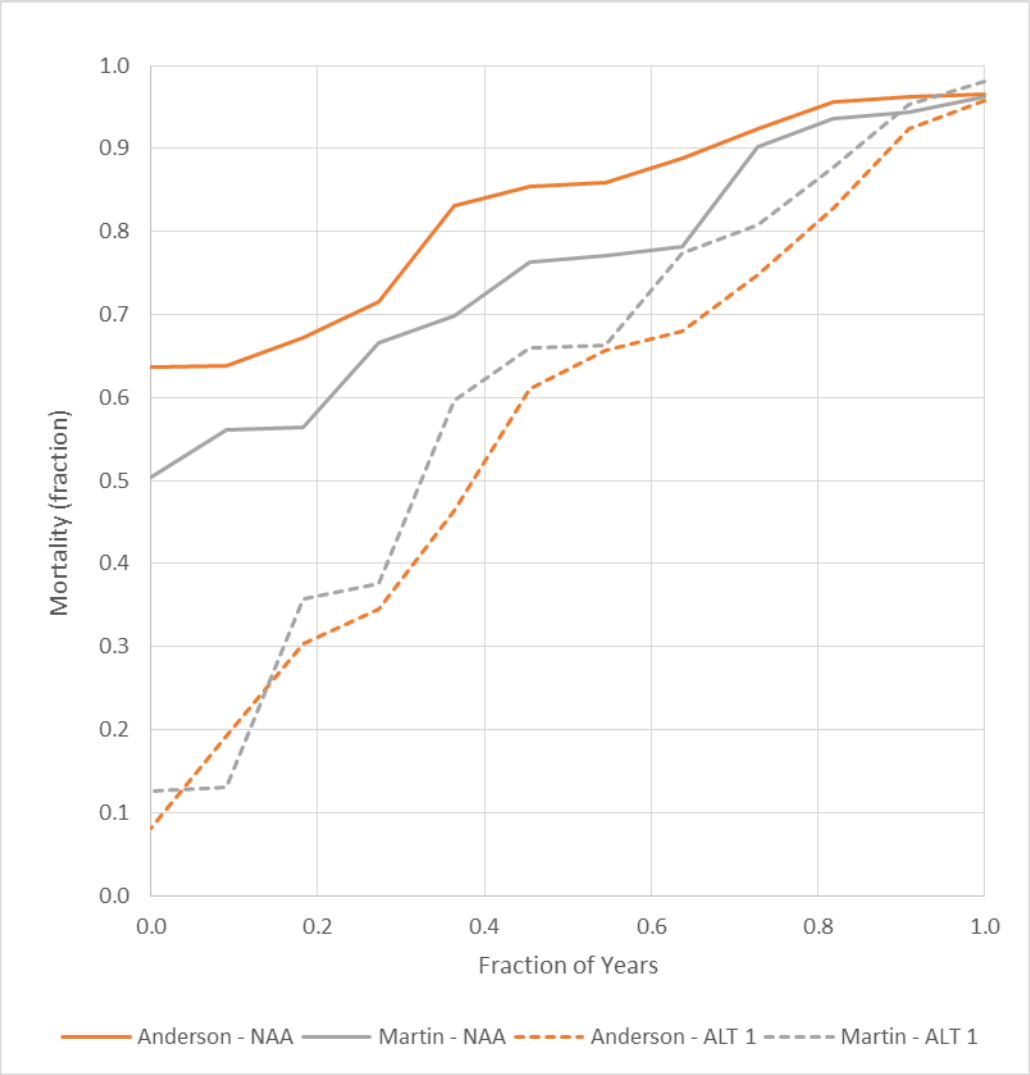


Figure O.3-27. Exceedances of Winter-Run Chinook Salmon Temperature-Dependent Egg Mortality, Alternative 1 vs. No Action Alternative; Critically Dry Water Years

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 structures proposed for Alternative 1. It is expected that, throughout 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. 2001a, 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 action 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.

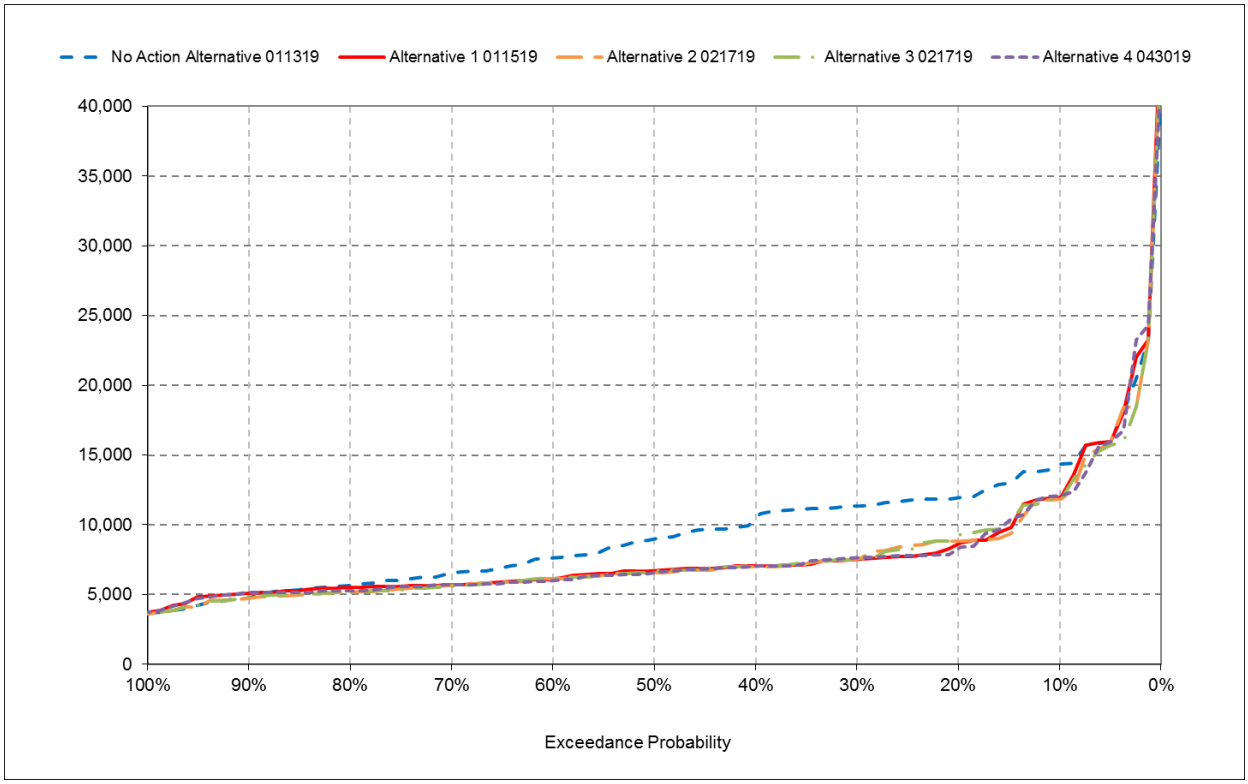


Figure O.3-28. CalSim II Sacramento River Flow at Hamilton City under the No Action Alternative, Alternative 1, Alternative 2, Alternative 3 and Alternative 4; November

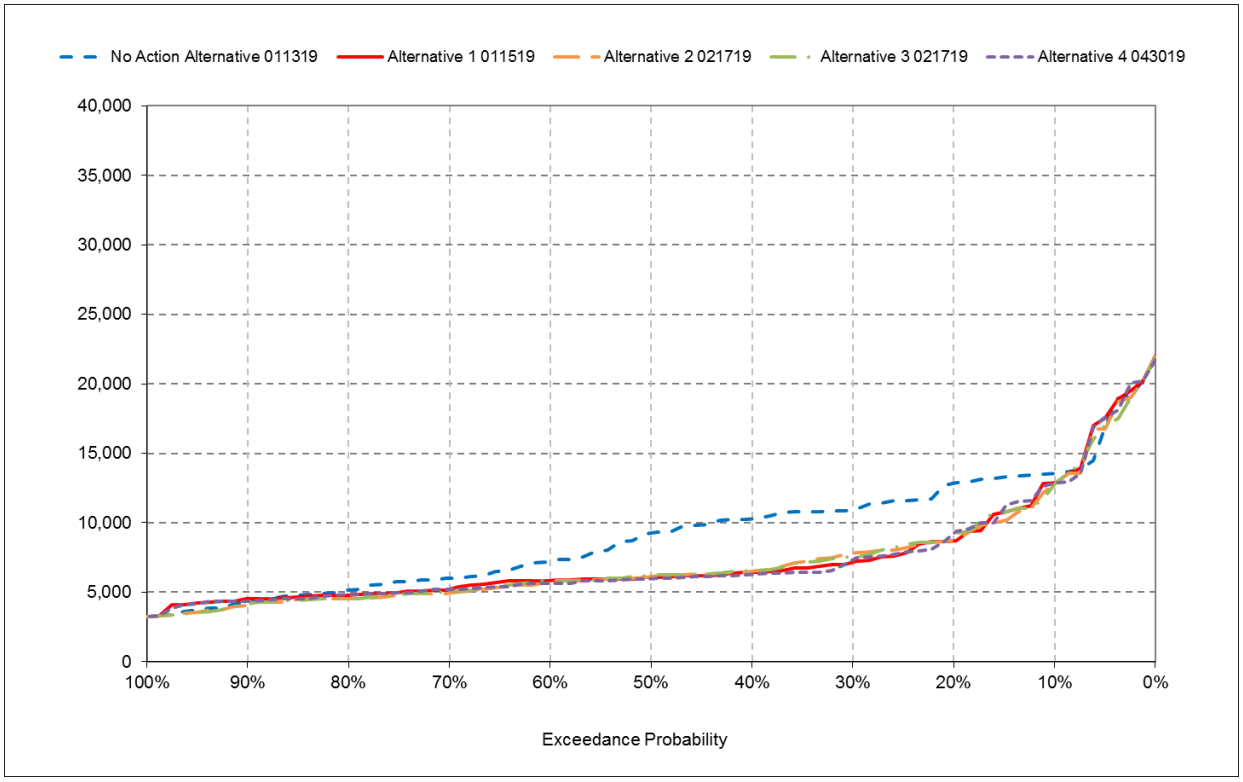


Figure O.3-29. CalSim II Sacramento River Flow at Wilkins Slough under the No Action Alternative, Alternative 1, Alternative 2, Alternative 3 and Alternative 4; November

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 RBDD (NMFS 2011b; 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 action 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 differences 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 2011b: 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 structures 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.3.3.2.2 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 2017c). 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, especially 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).

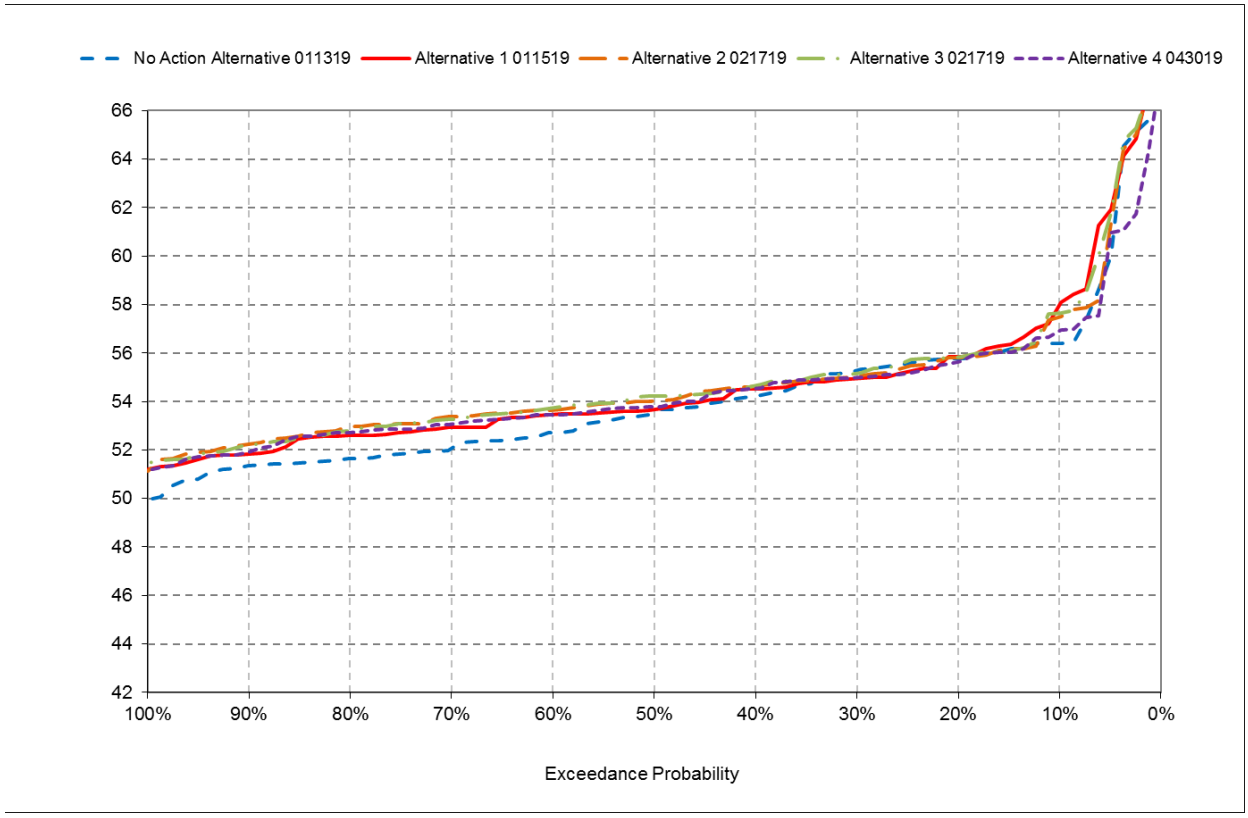


Figure O.3-30. HEC-5Q Sacramento River Water Temperatures at Clear Creek Confluence under the No Action Alternative, Alternative 1, Alternative 2, and Alternative 3; September

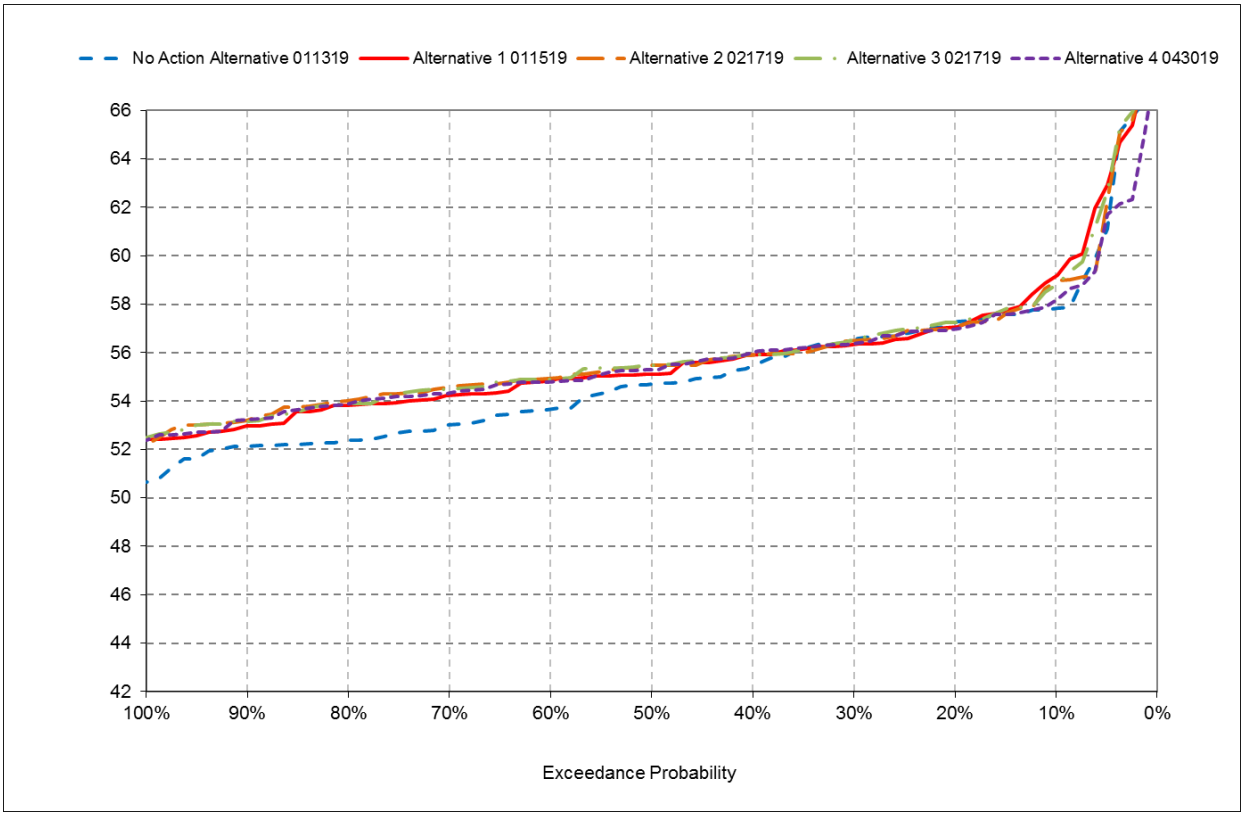


Figure O.3-31. HEC-5Q Sacramento River Water Temperatures at Balls Ferry under the No Action Alternative, Alternative 1, Alternative 2, and Alternative 3; September

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 (temperature control device) 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 temperature control device 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. 2001a, 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% (Tables 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.

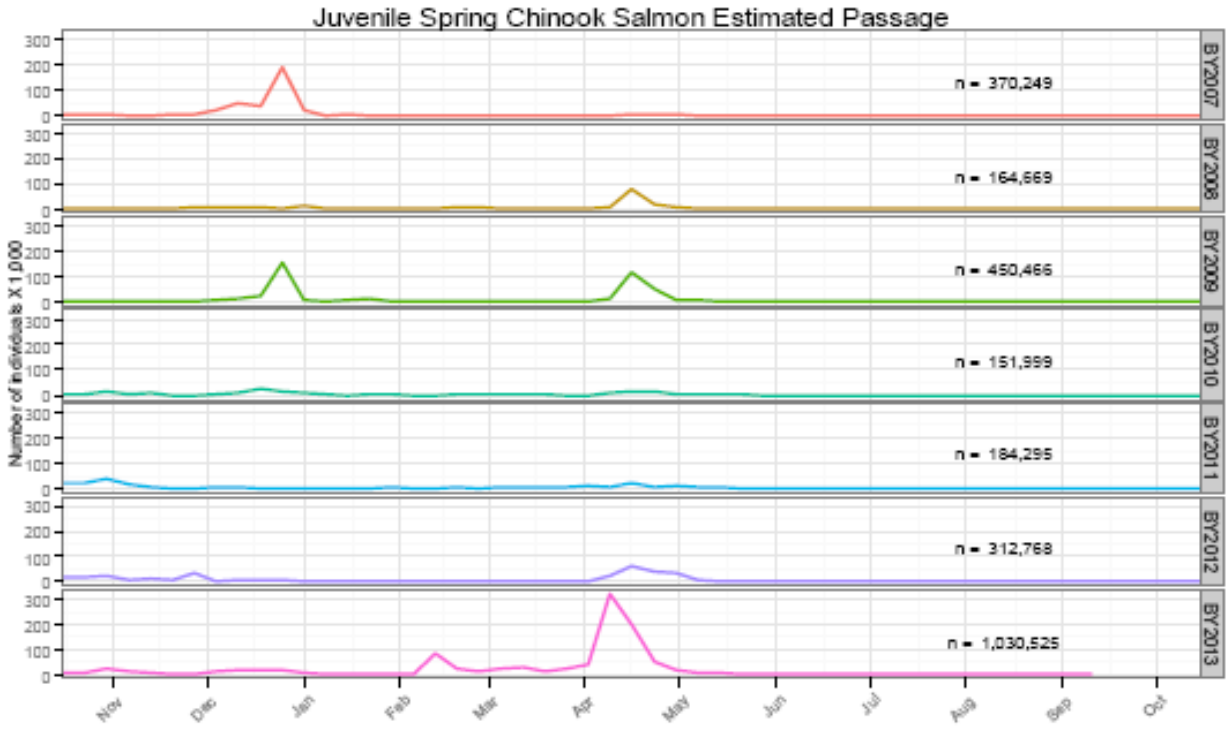


Figure O.3-31-A. Weekly Estimated Passage of Juvenile Spring-Run Chinook Salmon at Red Bluff Diversion Dam (RM244) by Brood Year (BY), Sampled using Rotary-Screw Trap.

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 action 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. 2013). 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 structures 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.3.3.2.3 Central Valley Steelhead

Spawning and Egg Incubation

Central Valley 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 Physical Habitat Simulation (PHABSIM) modeling results (flow versus WUA) developed by the USFWS (2003a) 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.

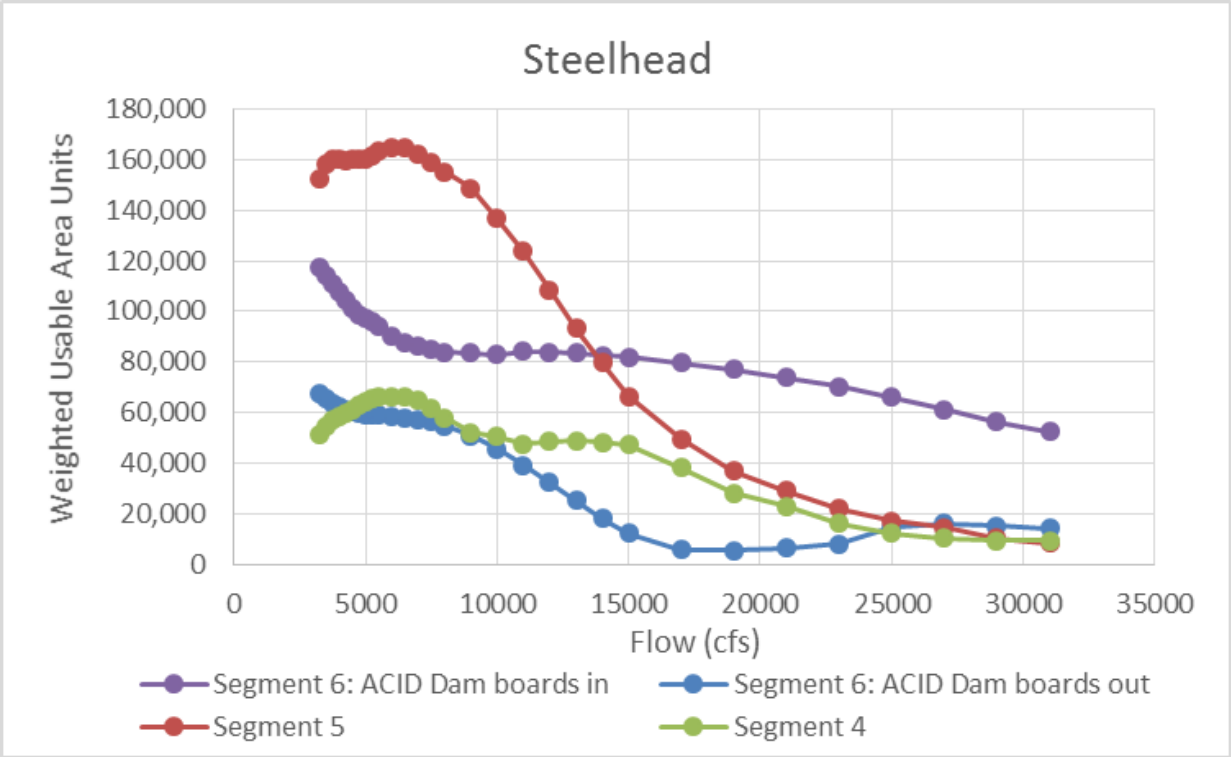


Figure O.3-31-B. Spawning WUA curves for CCV Steelhead in the Sacramento River. Segment 4: Battle Creek to Cow Creek; Segment 5: Cow Creek to the Anderson-Cottonwood Irrigation District (ACID) Dam; Segment 6: ACID to Keswick Dam

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

Central Valley 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).

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 2005a) 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.

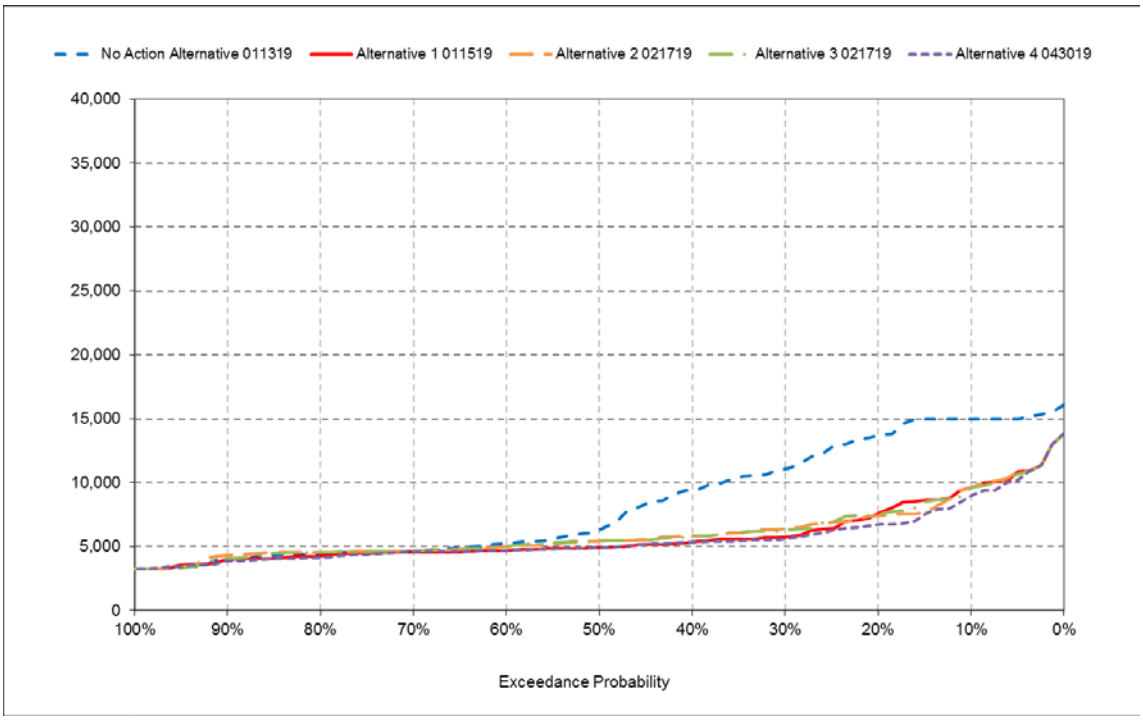


Figure O.3-32. CalSim II Sacramento River Flow at Wilkins Slough under the No Action Alternative, Alternative 1, Alternative 2, Alternative 3, and Alternative 4; September

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 temperatures 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.3.3.2.4 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 (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. 2017).

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, 2017; 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. 2017). 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. 2017). 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°F 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°F 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°F 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 (temperature control device) 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.

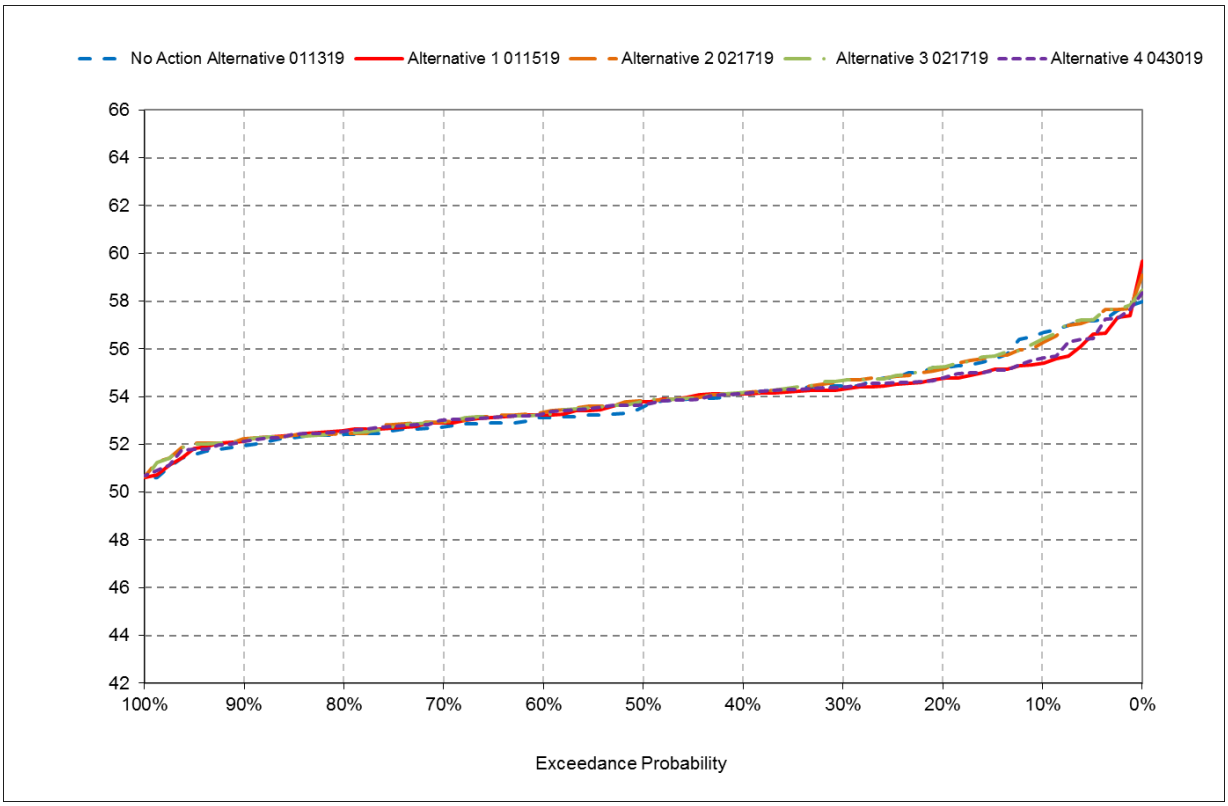


Figure O.3-33. HEC-5Q Sacramento River Water Temperatures at Balls Ferry under the No Action Alternative, Alternative 1, Alternative 2, Alternative 3 and Alternative 4; July

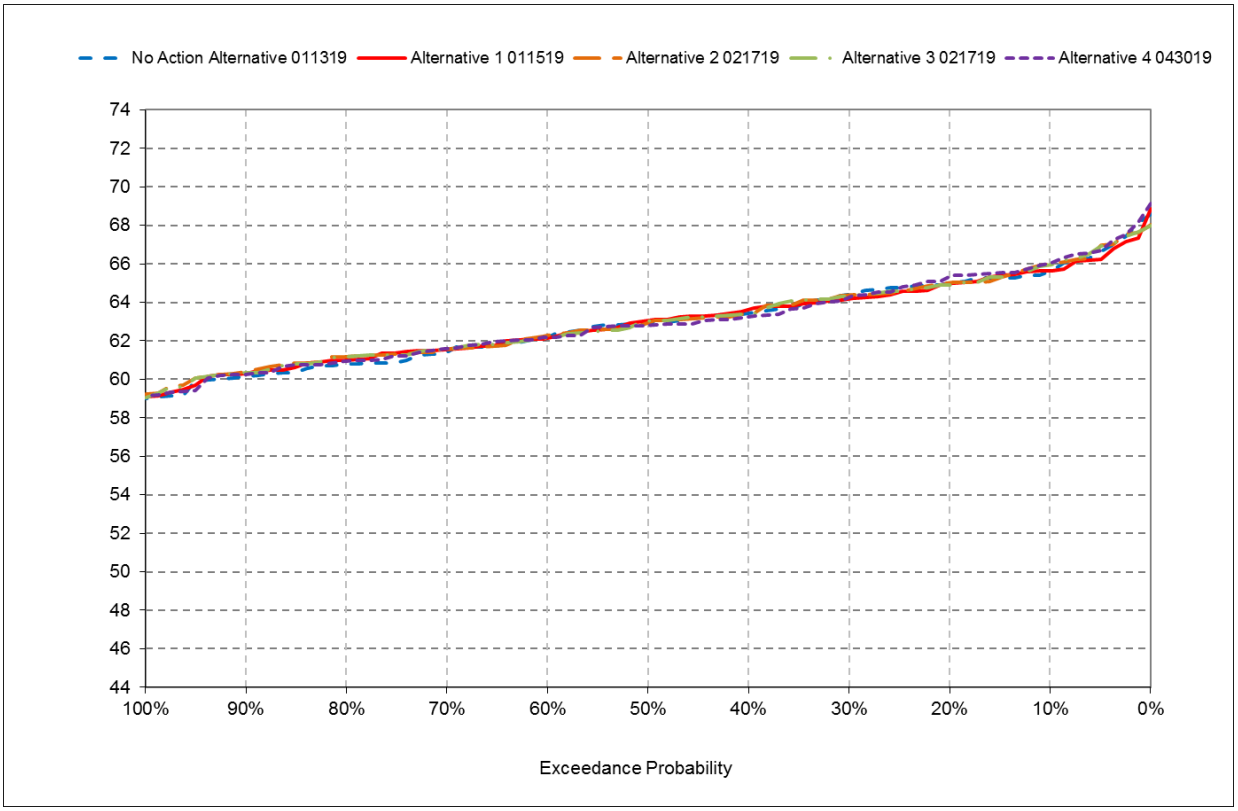


Figure O.3-34. HEC-5Q Sacramento River Water Temperatures at Hamilton City under the No Action Alternative, Alternative 1, Alternative 2, Alternative 3, and Alternative 4; July

O.3.3.2.5 Larval and Juvenile Rearing and Emigration

According to field observations, Green Sturgeon larvae begin to disperse from hatching areas at 18 days post hatch, and dispersion is complete at about 35 days post hatch (Poytress et al. 2011, cited in Heublein et al. 2017). They begin exogenous feeding at about 15 days post hatch. 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. 2017). 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 days post hatch and about 75 mm in length (Heublein et al. 2017). It is likely that juveniles rear near spawning habitat for a few months or more before migrating to the Delta (Heublein et al. 2017). The juveniles rear in the Sacramento River from about May through December (NMFS 2017c: 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. 2017). 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.

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. 2017). Based on laboratory studies, Van Eenennaam et al. (2005 cited in Heublein et al. 2017) 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. 2017) 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-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 1 would provide a minor potential benefit to rearing larval and juvenile Green Sturgeon relative to the No Action Alternative.

O.3.3.2.6 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. 2017). 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 2018b). 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. 2017).

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°F and 61°F thresholds more often under Alternative 1 than under the No Action Alternative. Under Alternative 1, the temperatures exceeds the 63°F 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 Southern 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 conclusions about the water temperature results. As previously 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°F, 63°F, 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 cold water 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.3.3.2.7 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 (USFWS 2003, 2005b).

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 spawning and eggs and alevins are present. Based on PHABSIM results (flow-habitat relationships) developed by the USFWS (2003a) 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.3-35). 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.

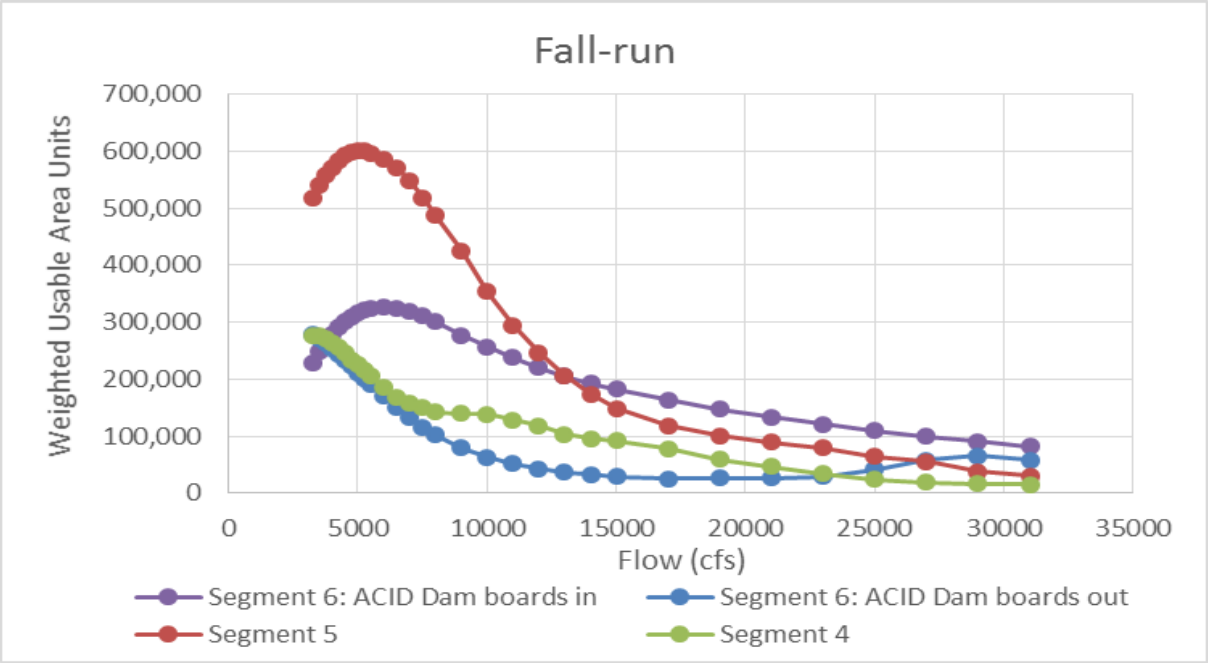


Figure O.3-35. Spawning WUA Curves for Fall-Run Chinook Salmon in the Sacramento River. Segment 4: Battle Creek to Cow Creek; Segment 5: Cow Creek to the Anderson-Cottonwood Irrigation District (ACID) Dam; Segment 6: ACID to Keswick Dam

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 temperatures 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 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).

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 WUA). (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 increases 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, these reductions would be offset by improved emigration conditions associated with higher flows during the spring emigration period (see Section O.3.3.2.2, *Central Valley Spring-Run Chinook Salmon*). Therefore, changes in flow resulting from Alternative 1 are not expected to substantially affect rearing and emigrating juvenile Fall-Run Chinook Salmon.

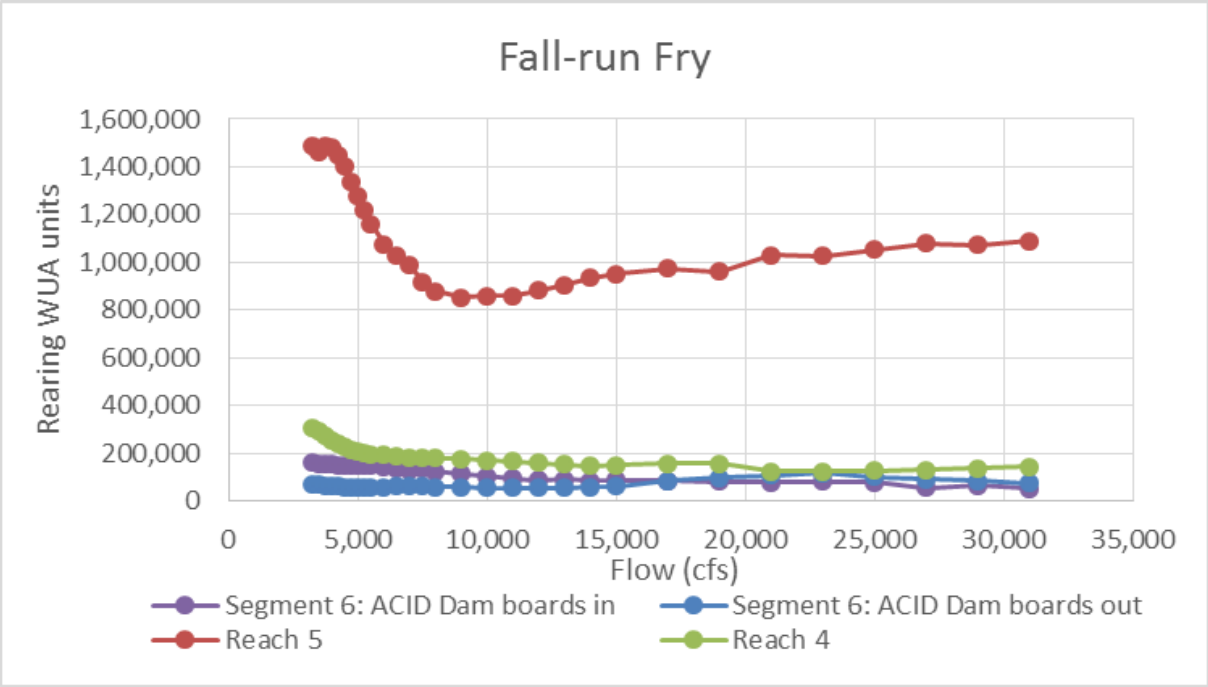


Figure O.3-36. Fry Rearing WUA Curves for Fall-Run Chinook Salmon in the Sacramento River. Segment 4: Battle Creek to Cow Creek; Segment 5: Cow Creek to the Anderson-Cottonwood Irrigation District (ACID) Dam; Segment 6: ACID to Keswick Dam

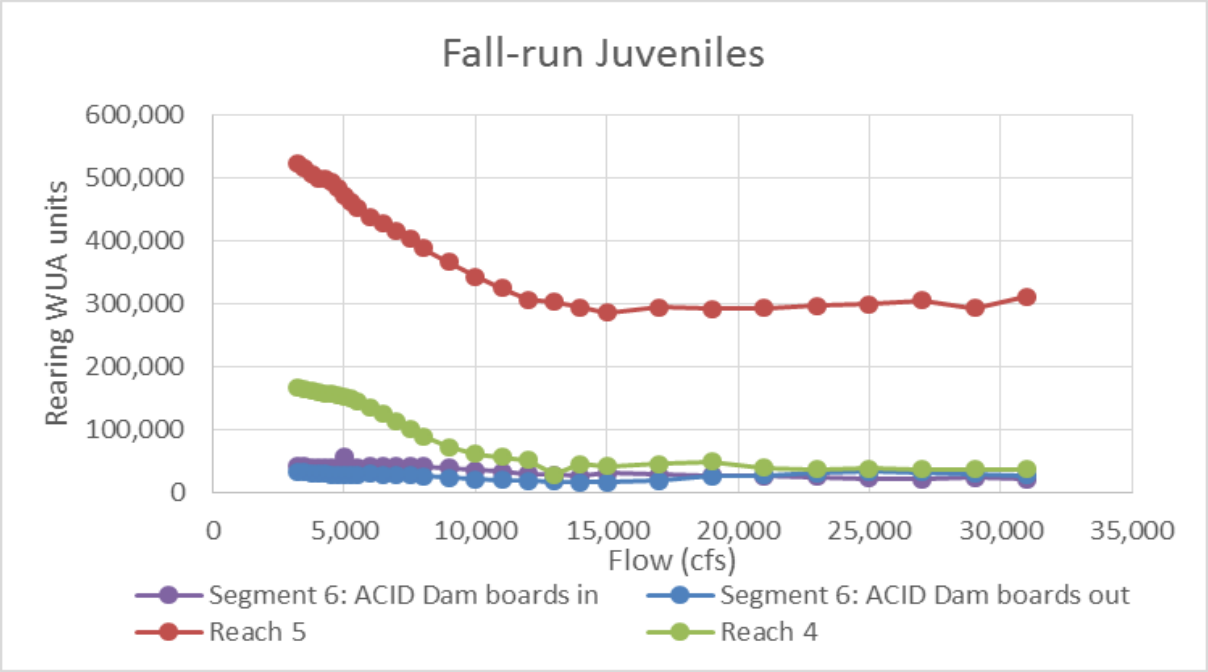


Figure O.3-37. Juvenile Rearing WUA Curves for Fall-Run Chinook Salmon in the Sacramento River. Segment 4: Battle Creek to Cow Creek; Segment 5: Cow Creek to the Anderson-Cottonwood Irrigation District (ACID) Dam; Segment 6: ACID to Keswick Dam

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 action 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 from July to 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 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 action 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 temperatures 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.3.3.2.8 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 RBDD, with the majority spawning between Keswick Dam and the ACID Dam.

During the primary Late Fall–Run Chinook Salmon spawning and incubation period (December through 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 through 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.

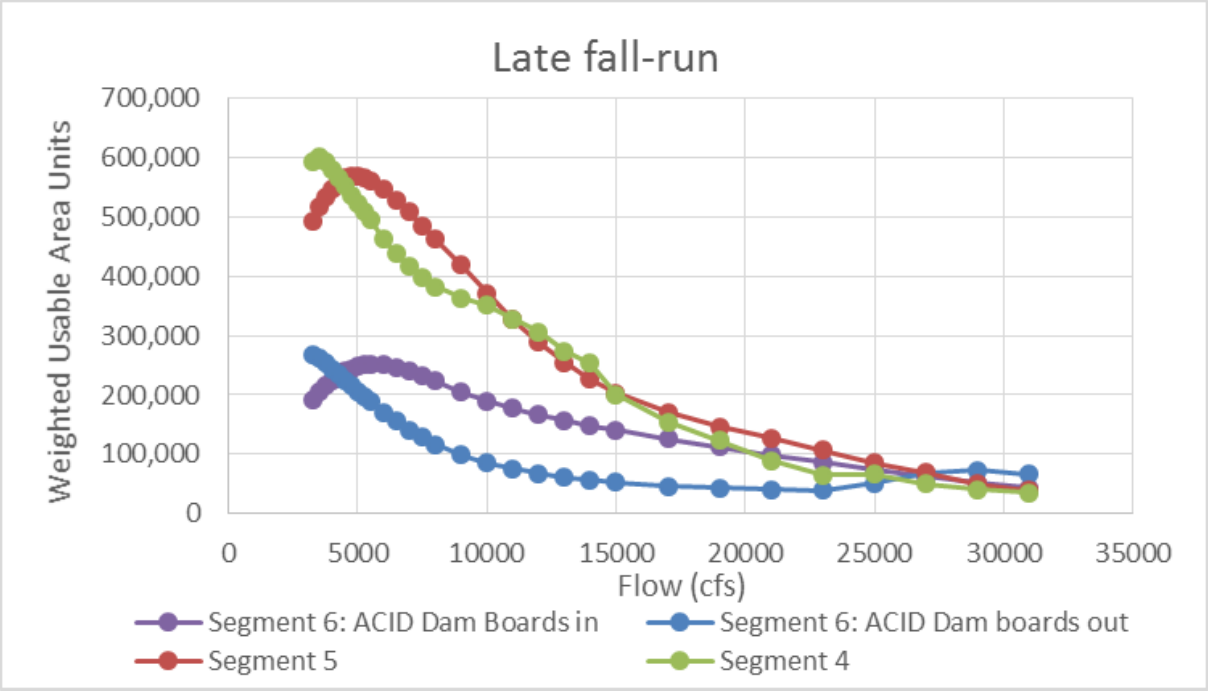


Figure O.3-38. Spawning WUA Curves for Late Fall–Run Chinook Salmon in the Sacramento River. Segment 4: Battle Creek to Cow Creek; Segment 5: Cow Creek to the Anderson-Cottonwood Irrigation District (ACID) Dam; Segment 6: ACID to Keswick Dam

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 2005a), 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.

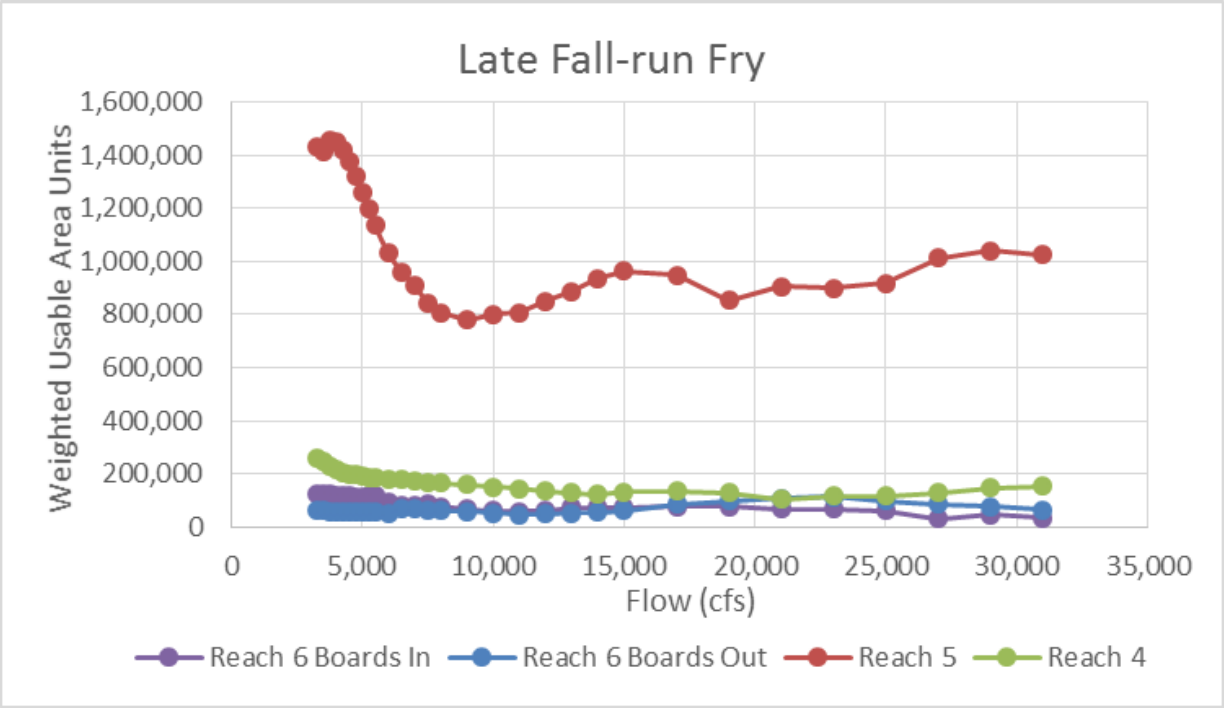


Figure O.3-39. Fry Rearing WUA Curves for Late Fall–Run Chinook Salmon in the Sacramento River. Segment 4: Battle Creek to Cow Creek; Segment 5: Cow Creek to the Anderson-Cottonwood Irrigation District (ACID) Dam; Segment 6: ACID to Keswick Dam

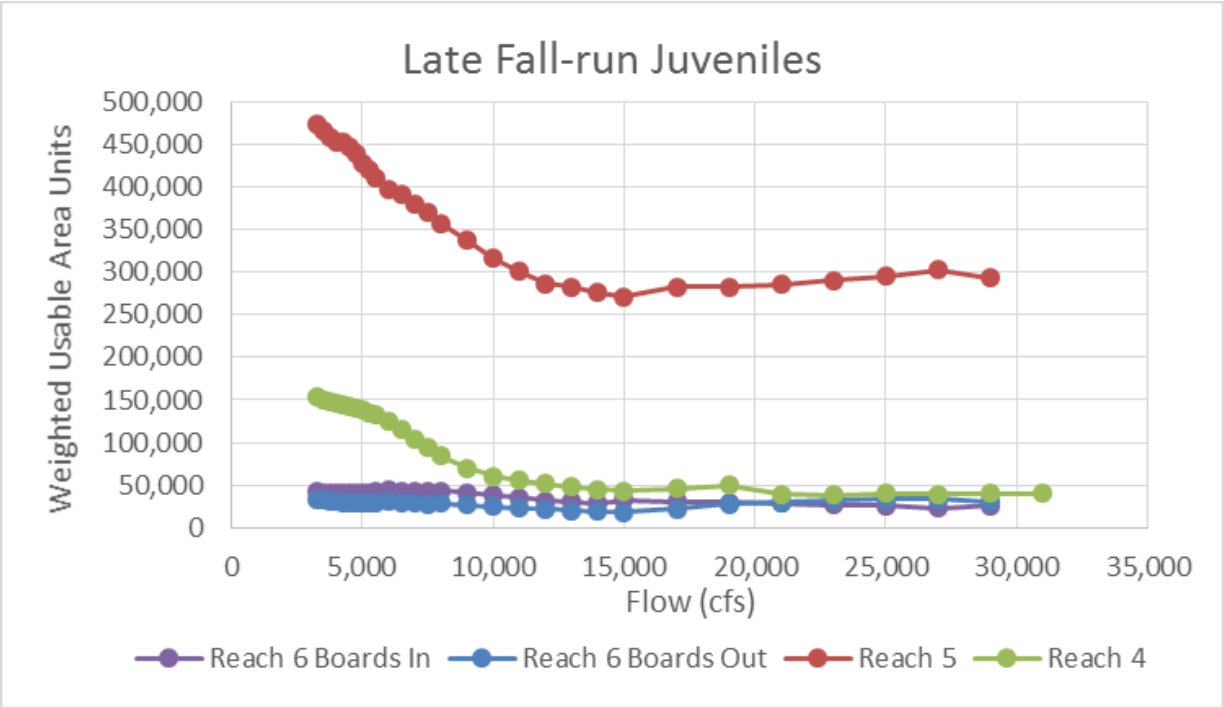


Figure O.3-40. Juvenile Rearing WUA Curves for Late Fall–Run Chinook Salmon in the Sacramento River. Segment 4: Battle Creek to Cow Creek; Segment 5: Cow Creek to the Anderson-Cottonwood Irrigation District (ACID) Dam; Segment 6: ACID to Keswick Dam

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.

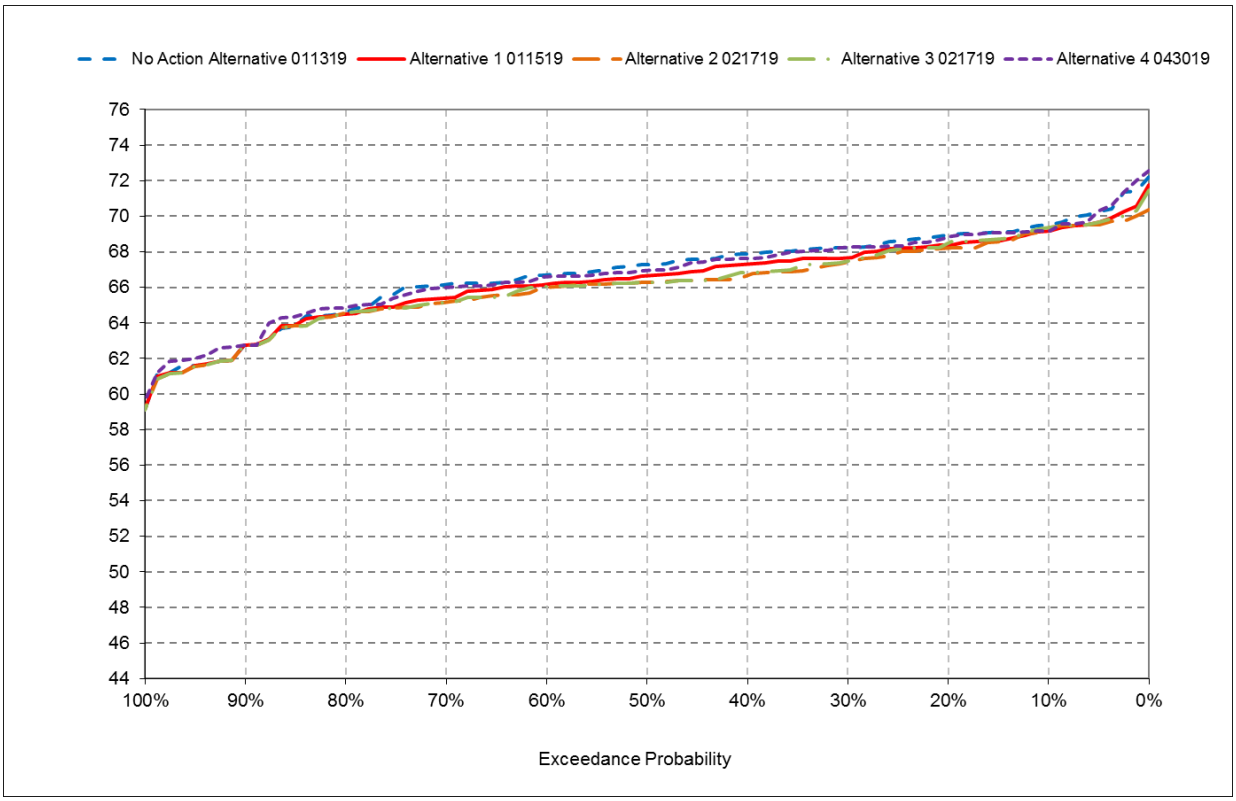


Figure O.3-41. HEC-5Q Sacramento River Water Temperatures at Knights Landing under the No Action Alternative, Alternative 1, Alternative 2, Alternative 3, and Alternative 4; May

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 action alternatives in the frequency and magnitude of water temperatures above this threshold (Figure O.3-42). Therefore, changes in Sacramento River flows and water temperatures 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.

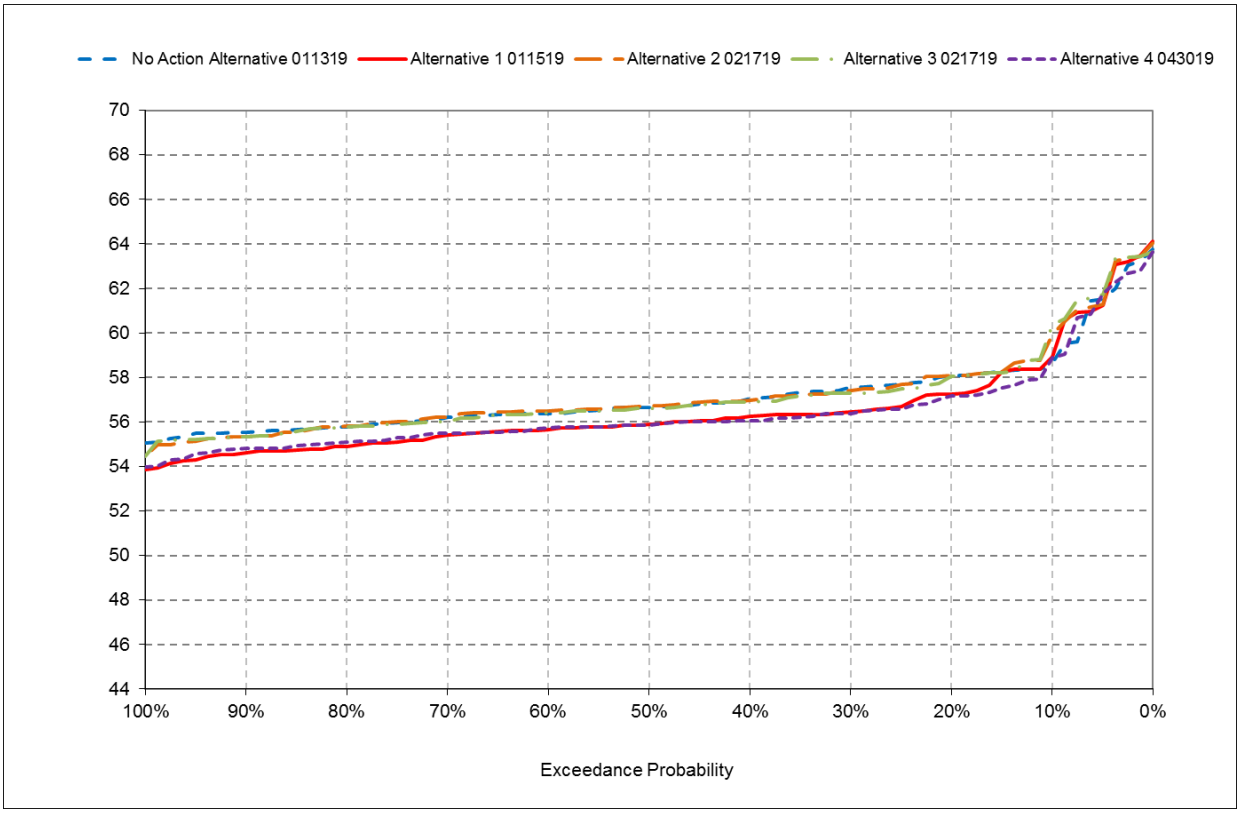


Figure O.3-42. HEC-5Q Sacramento River Water Temperatures at Red Bluff Diversion Dam under the No Action Alternative, Alternative 1, Alternative 2, Alternative 3, and Alternative 4; October

O.3.3.2.9 White Sturgeon

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 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°F 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°F to 63°F (Wang et al. 1985, cited in Heublein 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 days post hatch (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. The relationship of White Sturgeon year class recruitment 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.3.3.2.10 Adult Upstream Migration and Holding

As previously noted, White Sturgeon adults 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 7,800 to 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-significant impact on White Sturgeon relative to the No Action Alternative.

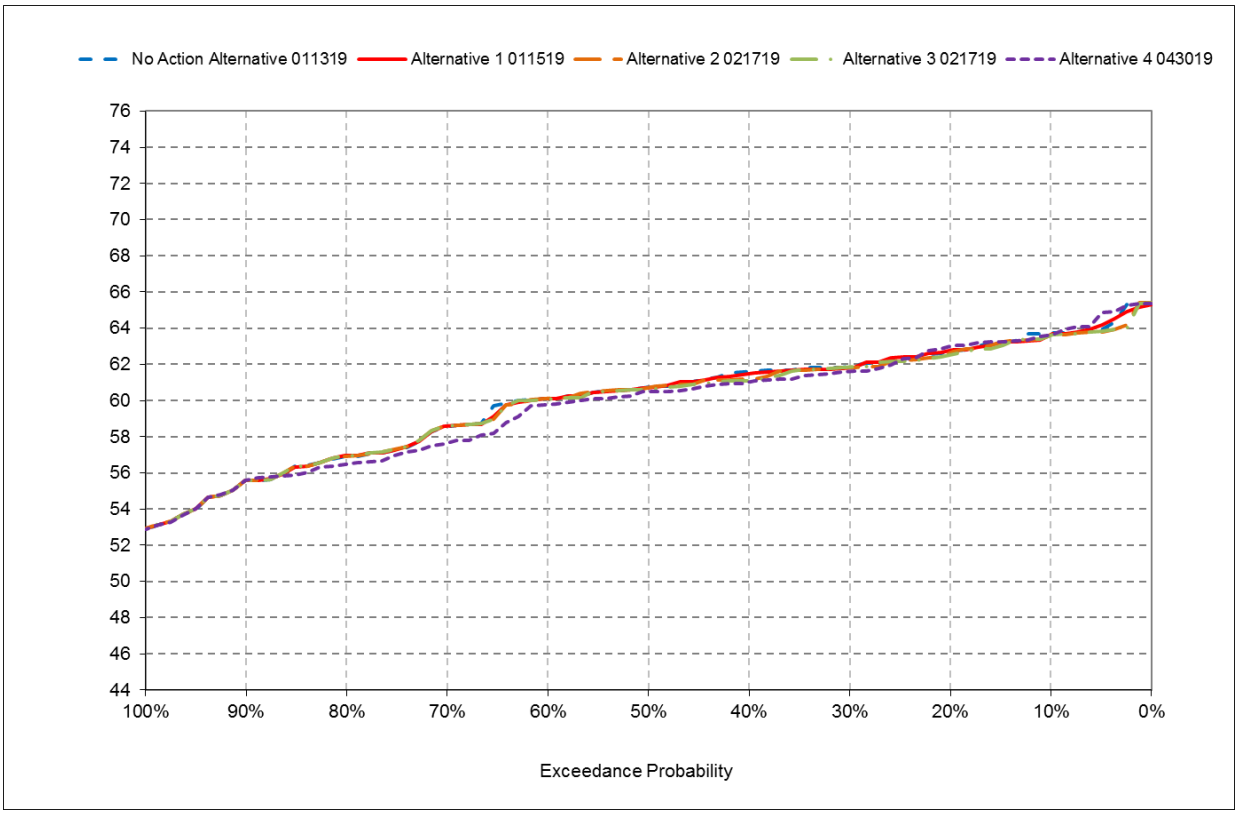


Figure O.3-43. HEC-5Q Sacramento River Water Temperatures at Knights Landing under the No Action Alternative, Alternative 1, Alternative 2, Alternative 3 and Alternative 4; April

O.3.3.2.11 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. 2007a; 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 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.

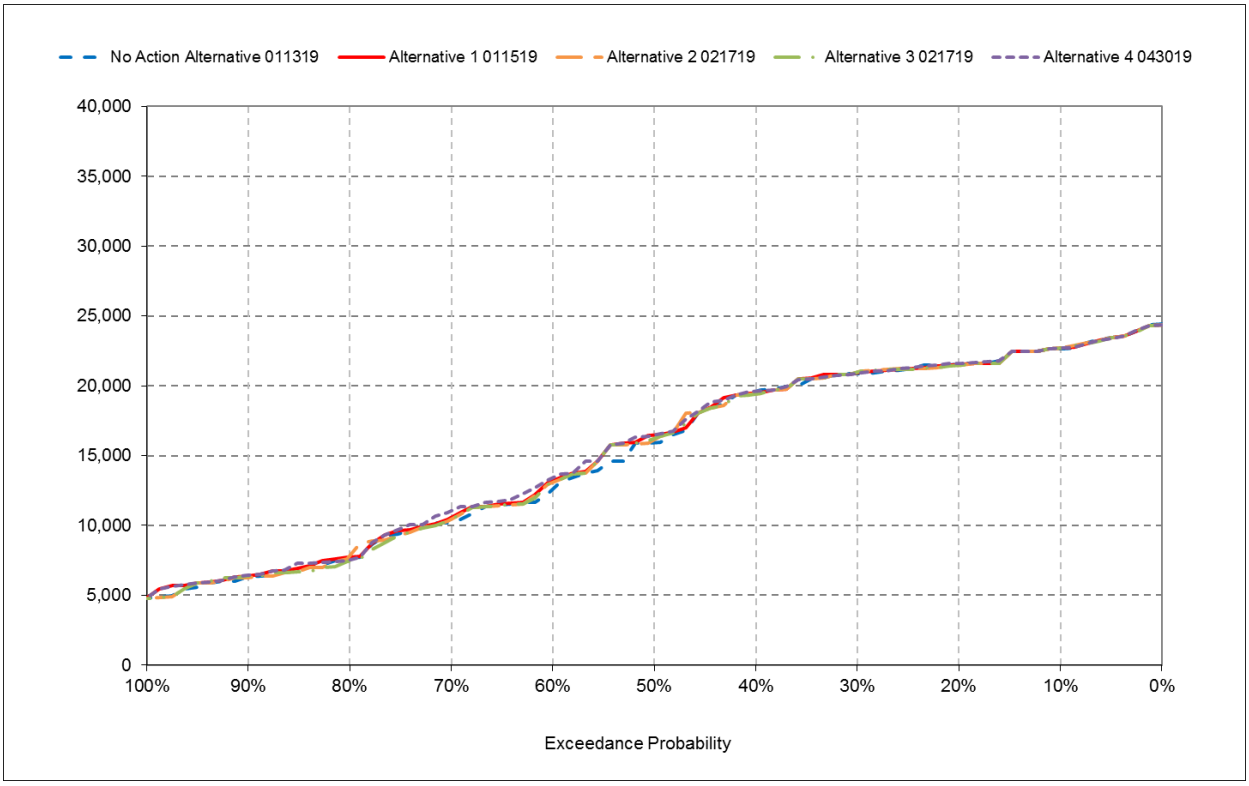


Figure O.3-44. CalSim II Sacramento River Flow at Wilkins Slough under the No Action Alternative, Alternative 1, Alternative 2, Alternative 3 and Alternative 4; February

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 action alternatives at Knights Landing during the December through May period that Sacramento Splittail 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-significant impact on Sacramento Splittail relative to the No Action Alternative.

O.3.3.2.12 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 foot), 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 action 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 year-round 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-significant impact on Pacific Lamprey relative to the No Action Alternative.

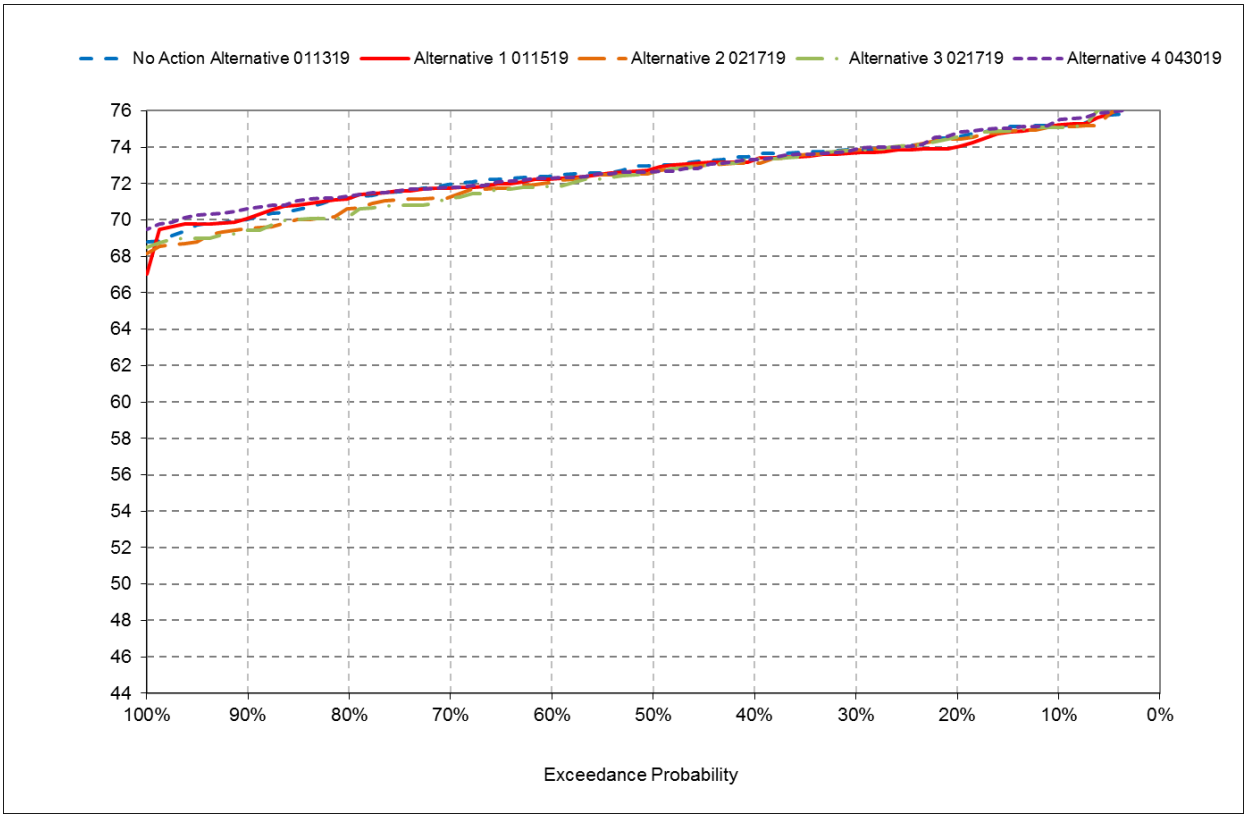


Figure O.3-45. HEC-5Q Sacramento River Water Temperatures at Knights Landing under the No Action Alternative, Alternative 1, Alternative 2, Alternative 3 and Alternative 4; August

O.3.3.2.13 River Lamprey

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 (macropthalmia) 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 year-round 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 known 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 prelarvae and 72°F for minimum survival of eggs and prelarvae, 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 action 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-significant impact on River Lamprey relative to the No Action Alternative.

O.3.3.2.14 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 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 action 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-significant impact on Hardhead relative to the No Action Alternative.

O.3.3.2.15 Central California Roach

Central California Roach primarily inhabit 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 temperature conditions under Alternative 1 would adversely affect Central California Roach. Therefore, Alternative 1 is expected to have no impact on Central California Roach relative to the No Action Alternative.

O.3.3.2.16 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). 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°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).

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°F to 68°F and spawning ceases at about 70°F (Moyle 2002). The eggs can withstand temperatures of about 54°F to 75°F, with the optimum being about 64°F (Emmett et al. 1991). Larvae tolerate temperatures of 50°F to 77°F, but optimal temperatures for survival are 59°F 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°F to 75°F (Emmett et al. 1991) and juveniles prefer rearing temperatures of 61°F 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.3-11). 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-significant impact on Striped Bass relative to the No Action Alternative.

O.3.3.2.17 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 fresh water, 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 2002b, 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 1 appear to have minor benefits to American Shad relative to the No Action Alternative, but because the potential

effects are highly uncertain, Alternative 1 is considered to have a less-than-significant effect on American Shad.

O.3.3.2.18 Largemouth Bass

Largemouth Bass are warm water 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 warm water 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.3.3.2.19 Smallmouth Bass

Smallmouth Bass prefer large, clear lakes and streams and rivers with abundant cover and cool (68°F to 80°F) summer temperatures (Moyle 2002). The optimal temperature range for spawning is 55°F to 70°F (Brown et al. 2009b) and the optimal for adult growth is approximately 77°F 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°F 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°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 feet to 8 feet (Brown et al. 2009b). 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 55°F 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°F 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.3.3.2.20 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°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 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°F to 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 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 be within the 59°F to 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°F 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 cold water pool storage on May 1, combined with summer and fall storage predictions from water temperature modeling. In years with high May 1 cold water 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 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 cold water 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 cold water pool on May 1. In years with low May 1 cold water 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 cold water 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 evaluate the performance of the cold water 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 Sacramento River Temperature Task Group to develop alternative protective strategies and measures for the early life stages. More detailed description of this component is provided in Appendix D. Management of the Shasta cold water 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 significant impact of elevated temperature on Southern DPS

Green Sturgeon adults relative to the No Action Alternative (see Section O.3.3.2.4, *Southern DPS Green Sturgeon*), but this impact results from the cessation of Delta fall X2 flows under Alternative 1 rather than Shasta cold water pool management. Alternative 1 is expected to benefit Winter-Run Chinook Salmon and Spring-Run Chinook Salmon with respect to cold water pool management relative to the No Action Alternative, and is considered to have a less-than-significant 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 cold water pool management through the summer and fall. Reclamation would not make a spring pulse flow release if the release would reduce the cold water pool such that summer Shasta temperature management drops into a Tier 4 schedule (see Appendix D, Section 4.3.1.4, *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 cold water 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 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 substantially 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 flows 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 cold water 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 cold water 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.

Whiskeytown Storage / monthly statistics (5-2-12-1b):

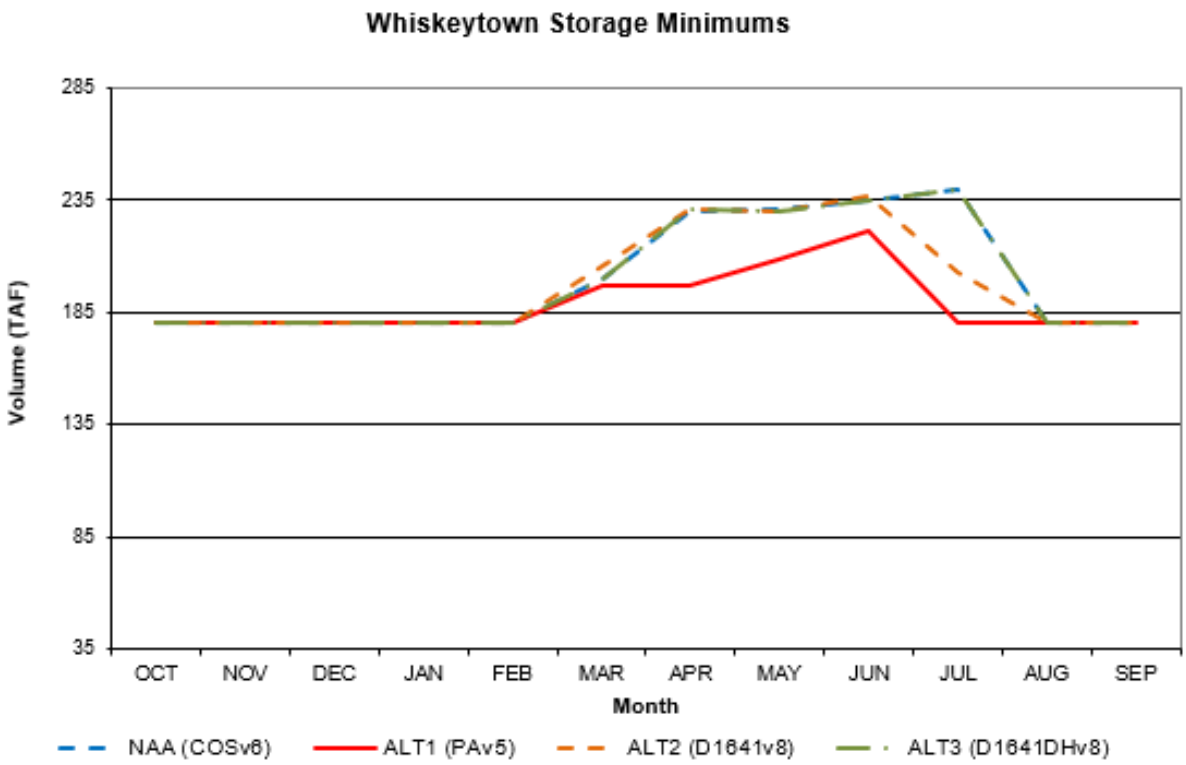


Figure O.3-46. Modeled Whiskeytown Lake Monthly Minimum Storage Volume under the No Action Alternative, Alternative 1, Alternative 2, and Alternative 3 during All Water Year Types

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 on 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.

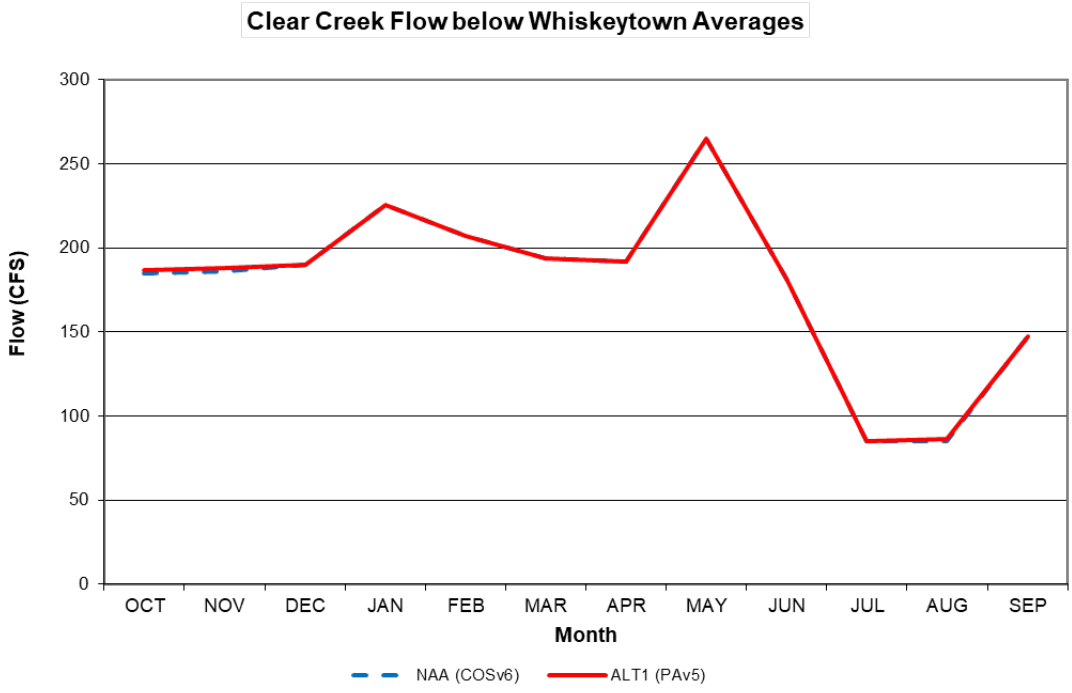


Figure O.3-47. Average Annual Flow in Clear Creek below Whiskeytown Dam for the No Action Alternative and Alternative 1 (40-30-30 Index)

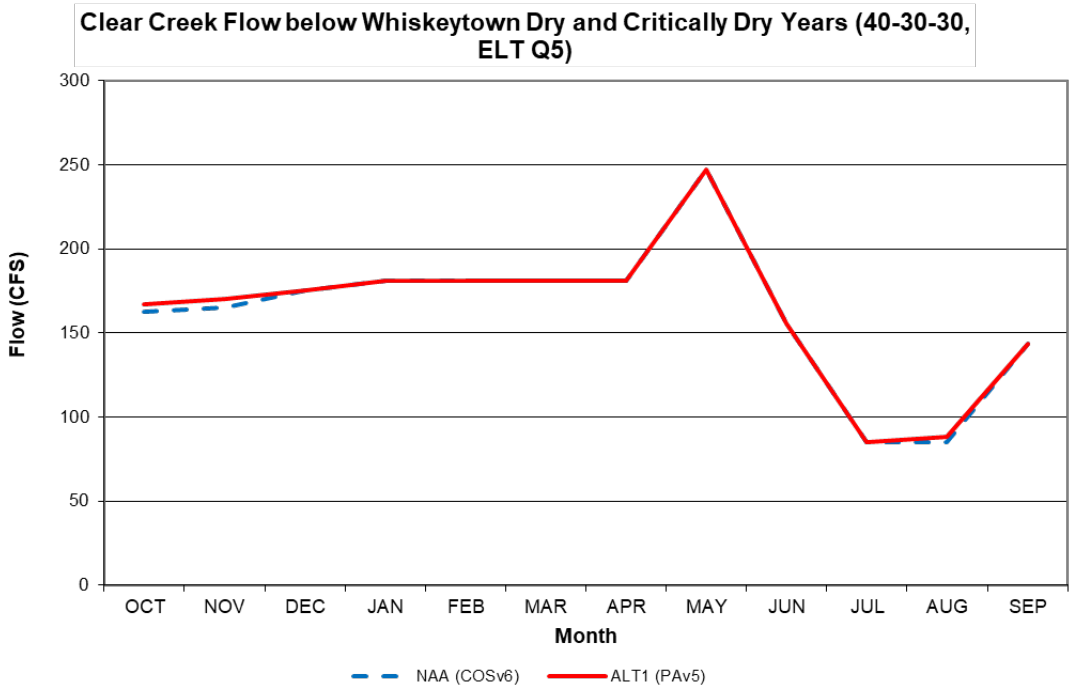


Figure O.3-48. Average Annual Flow in Clear Creek below Whiskeytown Dam for the No Action Alternative and Alternative 1 during Dry and Critically Dry Water Years (40-30-30 Index)

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).

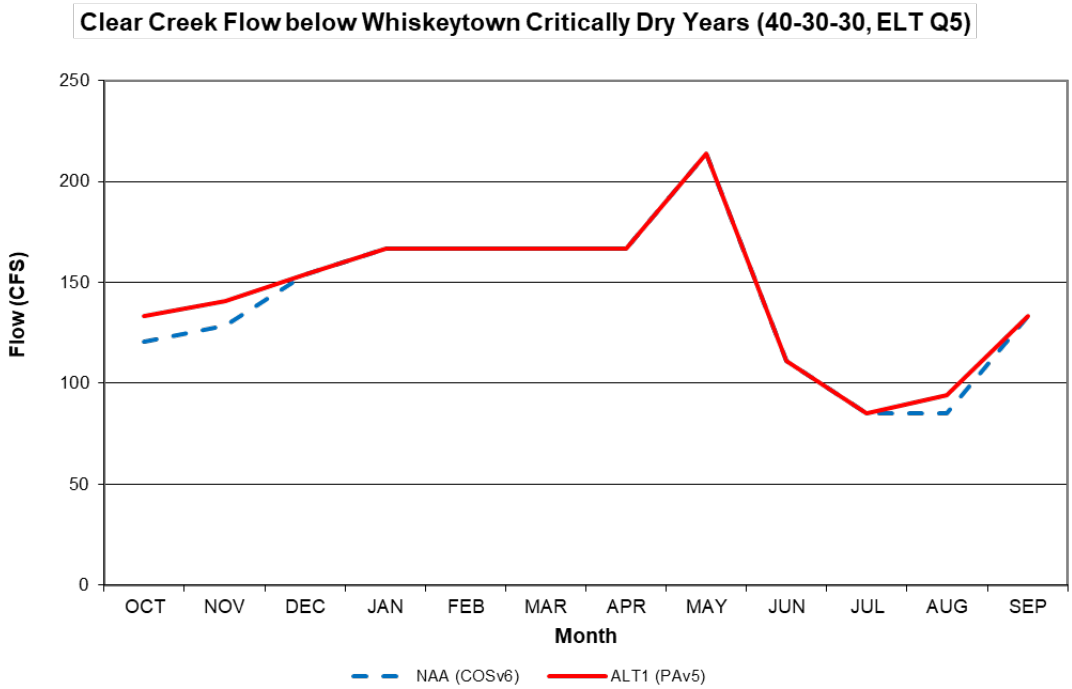


Figure O.3-49. Average Monthly Flow in Clear Creek below Whiskeytown Dam for the No Action Alternative and Alternative 1 during Critically Dry Water Years (40-30-30 Index)

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 out-migrating 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 out-migrating 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).

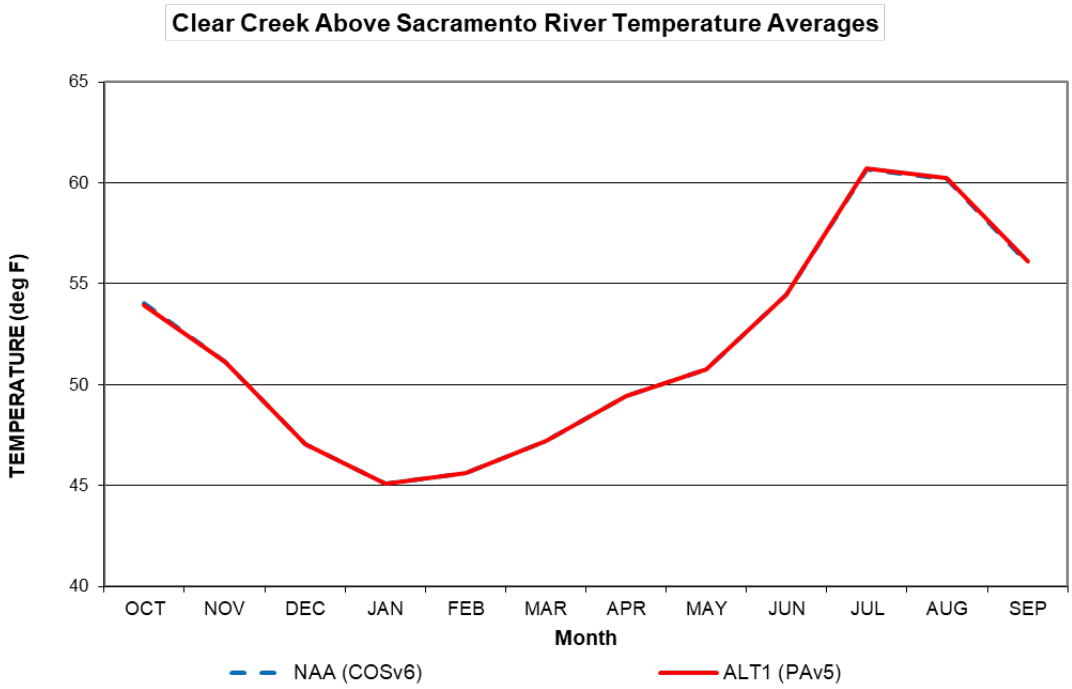


Figure O.3-50. Average Monthly Water Temperatures in Clear Creek above the Sacramento River for the No Action Alternative and Alternative 1

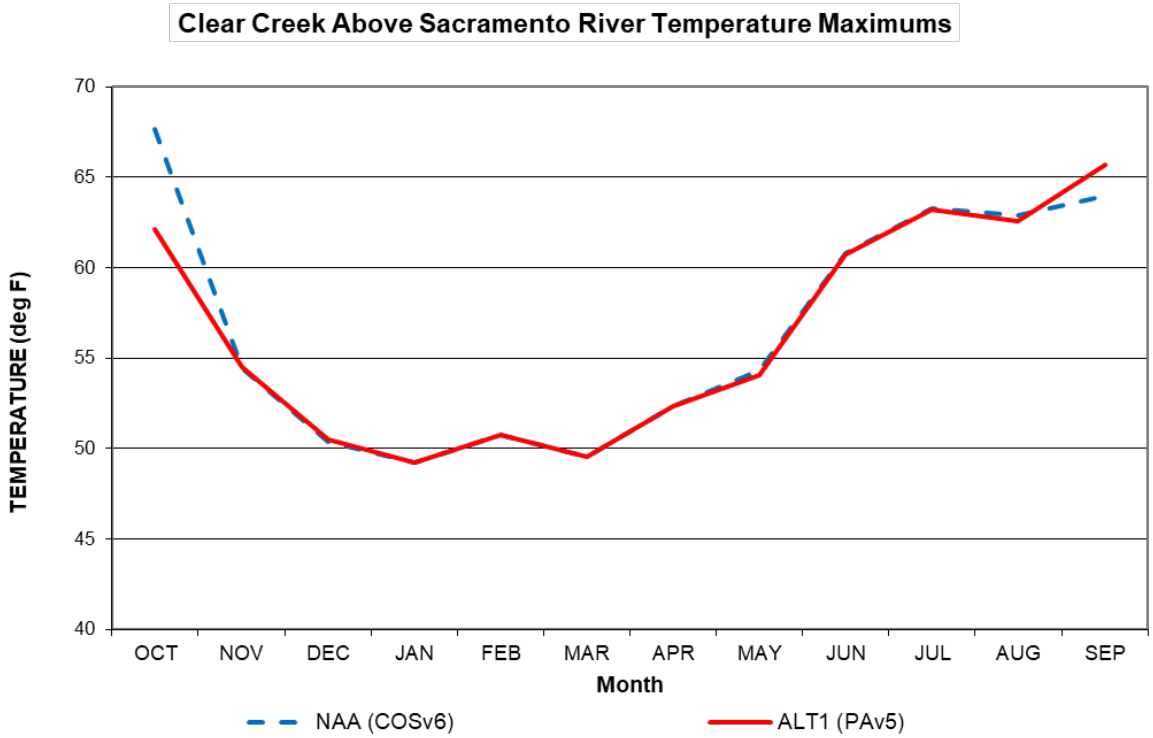


Figure O.3-51. Maximum Modeled Water Temperatures in Clear Creek above the Sacramento River under the No Action Alternative and Alternative 1

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 5-year review of the project (USEPA 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 No Action Alternative) 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. From 2012 to 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-CDFW 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).

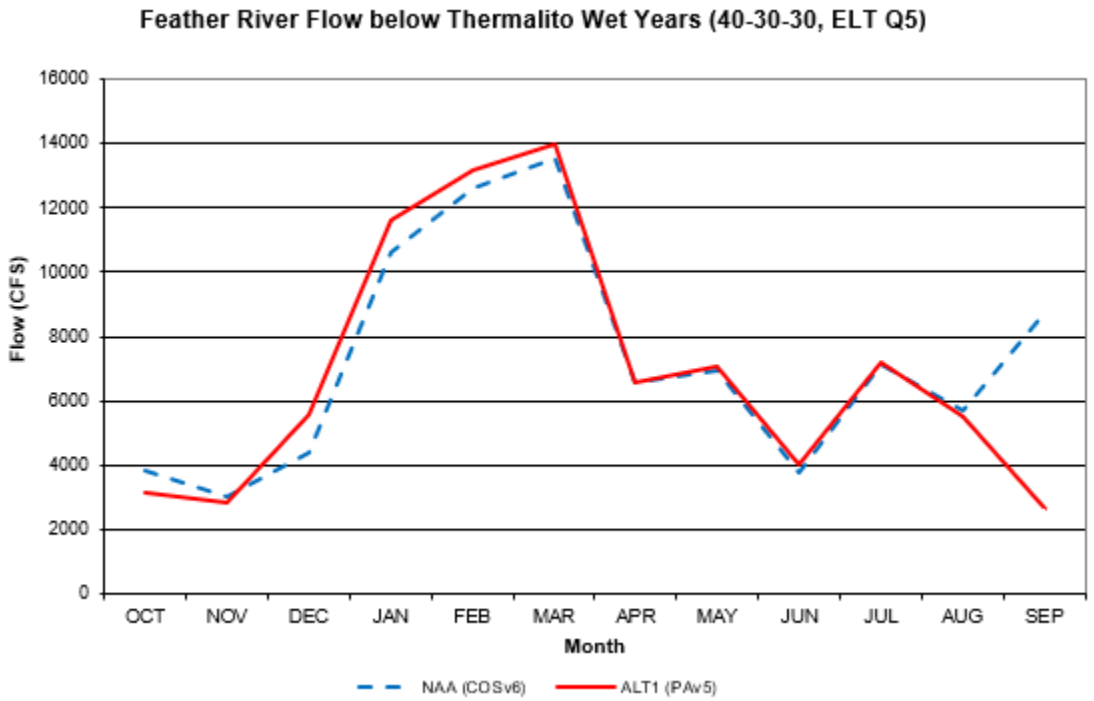
Under the No Action Alternative, DWR would operate Oroville Dam in accordance with ongoing management policies, criteria, and regulations, including water right permits and licenses issued by the SWRCB and operational requirements of the 2008 USFWS BO and the 2009 NMFS BO. Under the No Action Alternative, DWR typically releases water from Lake Oroville to meet the requirements of instream flows and D-1641.

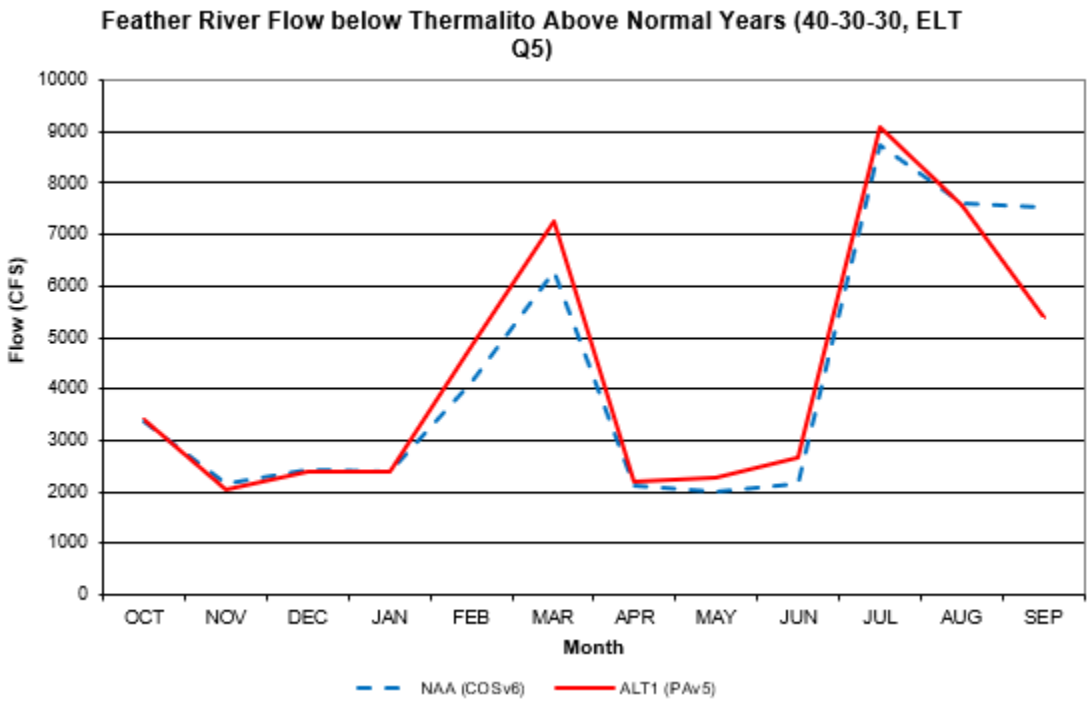
Table O.3-19. Feather River HFC Minimum Instream Flow Requirements

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 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)
ALT1 (PAv5)


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
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MAY
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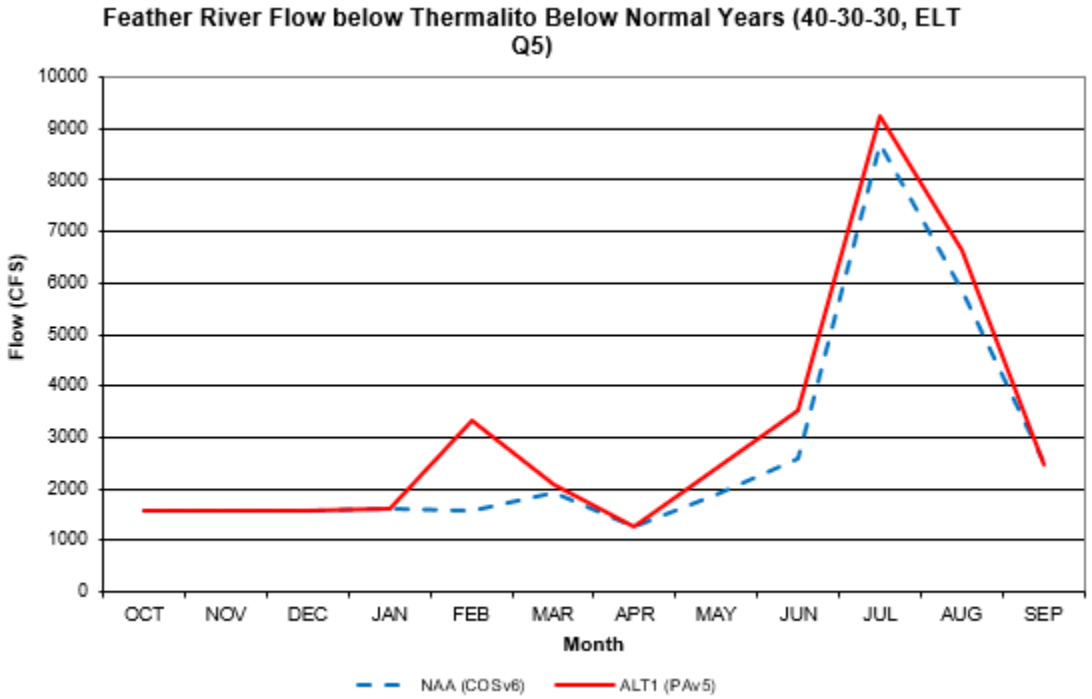
Month
NAA (COSv6)
ALT1 (PAv5)


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
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MAR
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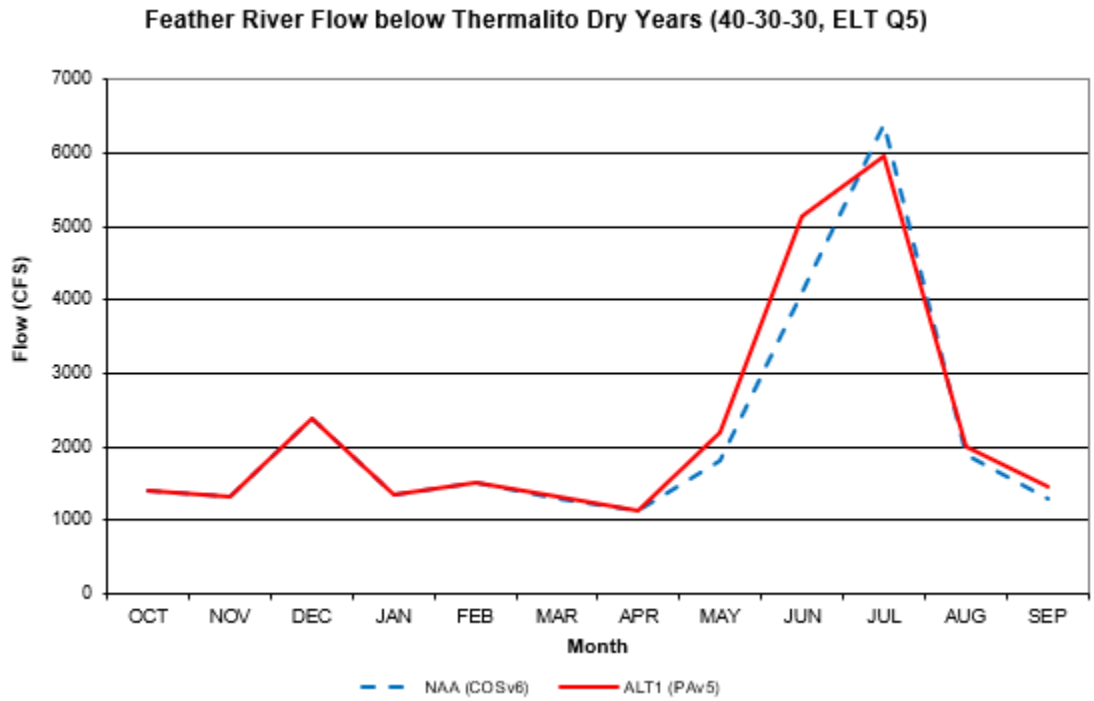
Month
NAA (COSv6)
ALT1 (PAv5)


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
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JUN
JUL
AUG
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Month
NAA (COSv6)
ALT1 (PAv5)

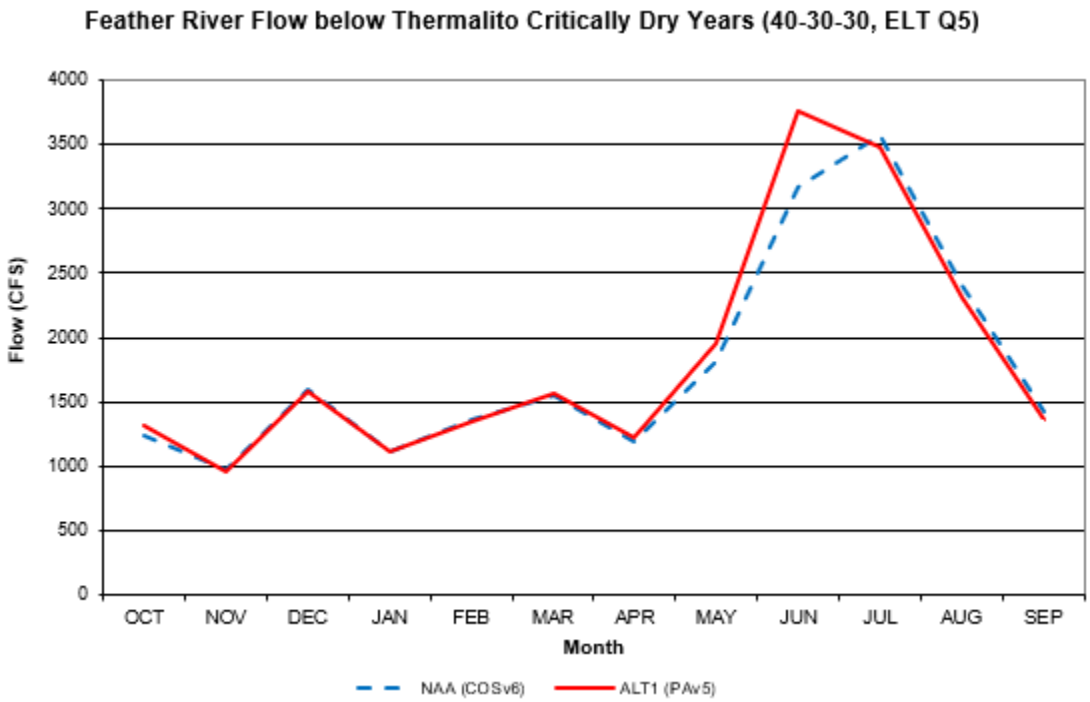


Figure O.3-52. CalSim II Estimates of Feather River Long-Term Average Flow below Thermalito, All Scenarios in Wet, Above Normal, Below Normal, Dry, and Critically Dry Water Years

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 oxygen content (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 from January to April; juveniles out-migrating year-round with peaks from January to April and August to November; and holding and migrating adults occurring from April to 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 oxygen due 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 oxygen content (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

oxygen 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 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).

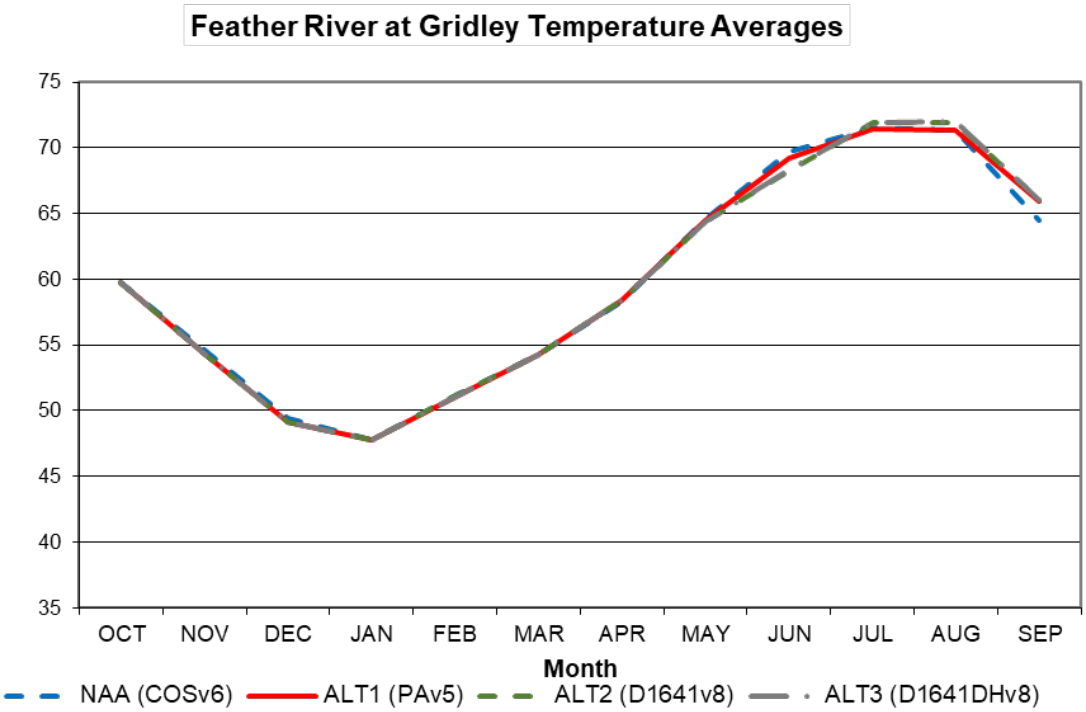
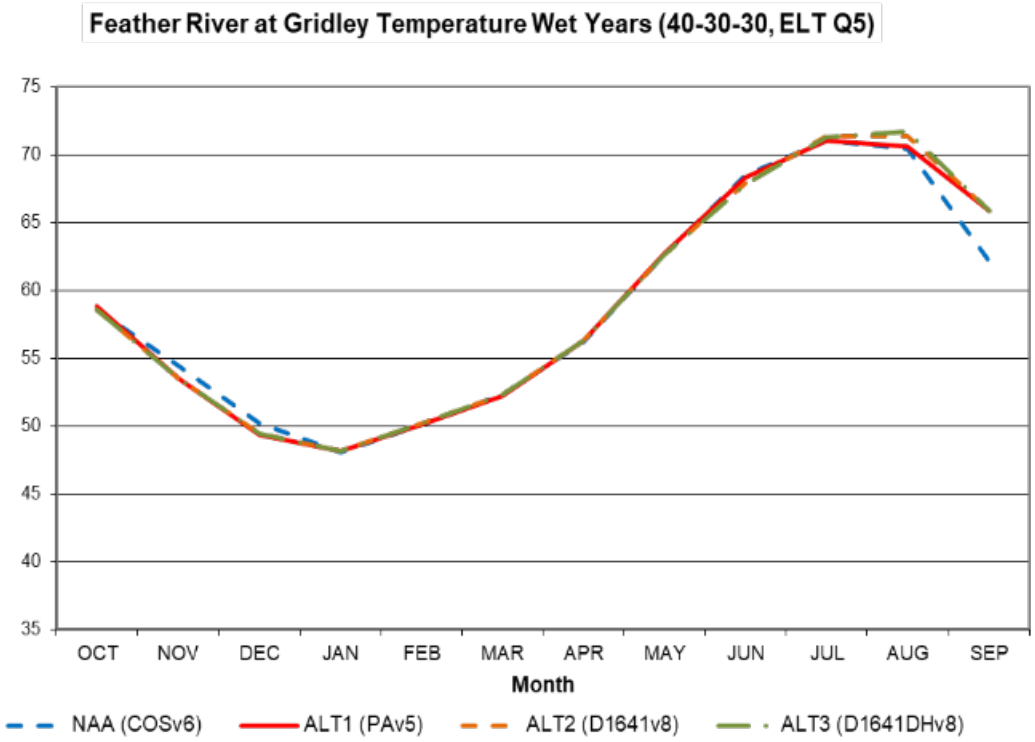


Figure O.3-53. RecTemp Average Feather River Water Temperatures at Gridley Bridge under the No Action Alternative, Alternative 1, Alternative 2, and Alternative 3 Scenarios



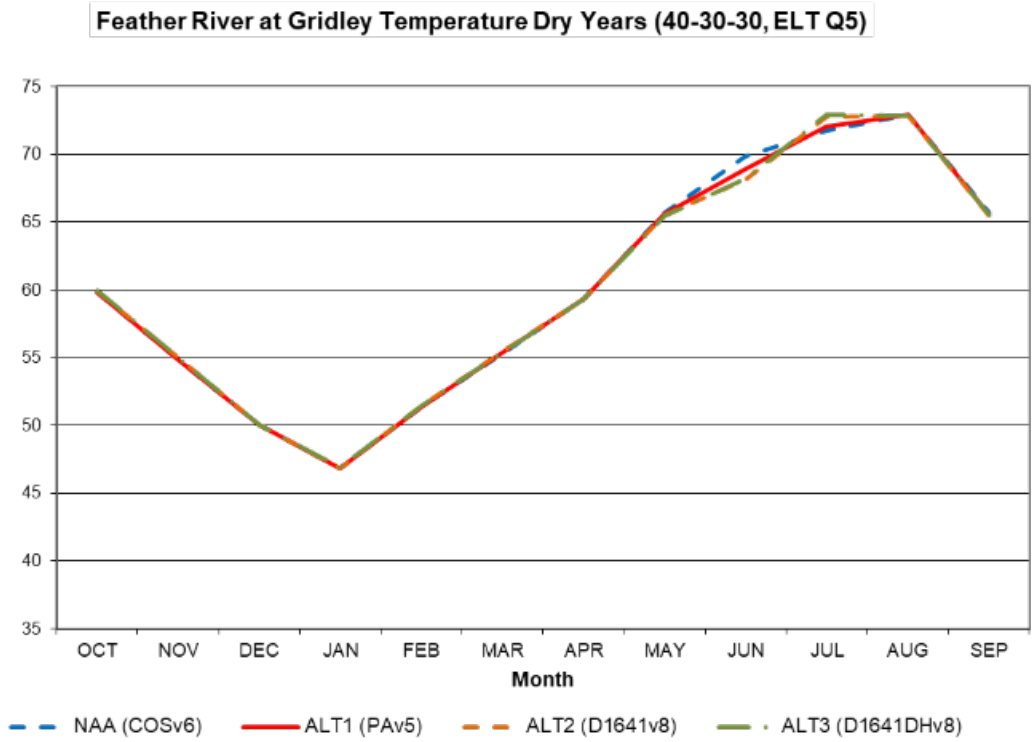


Figure O.3-54. RecTemp Average Estimated Feather River Water Temperatures at Gridley Bridge in Wet and Dry Water Year Types under the No Action Alternative, Alternative 1, Alternative 2, and Alternative 3 Scenarios

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 from October to 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 during 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 from March to 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 cold water 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.

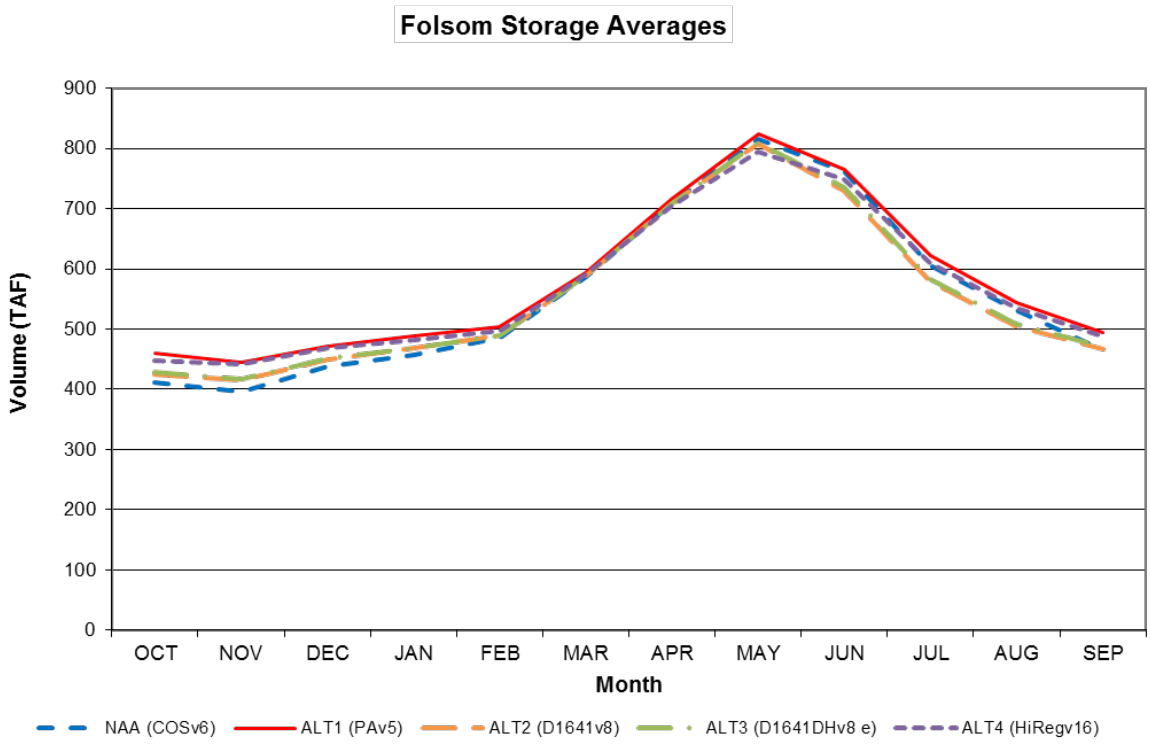


Figure O.3-55. Folsom Reservoir Storage under Average Conditions

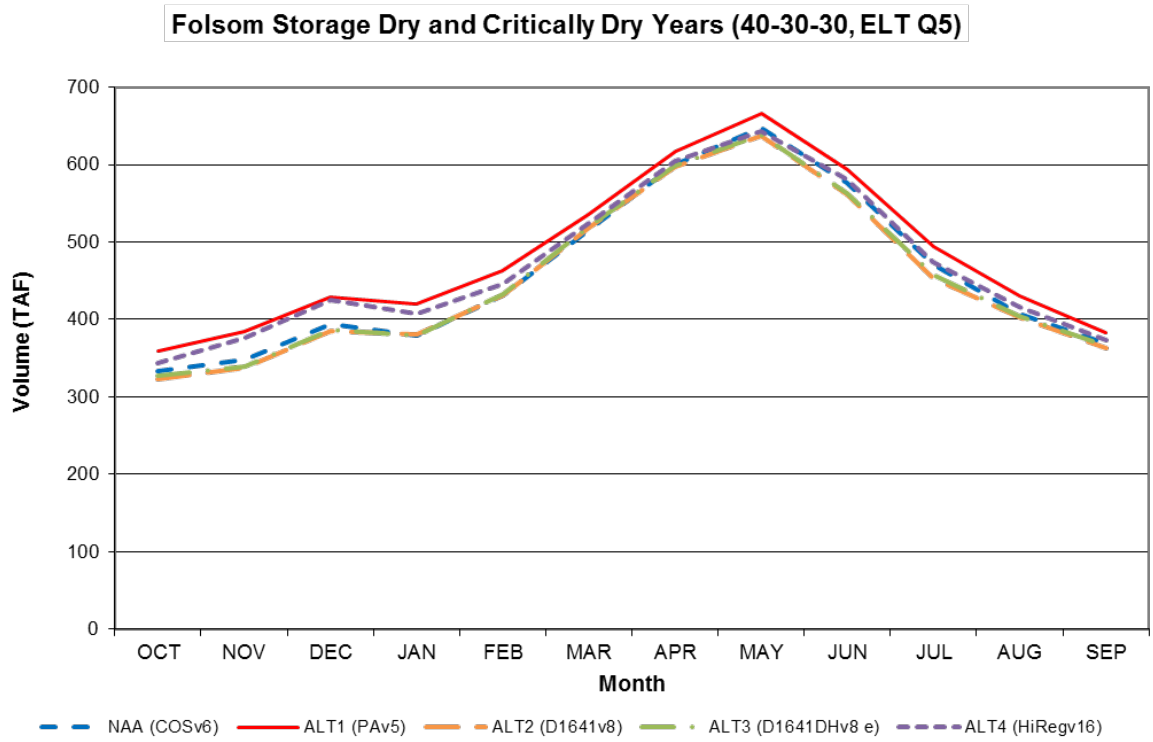


Figure O.3-56. Folsom Reservoir Storage in Dry and Critically Dry Years

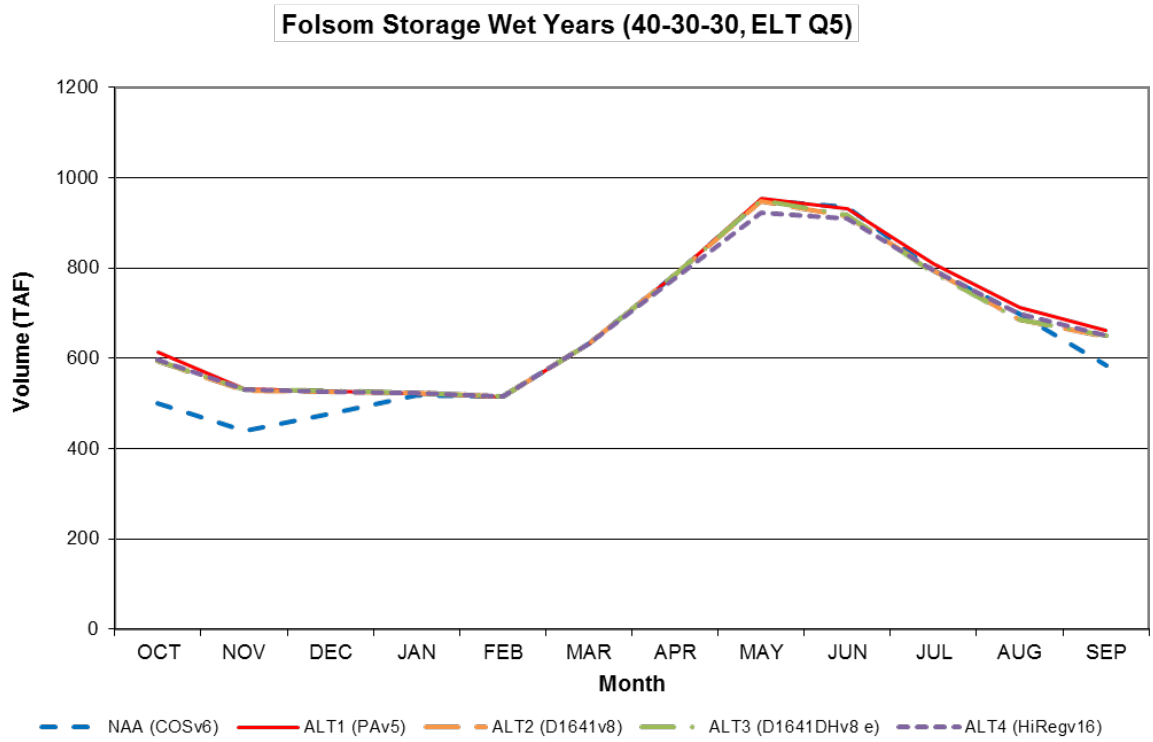


Figure O.3-57. Folsom Reservoir Storage in Wet Water Years

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).

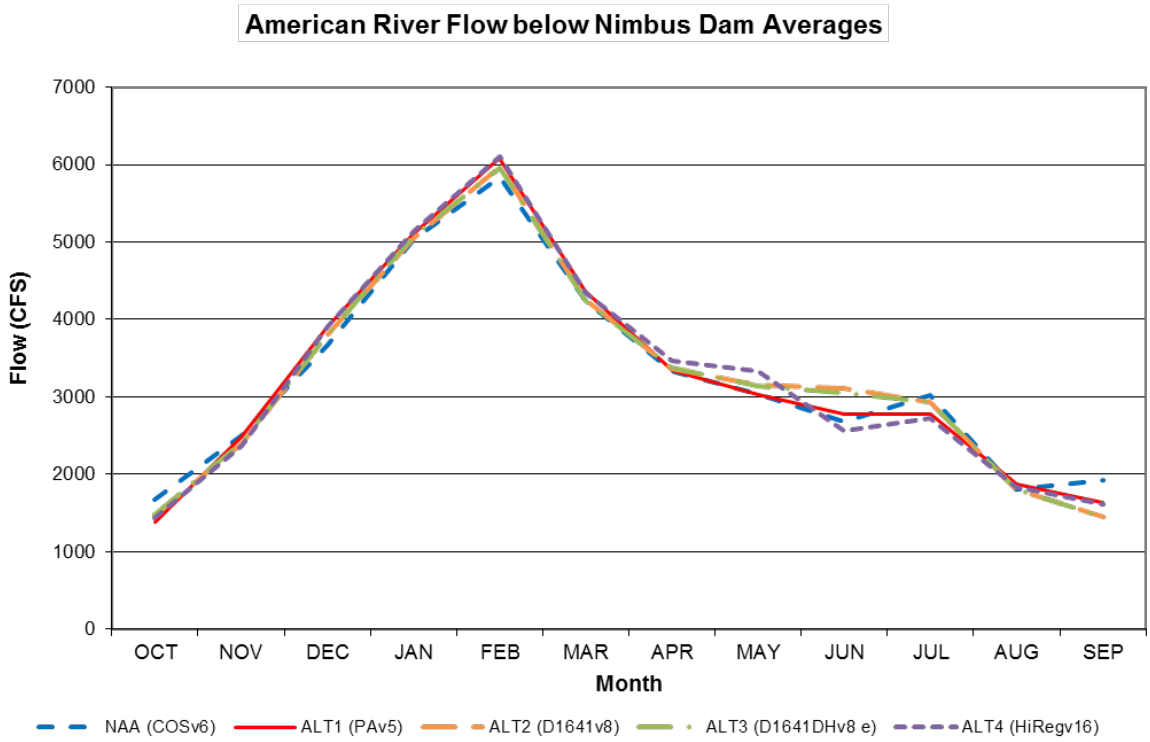


Figure O.3-58. Average Flows in the American River below Nimbus Dam at Watt Avenue

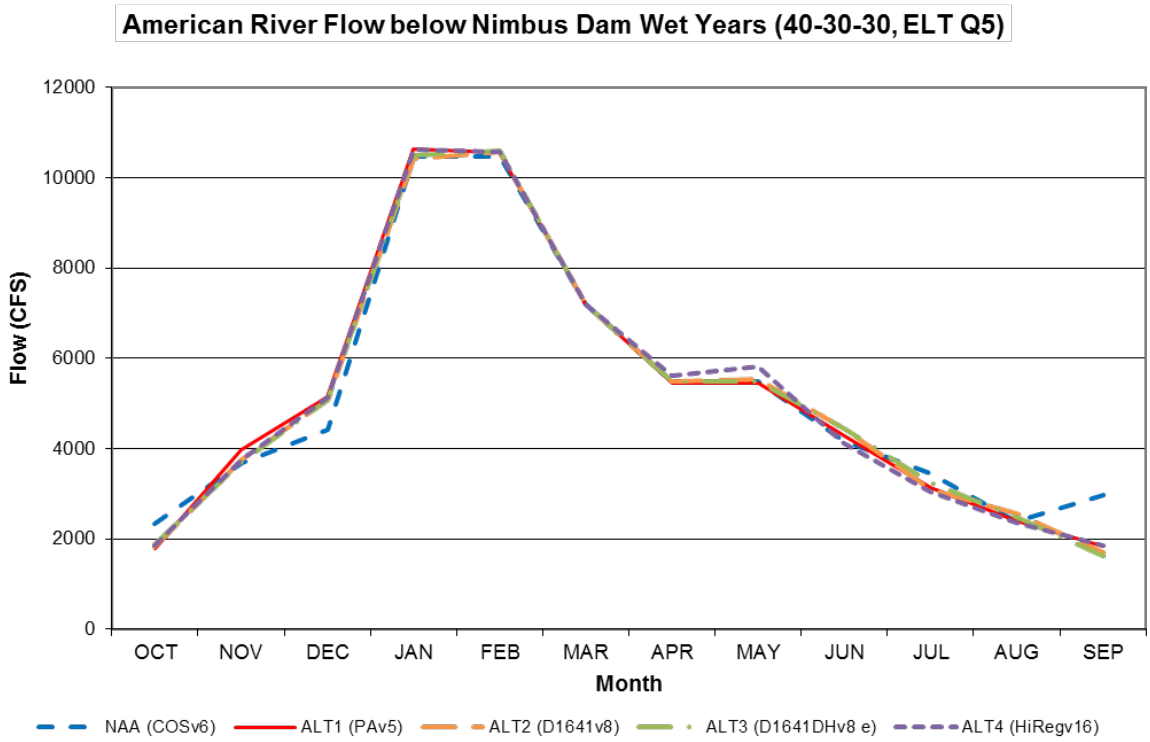


Figure O.3-59. Flows in the American River below Nimbus Dam in Wet Water Years

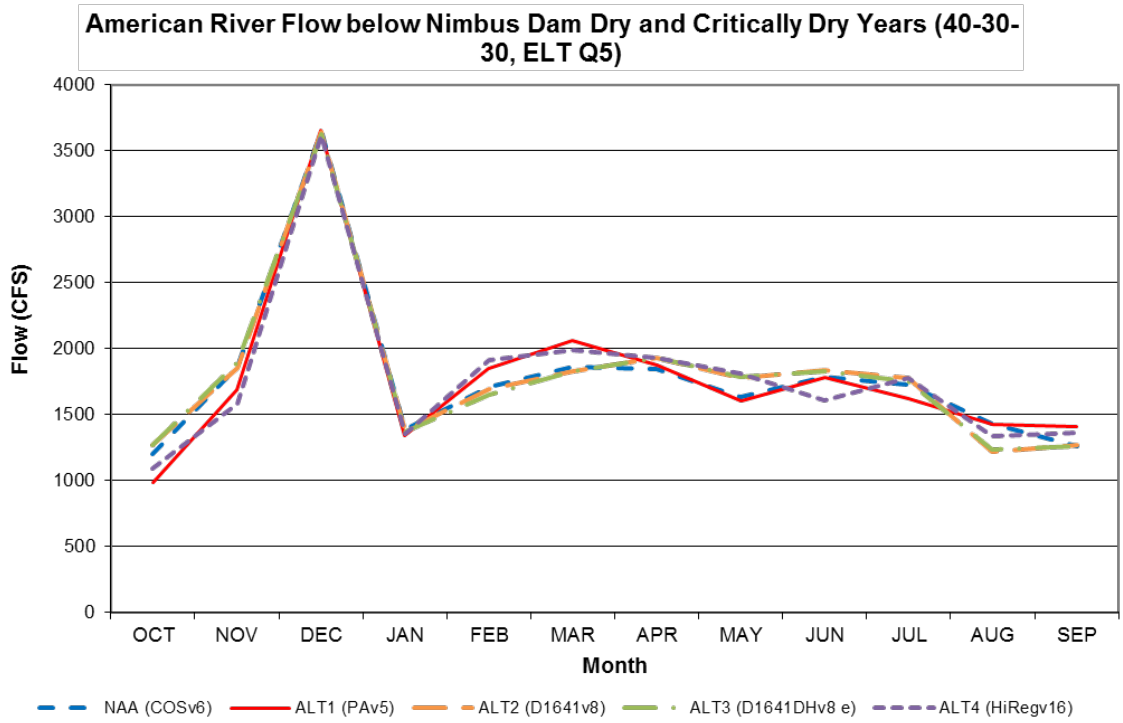


Figure O.3-60. Flows in the American River below Nimbus Dam in Dry and Critically Dry Years

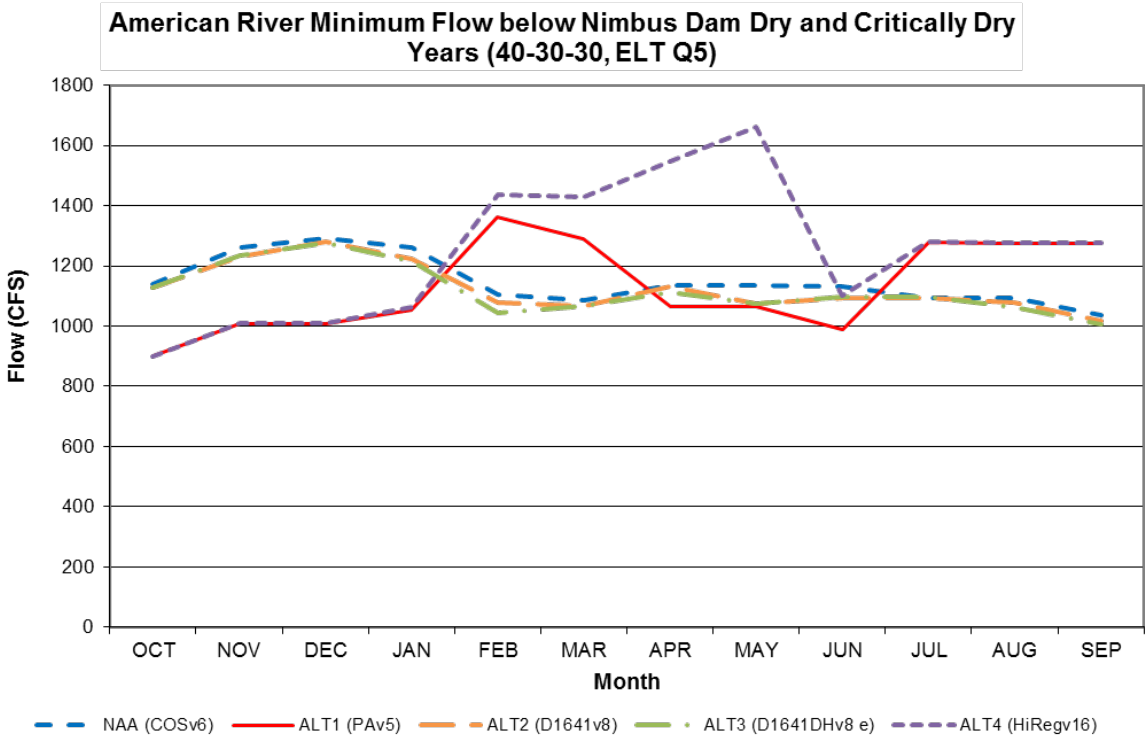


Figure O.3-61. Minimum Flows in the American River below Nimbus Dam in Dry and Critically Dry Years

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).

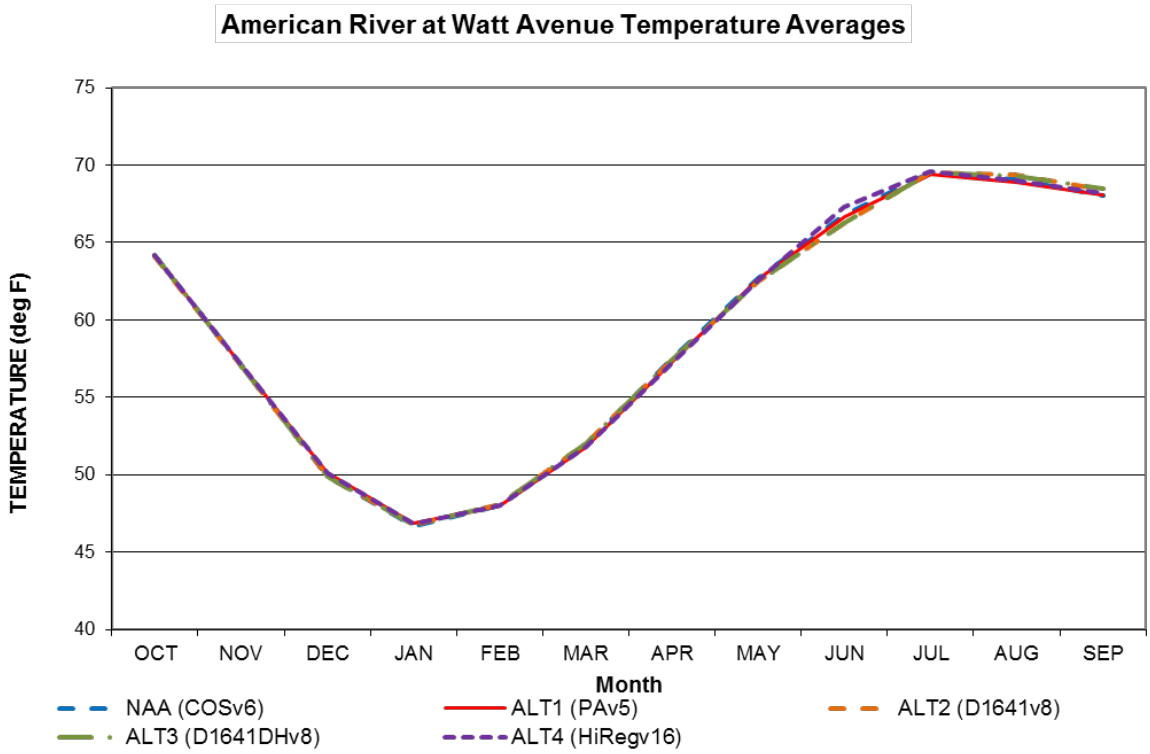


Figure O.3-62. Average Temperatures at Watt Avenue on the American River

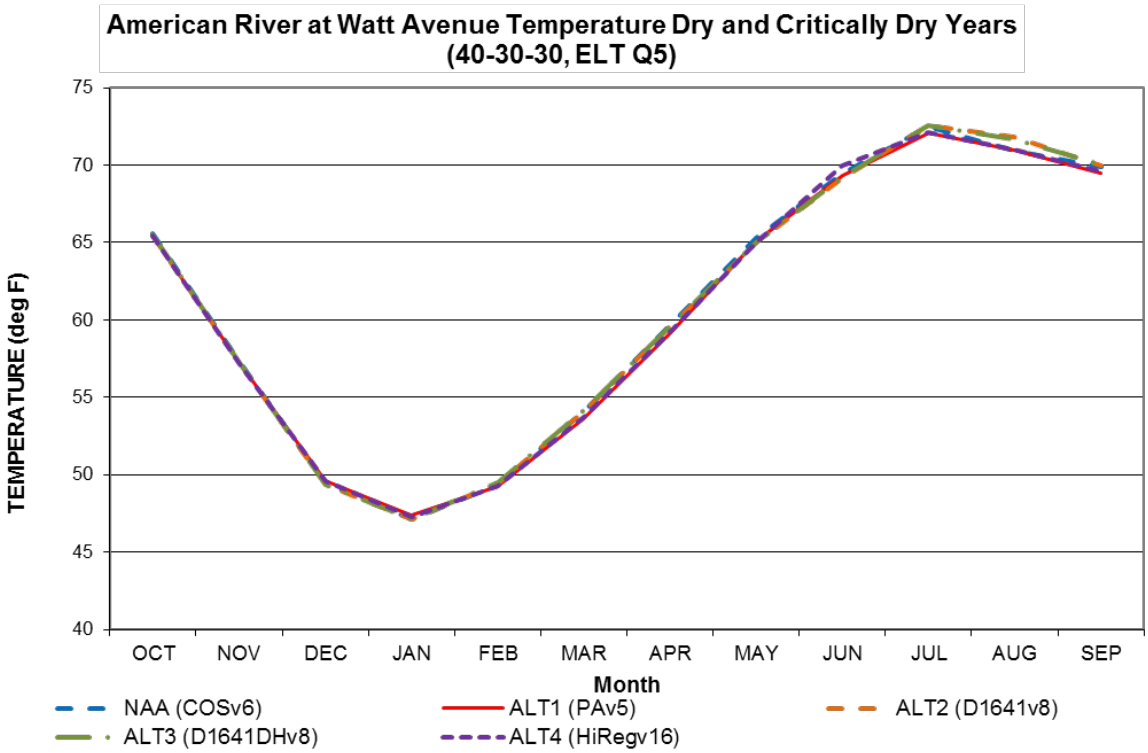


Figure O.3-63. Average Temperatures at Watt Avenue on the American River in Dry and Critically Dry Years

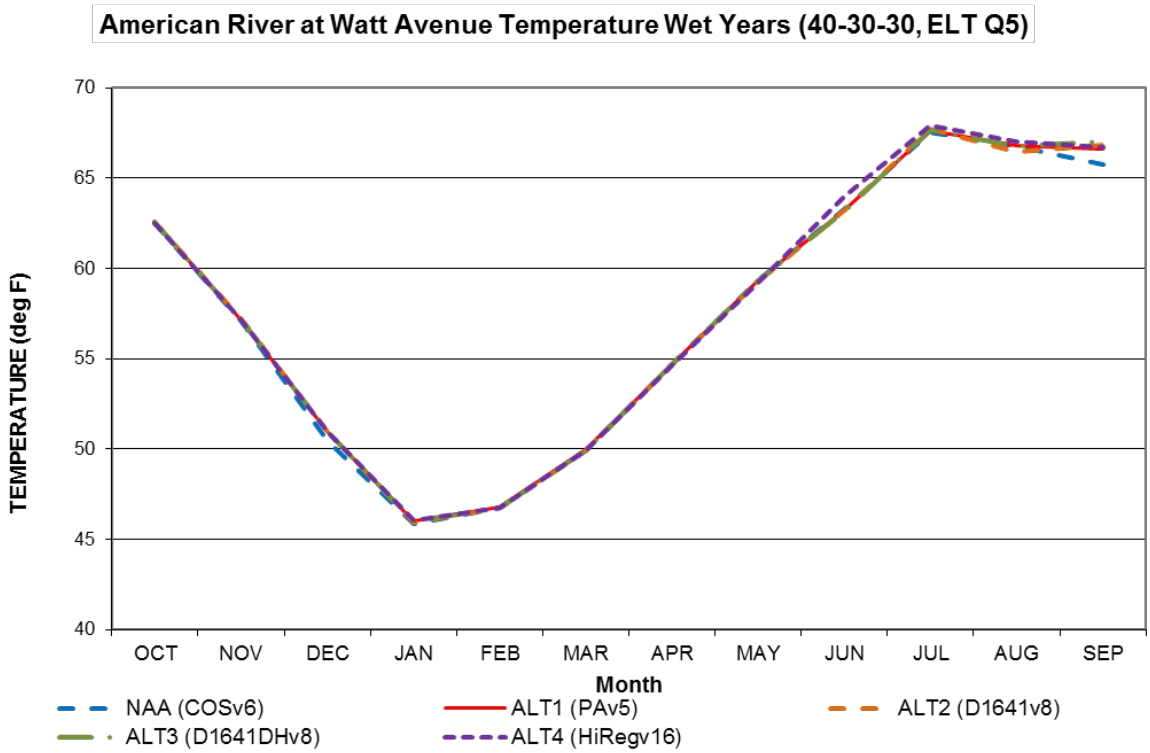


Figure O.3-64. Average Temperatures at Watt Avenue on the American River

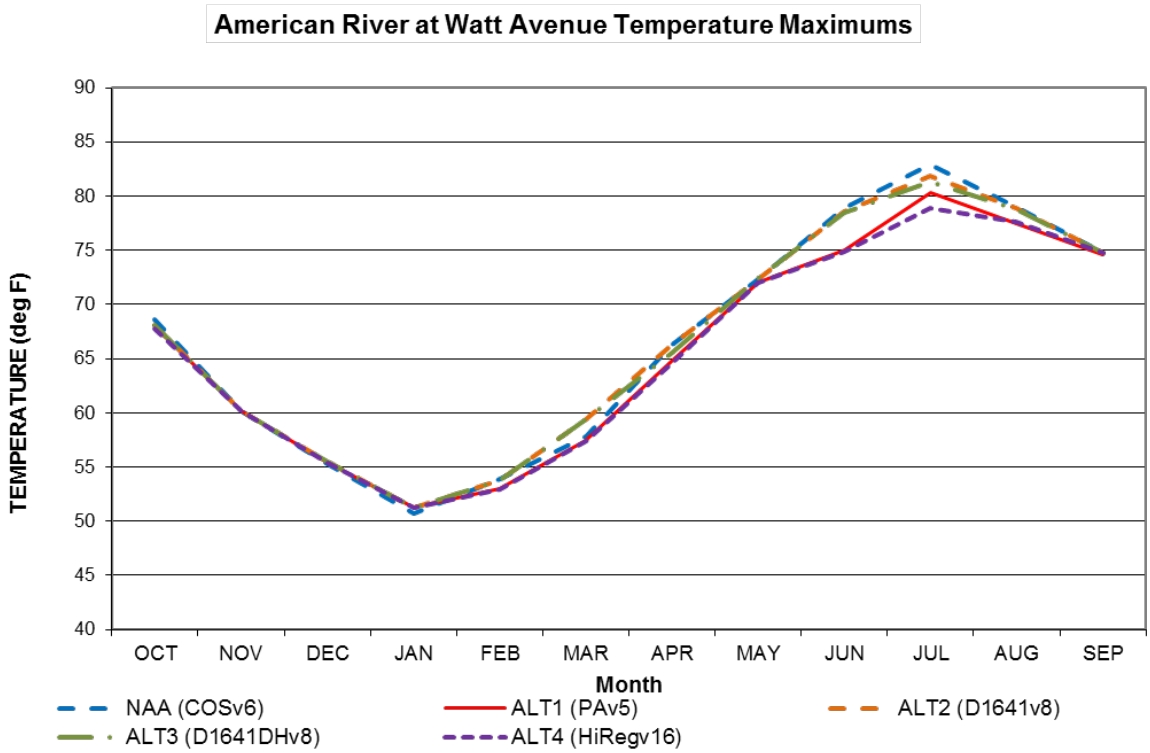


Figure O.3-65. Maximum Temperatures at Watt Avenue on the American River

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 on salmonids are similar to those described above due to water operations being similar to the No Action Alternative.

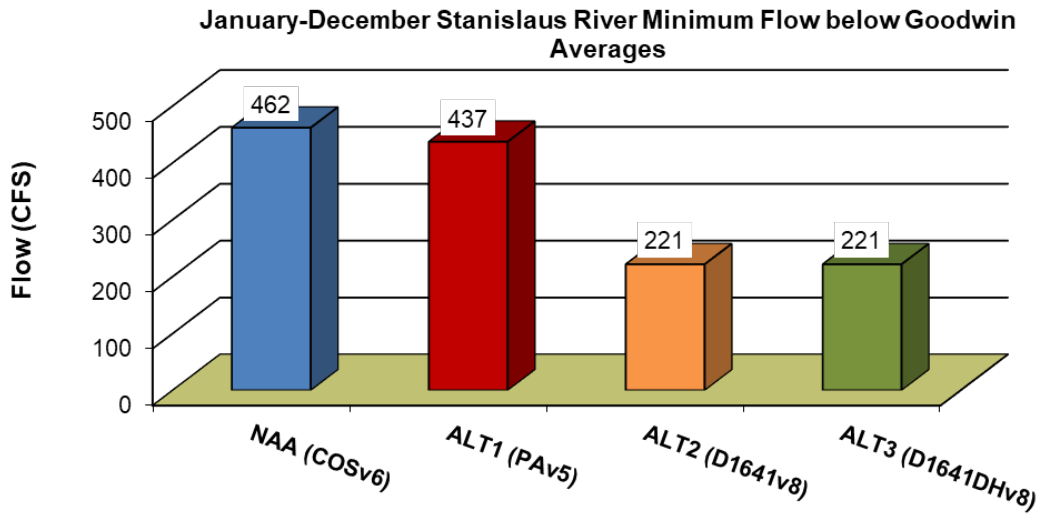


Figure O.3-66. Annual Average Minimum Flow below Goodwin Dam for Each Action Alternative

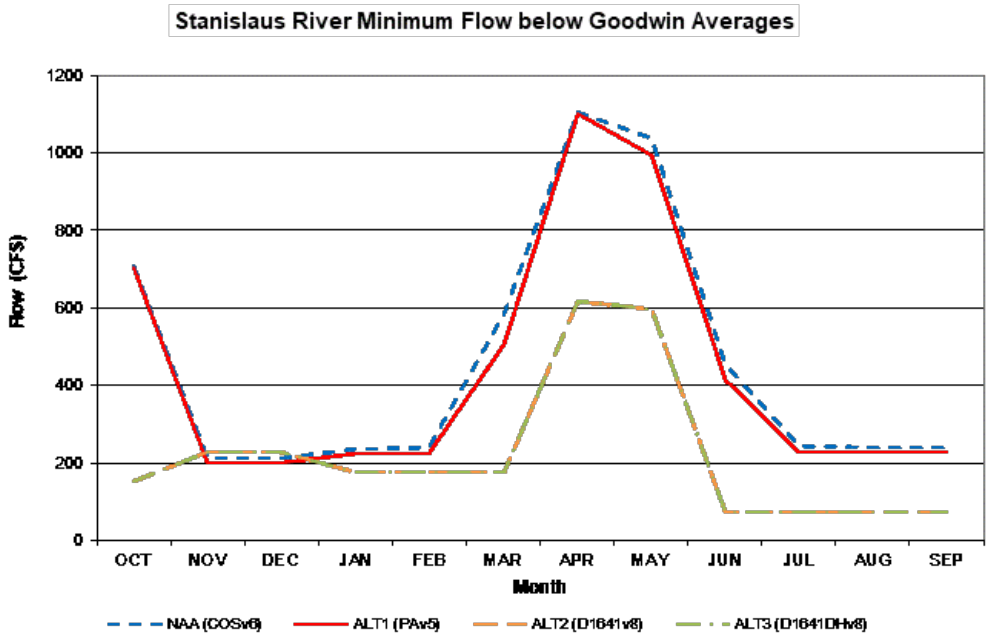


Figure O.3-67. Stanislaus River Average Minimum Flow below Goodwin Dam

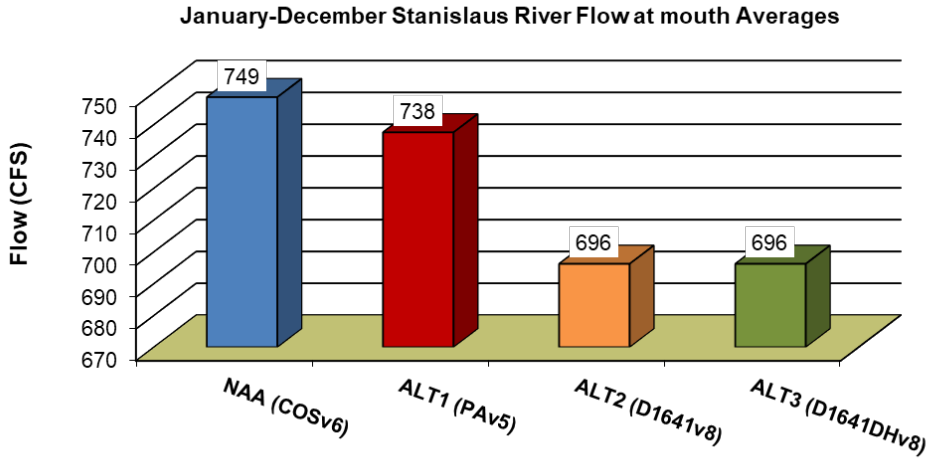


Figure O.3-68. Average Annual Flow at the Mouth of the Stanislaus River

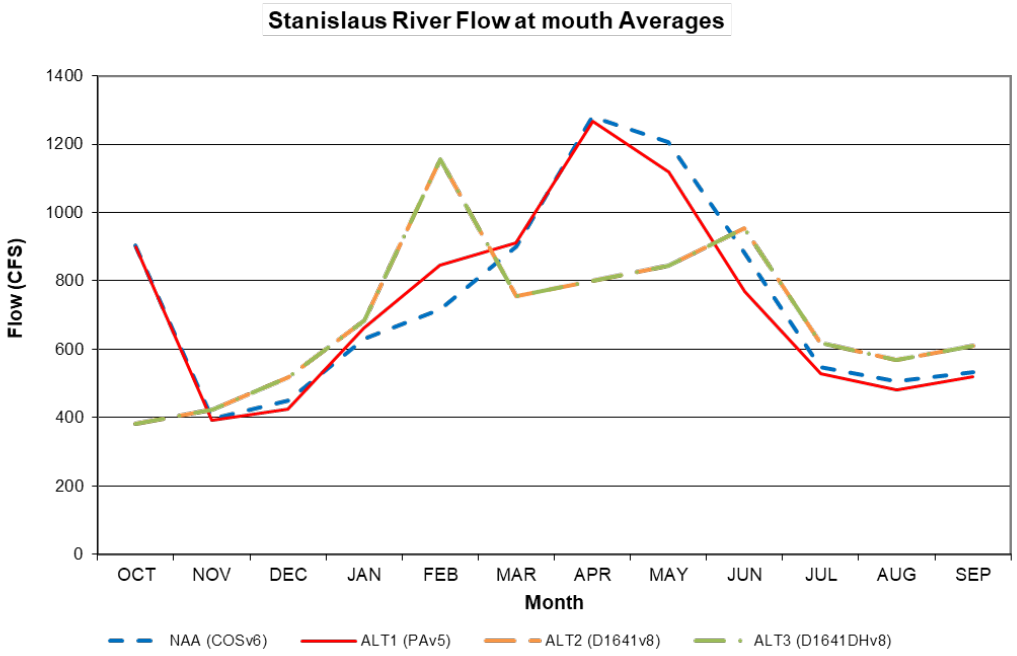


Figure O.3-69. Average Monthly Flow at the Mouth of the Stanislaus River

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 SRP 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 for Chinook salmon identified by the Fisheries Management Working Group for the San Joaquin River Restoration Program are provided in Table O.3-23 (SJRRP 2010)**.**

Table O.3-23. Temperature Objectives for the Restoration of Central Valley Chinook Salmon

Table 3-1.
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. **Table 3-1 from Exhibit A of SJRRP (2010).**
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

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 cold water pool, leads to improved cold water pool performance in droughts, benefitting salmonid eggs.

The SRP under Alternative 1 would provide cold water 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 out-migrating 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 cold water 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, *San Joaquin River*.

O.3.3.8 *Bay-Delta*

O.3.3.8.1 Delta Smelt

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 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 D, Attachment 3-2, Figures 32-9 through 32-14 of the ROC LTO BA), 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 D, Attachment 3-3, Figures 53-12 through 53-14 of the ROC LTO BA), 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 D, Attachment 3-2, Figures 29-15 through 29-18 of the ROC LTO BA), 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 2019). However, CalSim modeling suggests little difference in Yolo Bypass flows between Alternative 1 and the No Action Alternative (Appendix D, Attachment 3-2, Figures 25-6 through 25-18 of the ROC LTO BA). 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 D, 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 to 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.

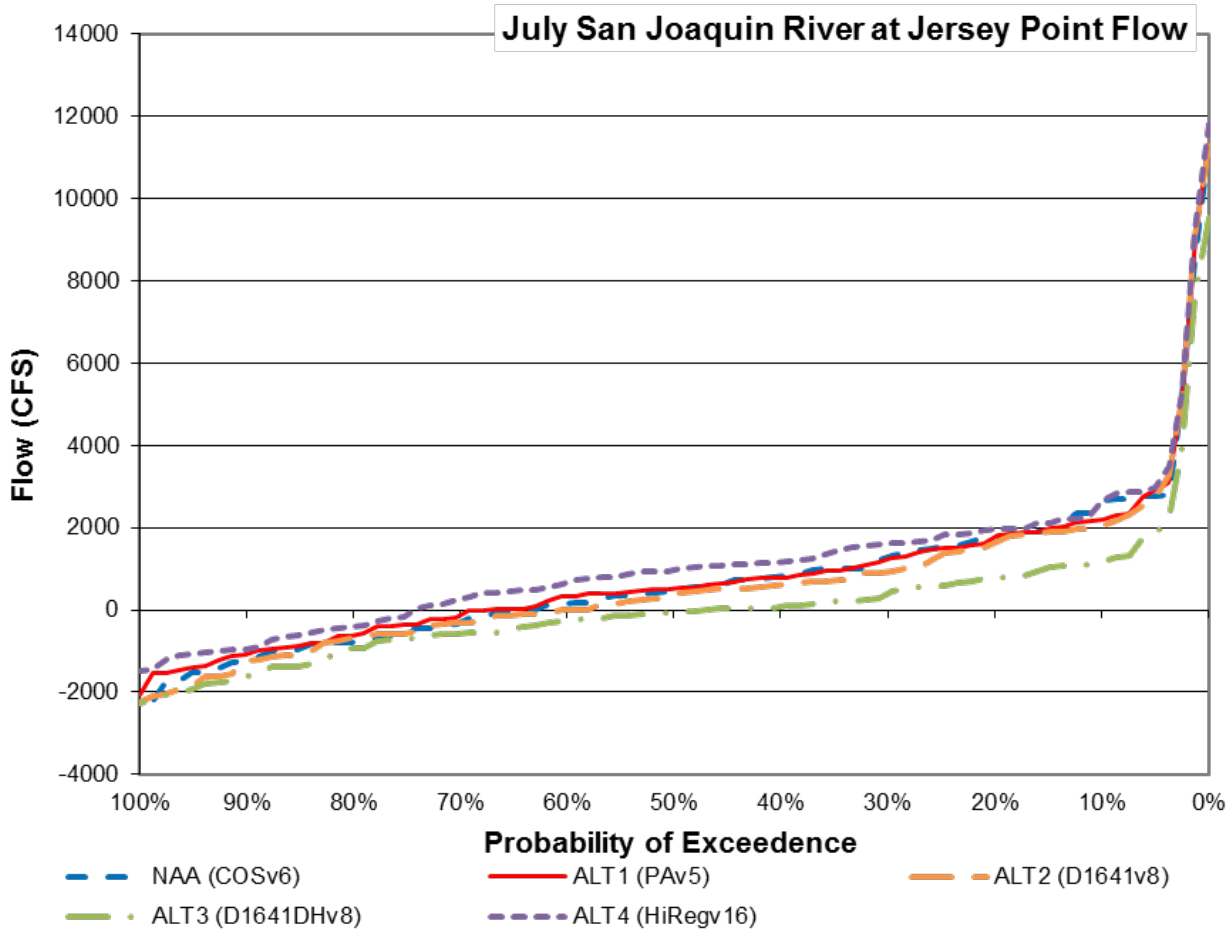


Figure O.3-70. DSM2-HYDRO-Modeled Probability of Exceedance of San Joaquin River Flow at Jersey Point, July

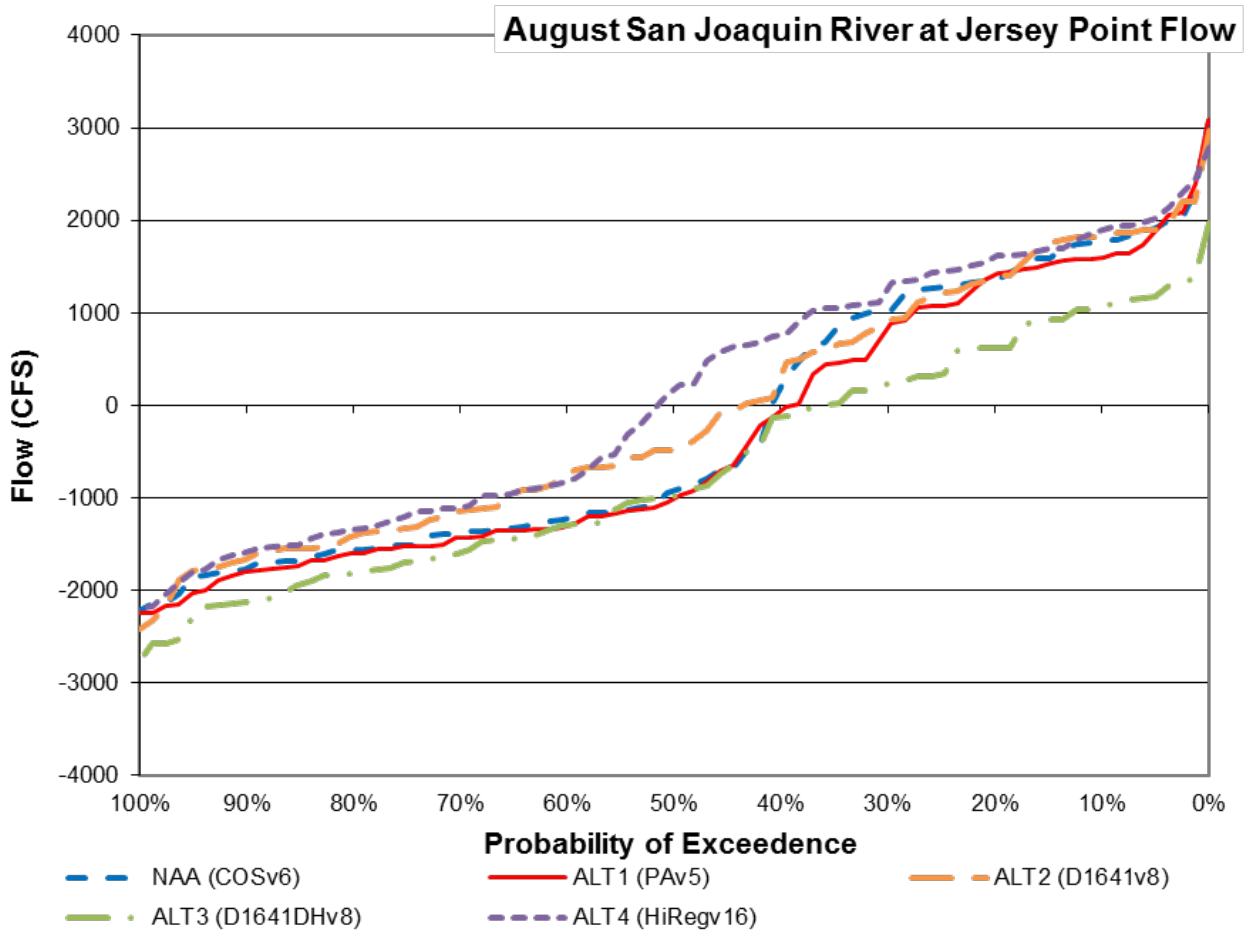


Figure O.3-71. DSM2-HYDRO-Modeled Probability of Exceedance of San Joaquin River Flow at Jersey Point, August

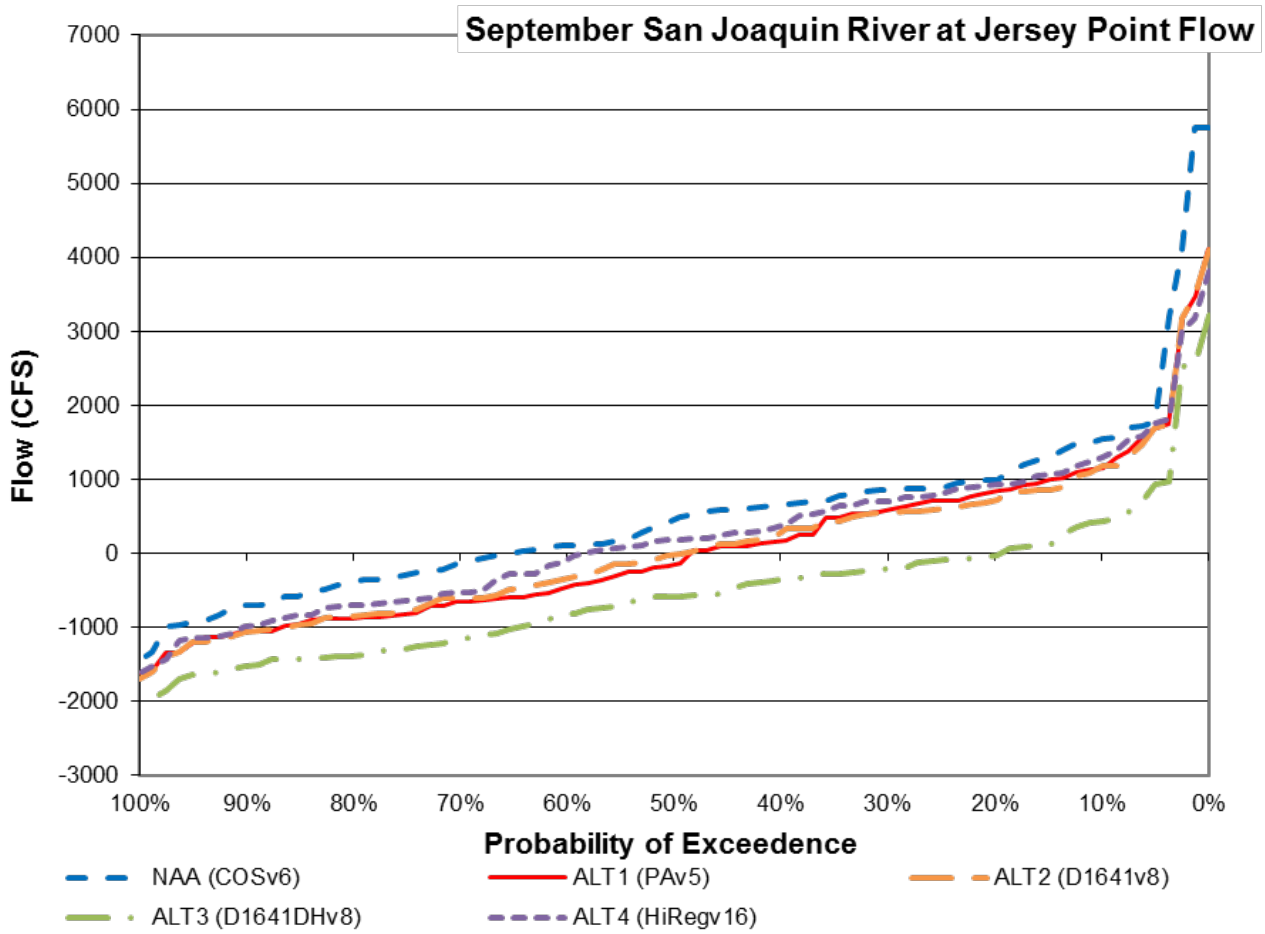


Figure O.3-72. DSM2-HYDRO-Modeled Probability of Exceedance of San Joaquin River Flow at Jersey Point, September

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 on 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.

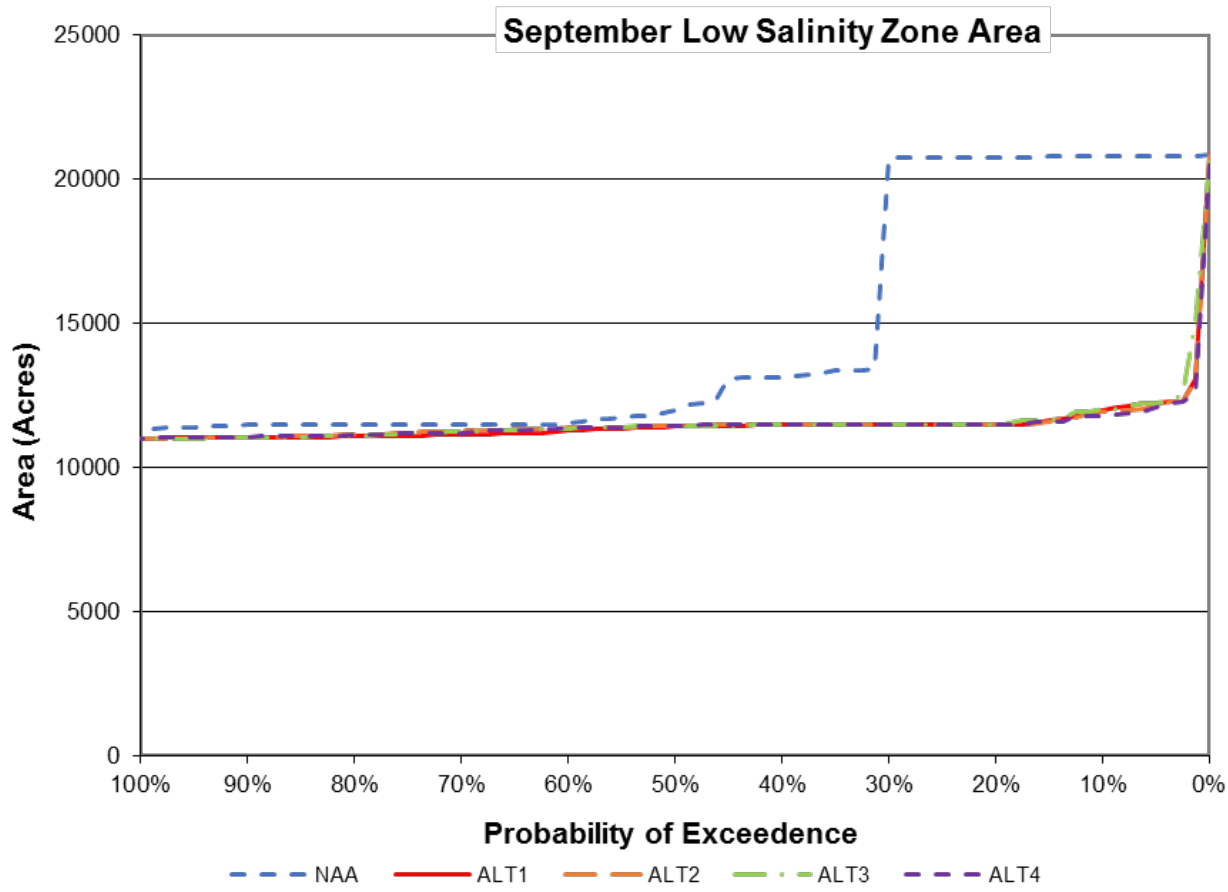


Figure O.3-73. Low Salinity Zone Area Estimated from CalSim X2, September

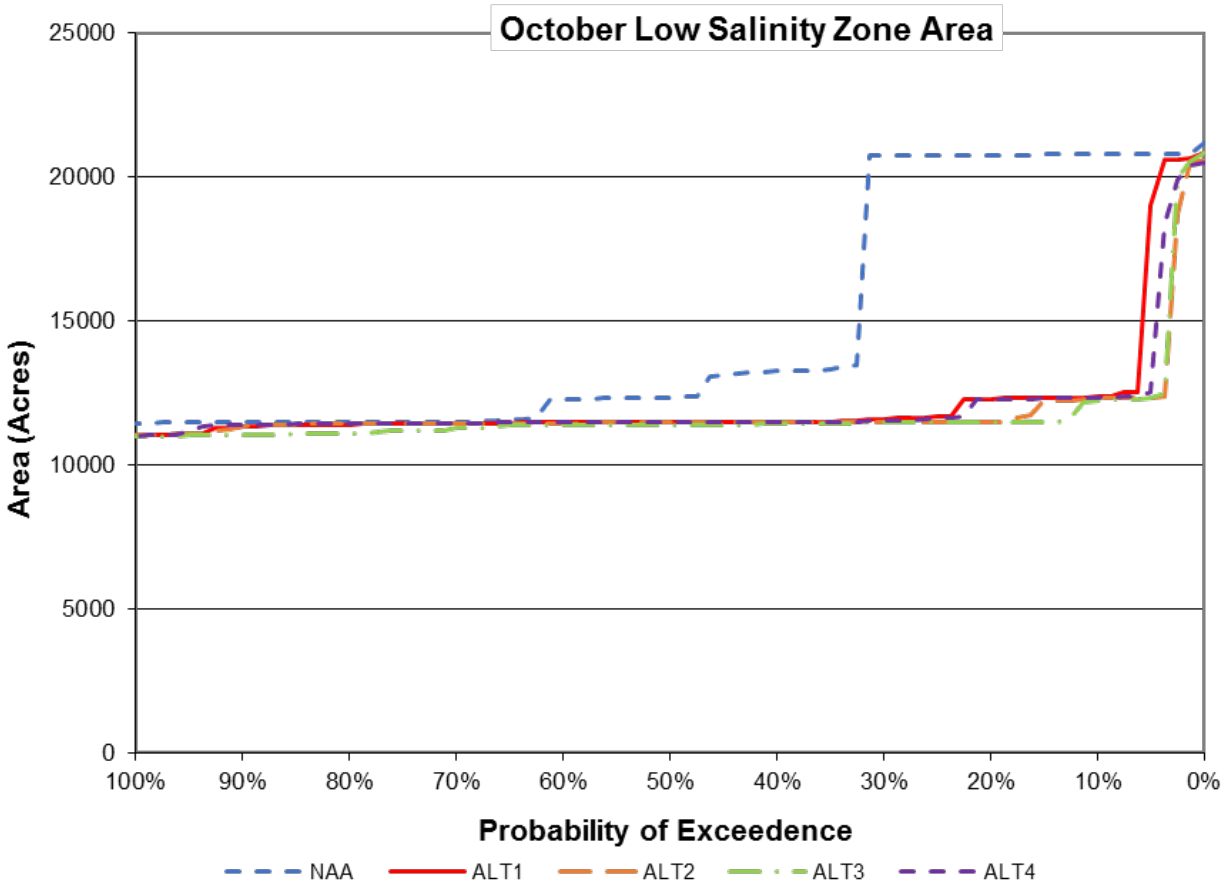


Figure O.3-74. Low Salinity Zone Area Estimated from CalSim X2, October

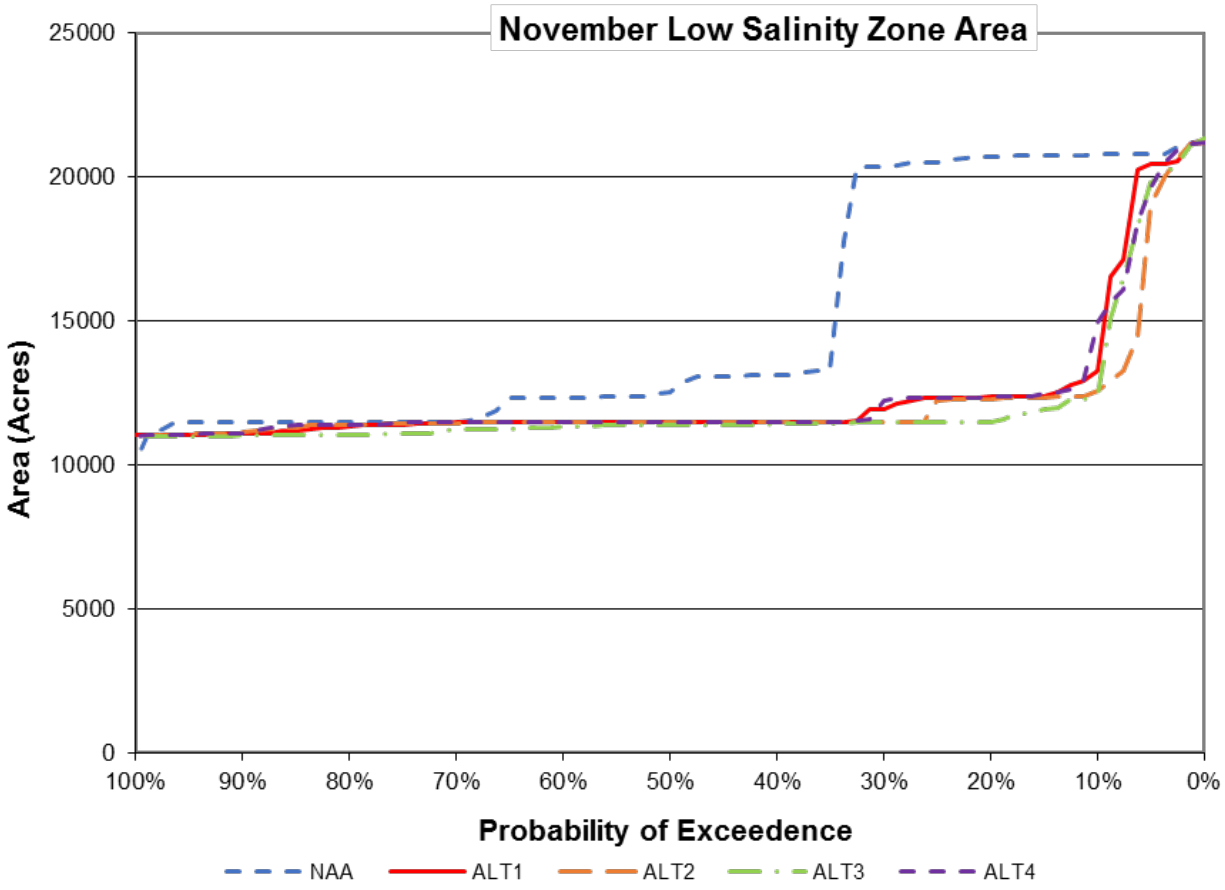


Figure O.3-75. Low Salinity Zone Area Estimated from CalSim X2, November

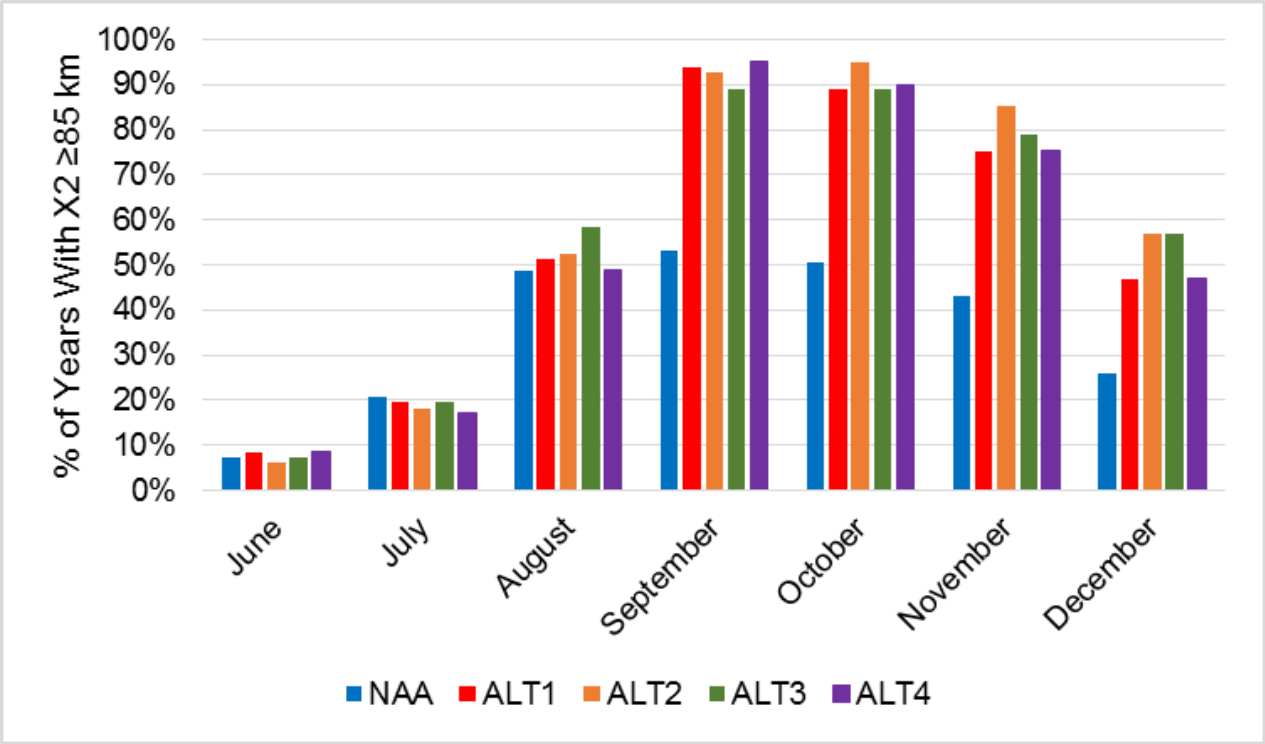


Figure O.3-76. Percentage of Years with Mean X2 ≥ 85 km, June–December

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 to 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 D, Attachment 3-2, Figures 40-9 through 40-12 of the ROC LTO BA). During March through 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 Appendix D, Section 4.3.6.6, *OMR Management*. 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 on Delta Smelt between the No Action Alternative and Alternative 1.

Potential changes to Delta Smelt from Contra Costa Water District operations

CCWD operations would not differ between Alternative 1 and the No Action Alternative, so the effects on 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 on 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 Forebay aquatic weed and algal bloom management

As described in Appendix D, Section 4.3.6.5, *Clifton Court Aquatic Weed and Algal Bloom Management*, under Alternative 1 Clifton Court Forebay aquatic weed removal efforts may be expanded relative to the No Action Alternative by including additional herbicides and extending 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 Forebay would be expected to have minimal effects on Delta Smelt. As discussed in Appendix D, *Alternatives Development Technical Memorandum*, treatment of harmful algal blooms with peroxide-based algaecide is proposed to occur as needed, year-round, but there are no anticipated impacts on 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 (CO_2) injection device to allow remote controlled anesthetization of predators in the secondary channels of the Tracy facility (see Section 4.3.6.7, *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 (SMSCG) 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 that 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 SMSCG 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 Delta Smelt Summer-Fall Habitat 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 4.3.6.9, *Additional Operations 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 D, Attachment 3-2, Figures 41-9 through 41-14 of the ROC LTO BA). 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 on 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. Mitigation measure AQUA-16 will monitor the presence of Longfin Smelt.

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 to 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 D, Attachment 3-2, Figures 40-9 through 40-12 of the ROC LTO BA). January to 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 and 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 D, Attachment 3-2, Figures 40-13 and 40-14 of the ROC LTO BA). 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 (2009c) 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 to 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.

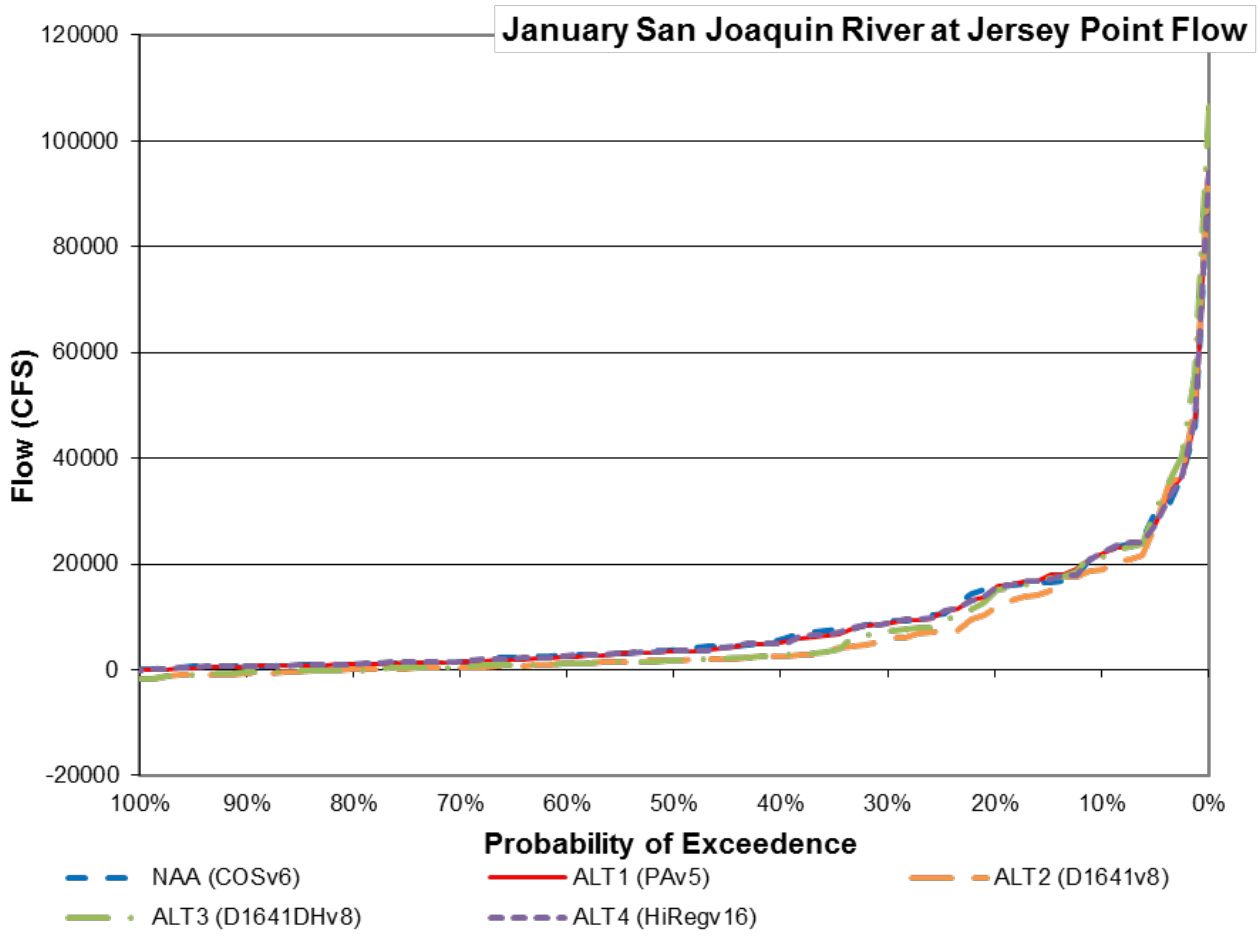


Figure O.3-77. DSM2-HYDRO-Modeled Probability of Exceedance of San Joaquin River Flow at Jersey Point, January

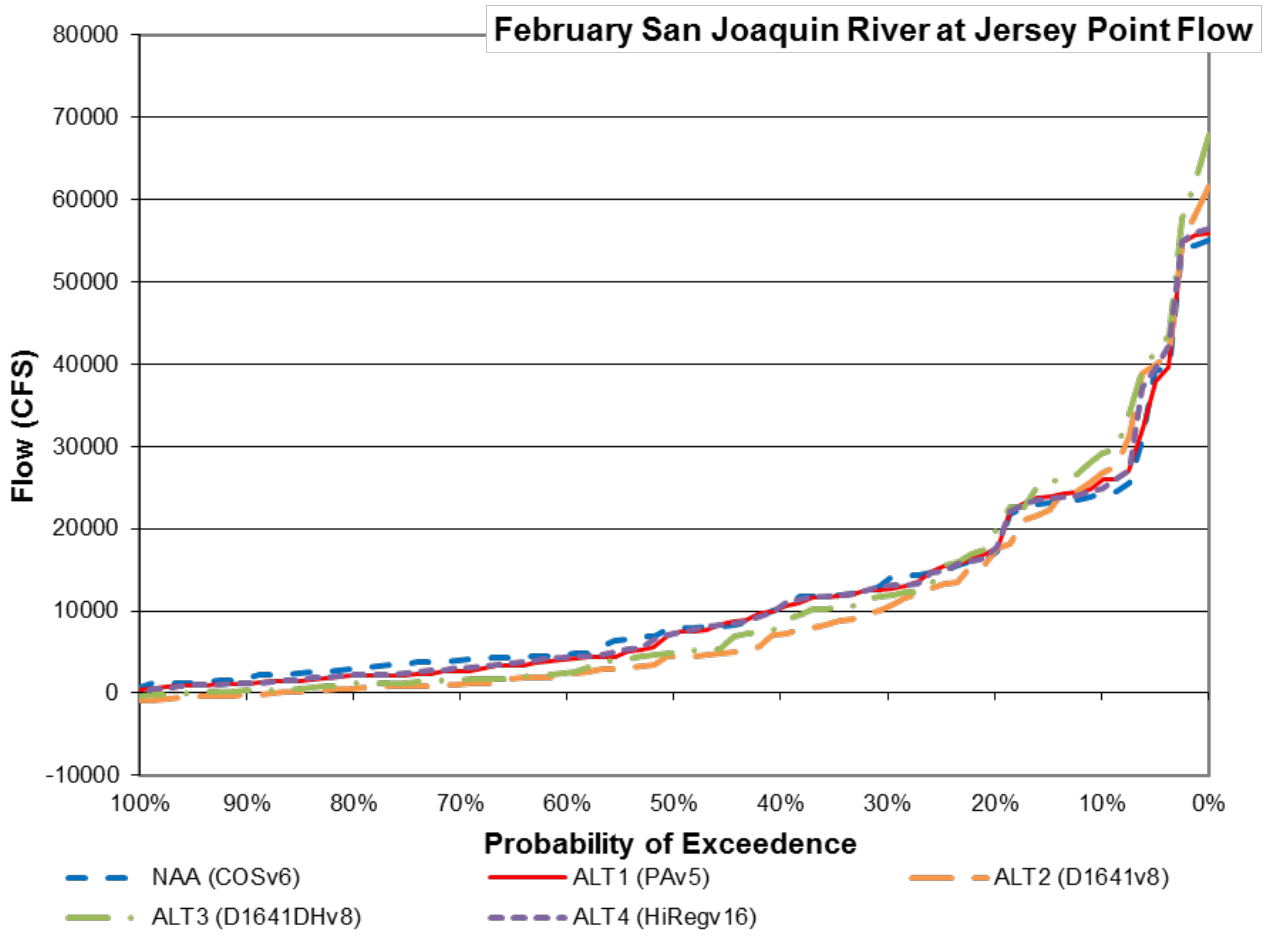


Figure O.3-78. DSM2-HYDRO-Modeled Probability of Exceedance of San Joaquin River Flow at Jersey Point, February

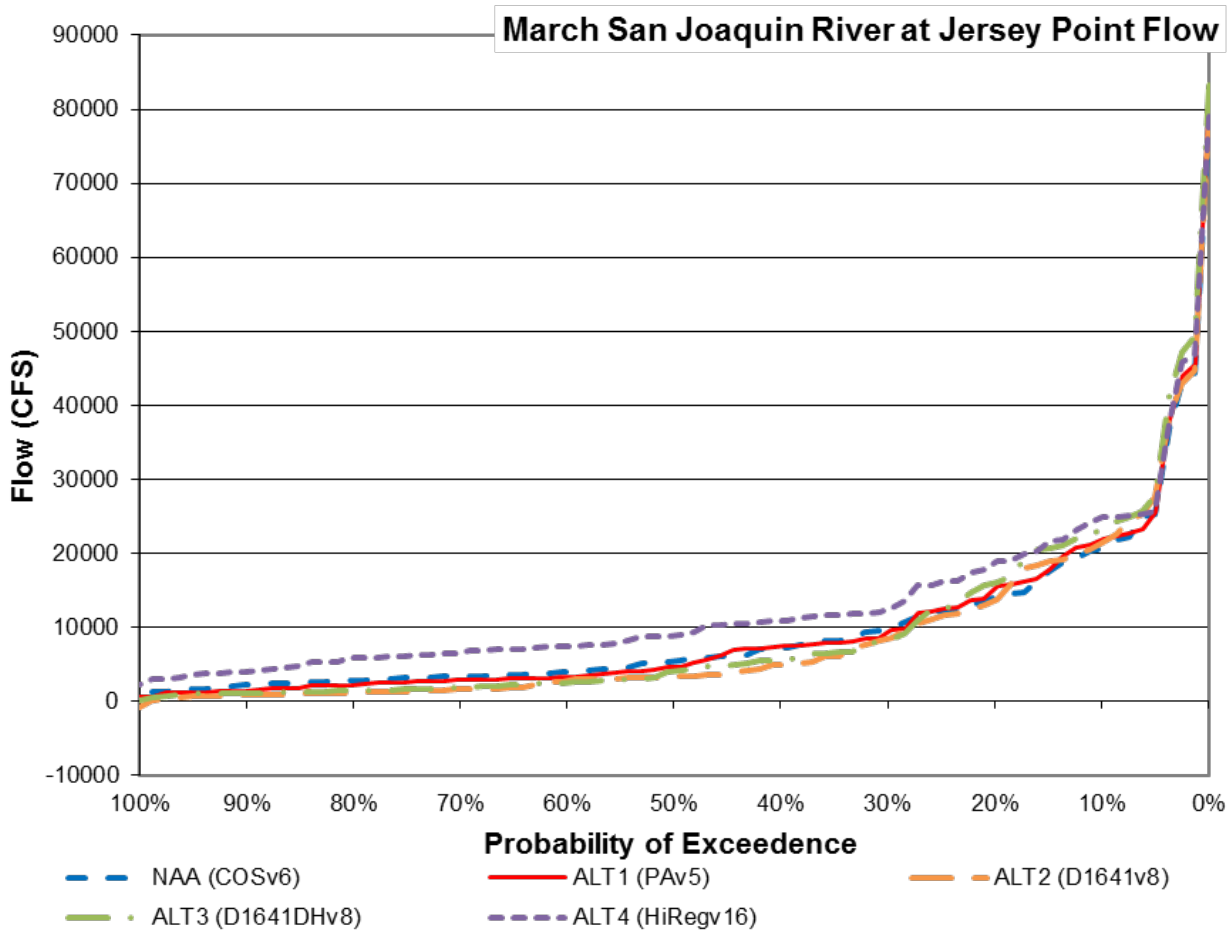


Figure O.3-79. DSM2-HYDRO-Modeled Probability of Exceedance of San Joaquin River Flow at Jersey Point, March

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 TBP (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

CCWD operations under Alternative 1 would not change from the No Action Alternative and therefore would be expected to have similar effects on 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 (2009c) 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 Forebay aquatic weed and algal bloom management

Although Clifton Court Forebay 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 on the species, consistent with the No Action Alternative. As previously described for Delta Smelt and as discussed in Appendix D, *Alternatives Development Technical Memorandum*, treatment of harmful algal blooms with peroxide-based algaecide is proposed to occur as needed, year-round, but there are no anticipated impacts on 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 CO_2 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 from October to 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.

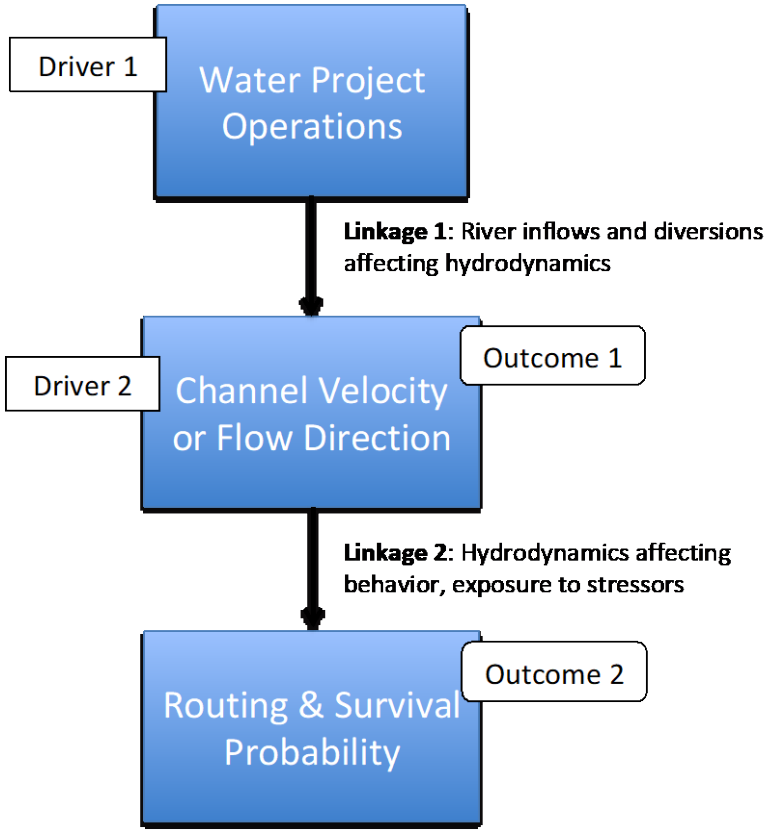


Figure O.3-80. Conceptual Model for Far-Field Effects of Water Project Operations on Juvenile Salmonids in the Delta. This CM is a Simplified Version of the Information Provided by the CAMT SST

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 (December to February and

March to May) in each water year (1922 to 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 from 0 to 1.5% (mean 0.1%) (Zeug and Cavallo 2014). With total exports greater than 6,500 cfs, entrainment losses range from 0 to 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 from November to March with peak abundance during February and March (Reclamation 2019).

During 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 from December to 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 DCC 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 available on survival of juvenile 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% to 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 out-migrating 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 the section above, *Potential changes to aquatic resources due to seasonal operations*, which integrates 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, 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 operations under 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, 2017c; 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 2017d), 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 2017d, 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 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 2017d). From 1999 to 2009, the 11 years prior to construction of the Rock Slough Fish Screen, CCWD's Fish Monitoring Program collected no juvenile or adult Winter-Run Chinook Salmon at the Rock Slough Headworks (Reclamation 2016; NMFS 2017d).

Since construction of the Rock Slough Fish Screen, 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 to 2018, 47 salmon were recovered at the fish screen (Reclamation 2016: Appendix A;

Tenera Environmental 2018a), but none of the captured fish were identified as Winter-Run Chinook Salmon (NMFS 2017d).

NMFS issued a biological opinion in 2017 (NMFS 2017d) that considered improvements to the Rock Slough Fish Screen facility including the hydraulic rake cleaning system, operation and maintenance of the fish screen and associated appurtenances, and administrative actions such as the transfer of operation and maintenance activities from Reclamation to CCWD. NMFS determined that operation and maintenance of Rock Slough Fish Screen 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 Rock Slough Fish Screen monitoring (NMFS 2017d). The incidental take provided in NMFS 2017d 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 2019a).

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 (2017c), 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 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 OMR 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, but varies depending on the tidal stage from approximately 56,000 square feet (at low tide and low San Joaquin River flow) to 68,000 square feet (at high tide and high San Joaquin River flow) as shown in Figure O.3-81.

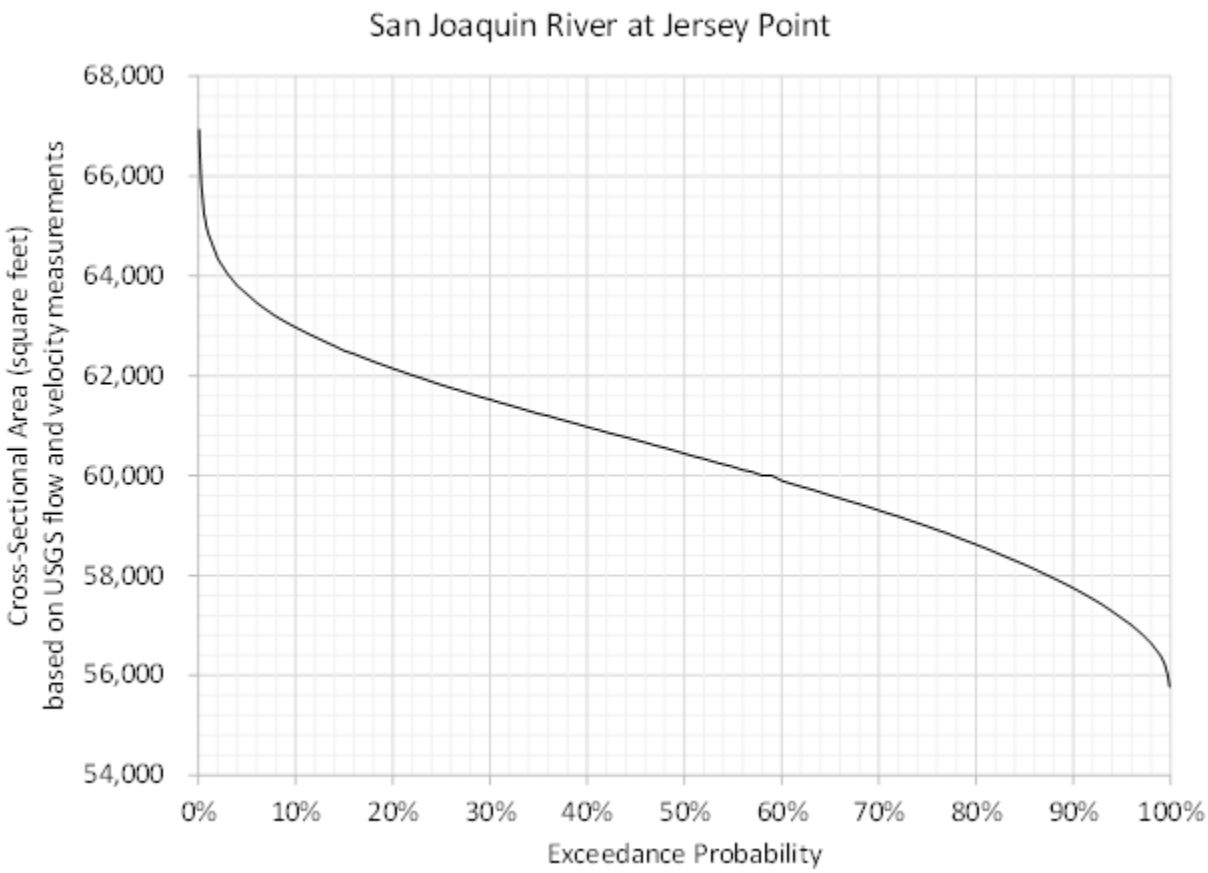


Figure O.3-81. Cross-Sectional Area of the San Joaquin River at Jersey Point (Station: 11337190) Calculated from USGS Measurements of Flow and Velocity every 15 Minutes for Water Years 2014 through 2018

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 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 feet 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 feet 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 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 are available at https://www.wildlife.ca.gov/Regions/3). There should be no discernable effect on 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 Chinook Salmon individuals occurring near the suction dredging. In addition, aquatic weed removal with a grappling system could disturb Winter-Run Chinook Salmon occurring near the removal. The low occurrence of Chinook Salmon in monitoring efforts suggest that any potential impacts 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 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 Forebay 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 from December to May with a peak in March and April (Reclamation 2019). The application of aquatic herbicide to the waters of Clifton Court Forebay will occur from June 28 to August 31, when temperatures 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 Clifton Court Forebay.

As discussed in Appendix D, *Alternatives Development Technical Memorandum*, treatment of harmful algal blooms with peroxide-based algaecide is proposed to occur as needed, year-round, but there are no anticipated impacts on 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 CO_2 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 CO_2injection 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*, in the ROC LTO BA) (Reclamation 2019). 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 AB, Attachment F of the ROC LTO BA) (Reclamation 2019).

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 on 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 Clifton Court Forebay could reduce pre-screen loss of juvenile Chinook Salmon entrained into Clifton Court Forebay. 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 SWRCB 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 SMSCG 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 RRDSs 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/sec, so that juvenile Winter-Run Chinook Salmon would be excluded from entrainment.

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, its unlikely juvenile Winter-Run Chinook Salmon will be entrained into the water distribution system, since Winter-Run Chinook Salmon 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 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 from June to September. Therefore, no effects would occur as a result of actions for Delta Smelt summer-fall habitat.

Potential changes to aquatic resources from Clifton Court Forebay predator management efforts

Clifton Court Forebay predator management efforts could reduce predation on listed fishes following entrainment into Clifton Court Forebay, reducing pre-screen loss.

Potential changes to aquatic resources due to the San Joaquin Basin Steelhead Telemetry Study

The San Joaquin Basin Steelhead Telemetry Study would not have effects on the Winter-Run Chinook Salmon population.

Potential changes to aquatic resources due to reintroduction changes from the Fish Conservation and Culture Laboratory

Reintroduction changes from the Fish Conservation and Culture Laboratory would not have effects on the Winter-Run Chinook Salmon population.

Potential changes to aquatic resources from monitoring

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 of the ROC LTO BA) 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 Juvenile Production Estimate (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 on 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 on 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 Section O.3.3.8.3, *Sacramento River Winter-Run Chinook Salmon*, for more detail concerning “far-field” and “near-field.”

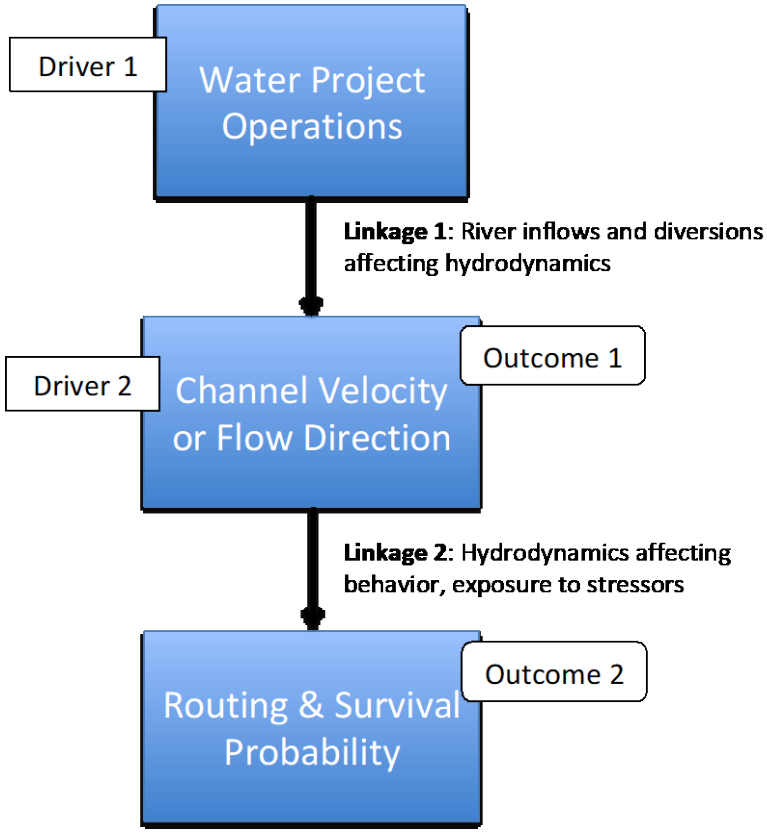


Figure O.3-82. Conceptual Model For Far-Field Effects of Water Project Operations on Juvenile Salmonids in the Delta. This CM Is a Simplified Version of the Information Provided by the CAMT SST

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 juvenile Fall-Run 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 Section O.3.3.8.3, *Sacramento River Winter-Run Chinook Salmon,*, 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 from November to 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 DCC 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 available on survival of juvenile 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% and 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 during 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 the section above, *Potential changes to aquatic resources due to seasonal operations*, which integrates OMR management.

Potential changes to aquatic resources due to Delta Cross Channel operations

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. 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 of 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 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 et al. 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, 2017c; USFWS 1993, 2000, 2007,

2010, 2017; CDFG 1994, 2009a; 58 FR 12854–12864). 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 2017d), 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 2017d, 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 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 2017d). From 1999 to 2009, the 11 years prior to construction of the Rock Slough Fish Screen, 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 2017d) and 4 juvenile Central Valley Spring-Run at Pumping Plant #1 (CCWD 2019a). 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 2017d). 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 Rock Slough Fish Screen, 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 to 2018, 47 salmon were recovered at the fish screen (Reclamation 2016: Appendix A; Tenera Environmental 2018a), but none of the captured fish were identified as Spring-Run Chinook Salmon (NMFS 2017d).

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 2019a).

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 (2017c), 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 the 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 under *Through-Delta Survival* in Section O.3.3.8.3, 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 under *Through-Delta Survival* in Section O.3.3.8.3, the diversions at the Rock Slough Intake could move a neutrally buoyant particle in the San Joaquin River at Jersey Point approximately 540 feet 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 feet 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 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 are available at https://www.wildlife.ca.gov/Regions/3). The North Bay Aqueduct is located within designated critical habitat for Spring-Run Chinook Salmon. There should be no discernable effect on 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 Chinook Salmon 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 impacts 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 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.3-83 through O.3-85).

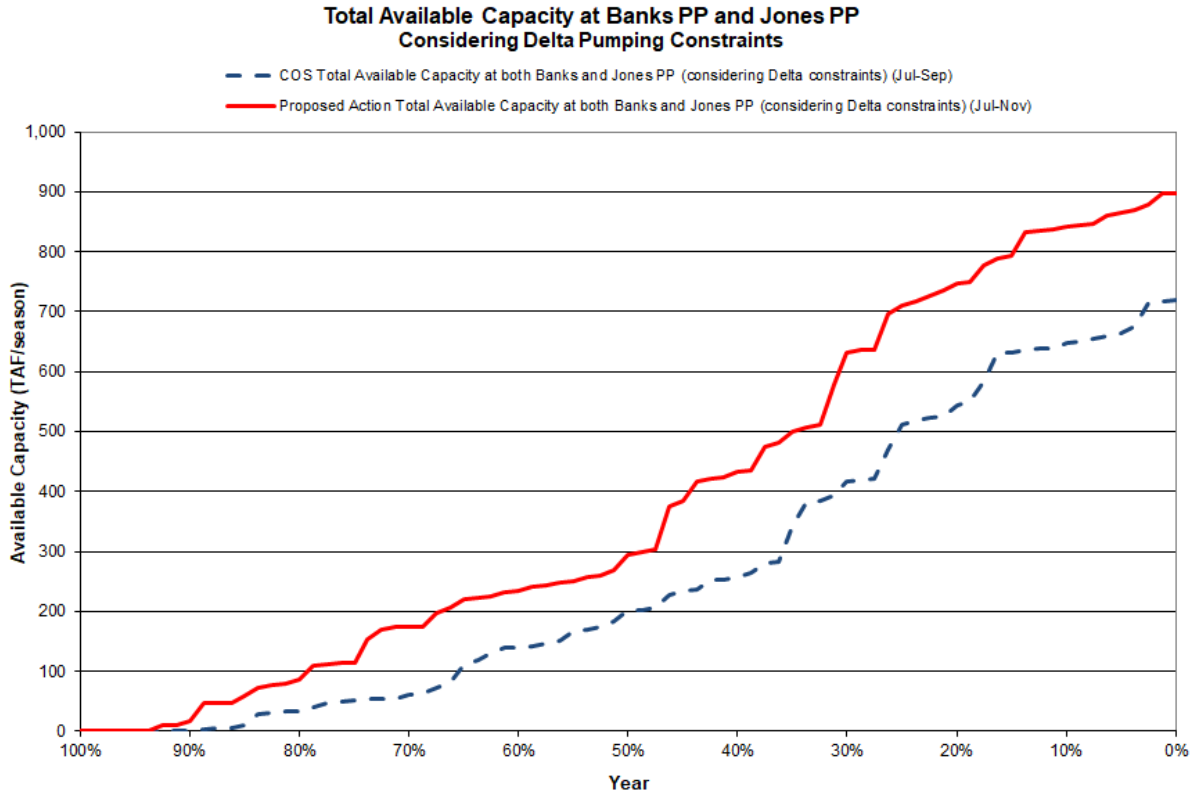


Figure O.3-83. Exceedance of Available Capacity for Transfers at Jones and Banks under the Alternative 1 and No Action Alternative

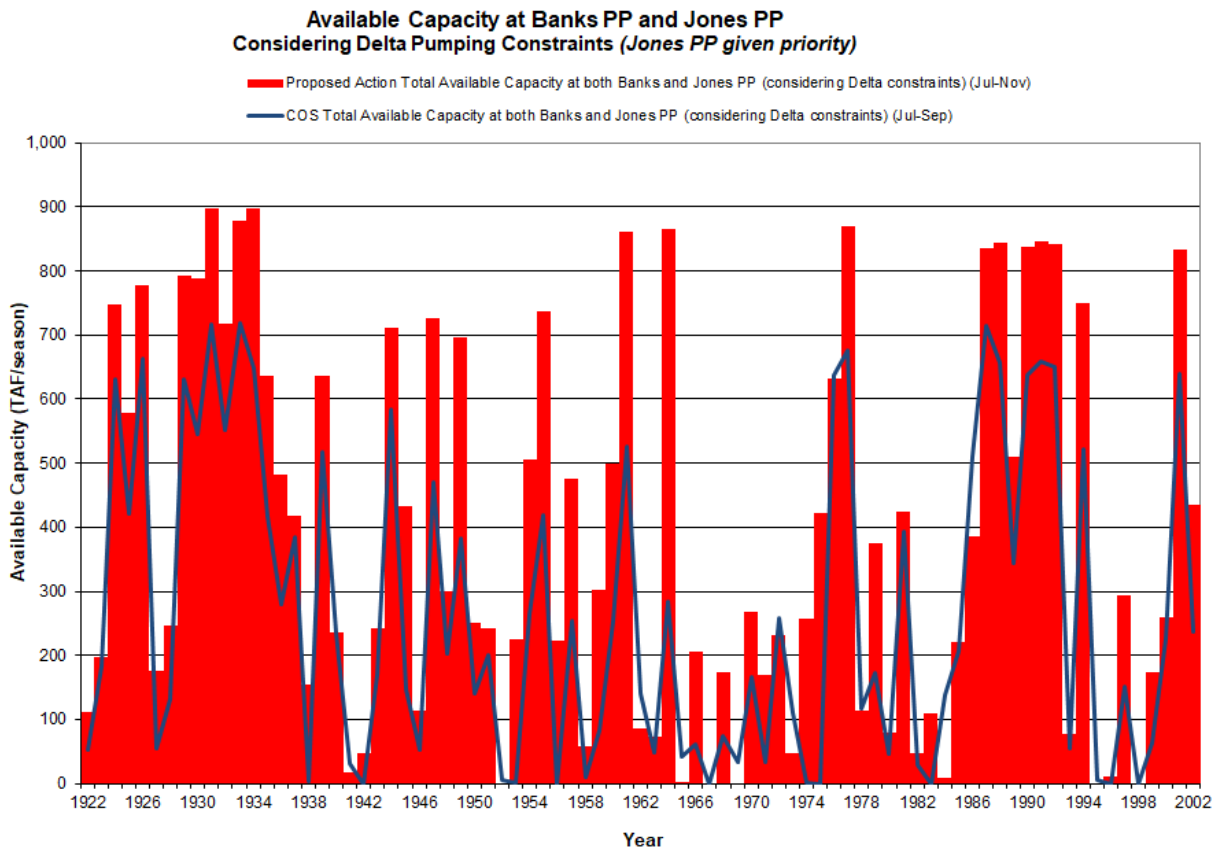


Figure O.3-84. Modeled Annual Maximum Available Capacity for Transfers under Alternative 1 and No Action Alternative, CalSim Period of Record (1922–2003)

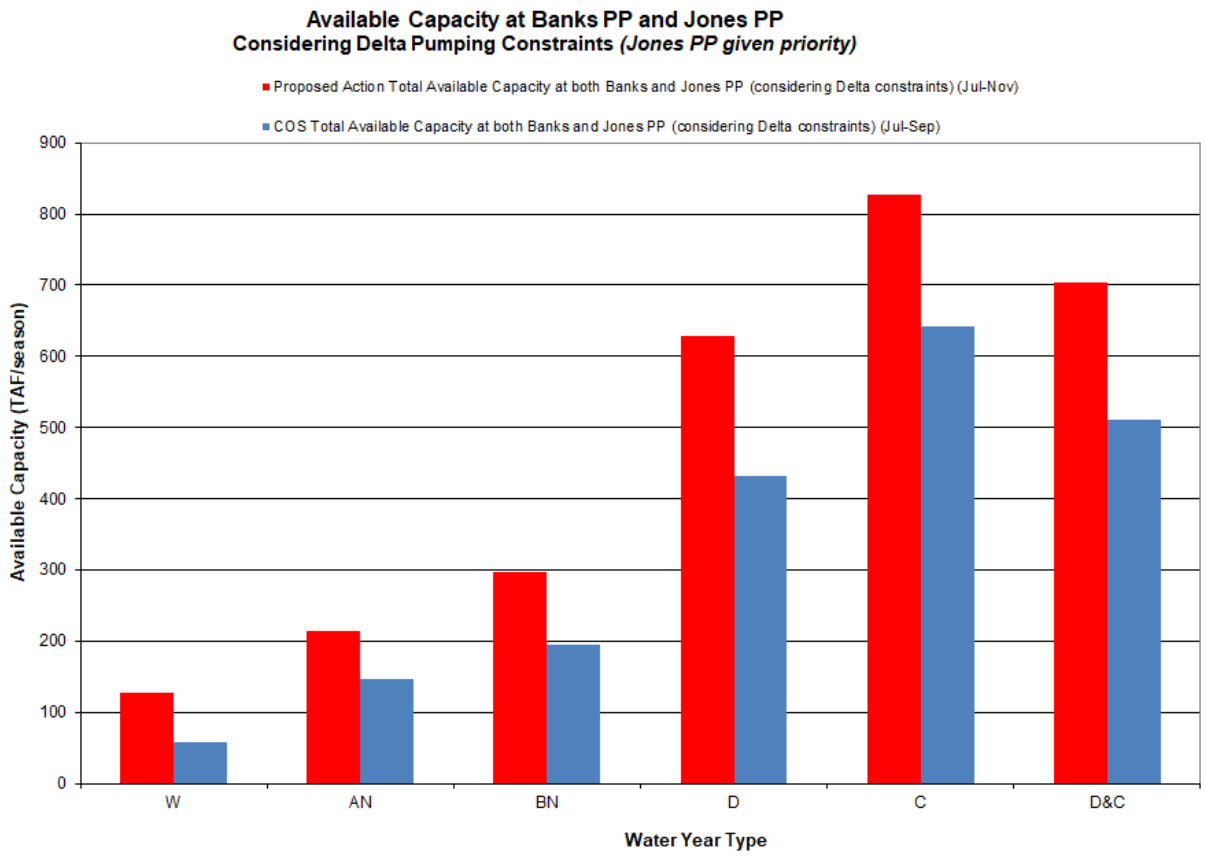


Figure O.3-85. Water Year Type Average Available Capacity at Jones and Banks Pumping Plants

Egg, 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 from December to 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 the *Potential changes to aquatic resources due to seasonal operations* 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 Forebay 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 from mid-November to early June with a peak in April (Reclamation 2019). The application of aquatic herbicide to the waters of Clifton Court Forebay will occur from June 28 to August 31. Herbicide application can occur before June 28 if temperatures are ≥ 25˚C, but Spring-

Run Chinook Salmon are unlikely to be present at these temperatures. 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 on 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 the Tracy fish facility, including installing a CO_2 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 AB, Attachment F of the ROC LTO BA: WR_salvage_unclipped_date, WR_salvage_clipped_date, and WR_salvage_clipped_CWT_race) (Reclamation 2019). 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 into 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 predator removal activities 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 SWRCB 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 SMSCG 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 RRDS 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/sec, so that juvenile Spring-Run Chinook Salmon would be excluded from entrainment.

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, its unlikely juvenile Central Valley Spring-Run Chinook Salmon will be entrained into the water distribution system, since Spring-Run Chinook Salmon 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 from June to September. Therefore, no effects would occur as a result of actions for Delta Smelt summer-fall habitat.

Potential changes to aquatic resources from Clifton Court Forebay 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

The San Joaquin Basin Steelhead Telemetry Study would not have effects on the Spring-Run Chinook Salmon population.

Potential changes to aquatic resources due to reintroduction changes from Fish Conservation and Culture Laboratory

Reintroduction changes from the Fish Conservation and Culture Laboratory would not have effects on the Spring-Run Chinook Salmon population.

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 on the Spring-Run Chinook Salmon 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 CAMT SST. The SST completed a thorough review of this subject and defined a 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.

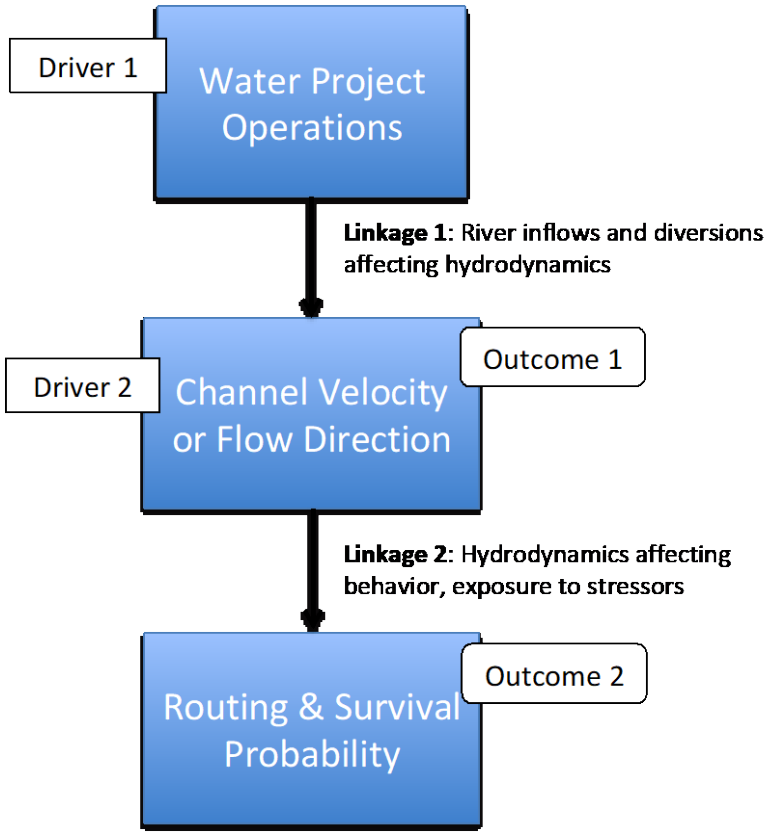


Figure O.3-86. Conceptual Model for Far-Field Effects of Water Project Operations on Juvenile Salmonids in the Delta. This CM Is a Simplified Version of the Information Provided by the CAMT SST

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. 2012).

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 (December to February and March to May) in each water year (1922 to 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.

Entrainment

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. These data are extremely useful because they represent 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–Run Chinook Salmon 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 from February to May and Late Fall–Run Chinook Salmon are present in the Delta from November to 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 >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 Chinook Salmon juveniles originating from the Sacramento River that enter the interior Delta via Georgiana Slough and the DCC 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).

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 available on survival of juvenile 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% and 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 the section above, *Potential changes to aquatic resources due to seasonal operations*, which integrates OMR management.

Potential changes to aquatic resources due to Delta Cross Channel operations

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 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 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 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 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 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 et al. 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, 2017c; USFWS 1993, 2000, 2007, 2010, 2017; CDFG 1994; 2009a; 58 FR 12854–12864). 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 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 Rock Slough Fish Screen, CCWD's Fish Monitoring Program collected 23 juvenile Fall-Run and 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 or 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 or Late Fall–Run Chinook Salmon at CCWD's Old River Intake or Middle River Intake (CCWD 2019a).

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 and Late Fall–Run Chinook Salmon are not likely to be in the vicinity of the Rock Slough Intake. However, according to NMFS (2017c), 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 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 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 Section O.3.3.8.3, *Sacramento River Winter-Run Chinook Salmon*, 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 and 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 Section O.3.3.8.3, *Sacramento River Winter-Run Chinook Salmon*, the diversions at the Rock Slough Intake could move a neutrally buoyant particle in the San Joaquin River at Jersey Point approximately 540 feet 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 feet 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 Chinook Salmon individuals occurring near the suction dredging. In addition, aquatic weed removal with a grappling system could disturb Fall-Run Chinook Salmon occurring near the removal. The low occurrence of Chinook Salmon in monitoring efforts suggest that any potential impacts from sediment and aquatic weed removal would be limited.

Potential changes to aquatic resources due to water transfers

Water transfers would not have effects on the Fall-Run and Late Fall-Run Chinook Salmon population.

Potential changes to aquatic resources from Clifton Court Forebay 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 from mid-November to 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 from June 28 to August 31. Treatment could occur before June 28 if temperatures exceed 25 ˚C; however, Fall-Run Chinook Salmon are not expected to occur 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 on 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 (Reclamation 2019). NMFS (2009) determined that operation of the SMSCG 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 RRDS 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/sec (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 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 in 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 Forebay 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, moderate proportions of San Joaquin River-origin Fall-Run Chinook Salmon arrive at the facilities. For fish that are entrained into Clifton Court 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 on the occasional capture of adult Fall-Run. 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

The San Joaquin Basin Steelhead Telemetry Study would not have effects on the Fall-Run Chinook Salmon population.

Potential changes to aquatic resources due to reintroduction changes from Fish Conservation and Culture Laboratory

Reintroduction changes from the Fish Conservation and Culture Laboratory would not have effects on the Fall-Run Chinook Salmon population.

O.3.3.8.6 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 from 2003 to 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 composed 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 during March to 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

Based on observations from acoustically tagged Chinook Salmon smolts, routing of juvenile Central Valley Steelhead into alternative migration routes is likely 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 from November to 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 available on survival of juvenile 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% and 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 the section above, *Potential changes to aquatic resources due to seasonal operations*, which integrates 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 on this life stage when compared to the No Action Alternative.

Potential changes to aquatic resources due to the Temporary Barriers Project

The 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 et al. 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 1 does not include HORB, which could result in negative impacts on 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, 2017c; USFWS 1993, 2000, 2007, 2010, 2017; CDFG 1994, 2009a; 58 FR 12854–12864). 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 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 Rock Slough Fish Screen, 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 2019a).

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 (2017c), 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 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 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 Section O.3.3.8.3, *Sacramento River Winter-Run Chinook Salmon*, 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 Section O.3.3.8.3, the diversions at the Rock Slough Intake could move a neutrally buoyant particle in the San Joaquin River at Jersey Point

approximately 540 feet 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 feet 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 North Bay Aqueduct's Barker Slough Pumping Plant relative to current op. Juvenile Central Valley Steelhead could occur in the vicinity of the Barker Slough Pumping Plant; 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 were 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 impacts 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 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 Forebay aquatic weed removal

Under Alternative 1, the application of aquatic herbicide to the waters of Clifton Court Forebay will occur from June 28 to August 31. Treatment could occur prior to June 28 at temperatures ≥ 25˚C; however, Steelhead would not be expected to occur at these temperatures. Treatment could also occur after August 31 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 from March to 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 on 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 from August to 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 CO_2 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 Clifton Court Forebay could reduce pre-screen loss of juvenile Central Valley Steelhead entrained into Clifton Court Forebay, thereby 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 SMSCG is unlikely to impede migration of juvenile salmonids or produce conditions that support unusually high numbers of predators.

Under Alternative 1, the RRDS 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/sec (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 Forebay predator management efforts

Clifton Court Forebay predator management under Alternative 1 could reduce pre-screen loss of juvenile Central Valley Steelhead entrained into Clifton Court Forebay, thereby 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

The San Joaquin Basin Steelhead Telemetry Study would not have effects on Central Valley Steelhead.

Potential changes to aquatic resources due to reintroduction changes from Fish Conservation and Culture Laboratory

Reintroduction changes from the Fish Conservation and Culture Laboratory would not have effects on Central Valley Steelhead.

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, Delta and San Francisco 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 on the population.

O.3.3.8.7 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

Impacts on 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 months) 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 months) 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 out-migrating salmonids, so it is hypothesized that juvenile Green Sturgeon have different routing-hydrology survival relationships. 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. 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 out-migrating 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 the section above, *Potential changes to aquatic resources due to seasonal operations*, which integrates 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 of the TBP are included in Alternative 1 and consist 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), out-migrating Chinook Salmon passage past the agricultural barrier was improved (DWR 2018). It could be inferred that passage of out-migrating 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, 2017c; USFWS 1993, 2000, 2007, 2010, 2017; CDFG 1994, 2009a; 58 FR 12854–12864). Therefore, CCWD operations, including operation 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 2017d), 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 40ºF in winter (December and January) to over 70ºF beginning in May and continuing through October (NMFS 2017d).

A review of the 24 years of fish monitoring data (1994 to 2018) near the Rock Slough Intake both pre- and post-construction of the Rock Slough Fish Screen showed that Southern DPS Green Sturgeon have never been observed in Rock Slough (CDFG 2002c; Reclamation 2016; NMFS 2017d; 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 2019a).

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 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 impacts 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 *Potential changes to aquatic resources due to seasonal operations* 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 Forebay aquatic weed removal

Few Southern DPS juvenile Green Sturgeon 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 occur from June 28 to August 31. Treatment could occur prior to June 28 at temperatures ≥ 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 on 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 on 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 Clifton Court Forebay 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 SMSCG 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 SMSCG 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 (Verhille 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 Forebay 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 Clifton Court Forebay, but individuals are salvaged infrequently.

Potential changes to aquatic resources due to the San Joaquin Basin Steelhead telemetry study

The San Joaquin Basin Steelhead Telemetry Study would not have effects on Green Sturgeon.

Potential changes to aquatic resources due to reintroduction changes from Fish Conservation and Culture Laboratory

Reintroduction changes from the Fish Conservation and Culture Laboratory would not have effects on Green Sturgeon.

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 on the population.

O.3.3.9 *Nearshore Pacific Ocean on the California Coast*

O.3.3.9.1 Southern Resident Killer Whale

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 on Southern Resident Killer Whale as a result of SWP/CVP operations could occur as a result of effects on 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 on Southern Resident Killer Whale Chinook Salmon prey. This suggests very 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 Project, as described in the project'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, *Mitigation 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 cold water pool and to benefit juvenile fish of all species by reducing entrainment.

Potential changes to aquatic resources due to Shasta temperature control device improvements

Reclamation would study the feasibility of infrastructure improvements to enhance Shasta temperature control device 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 cold water 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 Chinook 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, impingement, and injury at water diversions. The larvae are present in areas where substantial water volumes are diverted, such as RBDD and 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. 2017; 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 to 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 on 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 River 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 River 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 Winter-Run Chinook Salmon

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 Spring-Run Chinook Salmon

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 on 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, out-migrating 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 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 BA and 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 Appendix D, Section 4.3.6.9, *Additional Operations Components*, have the potential to provide small positive effects on Delta Smelt 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 on 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 on 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 CO_2 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 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 component of Alternative 1. This action would hydrologically connect the Sacramento River with the ship channel 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 ship channel. Estimates of salmonid survival in the Sacramento Deepwater Ship Channel are not available to compare with rates in the Sacramento River route. However, if survival rates are similar, fish entering the ship channel 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 Sacramento Deepwater Ship Channel could potentially attract adult Winter-Run Chinook Salmon. If the connection is maintained there would likely not be impacts on 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 from December to 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 from December to 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 on 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 on 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 DCC. 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 CO_2 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 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 F.2.7, F.2.8, and F.2.9 in Appendix AB, Attachment F of the ROC LTO BA) (Reclamation 2019). 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 AB, Attachment F of the ROC LTO BA) (Reclamation 2019).

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 on 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 Clifton Court Forebay could reduce pre-screen loss of juvenile Chinook Salmon entrained into Clifton Court Forebay. 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 out-migrating 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. The NEPA process for the facility (Horizon Water and Environment 2017) indicates 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 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 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 enter the Sacramento Deepwater Ship Channel. There are potential benefits to Spring-Run Chinook Salmon from this action. Fish entering the ship channel 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 Sacramento Deepwater Ship Channel 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 during January and February for adults, and November through June for juveniles, with a peak of juvenile migration during March and 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 on 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 DCC 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 DCC 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 CO_2 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 AB, Attachment F of the ROC LTO BA*:* WR_salvage_unclipped_date, WR_salvage_clipped_date, and WR_salvage_clipped_CWT_race) (Reclamation 2019). 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 out-migrating 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. The NEPA process for the facility (Horizon Water and Environment 2017) indicates 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 action. This action would hydrologically connect the Sacramento River with the Sacramento Deepwater Ship Channel 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 Sacramento Deepwater Ship Channel. Estimates of salmonid survival in the ship channel are not available to compare with rates in the Sacramento River route. However, fish entering the Sacramento Deepwater Ship Channel 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 on 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 DCC 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 DCC 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 - in Appendix AB, Attachment F of the ROC LTO BA) (Reclamation 2019). 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 on 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 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 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 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 out-migrating 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. The NEPA process for the facility (Horizon Water and Environment 2017) indicates 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 conservation measure under Alternative 1. This conservation measure would hydrologically connect the Sacramento River with the Sacramento Deepwater Ship Channel 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 Sacramento Deepwater Ship Channel. Estimates of salmonid survival in the ship channel are not available to compare with rates in the Sacramento River route. However, fish entering the Sacramento Deepwater Ship Channel 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 Steelhead 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 on 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 from December to 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 on 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 from August to 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 from August to 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 CO_2 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 Clifton Court Forebay could reduce pre-screen loss of juvenile Central Valley Steelhead entrained into Clifton Court Forebay, thereby 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 life stage in the same ways described above. Juvenile Central Valley Steelhead out-migrating 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. The NEPA process for the facility (Horizon Water and Environment 2017) indicates 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 from August to 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 Sacramento Deepwater Ship Channel. Fish entering the ship channel 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 Sacramento Deepwater Ship Channel 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 on 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 on 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 Clifton Court Forebay, 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 Southern Resident Killer Whale

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,* 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 on Southern Resident Killer Whale Chinook Salmon prey. This suggests very 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.

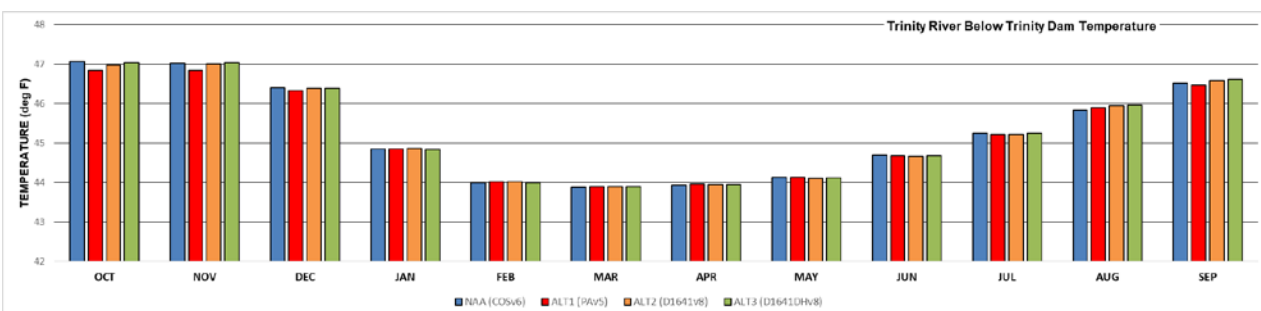


Figure O.3-87. Average Trinity River Water Temperatures below Trinity Dam for the Period October to September, Average of All Water Year Types

Reservoir Fish Species

Increased storage under Alternative 2 compared to the No Action Alternative would increase fish habitat, particularly for species that utilize margins, such as Black Bass. Increased stoarge during November may improve access to spawning areas for the fall-spawning Brown Trout and Kokanee Salmon (Figure O.3-87b and Table O.3-23b). Effects of Trinity Reservoir storage on fish in the Trinity River downstream of Lewiston Dam are described below.

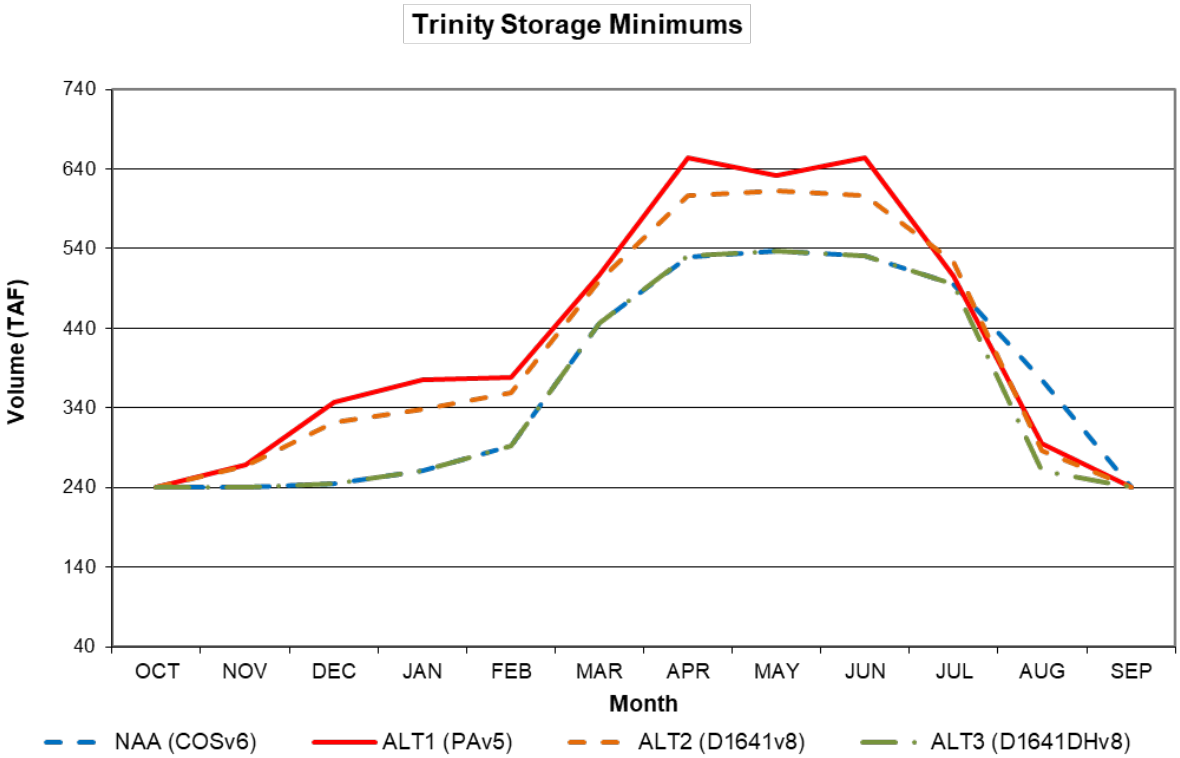


Figure O.3-87b. Modeled Trinity Lake Monthly Minimum Storage Volume under the No Action Alternative, Alternative 1, Alternative 2, and Alternative 3 during All Water Year Types

Table O.3-23b. Modeled Differences in Trinity Lake Minimum Storage Volumes under Alternative 2 Relative to the No Action Alternative

Month	Change in Volume from No Action Alternative (TAF) Alt 2
October	1
November	28
December	77
January	77
February	67
March	54
April	77
May	76
June	76

July	28
August	90
September	0

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.

Under Alternative 2, diseases affecting salmon, such as *C. shasta* (Ich) and *columnaris*, could continue to have substantial impact on adult salmon compared to the No Action Alternative, particularly in September or October of critically dry years, when habitat conditions could include lower flows and higher water temperatures, compared to the No Action Alternative. However, Alternative 2 continues to consider 10 years of additional TRRP projects (through 2030), which would otherwise be expected to reduce the threat of disease outbreaks. Nonetheless, disease pressures could change and there is uncertainty in how disease prevalence will affect future conditions under this 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 is not expected to result in redd scour based on previous studies in the Trinity River which reported sand and gravel substrate became mobile at flows of around 2,700 cfs or greater (McBain and Trush 1997). The flow increase could decrease available Coho fry and rearing habitat by approximately 20% to 25% during February based on WUA reported in USFWS et al. 1999. Habitat improvements under Alternative 2 would be expected to reduce the threat of disease outbreaks for Coho Salmon, although there is uncertainty in how disease prevalence will affect future conditions, and these conditions could be worsened in September or October of critically dry years, when habitat conditions could include lower flows and higher water temperatures, compared to the No Action Alternative.

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 is not expected to result in redd scour based on previous studies in the Trinity River which reported sand and gravel substrates became mobile at flows of around 2,700 cfs or greater (McBain and Trush 1997). The flow increase could also decrease available Spring-Run Chinook Salmon fry and juvenile rearing habitat by approximately 20% to 25% during February based on WUA reported in USFWS et al. 1999. Habitat improvements under Alternative 2 would also be expected to reduce the threat of disease outbreaks for Spring-Run Chinook Salmon, although there is uncertainty in how disease prevalence will affect future conditions, and these conditions coud be worsened in September or October of critically dry years, when habitat conditions could include lower flows and higher water temperatures, compared to the No Action Alternative.

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 is not expected to result in redd scour based on previous studies in the Trinity River which reported sand and gravel substrates became mobile at flows of around 2,700 cfs or greater (McBain and Trush 1997). The flow increase could also decrease available Fall-Run Chinook Salmon fry and juvenile rearing habitat by approximately 20% to 25% during February based on WUA reported in USFWS et al. 1999. Habitat improvements under Alternative 2 would also be expected to reduce the threat of disease outbreaks for Fall-Run Chinook Salmon, although there is uncertainty in how disease prevalence will affect future conditions, and these conditions coud be worsened in September or October of critically dry years, when habitat conditions could include lower flows and higher water temperatures, compared to the No Action Alternative.

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. Overall, habitat improvements under Alternative 2 would be expected to reduce the threat of disease outbreaks for Steelhead, although there is uncertainty in how disease prevalence will affect future conditions and Steelhead remain somewhat resistant to disease.

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.

Eulachon

Eulachon are only found in the lower Klamath River. Water temperature and habitat conditions within the lower Klamath River downstream of the confluence with the Trinity River are heavily influenced by several large tributaries that enter the Trinity River as well the Klamath River itselft. 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 Eulachon.

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).

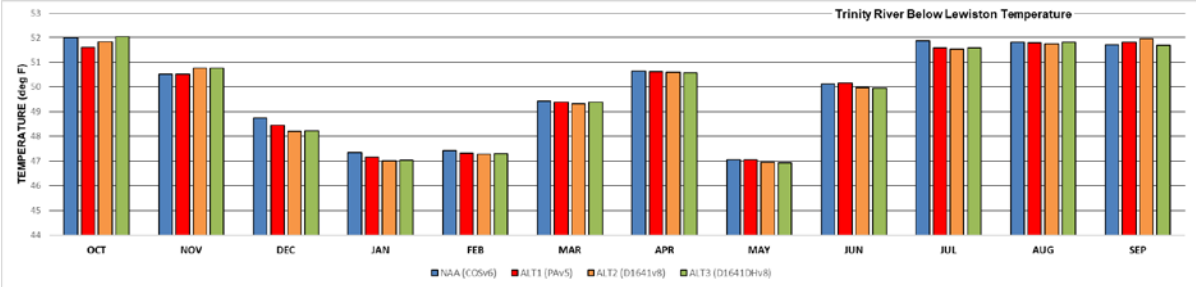


Figure O.3-88. Average Trinity River Water Temperatures below Lewiston Dam for the Period October to September, Average of All Water Year Types

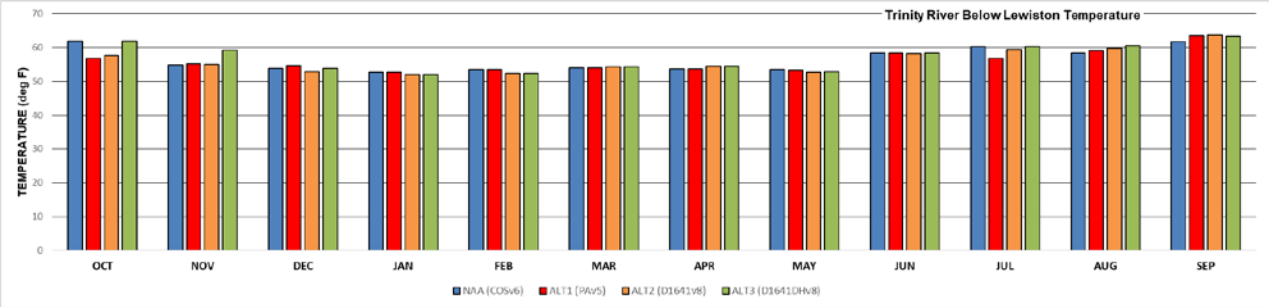


Figure O.3-89. Maximum Trinity River Water Temperatures below Lewiston Dam for the Period October to September, Average of All Water Year Types

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 from October to 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.

Eulachon

Eulachon are only found in the lower Klamath River. Water temperature and habitat conditions within the Lower Klamath River downstream of the confluence with the Trinity River are heavily influenced by several large tributaries that enter the Trinity River as well the Klamath River itselft. 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 2 would not affect Eulachon.

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 action 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]	**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 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 action 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 action 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, and Fall-Run 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 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	Monthly Temperature (°F)											
Water Year Type4	**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]	**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]	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]	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]	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 action 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]	**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 2												
Wet (32%)	56.1	53.5	49.2	46.5	47.0	49.4	53.7	56.5	58.5	58.2	58.7	58.3
Above Normal (16%)	56.2	52.9	48.7	46.7	47.1	50.1	55.0	56.5	56.6	56.7	58.1	59.6
Below Normal (13%)	56.9	53.7	49.0	46.8	48.0	51.5	56.0	55.8	56.5	57.4	58.1	59.2
Dry (24%)	57.2	53.3	48.6	47.0	48.3	51.7	56.1	56.5	57.3	58.6	60.7	60.5
Critically Dry (15%)	61.1	54.9	48.7	47.3	49.1	52.2	56.4	57.6	59.5	61.3	63.3	64.4
Alternative 2 minus No Action Alternative[6]												
Wet (32%)	-0.2	-0.8	0.0	0.0	0.0	0.0	0.0	-0.2	-0.5	0.2	-0.2	2.9
Above Normal (16%)	0.0	-0.8	-0.1	0.0	0.0	0.0	0.1	-0.4	-1.2	0.2	-0.2	3.4
Below Normal (13%)	0.3	0.4	0.1	0.1	0.0	-0.2	-0.4	-0.9	-0.9	0.1	-0.7	-0.9
Dry (24%)	0.0	0.3	0.1	0.0	0.0	0.1	0.0	-1.0	-0.7	0.1	0.1	-0.5
Critically Dry (15%)	0.4	0.3	0.1	0.1	0.1	-0.2	-0.2	-0.4	-0.4	0.0	-0.1	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.3-30. HEC-5Q Monthly Average Water Temperatures (degrees Fahrenheit) by Water Year Type and Month below Hamilton City 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]	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]	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
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.

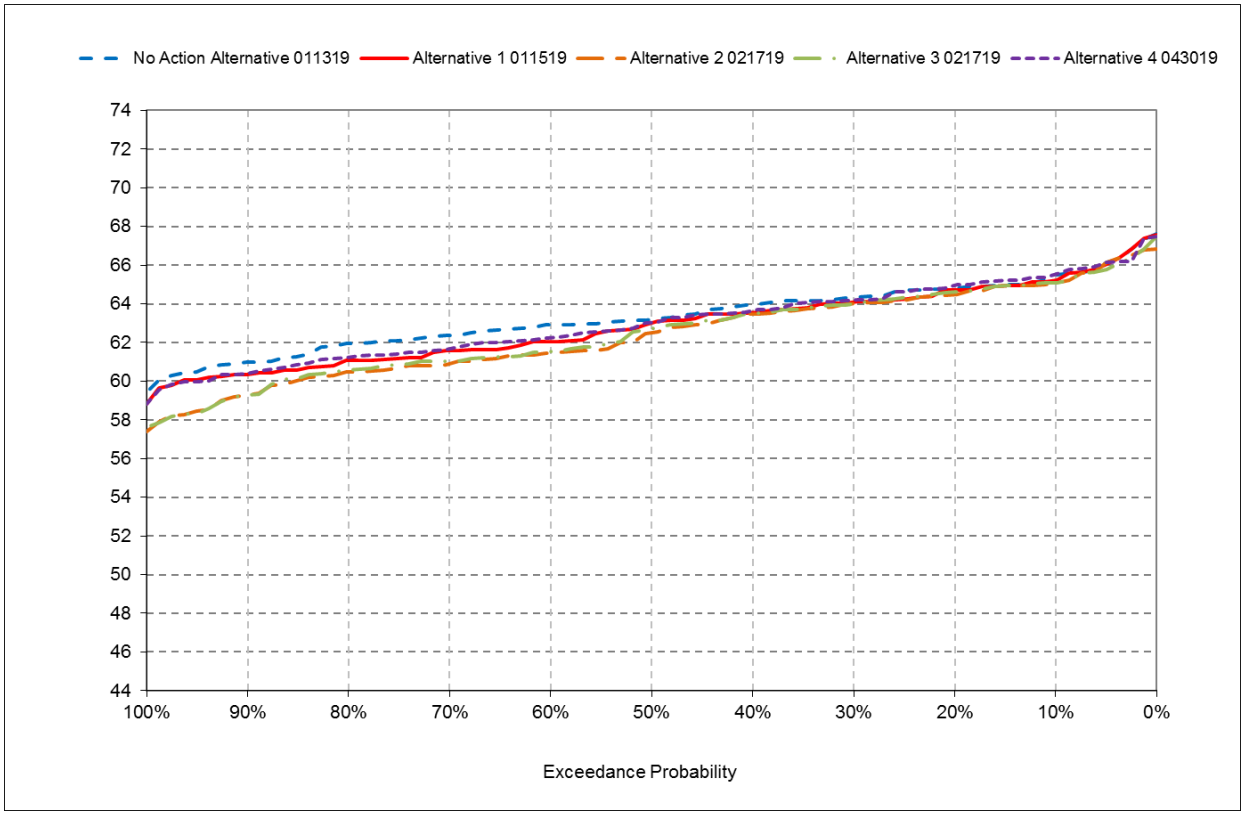


Figure O.3-90. HEC-5Q Sacramento River Water Temperatures at Hamilton City under the No Action Alternative and Alternative 1, Alternative 2, Alternative 3, and Alternative 4; June

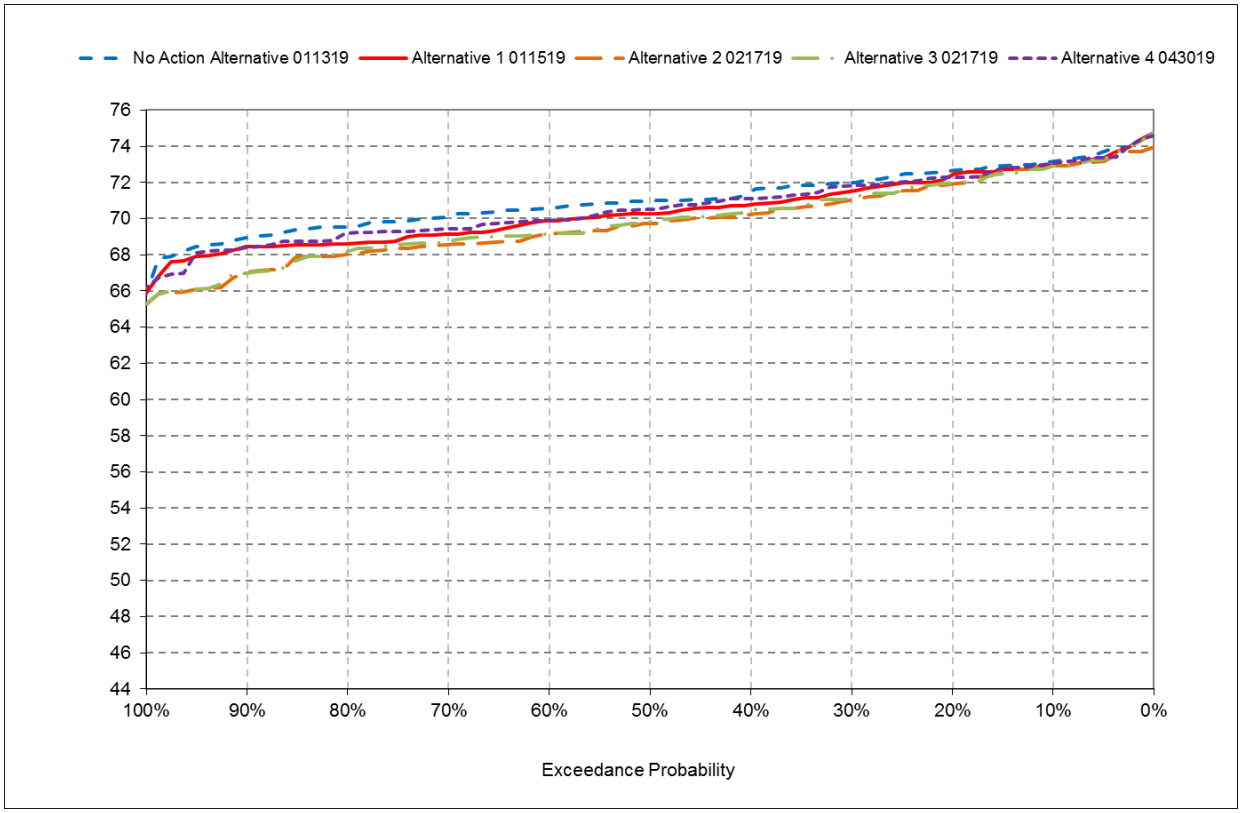


Figure O.3-91. HEC-5Q Sacramento River Water Temperatures at Knights Landing under the No Action Alternative and Alternatives 1, Alternative 2, Alternative 3, and Alternative 4; June

Table O.3-32. CalSim II Monthly Average Flow (cfs) by Water Year Type and Month at Red Bluff Diversion Dam for No Action Alternative, Alternative 2 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 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]	**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
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]	**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
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.

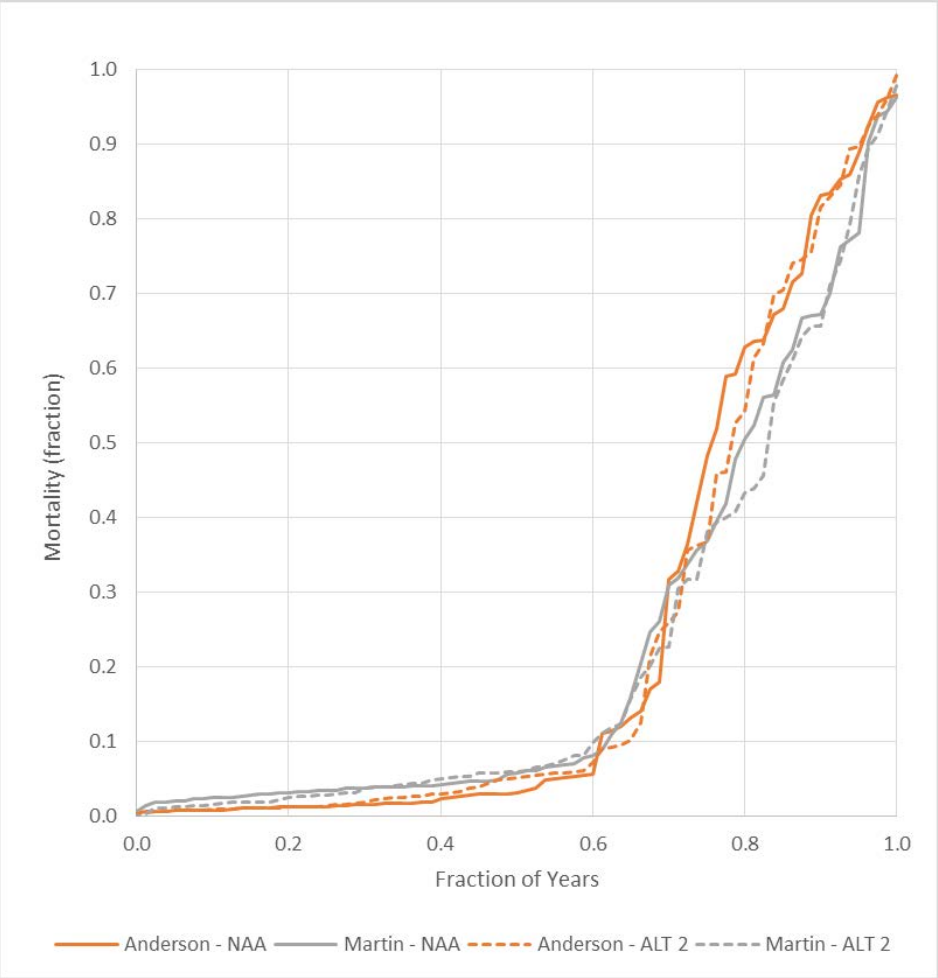


Figure O.3-92. Exceedances of Winter-Run Chinook Salmon Temperature-Dependent Egg Mortality, Alternative 2 vs. No Action Alternative; All Water Year Types.

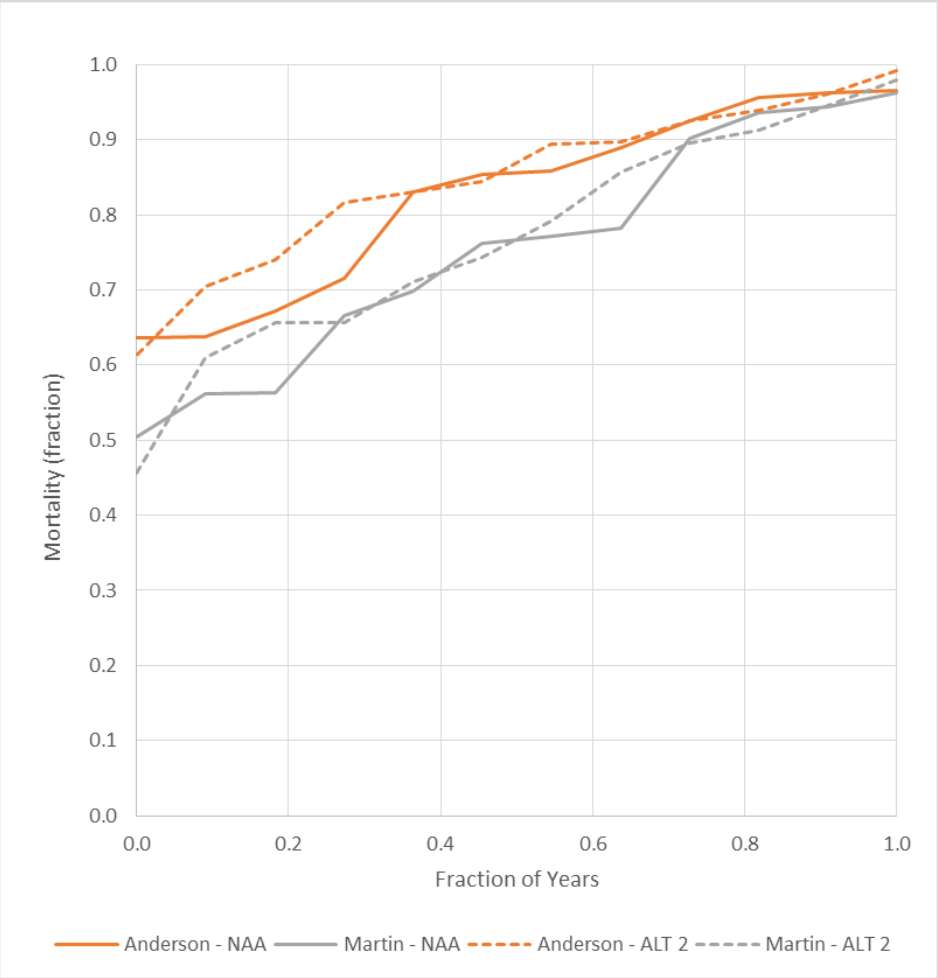


Figure O.3-93. Exceedances of Winter-Run Chinook Salmon Temperature-Dependent Egg Mortality, Alternative 2 vs. No Action Alternative; Critically Dry Water Years

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. 2001a, 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 2, 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 RBDD. Under Alternative 2, SWRCB's WRO 90-5 has similar but more flexible water temperature requirements for Reclamation (NMFS 2011b, 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°F 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 differences 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 2011b: 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-significant 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

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 2017c). 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.

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. 2001a, 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.

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 Chinook Salmon 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. 2013). 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.3.5.2.3 Central Valley Steelhead

Spawning and Egg Incubation

Central Valley 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

Central Valley 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.3.5.2.4 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. 2017). Spawning occurs primarily from April through July, although it periodically occurs in late summer and fall (as late as October) (Heublein et al. 2009, 2017; NMFS 2018b). Eggs hatch about a week after fertilization (at 60ºF) (Heublein et al. 2017). 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. 2017) concluded that the optimal range for normal embryo development of Southern DPS Green Sturgeon is 53°F 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°F and 52°F lower temperature thresholds for Green Sturgeon egg development (see Section O.3.3, *Alternative 1 — Project-Level Effects*) 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°F 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 in Section O.3.3, 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. 2017). The upstream limit is the Cow Creek confluence. Green Sturgeon juveniles rear in the Sacramento River from about May through December (NMFS 2017c). 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 in Section O.3.3, 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 on 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. 2017). 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. 2017).

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°F 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°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 exceed the 63°F 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.3.5.2.5 Fall-Run Chinook Salmon

Spawning and Egg/Alevin Incubation

Fall-Run Chinook Salmon migrate upstream past RBDD on the Sacramento River from July to 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 (USFWS 2003, 2005b).

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 *Potential changes to aquatic resources in the Sacramento River from seasonal operations* in Section O.3.3.2, *Sacramento River*) 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 from July to 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.3.5.2.6 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 RBDD, 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 2005a), 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.3.5.2.7 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 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.3.3.2, *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.3.5.2.8 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 (61ºF and 68°F, see Section O.3.3.2, *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.3.5.2.9 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. 2007a; 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.3-33). 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.3.5.2.10 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 foot), 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 year-round 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.3.5.2.11 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 (macropthalmia) 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 year-round 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 known 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 prelarvae 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°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 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-significant impact on River Lamprey relative to the No Action Alternative.

O.3.5.2.12 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.3.5.2.13 Central California Roach

As discussed under Alternative 1, Central 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 Central California Roach. Therefore, Alternative 2 is expected to have no impact on Central California Roach relative to the No Action Alternative.

O.3.5.2.14 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°F to 68°F and spawning ceases at about 70°F (Moyle 2002). The eggs can withstand temperatures of about 54°F to 75°F, with the optimum being about 64°F (Emmett et al. 1991). Larvae tolerate temperatures of 50°F to 77°F, but optimal temperatures for survival are 59°F 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°F to 75°F (Emmett et al. 1991) and juveniles prefer rearing temperatures of 61°F 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.3.5.2.15 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 fresh water, 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 2002b, 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.3.5.2.16 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°F 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°F to 70°F, although spawning is generally observed over a range of 55°F to 79°F (Stuber et al. 1982). Eggs hatch 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°F 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 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 2. Therefore, changes in Sacramento River flows and water temperatures associated with Alternative 2 would have a less-than-significant effect on Largemouth Bass in the Sacramento River relative to the No Action Alternative.

O.3.5.2.17 Smallmouth Bass

The temperature optimal range for Smallmouth Bass spawning is 55°F to 70°F (Brown et al. 2009b) and the optimal for adult growth is approximately 77°F 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°F 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°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. 2009b). 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 2 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°F 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.3.5.2.18 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°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 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°F to 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°F 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* at the beginning of Section O.3.5.2.

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 Whiskeytown Reservoir Operations

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) from November to 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.

Whiskeytown Storage / monthly statistics (5-2-12-1b):

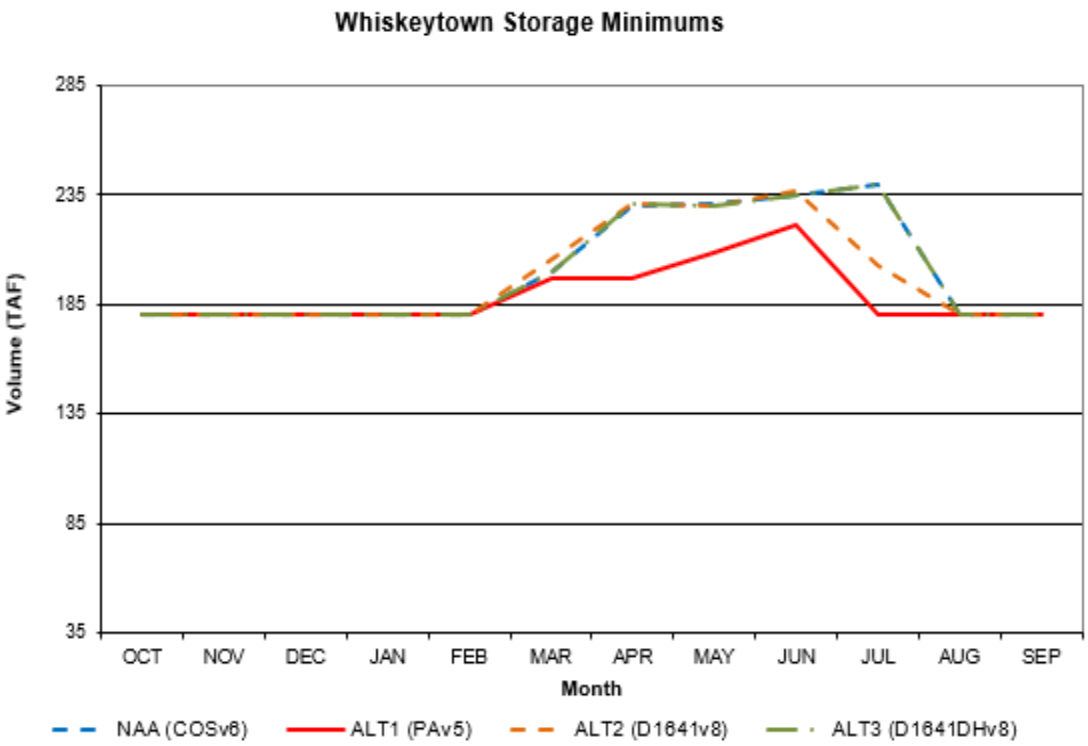


Figure O.3-94. Modeled Whiskeytown Lake Minimum Storage Volume under the No Action Alternative, Alternative 1, Alternative 2, and Alternative 3 during All Water Year Types

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 on 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).

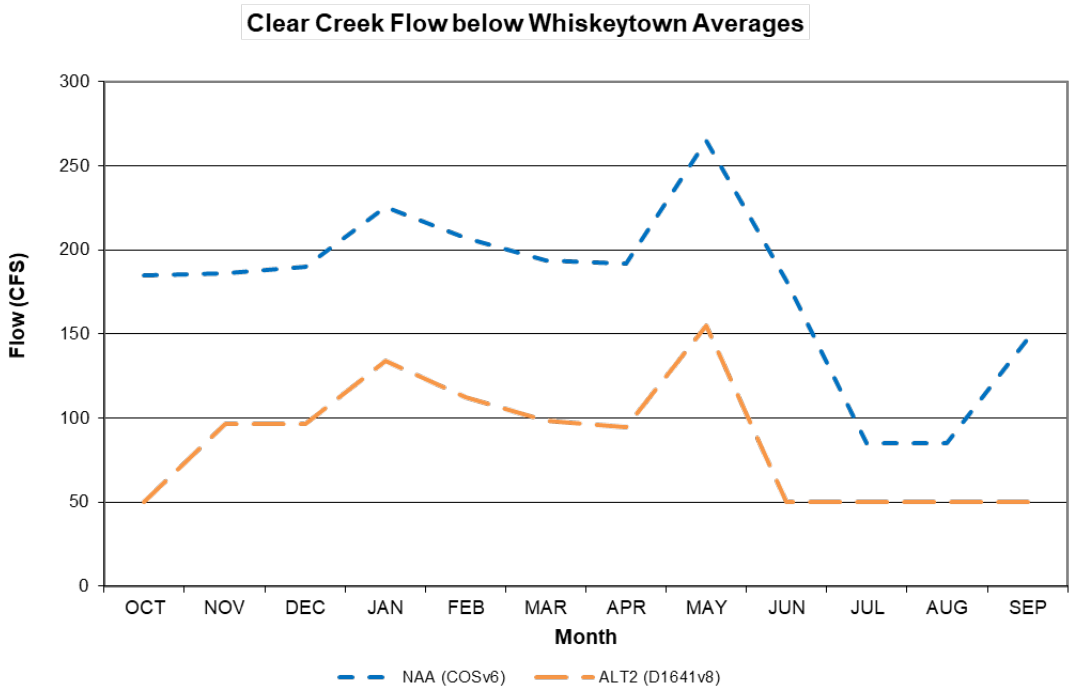


Figure O.3-95. Average Monthly Flow in Clear Creek below Whiskeytown Dam for the No Action Alternative and Alternative 2 during All Water Years (40-30-30 Index)

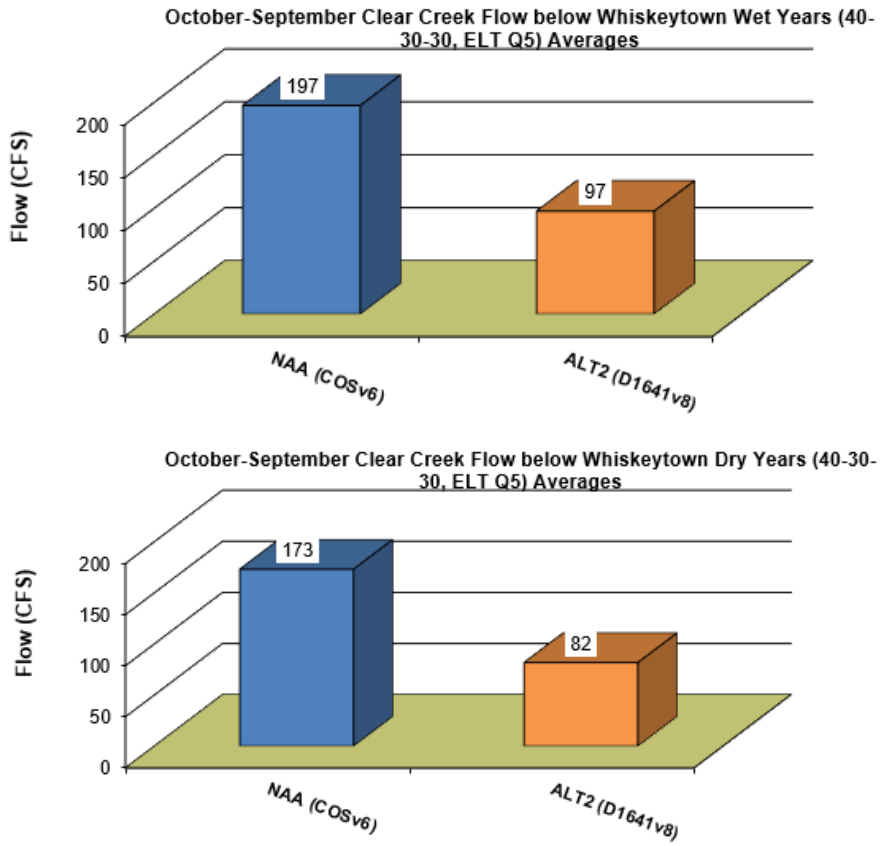


Figure O.3-96. Average Annual Flow in Clear Creek below Whiskeytown Dam for the No Action Alternative and Alternative 2 during Wet and Dry Water Years (40-30-30 Index).

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 out-migrating 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 out-migrating 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 out-migrating 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 out-migrating 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.

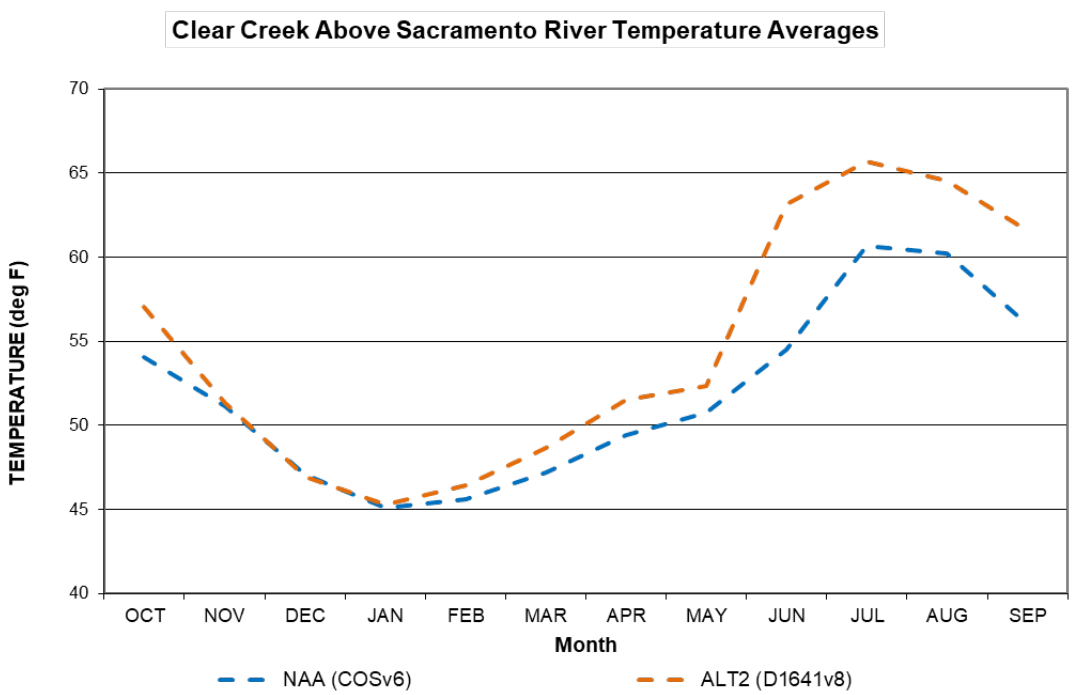


Figure O.3-97. Average Monthly Water Temperatures in Clear Creek above Sacramento River for the No Action Alternative and Alternative 2 during All Water Year Types (40-30-30 Index).

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	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

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 out-migrating 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 out-migrating 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 out-migrating 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 2-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 (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

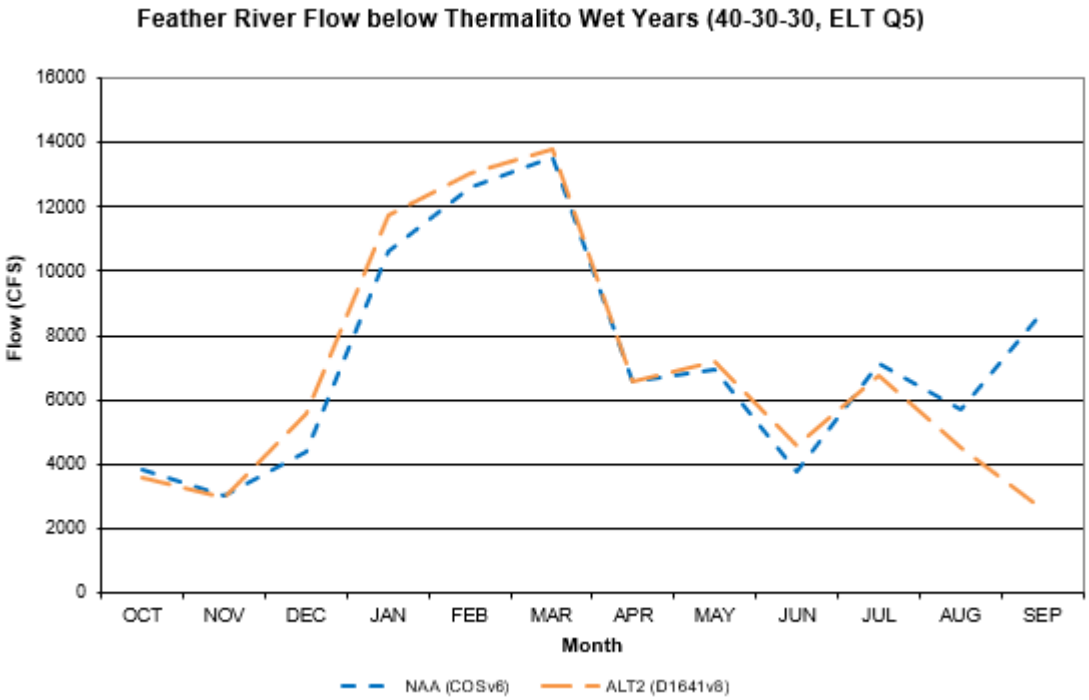
CalSim II model output shows that Feather River flows under Alternative 2 and the No Action Alternative would comply with Feather River HFC minimum instream flow requirements during all months in wet, above normal, and below normal water years. In dry years where the preceding April to July unimpaired 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).

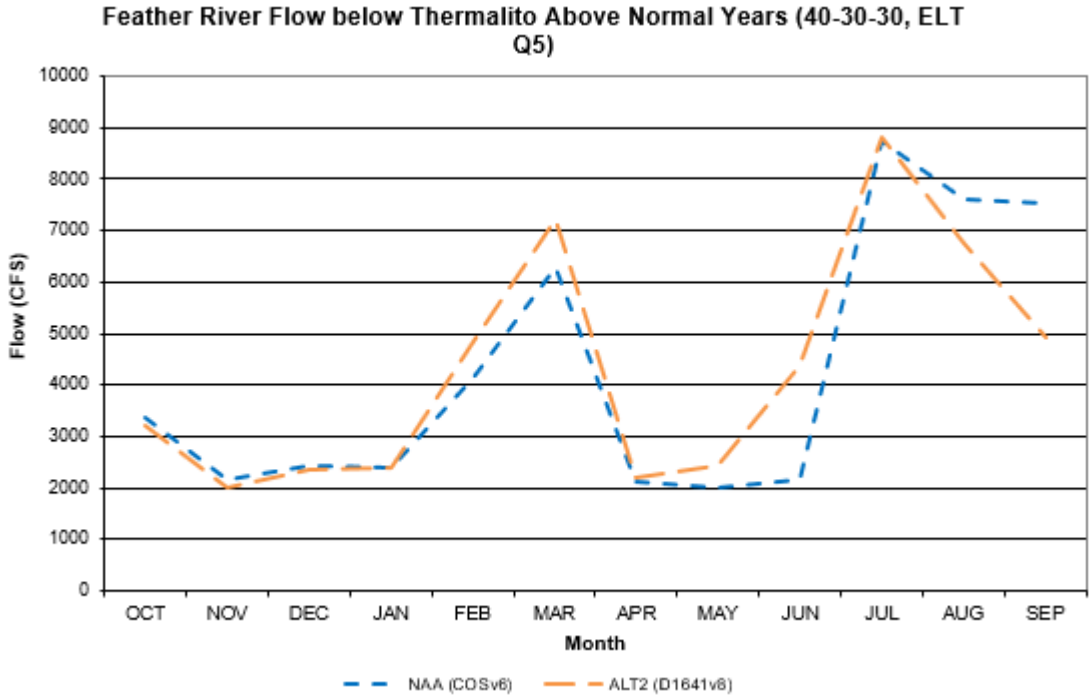
Table O.3-39. Feather River HFC Minimum Instream Flow Requirements

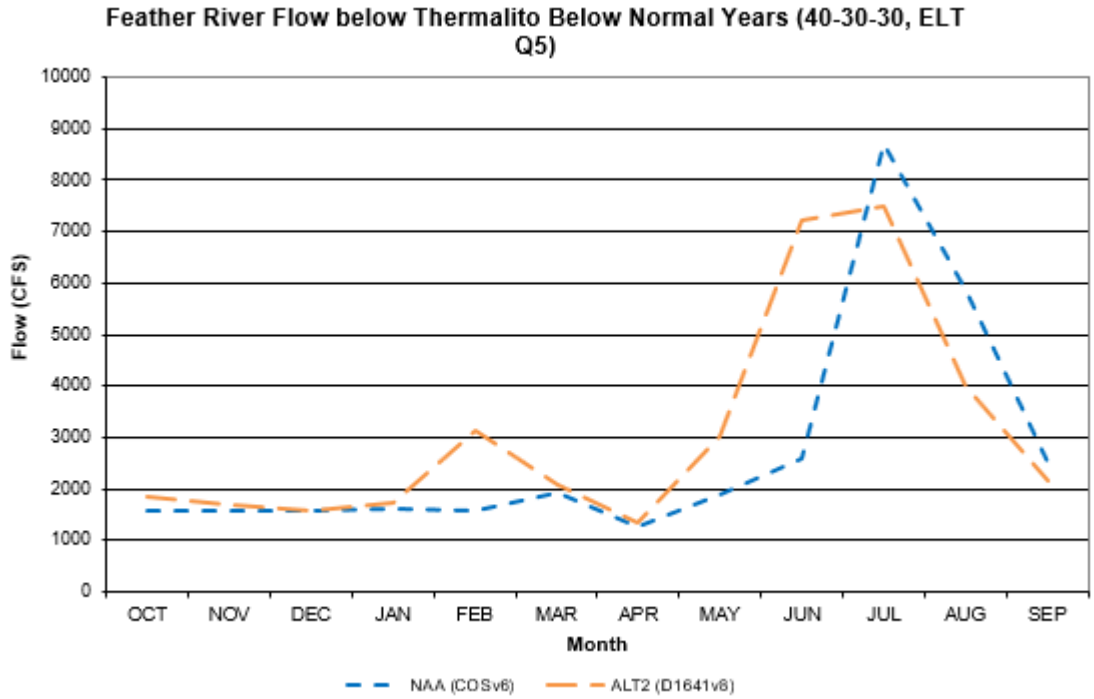
Preceding April to July Unimpaired Runoff (Percent of Normal)	Oct to Feb Minimum Instream Flow (cfs)	March Minimum Instream Flow (cfs)	April to Sept Minimum Instream Flow (cfs)
55% or greater	1,700	1,700	1,000
Less than 55%	1,200	1,000	1,000

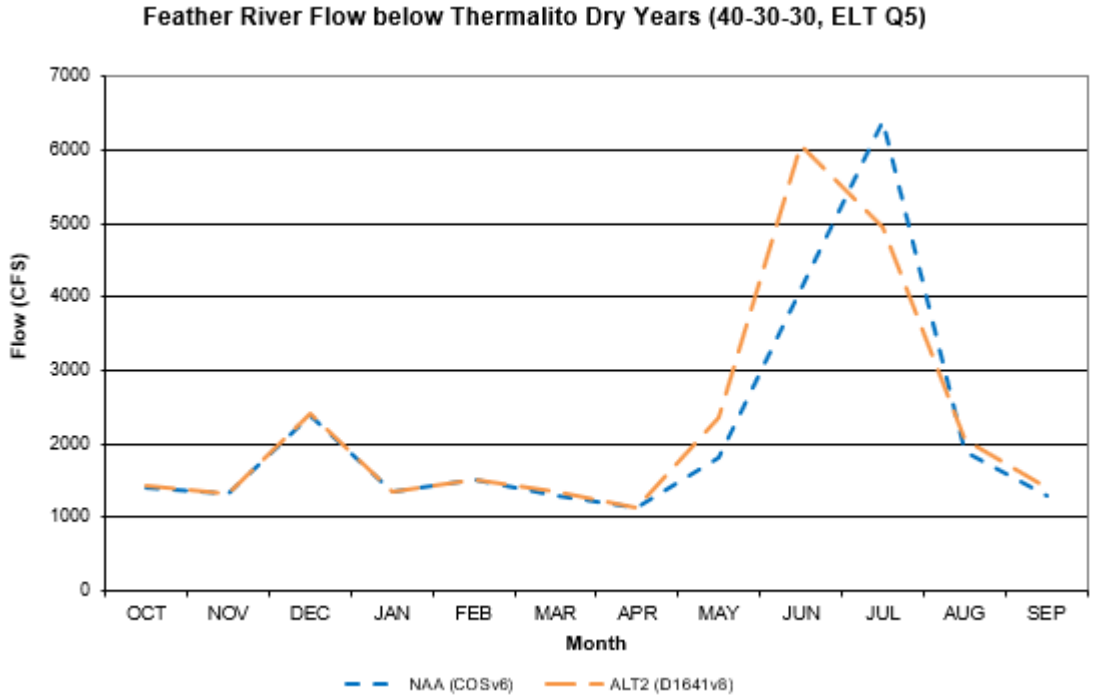
Overall, flows under Alternative 2 and the No Action Alternative are similar, but flows under the No Action Alternative are greater than flows under Alternative 2 from July through September of wet, above normal, and below normal years, and flows under Alternative 2 are greater than under the No

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 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 (D1641v6)


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 (D1641v6)

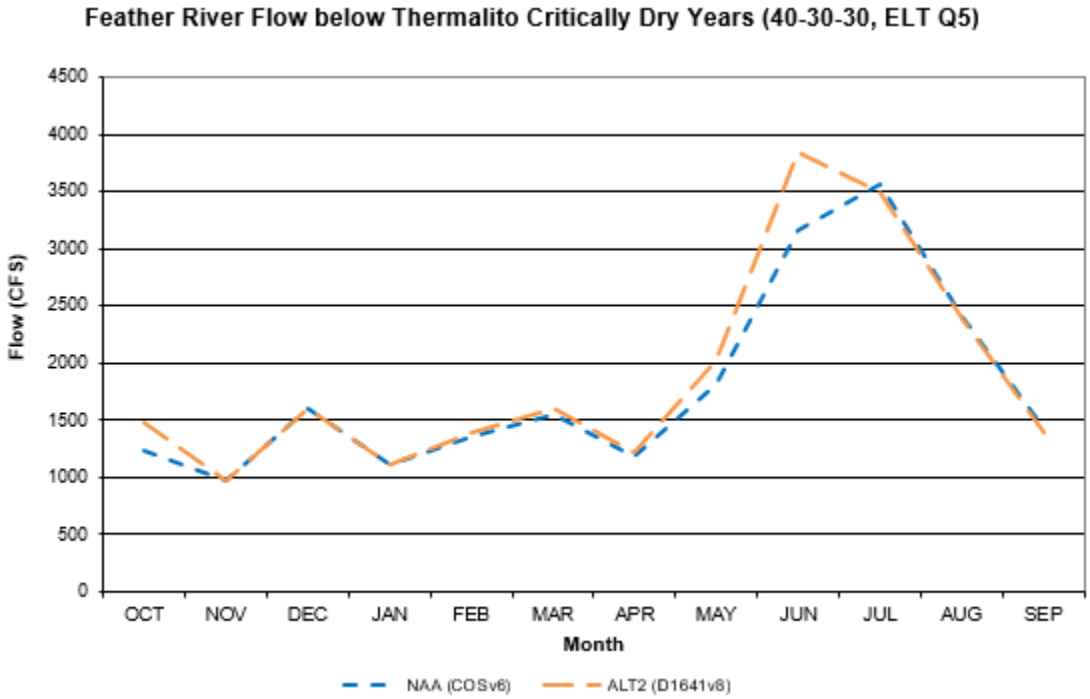


Figure O.3-98. CalSim II estimates of Feather River Long-Term Average Flow below Thermalito, All Scenarios in Wet, Above Normal, Below Normal, Dry, and Critically Dry Water Years

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 oxygen during 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 oxygen content (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 from January to April, juveniles out-migrating year-round with peaks from January to April and August to November, and holding and migrating adults occurring from April to 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 oxygen due 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 oxygen content (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 fresh water (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 oxygen content (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).

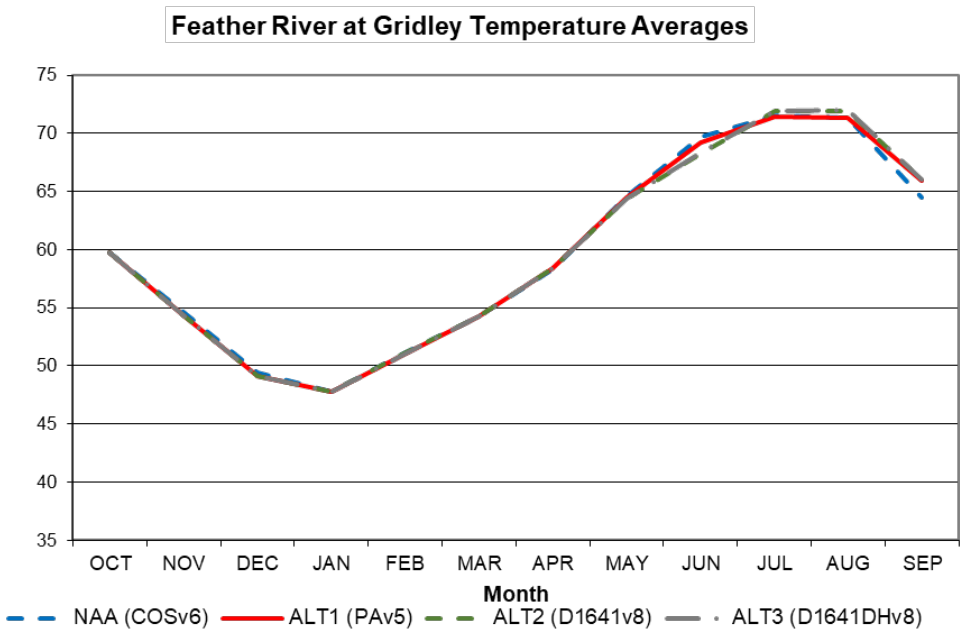


Figure O.3-99. RecTemp average Feather River water temperatures at Gridley Bridge under the No Action Alternative, Alternative 1, Alternative 2, and Alternative 3 scenarios

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 from November to 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 during March through 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 2 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 from May to 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 from June to 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 fresh water (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 during 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 during March through 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 from February through September. As mentioned previously, flows are currently managed to benefit various Central Valley life stages 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 from March through May (Figures 13 and 14). Similar to the discussions above, decreased flows compared to the No Action Alternative has effects on 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 cold water 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.

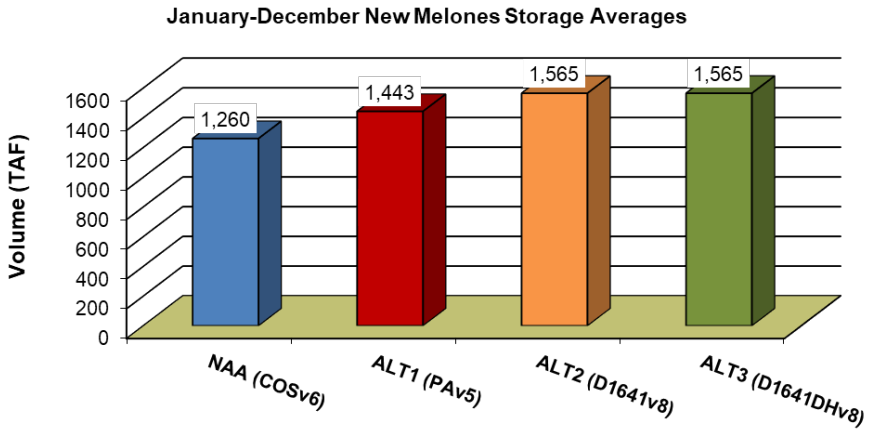


Figure O.3-101. Average Annual Storage at New Melones Reservoir by Project Alternative

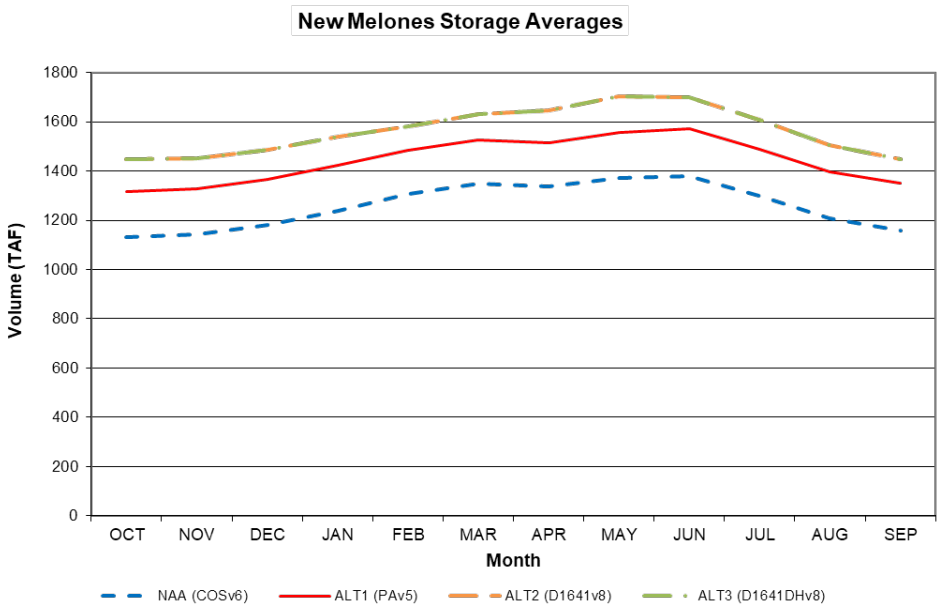


Figure O.3-102. Average Monthly Storage at New Melones Reservoir by Project Alternative

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 life stage. 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.

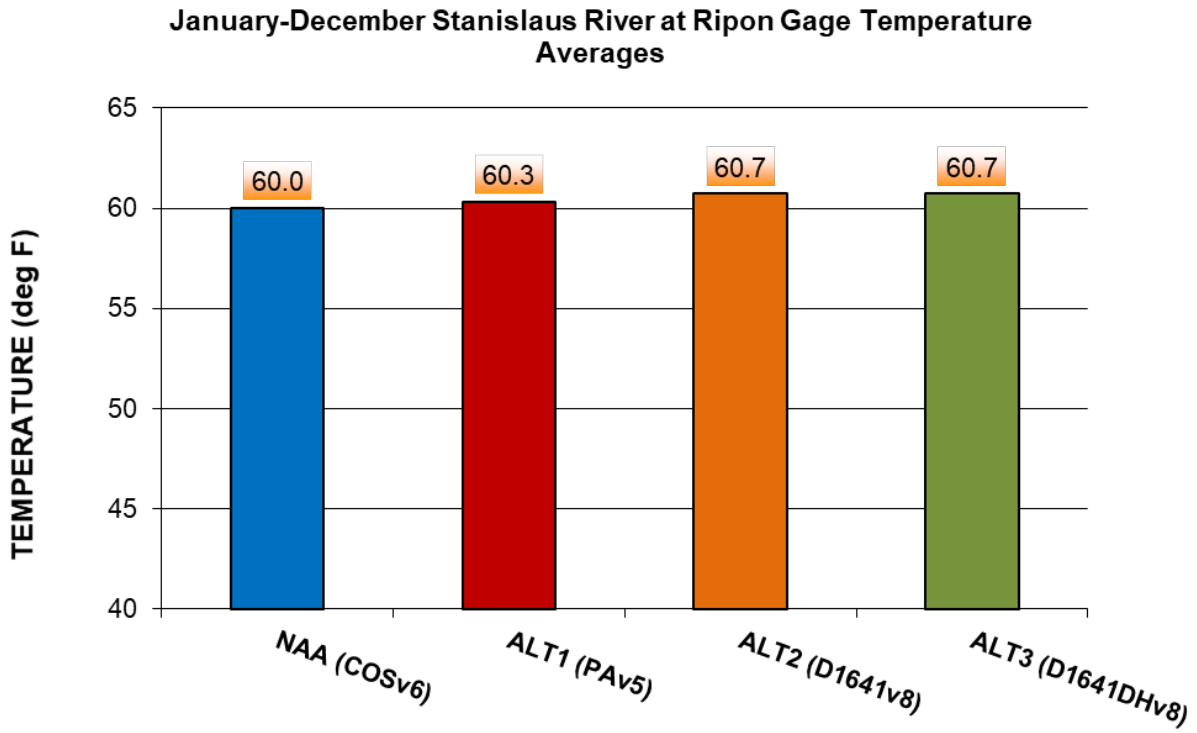


Figure O.3-103. Annual Average Water Temperature at Ripon on the Stanislaus River

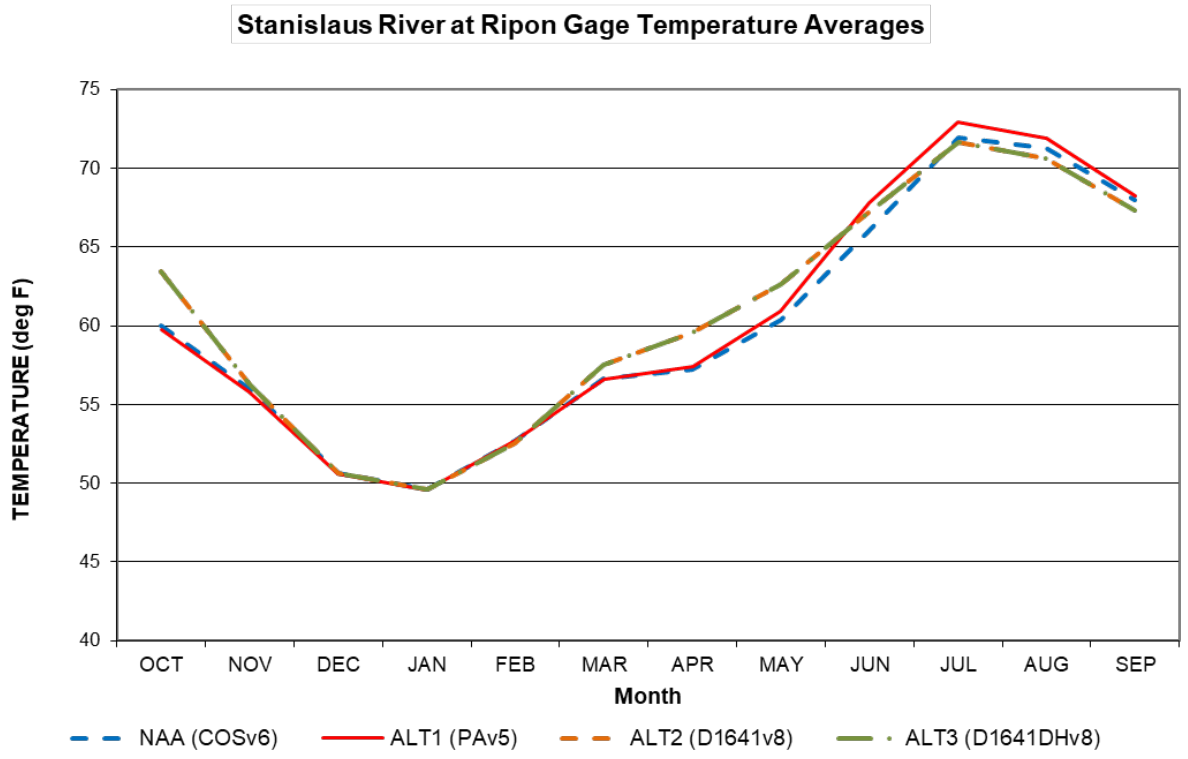


Figure O.3-104. Average Monthly Temperature at Ripon on the Stanislaus River

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 D, Attachment 3-2, Figures 40-9 through 40-15 of the ROC LTO BA), 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 D, Attachment 3-2, Figures 32-9 through 32-14 of the ROC LTO BA). 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 D, Attachment 3-2, Figures 25-6 through 25-18 of the ROC LTO BA). 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. Mitigation measure AQUA-15 will monitor the presence of Delta smelt under Alternative 2.

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 on 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 Forebay 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 D, Attachment 3-2, Figures 41-9 through 41-14 of the ROC LTO BA), 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 on 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 D, Attachment 3-2, Figures 40-9 through 40-15 of the ROC LTO BA) 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 (2009c) 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. Mitigation measure AQUA-16 will monitor the presence of Longfin Smelt under Alternatives 1 through 4.

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 on 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 Forebay aquatic weed and algal bloom management

Potential changes to Longfin Smelt due to changes from Suisun Marsh facilities

O.3.5.8.3 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 from October to 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 CAMT SST. The SST completed a thorough review of this subject and defined a 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.

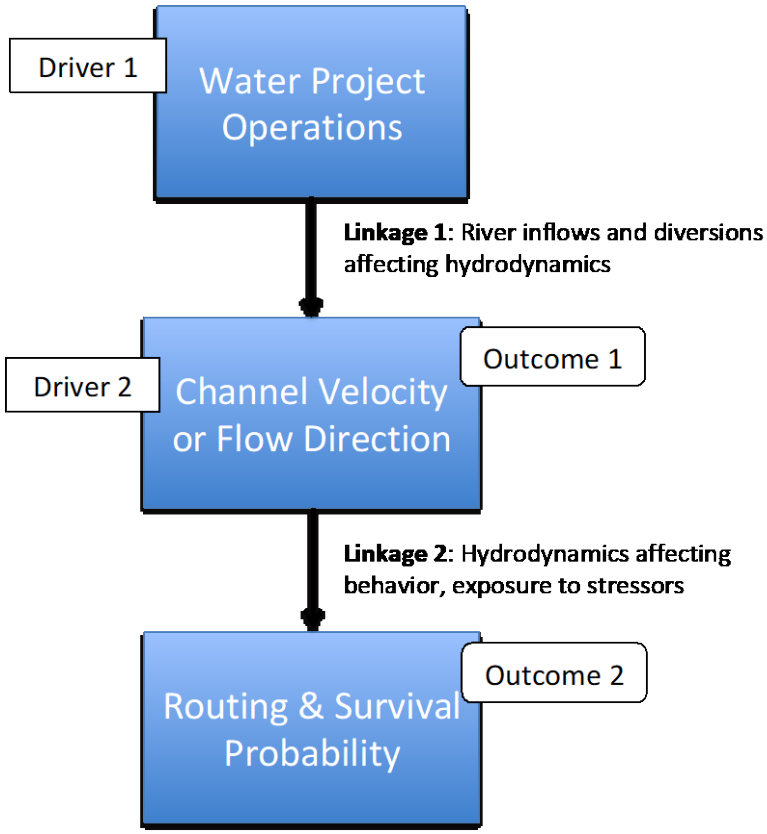


Figure O.3-105. Conceptual Model for Far-Field Effects of Water Project Operations on Juvenile Salmonids in the Delta. This CM is a Simplified Version of the Information Provided by the CAMT SST

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 February and March to May) in each water year (1922 to 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-Run, Late Fall–Run and Fall-Run Chinook Salmon. These data represent 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 from November to 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 from December to 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 DCC 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 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 (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% to 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 out-migrating 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, 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, 2017c; USFWS 1993, 2000, 2007, 2010, 2017; CDFG 1994, 2009a; 58 FR 12854–12864).

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 2017d), 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 2017d, 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 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 2017d). From 1999 to 2009, the 11 years prior to construction of the Rock Slough Fish Screen, CCWD's Fish Monitoring Program collected no juvenile or adult Winter-Run Chinook Salmon at the Rock Slough Headworks (Reclamation 2016; NMFS 2017d) and Contra Costa Canal Pumping Plant #1 (CCWD 2019a).

Since construction of the Rock Slough Fish Screen, 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 to 2018, 47 salmon were recovered at the fish screen (Reclamation 2016: Appendix A;

Tenera Environmental 2018a), but none of the captured fish were identified as Winter-Run Chinook Salmon (NMFS 2017d).

NMFS issued a biological opinion in 2017 (NMFS 2017d) that considered improvements to the Rock Slough Fish Screen facility including the hydraulic rake cleaning system, operation and maintenance of the fish screen and associated appurtenances, and administrative actions such as the transfer of operation and maintenance activities from Reclamation to CCWD. NMFS determined that operation and maintenance of Rock Slough Fish Screen 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 fish screen monitoring (NMFS 2017d). The incidental take provided in NMFS 2017d 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 2019a).

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 (2017c), 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 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 OMR 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, but varies depending on the tidal stage from approximately 56,000 square feet (at low tide and low San Joaquin River flow) to 68,000 square feet (at high tide and high San Joaquin River flow) as shown in Figure O.3-106.

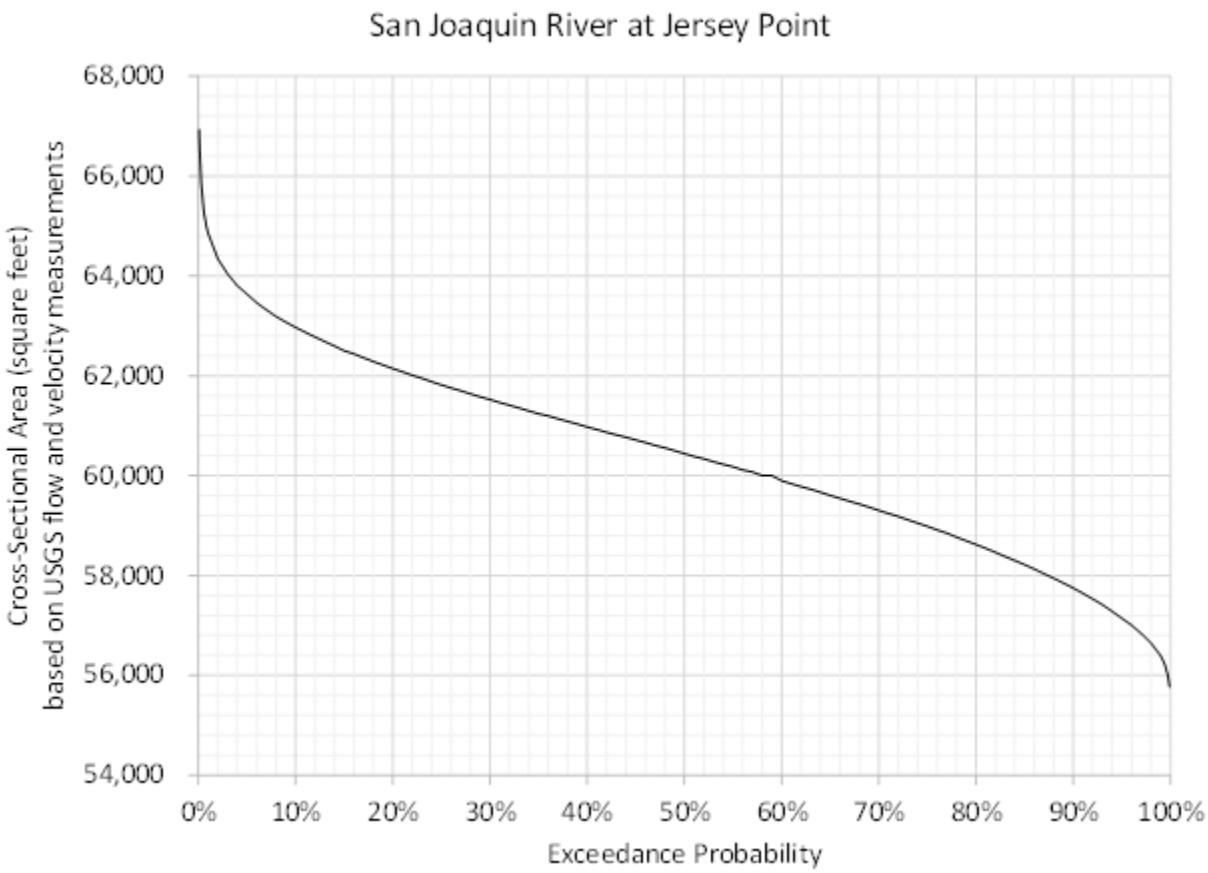


Figure O.3-106. Cross-sectional area of the San Joaquin River at Jersey Point (Station: 11337190) Calculated from USGS Measurements of Flow and Velocity every 15 Minutes for Water Years 2014 through 2018.

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 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 feet 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 feet 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 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 are available at https://www.wildlife.ca.gov/Regions/3 (CDFW 2019b). There should be no discernable effect on 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 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.

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 on 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 Section O.3.5.8.3, *Sacramento River Winter-Run Chinook Salmon*, for more detail concerning "far-field" and "near-field."

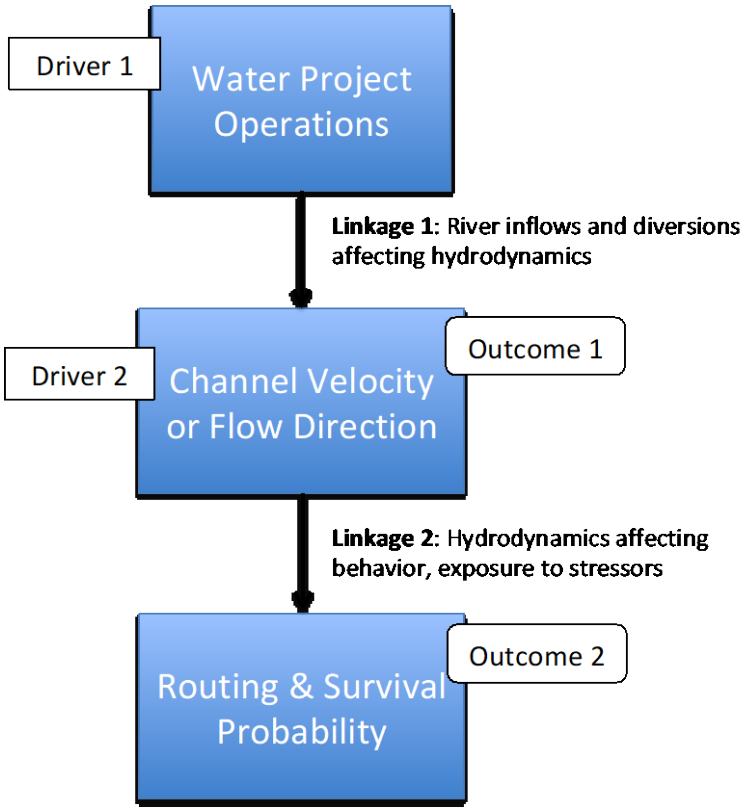


Figure O.3-107. Conceptual model for far-field effects of water project operations on juvenile salmonids in the Delta. This CM is a simplified version of the information provided by the CAMT SST.

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 juvenile Fall-Run 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 Section O.3.5.8.3, *Sacramento River Winter-Run Chinook Salmon*, 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 from November to 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 DCC 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 from November to 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% to 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 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. 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 of 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 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 et al. 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, 2017c; USFWS 1993, 2000, 2007, 2010, 2017; CDFG 1994, 2009a; 58 FR 12854–12864). 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 2017d), 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 2017d, 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 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 2017d). From 1999 to 2009, the 11 years prior to construction of the Rock Slough Fish Screen, 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 2017d) and 4 juvenile Central Valley Spring-Run Chinook Salmon at Pumping Plant #1 (CCWD 2019a). No adult Spring-Run were collected in the vicinity of the Rock Slough Intake from 1994 through 2009 (CDFG 2002c; Reclamation 2016; NMFS 2017d). 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 Rock Slough Fish Screen, 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 to 2018, 47 salmon were recovered at the fish screen (Reclamation 2016: Appendix A; Tenera Environmental 2018a), but none of the captured fish were identified as Spring-Run Chinook Salmon (NMFS 2017d).

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 2019a).

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 (2017c), 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 Section O.3.5.8.3, *Sacramento River Winter-Run Chinook Salmon*, 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 under *Through-Delta Survival* in Section O.3.5.8.3, the diversions at the Rock Slough Intake could move a neutrally buoyant particle in the San Joaquin River at Jersey Point approximately 540 feet 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 feet 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 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 are available at https://www.wildlife.ca.gov/Regions/3). The North Bay Aqueduct is located within designated critical habitat for Spring-Run Chinook Salmon.

There should be no discernable effect on 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 2 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.3-108 through O.3-110).

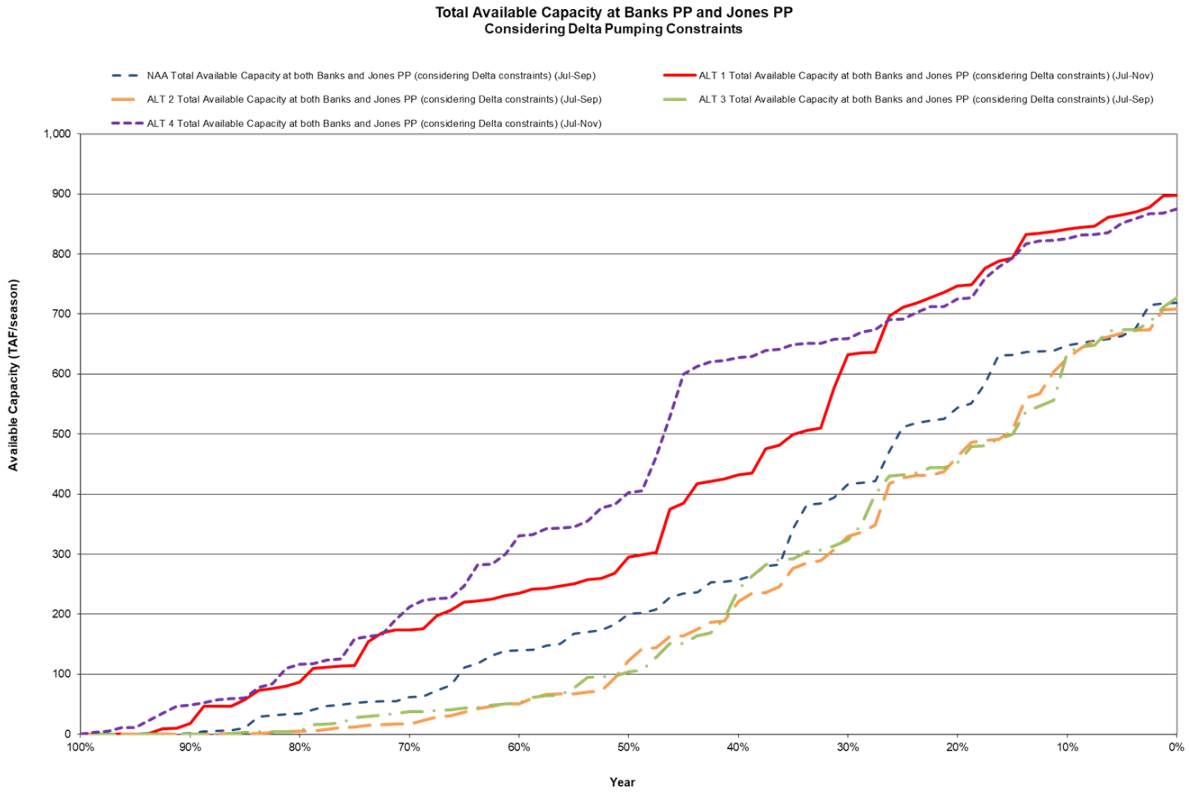


Figure O.3-108. Exceedance of Available Capacity for Transfers at Jones and Banks under Alternative 2 and No Action Alternative

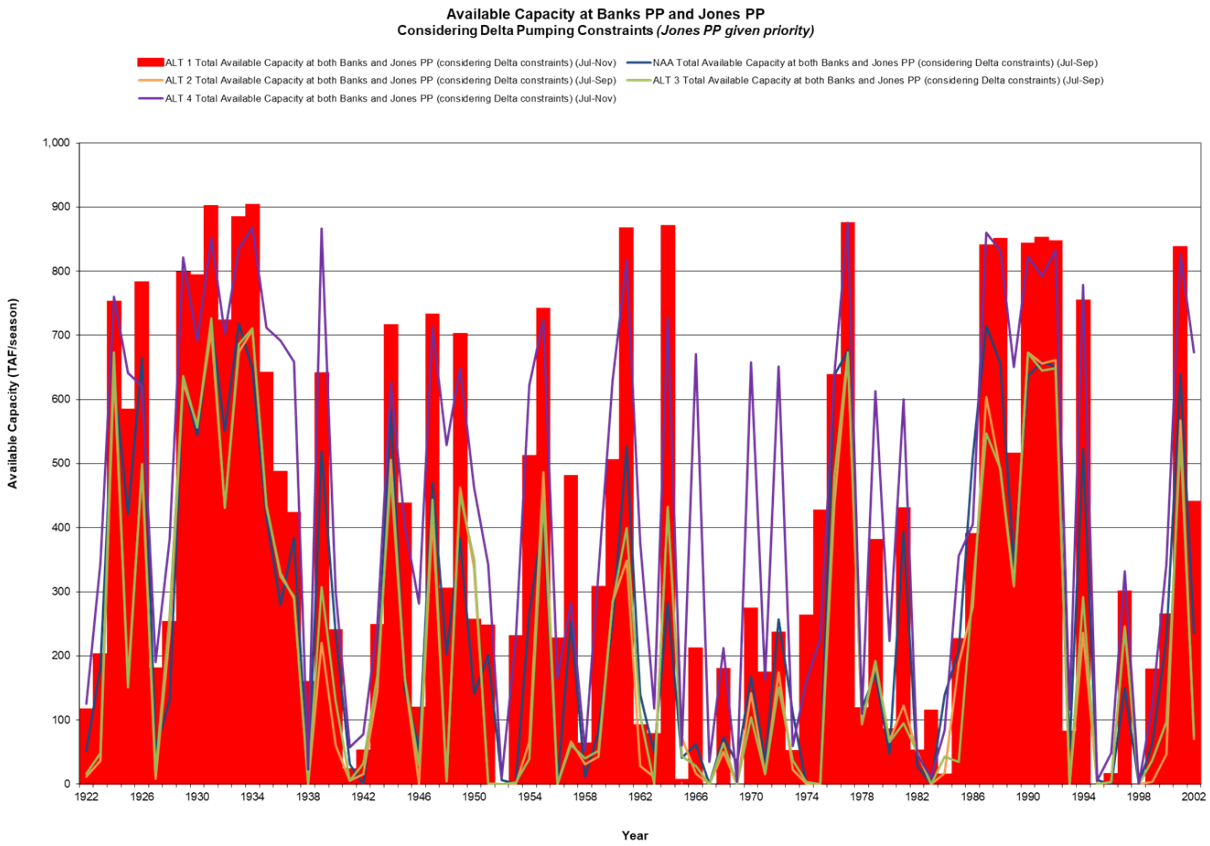


Figure O.3-109. Modeled annual maximum available capacity for transfers under Alternative 2 and No Action Alternative, CalSim period of record (1922–2003)

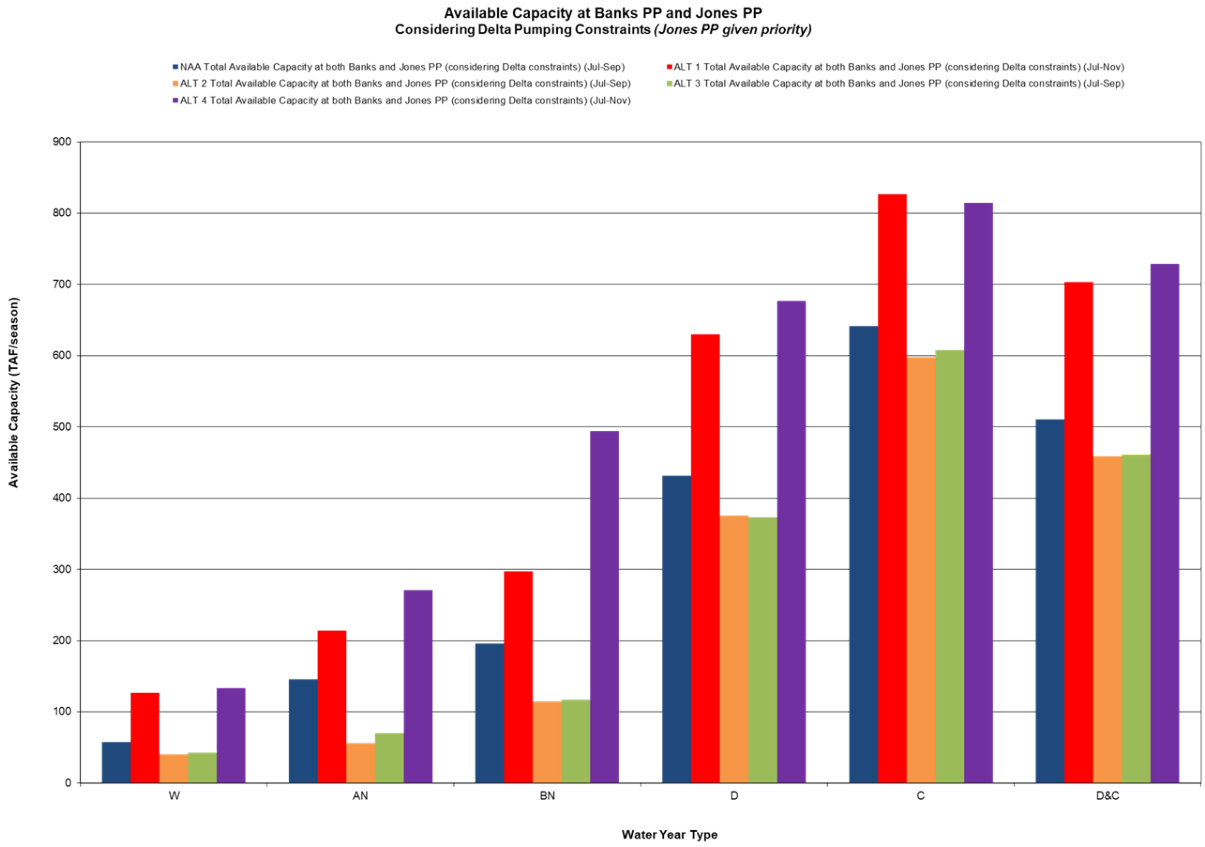


Figure O.3-10. Water Year Type average available capacity at Jones and Banks Pumping Plants

Egg, 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 from December to 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 the *Potential changes to aquatic resources due to seasonal operations* 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 CAMT SST). The SST completed a thorough review of this subject and defined a 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.

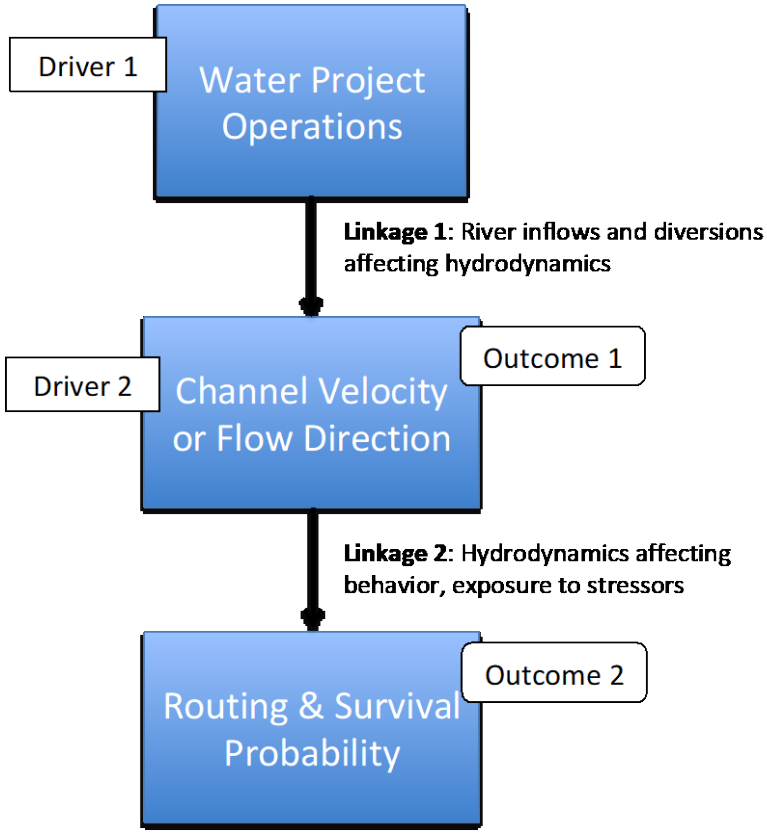


Figure O.3-111. Conceptual model for far-field effects of water project operations on juvenile salmonids in the Delta. This CM is a simplified version of the information provided by the CAMT SST.

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, 2012, 2015; Michel et al. 2012).

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 (December to February and March to May) in each water year (1922 to 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 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. These data are extremely useful because they represent 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–Run Chinook

Salmon 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 2 were evaluated using DSM2 as described above. Juvenile Fall-Run Chinook Salmon abundance in the Delta is greatest from February to May and Late Fall–Run are present in the Delta from November to July with peaks in January through February and April through May (Reclamation 2019). In the December through February period, velocity overlap between Alternative 2 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 DCC 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 during the March through May period, overlap between Alternative 2 and No Action Alternative was moderate in all water year types (41% to 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 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 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 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 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 et al. 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, 2017c; USFWS 1993, 2000, 2007, 2010, 2017; CDFG 1994, 2009a; 58 FR 12854–12864). 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 indicates the timing and magnitude of Fall-Run and Late Fall–Run Chinook Salmon presence near the Rock Slough Intake. From 1999 to 2011, the 11 years prior to construction of the Rock Slough Fish Screen, CCWD’s Fish Monitoring Program collected 23 juvenile Fall-Run and 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 or 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 or Late Fall–Run Chinook Salmon at CCWD’s Old River Intake or Middle River Intake (CCWD 2019a).

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- /Late Fall–Run Chinook Salmon are not likely to be in the vicinity of the Rock Slough Intake. However, according to NMFS (2017c), 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 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 the 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 Section O.3.5.8.3, *Sacramento River Winter-Run Chinook Salmon*, 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- /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 Section O.3.5.8.3, the diversions at the Rock Slough Intake could move a neutrally buoyant particle in the San Joaquin River at Jersey Point

approximately 540 feet 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 feet 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 from 2003 to 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 composed 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 during March to 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 from November to 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 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 during the March through May period, overlap between Alternative 2 and

No Action Alternative was moderate in all water year types (41% to 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 on this life stage when compared to the No Action Alternative.

Potential changes to aquatic resources due to the Temporary Barriers Project

The 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), 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 on 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 2 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, 2017c; USFWS 1993, 2000, 2007, 2010, 2017; CDFG 1994, 2009a; 58 FR 12854–12864). 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 indicates the timing and magnitude of presence near the Rock Slough Intake. From 1999 to 2011, the 11 years prior to construction of the Rock Slough Fish Screen, 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 2019a).

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 (2017c), 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 OMR corridor that are not salvaged at TFCF or the 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 Section O.3.5.8.3, *Sacramento River Winter-Run Chinook Salmon*, 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 Section O.3.5.8.3, the diversions at the Rock Slough Intake could move a neutrally buoyant particle in the San Joaquin River at Jersey Point approximately 540 feet 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 feet 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 negligible.

Potential changes to aquatic resources in North Bay Aqueduct operations

Under Alternative 2, there would be no changes to operational criteria at the North Bay Aqueduct's Barker Slough Pumping Plant relative to current operations. Juvenile Central Valley Steelhead could occur in the vicinity of the Barker Slough Pumping Plant; 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 were 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 life stages 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 on 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 months) 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 months) 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 out-migrating 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 out-migrating 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 of the TBP are included in Alternative 2 and consist 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), out-migrating Chinook Salmon passage past the agricultural barrier was improved (DWR 2018). It could be inferred that passage of out-migrating 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, 2017c; USFWS 1993, 2000, 2007, 2010, 2017; CDFG 1994, 2009a; 58 FR 12854–12864). 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 2017d), 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 40ºF in winter (December and January) to over 70ºF beginning in May and continuing through October (NMFS 2017d).

A review of the 24 years of fish monitoring data (1994 to 2018) near the Rock Slough Intake both pre- and post-construction of the Rock Slough Fish Screen showed that Southern DPS Green Sturgeon have never been observed in Rock Slough (CDFG 2002c; Reclamation 2016; NMFS 2017d; 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 2019a).

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 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 *Potential changes to aquatic resources due to water transfers* in Section 3.5.8.4, *Central Valley Spring-Run Chinook Salmon*, 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 *Potential changes to aquatic resources due to seasonal operations* 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 on 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 Section O.3.5.1, *Trinity River*, Section O.3.5.2, *Sacramento River*, Section O.3.5.3, *Clear Creek*, Section O.3.5.4, *Feather River*, Section O.3.5.5, *American River*, Section O.3.5.6, *Stanislaus River*, Section O.3.5.7, *San Joaquin River*, and Section O.3.5.8, *Bay-Delta*. While no longer the current BO, considering 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 2009:718), Alternative 2 may result in potential negative effects on 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 (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 temperature control device improvements

Improvement of the Shasta temperature control device 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 River 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 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 component of Alternative 2. This action would hydrologically connect the Sacramento River with the ship channel 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 Sacramento Deepwater Ship Channel. Estimates of salmonid survival in the ship channel are not available to compare with rates in the Sacramento River route. However, if survival rates are similar, fish entering the Sacramento Deepwater Ship Channel 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 Sacramento Deepwater Ship Channel could potentially attract adult Winter-Run Chinook Salmon. If the connection is maintained there would likely not be impacts on 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 from December to 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 from December to 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 on 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 on 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 DCC. 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 CO_2 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 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 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 on 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 Clifton Court Forebay could reduce pre-screen loss of juvenile Chinook Salmon entrained into Clifton Court Forebay. 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 out-migrating 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. The NEPA process for the facility (Horizon Water and Environment 2017) indicates 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.3.6.2.4 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 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 enter the Sacramento Deepwater Ship Channel. There are potential benefits to Spring-Run Chinook Salmon from this action. Fish entering the ship channel 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 Sacramento Deepwater Ship Channel 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 during 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 during 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 on 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 DCC 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 DCC 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 the Tracy fish facility, including installing a CO_2 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 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 out-migrating 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. The NEPA process for the facility (Horizon Water and Environment 2017) indicates 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 aquatic resources 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.3.6.2.5 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 action. This action would hydrologically connect the Sacramento River with the ship channel 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 Sacramento Deepwater Ship Channel. Estimates of salmonid survival in the ship channel are not available to compare with rates in the Sacramento River route. However, fish entering the Sacramento Deepwater Ship Channel 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 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 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 on 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 DCC under Alternative 2 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 DCC 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; see Figure WR_CM4 of the ROC LTO BA), there could be a minor effect on 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 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 to the small screen program

Although there may be moderate overlap of Fall-Run and 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-Run or Late Fall–Run Chinook Salmon rearing and out-migrating in the Bay-Delta are expected to be exposed to the effects of construction of screens on water diversion intakes. Juvenile Sacramento River Fall-Run and 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. The NEPA process for the facility (Horizon Water and Environment 2017) indicates 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 conservation measure under Alternative 2. This conservation measure would hydrologically connect the Sacramento River with the Sacramento Deepwater Ship Channel 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 ship channel. Estimates of salmonid survival in the Sacramento Deepwater Ship Channel are not available to compare with rates in the Sacramento River route. However, fish entering the Sacramento Deepwater Ship Channel 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 Central Valley Steelhead 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 on 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 from December to 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 on 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 from August to 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 from August to 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 CO_2 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 Clifton Court Forebay could reduce pre-screen loss of juvenile Central Valley Steelhead entrained into Clifton Court Forebay, thereby 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 life stage in the same ways described above. Juvenile Central Valley Steelhead out-migrating 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. The NEPA process for the facility (Horizon Water and Environment 2017) indicates 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 from August to 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 Sacramento Deepwater Ship Channel. Fish entering the ship channel 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 ship channel 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 on 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 on 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 Clifton Court Forebay, 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 the analysis of 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 on Southern Resident Killer Whale Chinook Salmon prey. This suggests very 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 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 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.

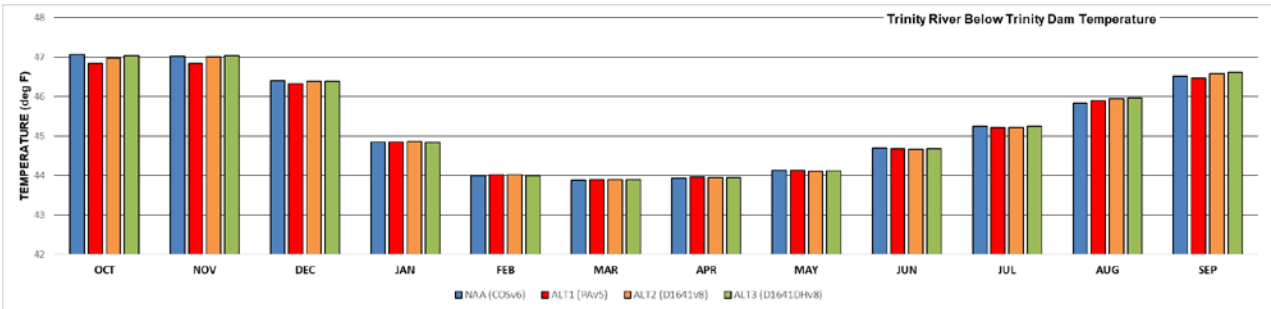


Figure O.3-112. Average Trinity River Water Temperatures below Trinity Dam for the Period October to September, Average of All Water Year Types

Reservoir Fish Species

Reservoir storage conditions are expected to be similar under Alternative 3 compared to the No Action Alternative with only slight decreases in storage anticipated during July and August (Figure O.3-112b and Table O.3-41b). Therefore, effects on reservoir fish are expected to be similar under Alternative 3

compared to the No Action Alternative. Effects of Trinity Reservoir storage on fish in the Trinity River downstream of Lewiston Dam are described below.

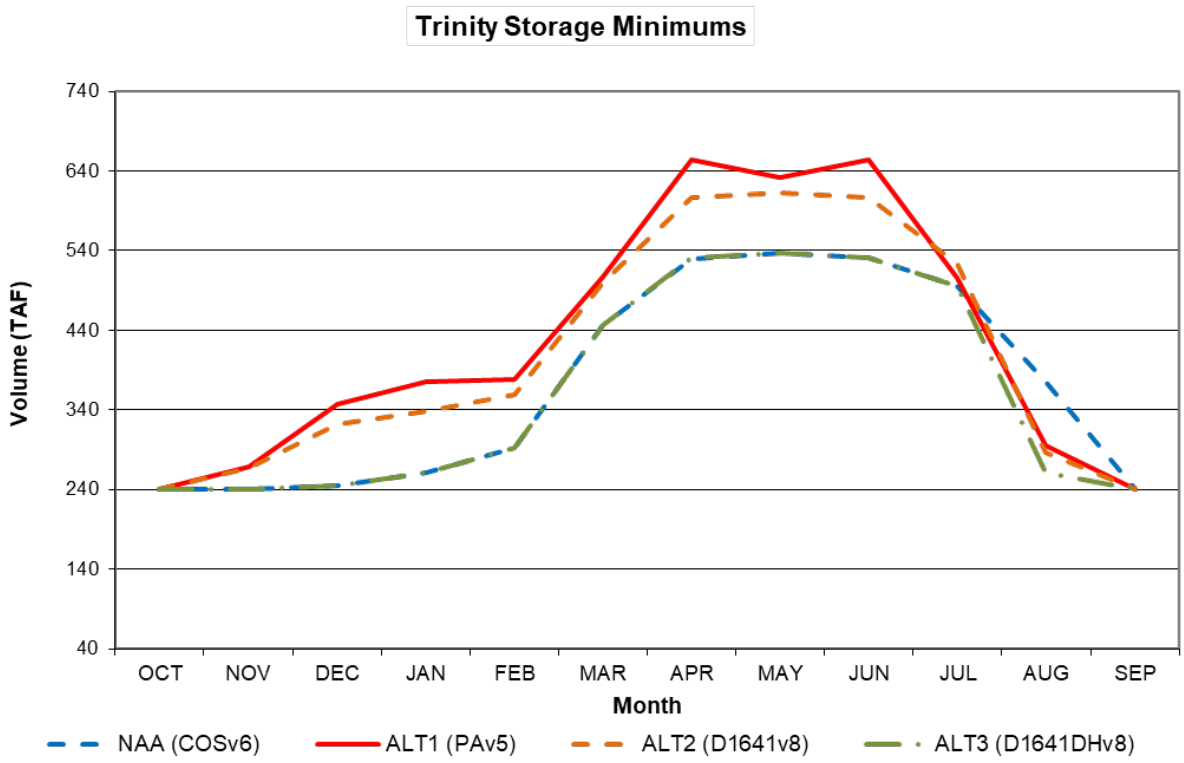


Figure O.3-112b. Modeled Trinity Lake Monthly Minimum Storage Volume under the No Action Alternative, Alternative 1, Alternative 2, and Alternative 3 during All Water Year Types

Table O.3-41b. Modeled Differences in Trinity Lake Minimum Storage Volumes under Alternative 3 Relative to the No Action Alternative

Month	Change in Volume from No Action Alternative (TAF) Alt 3
October	0
November	0
December	0
January	0
February	0
March	0
April	0
May	0
June	0
July	0

August	115
September	0

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.

Under Alternative 3, diseases affecting salmon, such as *C. shasta* (Ich) and *columnaris*, could continue to have substantial impact on adult salmon compared to the No Action Alternative, and conditions could be worsened in September or October of critically dry years, when habitat conditions could include lower flows and higher water temperatures compared to the No Action Alternative. However, Alternative 3 continues to consider 10 years of additional TRRP projects (through 2030), which would otherwise be expected to reduce the threat of disease outbreaks. Nonetheless, disease pressures could change and there is uncertainty in how disease prevalence will affect future conditions under this alternative.

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 is not expected to result in redd scour based on previous studies in the Trinity River which reported sand and gravel substrates became mobile at flows around 2,700 cfs or greater (McBain and Trush 1997) but could decrease available Coho fry and juvenile rearing habitat by approximately 20% to 25% during February based on WUA reported in USFWS et al. 1999. Habitat improvements under Alternative 3 would also be expected to reduce the threat of disease outbreaks for Coho Salmon overall, although there is uncertainty in how disease prevalence will affect future conditions, and these conditions could be worsened in September or October of critically dry years, when habitat conditions could include lower flows and higher water temperatures, compared to the No Action Alternative.

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 is not expected to result in redd scour based on previous studies in the Trinity River which reported sand and gravel substrates became mobile at flows of around 2,700 cfs or greater (McBain and Trush 1997). The flow increase could decrease available Chinook fry and juvenile rearing habitat by approximately 25% to 30% during February based on WUA reported in USFWS et al. 1999. Habitat improvements under Alternative 3 would also be expected to reduce the threat of disease outbreaks for Spring-Run Chinook Salmon overall, although there is uncertainty in how disease prevalence will affect future conditions, and these conditions could be worsened in September or October of critically dry years, when habitat conditions could include lower flows and higher water temperatures, compared to the No Action Alternative.

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 is not expected to result in redd scour based on previous studies in the Trinity River which reported sand and gravel substrates became mobile at flows of around 2,700 cfs or greater (McBain and Trush 1997). The flow increase could decrease available Chinook fry rearing habitat by approximately 25% during February based on WUA reported in USFWS et al. 1999. Habitat improvements under Alternative 3 would also be expected to reduce the threat of disease outbreaks for Fall-Run Chinook Salmon overall, although there is uncertainty in how disease prevalence will affect future conditions, and these conditions could be worsened in September or October of critically dry years, when habitat conditions could include lower flows and higher water temperatures, compared to the No Action Alternative.

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. Habitat improvements under Alternative 3 would be expected to reduce the threat of disease outbreaks for Steelhead overall, although there is uncertainty in how disease prevalence will affect future conditions, and Steelhead remain resistant to these diseases.

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 3 would not affect Green Sturgeon.

White Sturgeon

White Sturgeon are not likely to be affected by changes in reservoir operations under Alternative 3 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.

Eulachon

Eulachon are only found in the lower Klamath River. Water temperature and habitat conditions within the Lower Klamath River downstream of the confluence with the Trinity River are heavily influenced by several large tributaries that enter the Trinity River as well the Klamath River itselft. 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 Eulachon.

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).

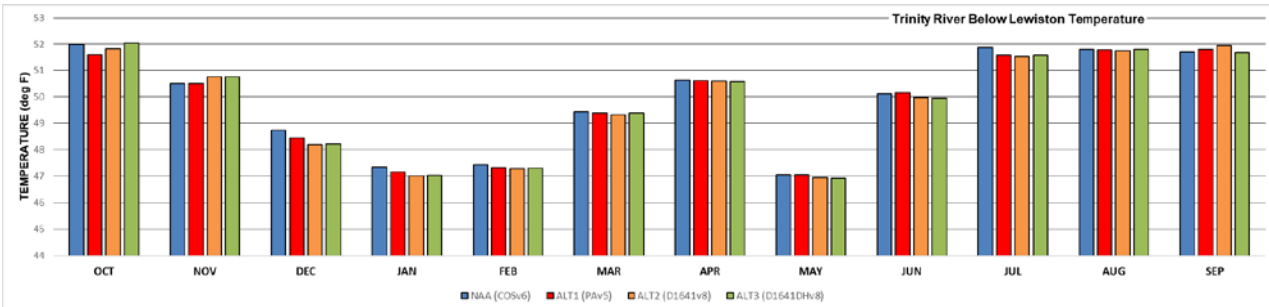


Figure O.3-113. Average Trinity River Water Temperatures below Lewiston Dam for the Period October to September, Average of All Water Year Types

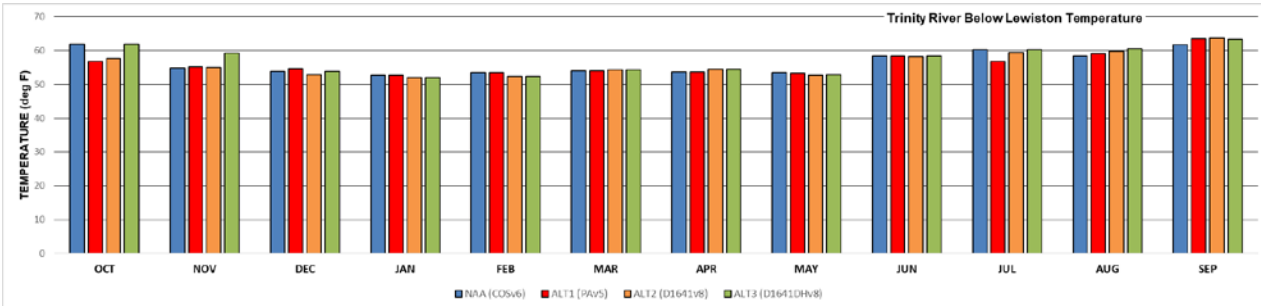


Figure O.3-114. Maximum Trinity River Water Temperatures below Lewiston Dam for the Period October to September, Average of All Water Year Types

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 from October to 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 3 would not affect Green Sturgeon.

White Sturgeon

White Sturgeon would not be affected by changes in reservoir operations under Alternative 3 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.

Eulachon

Eulachon are only found in the lower Klamath River. Water temperature and habitat conditions within the Lower Klamath River downstream of the confluence with the Trinity River are heavily influenced by several large tributaries that enter the Trinity River as well the Klamath River itselft. 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 Eulachon.

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 action 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 temperature 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]	**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 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 Alternative6												
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

Alternative1,2,3	Monthly Temperature (°F)											
Water Year Type4	**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 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 Alternative6												
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 3, 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]	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]	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]	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]	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 3 and Differences between Them

Alternative[1,2,3]	**Monthly Temperature (°F)**											
Water Year Type4	**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 3												
Wet (32%)	56.0	53.5	49.3	46.5	47.0	49.4	53.6	56.7	58.6	58.2	58.5	58.5
Above Normal (16%)	56.2	52.9	48.7	46.6	47.1	50.1	55.0	56.4	56.7	56.7	58.2	59.5
Below Normal (13%)	56.8	53.7	49.0	46.8	48.0	51.5	55.9	55.8	56.6	57.5	58.2	59.2
Dry (24%)	57.0	53.3	48.6	47.0	48.3	51.7	56.1	56.5	57.2	58.6	60.7	60.5
Critically Dry (15%)	61.2	54.9	48.6	47.4	49.1	52.2	56.4	57.7	59.6	61.3	63.4	64.6

Alternative[1,2,3]	**Monthly Temperature (°F)**											
Water Year Type4	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
Alternative 3 minus No Action Alternative[6]												
Wet (32%)	-0.2	-0.8	0.0	0.0	0.0	0.0	-0.1	0.0	-0.4	0.1	-0.3	3.1
Above Normal (16%)	0.0	-0.8	-0.1	0.0	0.0	0.1	0.1	-0.5	-1.1	0.1	-0.2	3.2
Below Normal (13%)	0.2	0.4	0.1	0.1	0.0	-0.2	-0.4	-0.9	-0.8	0.1	-0.6	-0.9
Dry (24%)	-0.2	0.2	0.1	0.0	0.0	0.2	0.0	-1.0	-0.7	0.1	0.1	-0.5
Critically Dry (15%)	0.6	0.3	0.0	0.1	0.1	-0.2	-0.2	-0.3	-0.3	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.

Table O.3-48. HEC-5Q Monthly Average Water Temperatures (degrees Fahrenheit) by Water Year Type and Month below Hamilton City for No Action Alternative, Alternative 3 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
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]	Monthly Temperature (°F)											
Water Year Type[5]	**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 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]	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
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]	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
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.

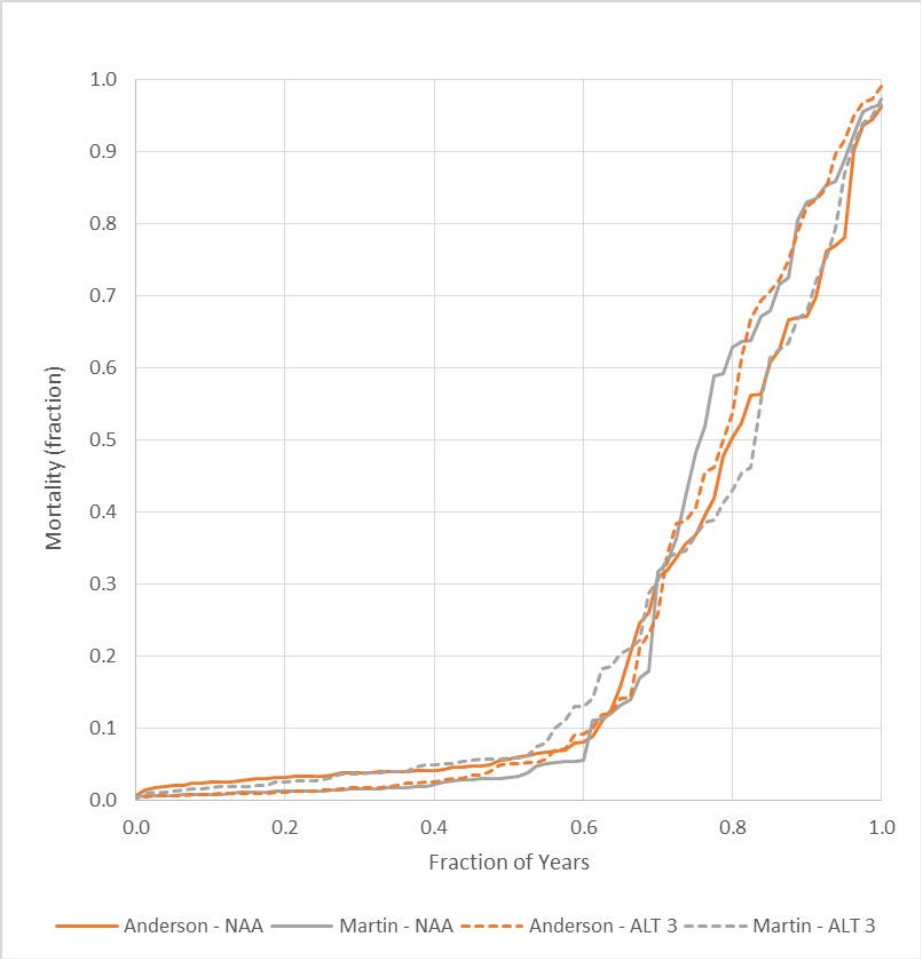


Figure O.3-115. Exceedances of Winter-Run Chinook Salmon Temperature-Dependent Egg Mortality, Alternative 3 vs. No Action Alternative; All Water Year Types.

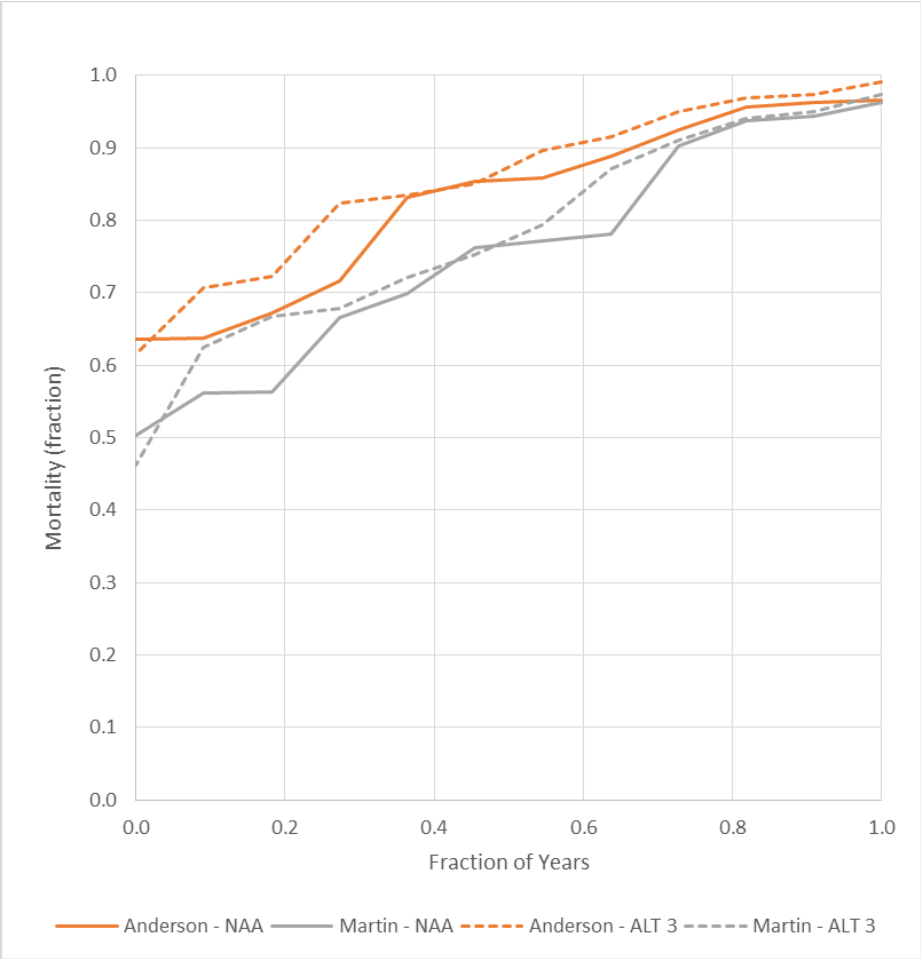


Figure O.3-116. Exceedances of Winter-Run Chinook Salmon Temperature-Dependent Egg Mortality, Alternative 3 vs. No Action Alternative; Critically Dry Water Years

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. 2001a, 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 RBDD. 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 differences 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 2011b: 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-significant 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 2017c). 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. 2001a, 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 3 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 3 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. 2013). 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

Central Valley 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

WUA) developed by the USFWS (2003a) 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

Central Valley 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 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. 2017). 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, 2017; NMFS 2018b). Eggs hatch about a week after fertilization (at 60ºF) (Heublein et al. 2017). 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. 2017) concluded that the optimal range for normal embryo development of Southern DPS Green Sturgeon is 53°F 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 53ºF 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°F 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 for Alternative 1 in Section O.3.3, *Alternative 1 — Project-Level Effects*, 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. 2017). The upstream limit is the Cow Creek confluence. Green Sturgeon juveniles rear in the Sacramento River from about May through December (NMFS 2017c). 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. 2017). 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. 2017).

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 66ºF 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 58ºF 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 63ºF 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 from July to 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 (USFWS 2003, 2005b).

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.

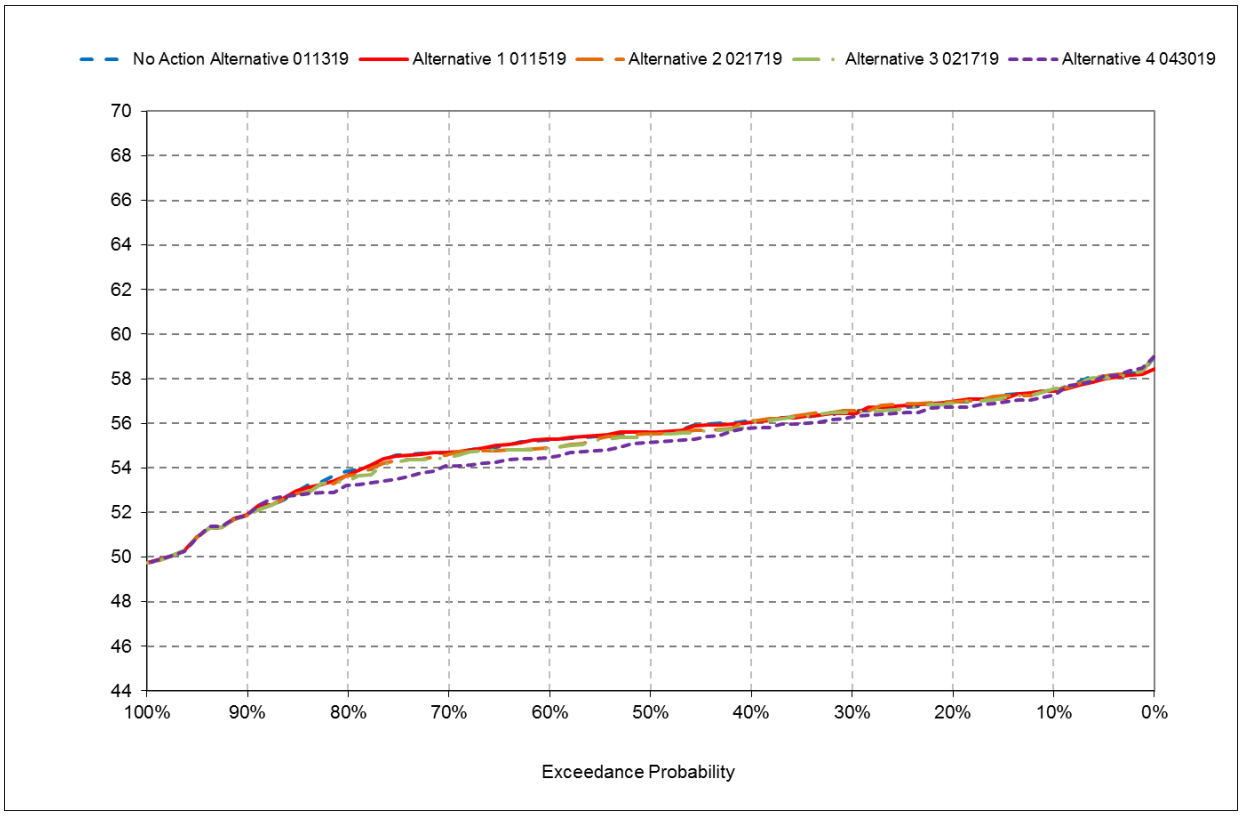


Figure O.3-117. HEC-5Q Sacramento River Water Temperatures at Red Bluff Diversion Dam under the No Action Alternative, Alternative 1, Alternative 2, Alternative 3 and Alternative 4; April

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 3 (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 from July to 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 RBDD, 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 2005a), 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 3, 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 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 3 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.3.3.2, *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°F and 68°F, see Section O.3.3.2, *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 7,700 to 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 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. 2007a; 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 foot), 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 year-round 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 (macropthalmia) 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 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 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 year-round 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 known 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 prelarvae 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°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 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 3 would have a less-than-significant 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 Central 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°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 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 59ºF to 68°F and spawning ceases at about 70°F (Moyle 2002). The eggs can withstand temperatures of about 54ºF to 75°F, with the optimum being about 64°F (Emmett et al. 1991). Larvae tolerate temperatures of 50ºF to 77°F, but optimal temperatures for survival are 59ºF 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°F 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°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 fresh water, 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 2002b, 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°F 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°F to 70°F, although spawning is generally observed over a range of 55°F to 79°F (Stuber et al. 1982). Eggs hatch 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°F 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. 2009b). 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 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°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 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°F 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.

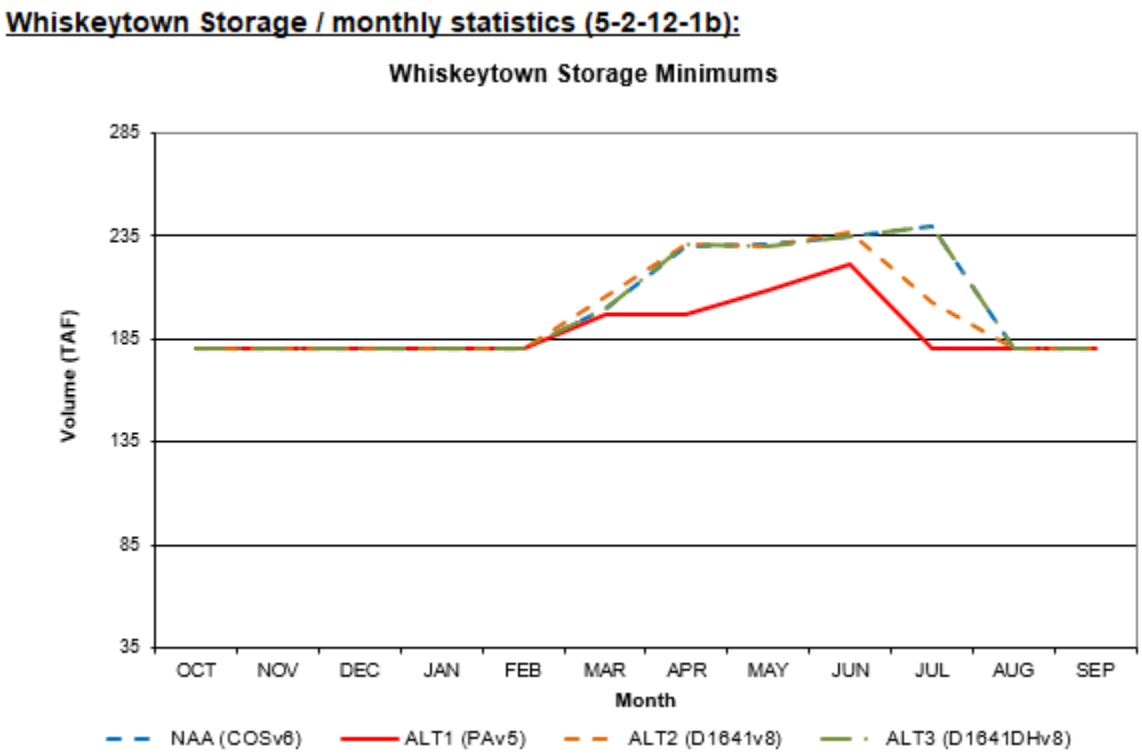


Figure O.3-118. Modeled Whiskeytown Lake Monthly Minimum Storage Volume under the No Action Alternative, Alternative 1, Alternative 2, and Alternative 3 during all Water Year Types

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 on 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 <u>Clear Creek Flows</u>

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 FERC Project #2100-134

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.

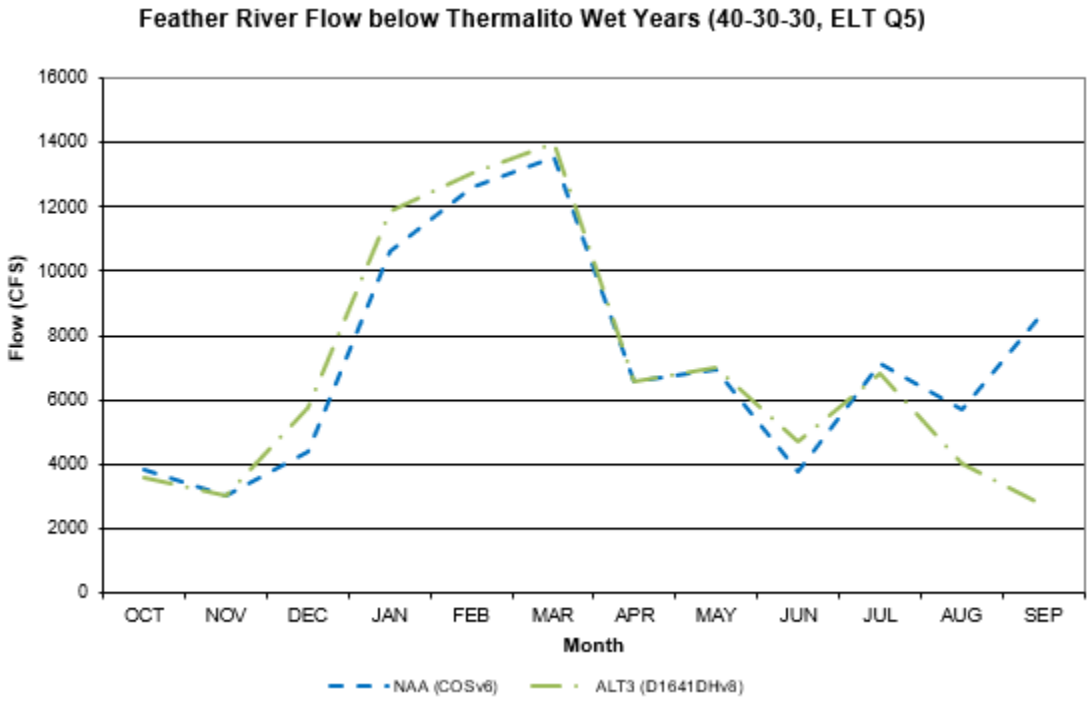
Potential changes to aquatic resources in the Feather River due to seasonal variation in flow

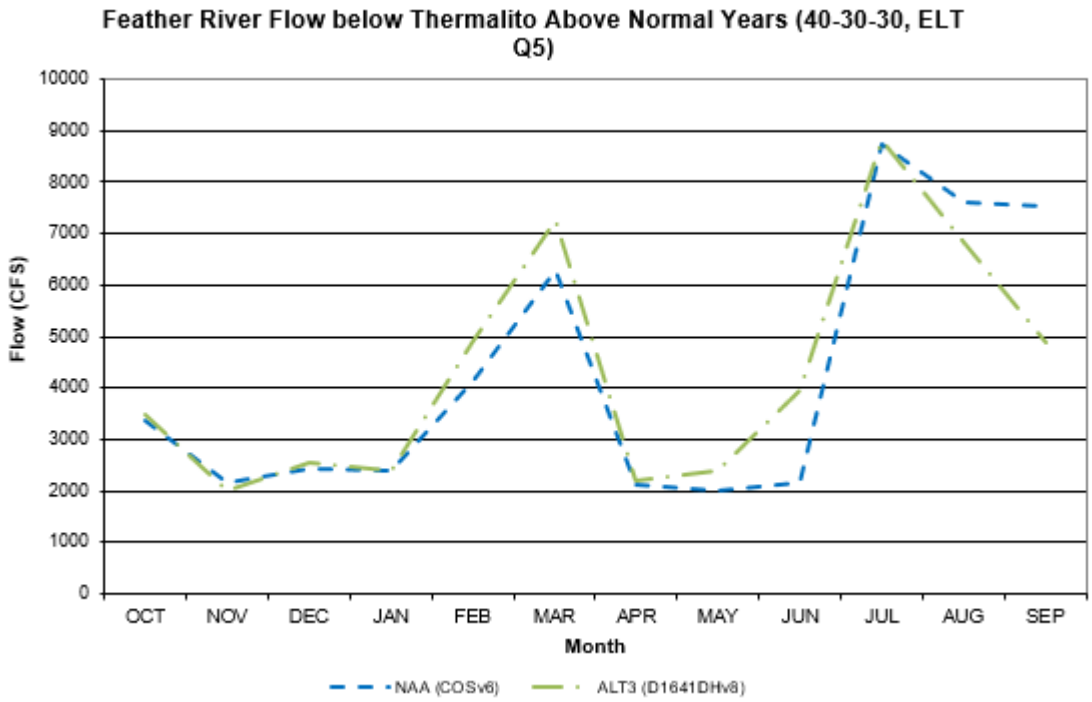
CalSim II model output shows that Feather River flows under Alternative 3 and the No Action Alternative would comply with Feather River HFC minimum instream flow requirements during all months in wet, above normal, and below normal water years. In dry years where the preceding April to July unimpaired 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;

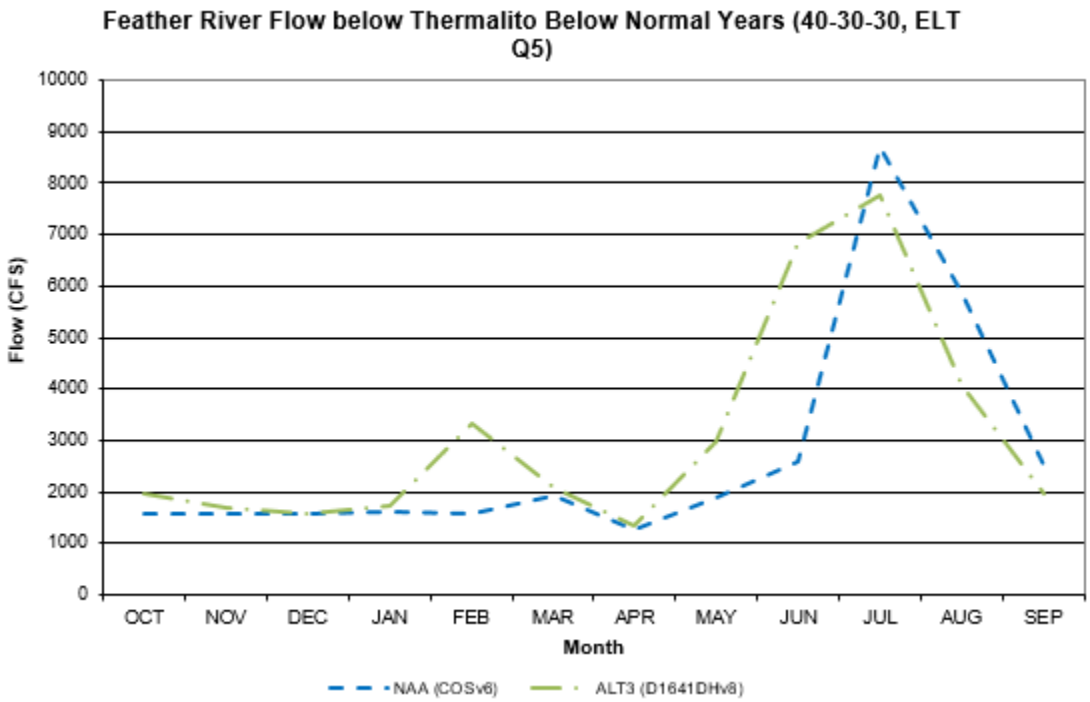
however, where the preceding April to July runoff is less than 55% of normal, Alternative 3 and the No Action Alternative would not comply with minimum instream flow requirements in the HFC only in November (Figure O.3-119).

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 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)
Flow (CFS)
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
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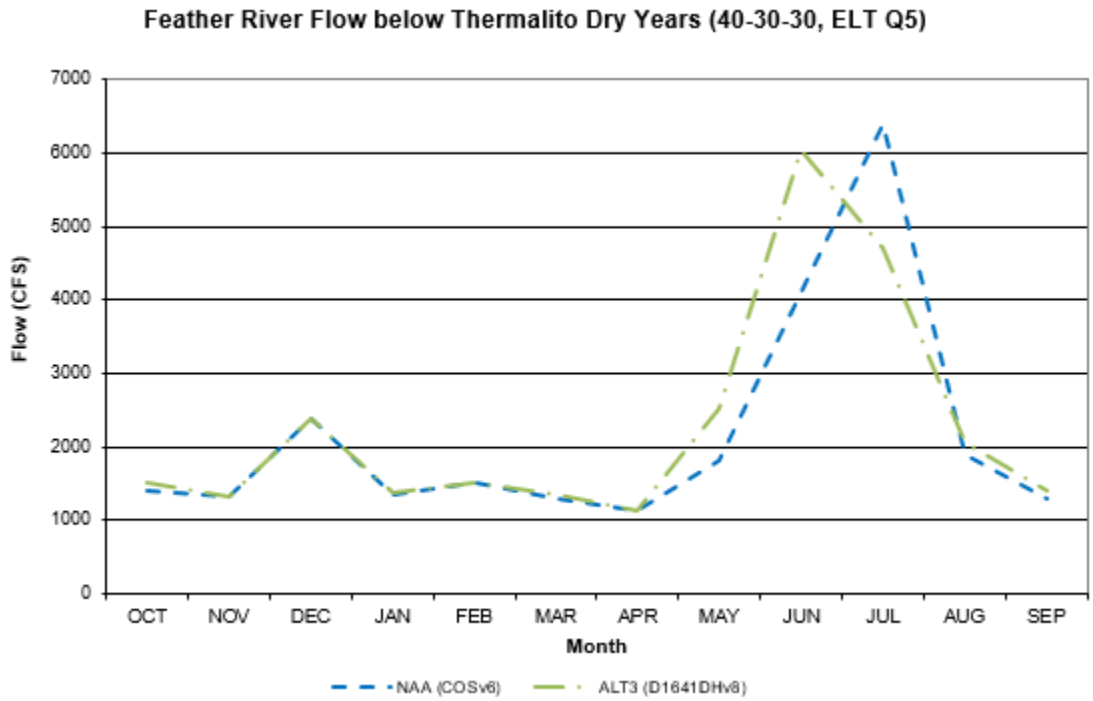
AUG
SEP
Month
NAA (COSv6)
ALT3 (D1641DHv8)



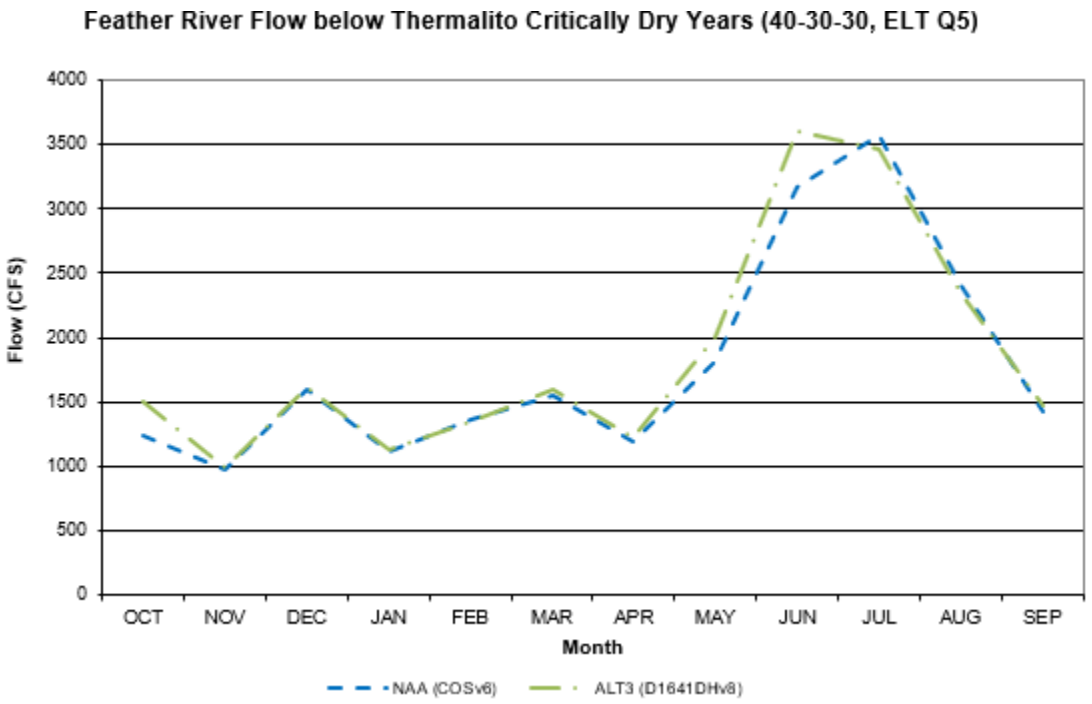


Figure O.3-119. CalSim II Estimates of Feather River Long-Term Average Flow below Thermalito, All Scenarios in Wet, Above Normal, Below Normal, Dry, and Critically Dry Water Years

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 oxygen and 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 oxygen content, 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 from January to April, juveniles out-migrating year-round with peaks from January to April and August to November, and holding and migrating adults occurring from April to 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 oxygen and 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 fresh water (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 oxygen content, 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

Life Stage	Peak Occurrence	Optimal	Suboptimal	Stress-inducing
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 3 and No Action Alternative scenarios would also occur in July, when Alternative 3 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.

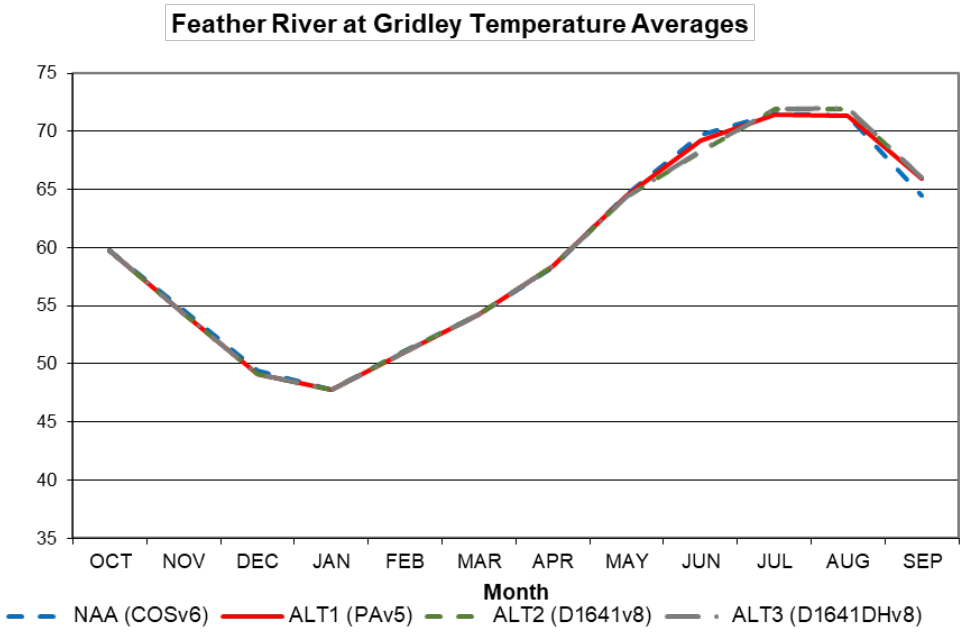


Figure O.3-120. RecTemp average Feather River water temperatures at Gridley Bridge under the No Action Alternative, Alternative 1, Alternative 2, and Alternative 3 scenarios.

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 from 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 3 and the No Action Alternative (Figure O.3-120). In June of above 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 migrating adults under both Alternative 3 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 3 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 during June to 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 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), 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 fresh water (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 during 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 during March to 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 3 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 Alternative 3 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 CO_2 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 Forebay 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 additional habitat restoration (25,000 acres within the Delta)*). Mitigation measure AQUA-16 will monitor the presence of Longfin Smelt under Alternatives 1 through 4.

Potential changes to Longfin Smelt due to changes from Tracy and Skinner fish facilities improvements

Alternative 3 would include the CO_2 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 Forebay 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 River Winter-Run Chinook Salmon

Potential changes to aquatic resources due to seasonal operations

Rearing Winter-Run Chinook Salmon are present in the Delta from October to 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 CAMT SST. The SST completed a thorough review of this subject and defined a 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.

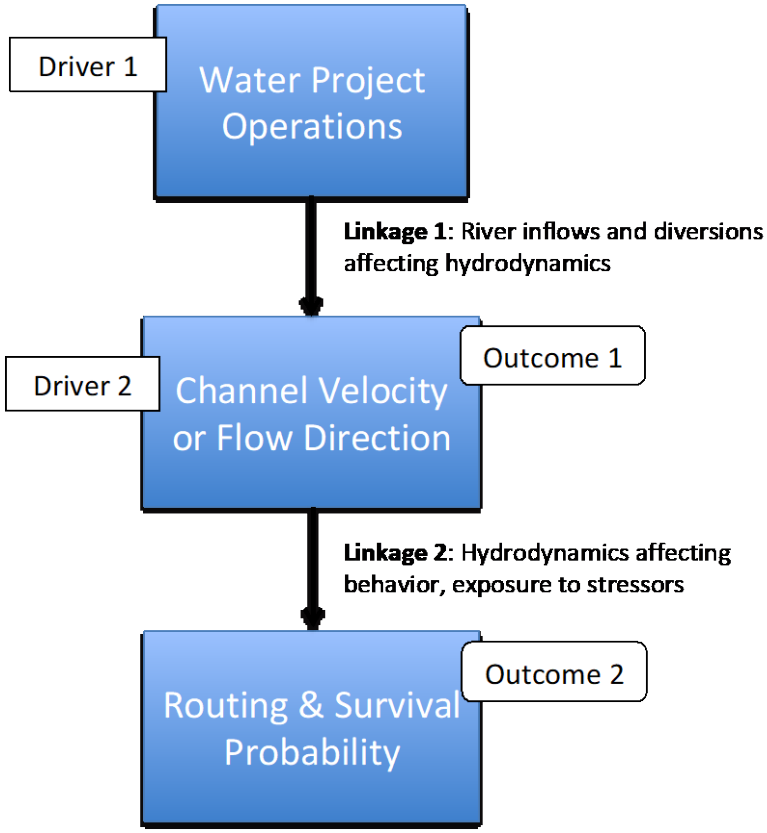


Figure O.3-122. Conceptual Model for Far-field Effects of Water Project Operations on Juvenile Salmonids in the Delta. This CM is a Simplified Version of the Information Provided by the CAMT SST.

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 (December to February and March to May) in each water year (1922 to 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-Run, Late Fall–Run and Fall-Run Chinook Salmon. These data represent 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 from November to 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 DCC 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% to 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 out-migrating 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 the section above, *Potential changes to aquatic resources due to seasonal operations*, which integrates 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, 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, 2017c; USFWS 1993, 2000, 2007, 2010, 2017; CDFG 1994, 2009a; 58 FR 12854–12864) 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 2017d), 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 2017d, 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 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 2017d). From 1999 to 2009, the 11 years prior to construction of the Rock Slough Fish Screen, CCWD's Fish Monitoring Program collected no juvenile or adult Winter-Run Chinook Salmon at the Rock Slough Headworks (Reclamation 2016; NMFS 2017d).

Since construction of the Rock Slough Fish Screen, 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 to 2018, 47 salmon were recovered at the fish screen (Reclamation 2016: Appendix A; Tenera Environmental 2018a), but none of the captured fish were identified as Winter-Run Chinook Salmon (NMFS 2017d).

NMFS issued a biological opinion in 2017 (NMFS 2017d) that considered improvements to the Rock Slough Fish Screen facility including the hydraulic rake cleaning system, operation and maintenance of the fish screen and associated appurtenances, and administrative actions such as the transfer of

operation and maintenance activities from Reclamation to CCWD. NMFS determined that operation and maintenance of Rock Slough Fish Screen 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 fish screen monitoring (NMFS 2017d). The incidental take provided in NMFS 2017d 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 2019a).

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 (2017c), 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 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 OMR 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, but varies depending on the tidal stage from approximately 56,000 square feet (at low tide and low San Joaquin River flow) to 68,000 square feet (at high tide and high San Joaquin River flow) as shown in Figure O.3-123.

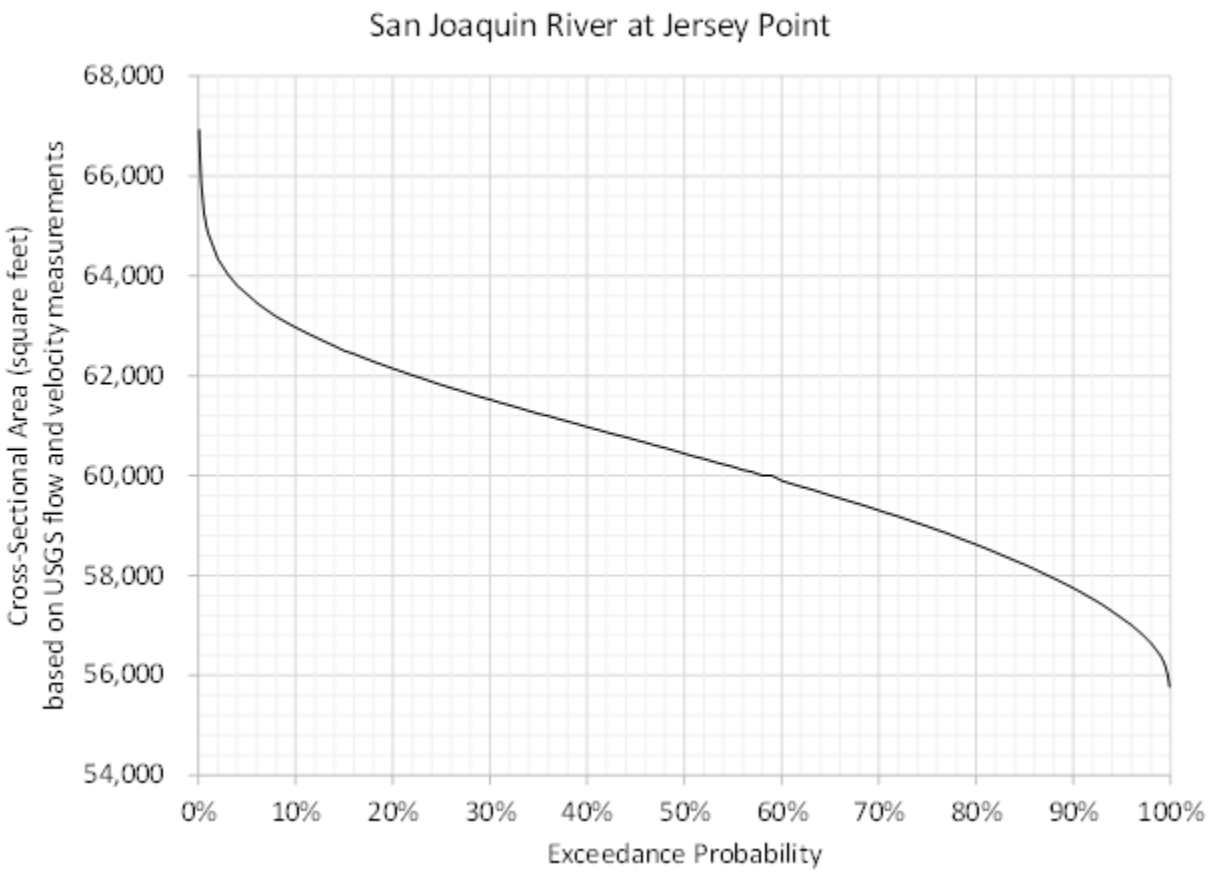


Figure O.3-23. Cross-sectional area of the San Joaquin River at Jersey Point (Station: 11337190) Calculated from USGS Measurements of Flow and Velocity every 15 Minutes for Water Years 2014 through 2018.

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 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 feet 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 feet 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 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 are available at https://www.wildlife.ca.gov/Regions/3). There should be no discernable effect on 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 3 also includes sediment removal with a suction dredge that could entrain Winter-Run Chinook Salmon individuals occurring near the suction dredging. In addition, aquatic weed removal with a grappling system could disturb Winter-Run Chinook Salmon occurring near the removal. The low occurrence of Chinook Salmon in monitoring efforts suggest that any potential impacts 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 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 Forebay 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 from December to May with a peak in March and April (Reclamation 2019). The application of aquatic herbicide to the waters of Clifton Court Forebay will occur from June 28 to August 31. Treatment could occur prior to June 28 at temperatures ≥ 25˚C; however, Winter-Run Chinook Salmon would not be expected to occur at these temperatures. Treatment could also occur after August 31 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, *Alternatives Development Technical Memorandum*, treatment of harmful algal blooms with peroxide-based algaecide is proposed to occur as needed, year-round, but there are no anticipated impacts on 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 CO_2 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 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 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 on 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 Clifton Court Forebay could reduce pre-screen loss of juvenile Chinook Salmon entrained into Clifton Court Forebay. 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 SWRCB 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 SMSCG 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 RRDS 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/sec, so that juvenile Winter-Run Chinook Salmon would be excluded from entrainment.

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, 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 from June to September. Therefore, no effects would occur as a result of actions for Delta Smelt summer-fall habitat.

Potential changes to aquatic resources due to changes from Clifton Court Forebay predator management

Clifton Court Forebay predator management efforts could reduce predation on listed fishes following entrainment into Clifton Court Forebay, reducing pre-screen loss.

Potential changes to aquatic resources due to the San Joaquin Basin Steelhead Telemetry Study

The San Joaquin Basin Steelhead Telemetry Study would not have effects on the Winter-Run Chinook Salmon population.

Potential changes to aquatic resources due to reintroduction changes from the Fish Conservation and Culture Laboratory

Reintroduction changes from the Fish Conservation and Culture Laboratory would not have effects on the Winter-Run Chinook Salmon population.

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, of the ROC LTO BA 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 on 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 on 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 Section O.3.7.8.3, *Sacramento River Winter-Run Chinook Salmon*, for more detail concerning “far-field” and “near-field.”

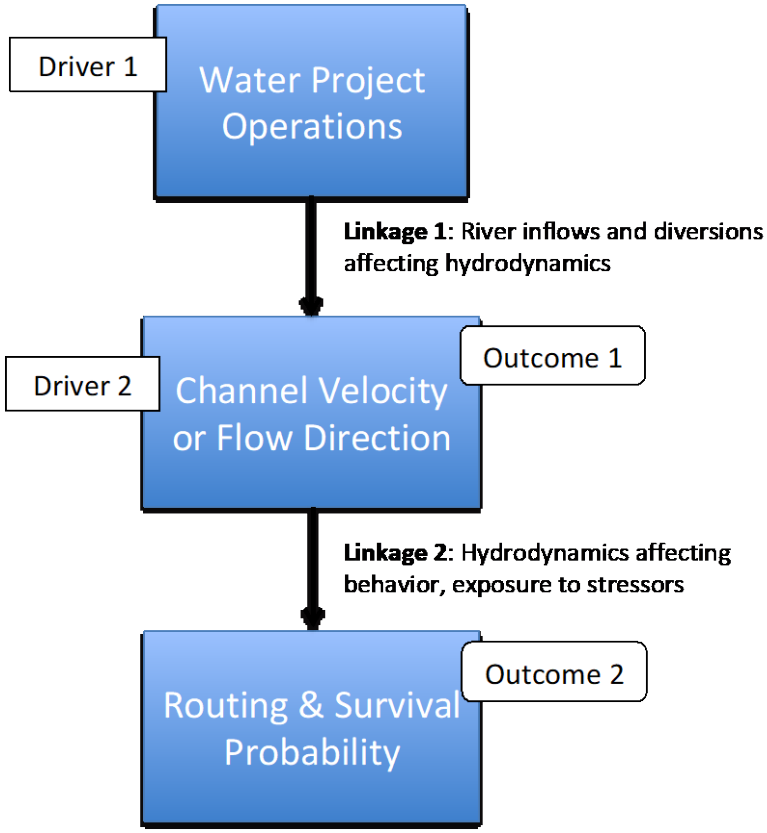


Figure O.3-124. Conceptual model for far-field effects of water project operations on juvenile salmonids in the Delta. This CM is a simplified version of the information provided by the CAMT SST.

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 juvenile Fall-Run 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 during March to 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 Section O.3.7.8.3, *Sacramento River Winter-Run Chinook Salmon*, 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 from November to 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 DCC 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 both the No Action Alternative scenarios (Figure O1-5 in Appendix O, Attachment 1). Similar results were obtained when comparing Alternative 3 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 from November to 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 3 and No Action Alternative scenarios (Figure O1-5 in Appendix O, Attachment 1). Similar results were obtained when comparing Alternative 3 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 3 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 during the March through May period, overlap between Alternative 3 and No Action Alternative was moderate in all water year types (41% to 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 the section above, *Potential changes to aquatic resources due to seasonal operations*, which integrates OMR management.

Potential changes to aquatic resources due to Delta Cross Channel operations

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. 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 of 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 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 et al. 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, 2017c; USFWS 1993, 2000, 2007, 2010, 2017; CDFG 1994, 2009a; 58 FR 12854–12864). 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 2017d), 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 2017d, 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 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 2017d). From 1999 to 2009, the 11 years prior to construction of the Rock Slough Fish Screen, 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 2017d) and 4 juvenile Central Valley Spring-Run at Pumping Plant #1 (CCWD 2019a). 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 2017d). 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 Rock Slough Fish Screen, 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 to 2018, 47 salmon were recovered at the fish screen (Reclamation 2016: Appendix A; Tenera Environmental 2018a), but none of the captured fish were identified as Spring-Run Chinook Salmon (NMFS 2017d).

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 2019a).

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 (2017c), 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 Section O.3.7.8.3, *Sacramento River Winter-Run Chinook Salmon*, 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 Section O.3.7.8.3, the diversions at the Rock Slough Intake could move a neutrally buoyant particle in the San Joaquin River at Jersey Point approximately 540 feet 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 feet 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 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 are available at https://www.wildlife.ca.gov/Regions/3). The North Bay Aqueduct is located within designated critical habitat for Spring-Run Chinook Salmon. There should be no discernable effect on 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 3 also includes sediment removal with a suction dredge that could entrain Spring-Run Chinook Salmon 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 impacts 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 3 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.3-125 through O.3-127).

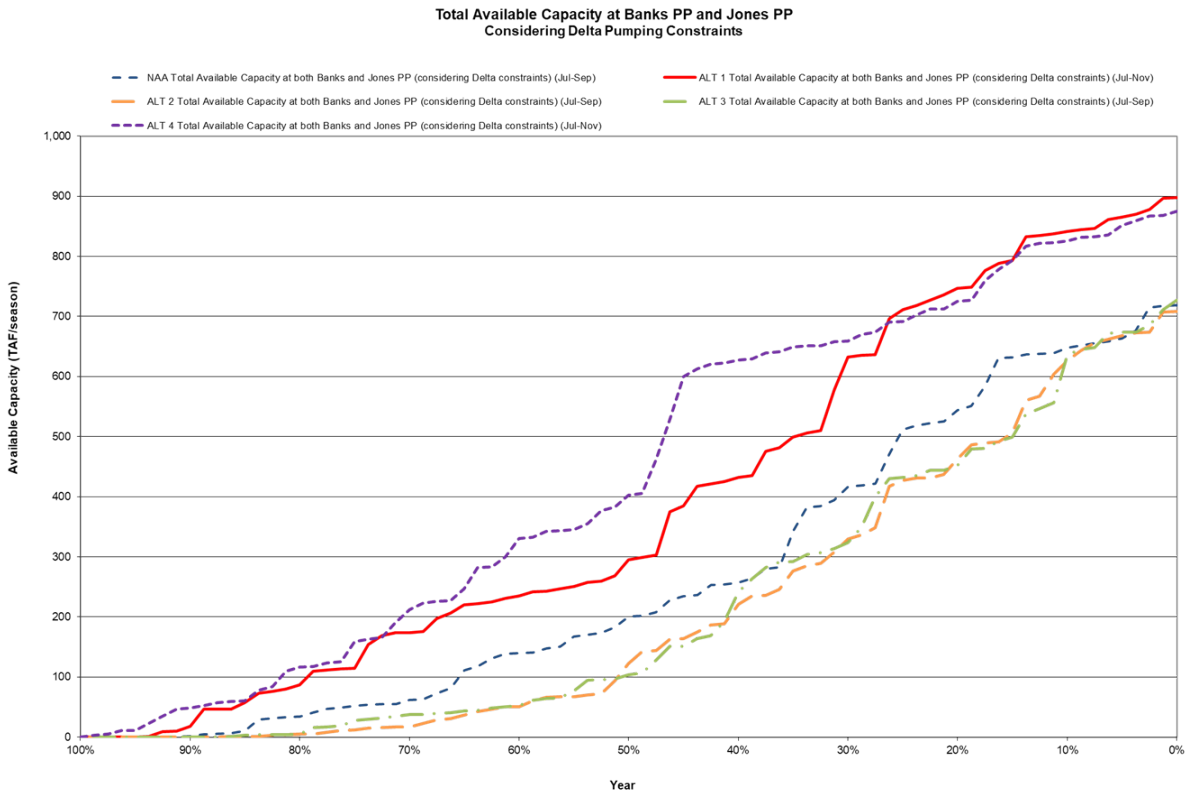


Figure O.3-125. Exceedance of Available Capacity for Transfers at Jones and Banks under Alternative 3 and No Action Alternative

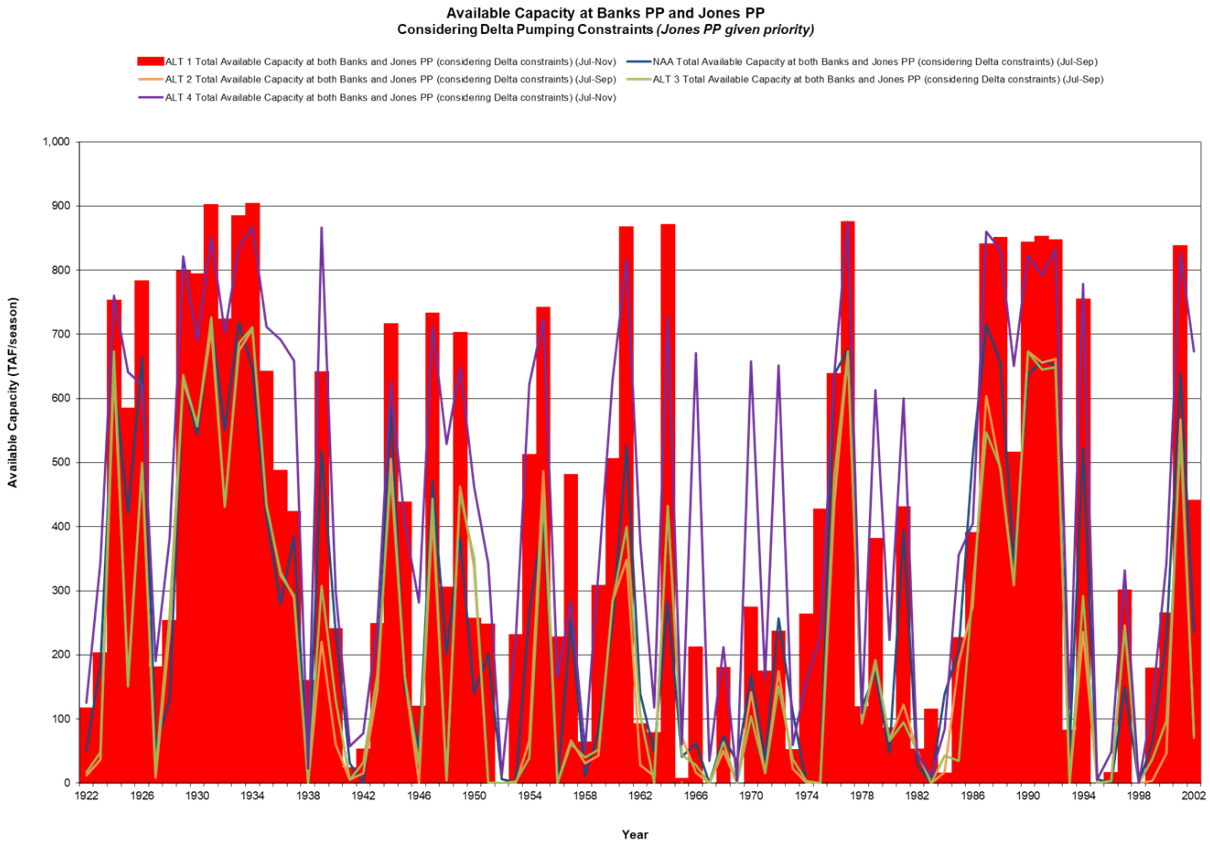


Figure O.3-126. Modeled Annual Maximum Available Capacity for Transfers under Alternative 3 and No Action Alternative, CalSim Period of Record (1922–2003)

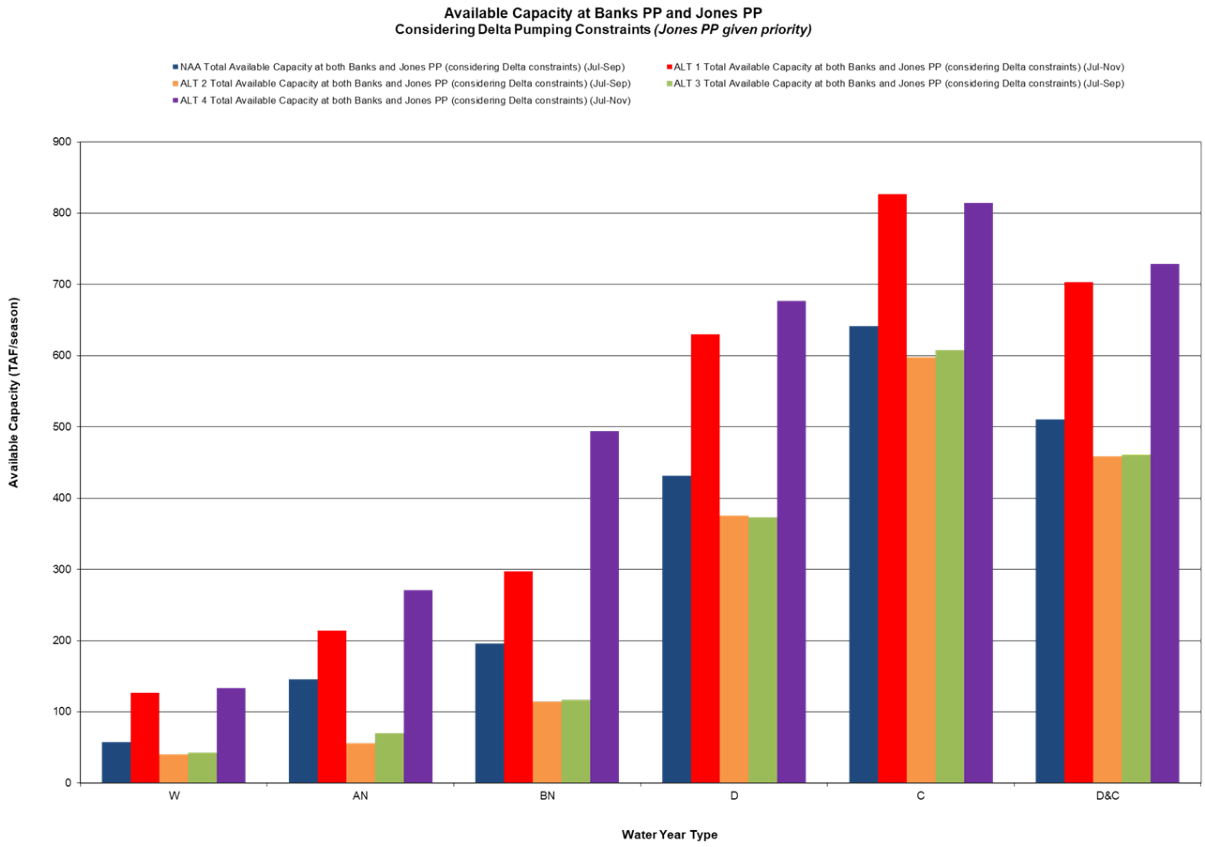


Figure O.3-127. Water Year Type average available capacity at Jones and Banks Pumping Plants

Egg, 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 from December to 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 the *Potential changes to aquatic resources due to seasonal operations* 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 Forebay 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 from mid-November to early June with a peak in April (Table5.6-1). The application of aquatic herbicide to the waters of Clifton Court Forebay will occur from June 28 to August 31. Treatment could occur prior to June 28 at temperatures $\geq 25^{\circ}C$; however, Spring-Run Chinook Salmon would not be expected to occur at these temperatures. Treatment could also occur after

August 31 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 on 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 the Tracy fish facility, including installing a CO_2 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 SWRCB 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 SMSCG 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 RRDS 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/sec, so that juvenile Spring-Run Chinook Salmon would be excluded from entrainment.

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, 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 from June to September. Therefore, no effects would occur as a result of actions for Delta Smelt summer-fall habitat.

Potential changes to aquatic resources due to changes from Clifton Court Forebay 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

The San Joaquin Basin Steelhead Telemetry Study would not have effects on the Spring-Run Chinook Salmon population.

Potential changes to aquatic resources due to reintroduction changes from the Fish Conservation and Culture Laboratory

Reintroduction changes from the Fish Conservation and Culture Laboratory would not have effects on the Spring-Run Chinook Salmon population.

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 on 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 CAMT SST. The SST completed a thorough review of this subject and defined a 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.

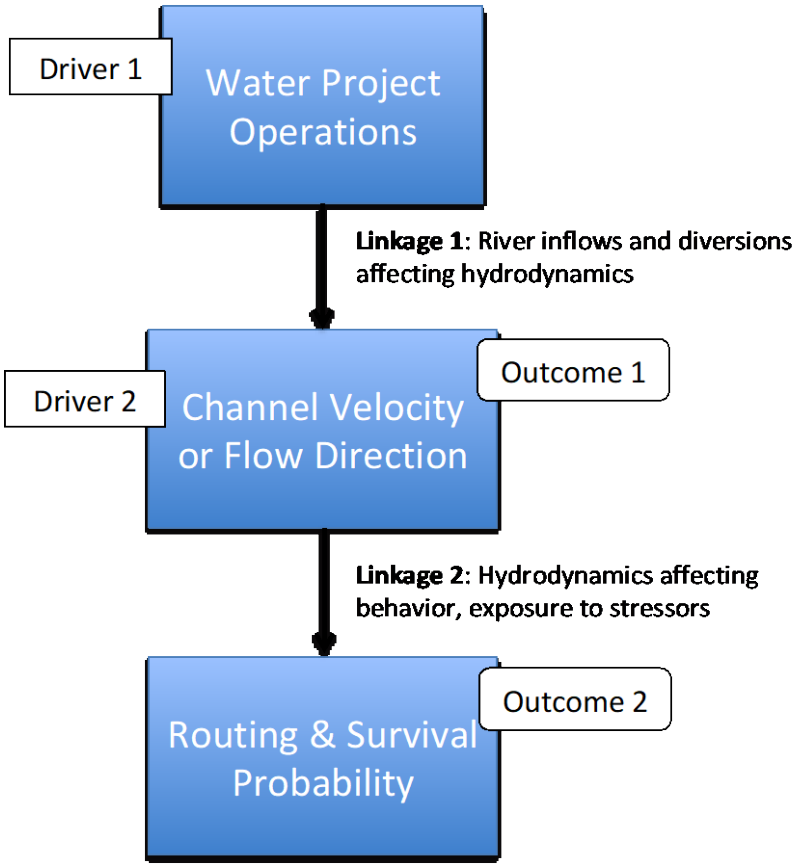


Figure O.3-128. Conceptual model for far-field effects of water project operations on juvenile salmonids in the Delta. This CM is a simplified version of the information provided by the CAMT SST.

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, 2012, 2015; Michel et al. 2012).

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 (December to February and March to May) in each water year (1922 to 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 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. These data are extremely useful because they represent 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–Run Chinook Salmon 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 3 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 3 during March through 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 3 were evaluated using DSM2 as described above. Juvenile Fall-Run Chinook Salmon abundance in the Delta is greatest from February to May and Late Fall–Run are present in the Delta from November to July with peaks in January through February and April through May (Reclamation 2019). In the December through February period, velocity overlap between Alternative 3 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 DCC 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 during the March through May period, overlap between Alternative 3 and No Action Alternative was moderate in all water year types (41% to 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 the section above, *Potential changes to aquatic resources due to seasonal operations*, which integrates OMR management.

Potential changes to aquatic resources due to Delta Cross Channel operations

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 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 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 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 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 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, 2017c; USFWS 1993, 2000, 2007, 2010, 2017; CDFG 1994, 2009a; 58 FR 12854–12864). 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 indicates the timing and magnitude of Fall-Run and Late Fall–Run Chinook Salmon presence near the Rock Slough Intake. From 1999 to 2011, the 11 years prior to construction of the Rock Slough Fish Screen, CCWD's Fish Monitoring Program collected 23 juvenile Fall-Run and 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 or 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 or Late Fall–Run Chinook Salmon at CCWD's Old River Intake or Middle River Intake (CCWD 2019a).

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 and Late Fall–Run Chinook Salmon are not likely to be in the vicinity of the Rock Slough Intake. However, according to NMFS (2017c), 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 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 the 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 Section O.3.7.8.3, *Sacramento River Winter-Run Chinook Salmon*, 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 and 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 Section O.3.7.8.3, the diversions at the Rock Slough Intake could move a neutrally buoyant particle in the San Joaquin River at Jersey Point approximately 540 feet 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 feet 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 Chinook Salmon individuals occurring near the suction dredging. In addition, aquatic weed removal with a grappling system could disturb Fall-Run Chinook Salmon occurring near the removal. The low occurrence of Chinook Salmon in monitoring efforts suggest that any potential impacts from sediment and aquatic weed removal would be limited.

Potential changes to aquatic resources from Clifton Court Forebay 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 from mid-November to 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. 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 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 (Reclamation 2019). NMFS (2009) determined that operation of the SMSCG 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 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/sec (for Delta Smelt protection), so that juvenile Fall-Run Chinook Salmon would be excluded from entrainment.

In their prior BO, 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 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 in 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 due to changes from Clifton Court Forebay 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 Chinook Salmon 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

The San Joaquin Basin Steelhead Telemetry Study would not have effects on the Fall-Run Chinook Salmon population.

Potential changes to aquatic resources due to reintroduction changes from the Fish Conservation and Culture Laboratory

Reintroduction changes from the Fish Conservation and Culture Laboratory would not have effects on the Fall-Run Chinook Salmon population.

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 from 2003 to 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 composed 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 during March to 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 from November to 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 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 during the March through May period, overlap between Alternative 3 and No Action Alternative was moderate in all water year types (41% to 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 the section above, *Potential changes to aquatic resources due to seasonal operations*, which integrates 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 (Table 5.10-1). Therefore under Alternative 3, 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 on this life stage when compared to the No Action Alternative.

Potential changes to aquatic resources due to the Temporary Barriers Project

The 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 et al. 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 3 does not include HORB, which could result in negative impacts on 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 3 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, 2017c; USFWS 1993, 2000, 2007, 2010, 2017; CDFG 1994, 2009a; 58 FR 12854–12864). 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 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 Rock Slough Fish Screen, 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 2019a).

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 (2017c), 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 OMR corridor that are not salvaged at TFCF or the 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 Section O.3.7.8.3, *Sacramento River Winter-Run Chinook Salmon*, 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 Section O.3.7.8.3, the diversions at the Rock Slough Intake could move a neutrally buoyant particle in the San Joaquin River at Jersey Point approximately 540 feet 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 feet 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 North Bay Aqueduct's Barker Slough Pumping Plant relative to current operations. Juvenile Central Valley Steelhead could occur in the vicinity of the Barker Slough Pumping Plant; 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 were 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 Chinook Salmon individuals occurring near the suction dredging. In addition, aquatic weed removal with a grappling system could disturb Fall-Run Chinook Salmon occurring near the removal. The low occurrence of Chinook Salmon in monitoring efforts suggest that any potential impacts 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 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 Forebay aquatic weed removal

Under Alternative 3, the application of aquatic herbicide to the waters of Clifton Court Forebay will occur from June 28 to August 31. Treatment could occur prior to June 28 at temperatures ≥ 25˚C; however, Steelhead would not be expected to occur at these temperatures. Treatment could also occur after August 31 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 during March through 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 Clifton Court Forebay. Potential direct and indirect effects on 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 from August to 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 CO_2 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*).

Skinner fish facility improvements under Alternative 3 to reduce predation on listed fishes following entrainment into Clifton Court Forebay could reduce pre-screen loss of juvenile Central Valley Steelhead entrained into Clifton Court Forebay, thereby 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 SMSCG is

unlikely to impede migration of juvenile salmonids or produce conditions that support unusually high numbers of predators.

Under Alternative 3, the RRDS 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/sec (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 actions 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 Forebay predator management

Clifton Court Forebay predator management under Alternative 3 could reduce pre-screen loss of juvenile Central Valley Steelhead entrained into Clifton Court Forebay, 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

The San Joaquin Basin Steelhead Telemetry Study would not have effects on Central Valley Steelhead.

Potential changes to aquatic resources due to reintroduction changes from the Fish Conservation and Culture Laboratory

Reintroduction changes from the Fish Conservation and Culture Laboratory would not have effects on Central Valley Steelhead.

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, Delta, and San Francisco 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 on 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 on 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 months) 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 months) 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 out-migrating 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 out-migrating 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 the section above, *Potential changes to aquatic resources due to seasonal operations*, which integrates 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 of the TBP are included in Alternative 3 and consist 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), out-migrating Chinook

Salmon passage past the agricultural barrier was improved (DWR 2018). It could be inferred that passage of out-migrating 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, 2017c; USFWS 1993, 2000, 2007, 2010, 2017; CDFG 1994, 2009a; 58 FR 12854–12864). 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 2017d), 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 40ºF in winter (December and January) to over 70ºF beginning in May and continuing through October (NMFS 2017d).

A review of the 24 years of fish monitoring data (1994 to 2018) near the Rock Slough Intake both pre- and post-construction of the Rock Slough Fish Screen showed that Southern DPS Green Sturgeon have never been observed in Rock Slough (CDFG 2002c; Reclamation 2016; NMFS 2017d; 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 2019a).

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 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 impacts from sediment and aquatic weed removal would be limited.

Potential changes to aquatic resources due to water transfers

As discussed under *Potential changes to aquatic resources due to water transfers* in Section O.3.7.8.4, *Central Valley Spring-Run Chinook Salmon*, 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 *Potential changes to aquatic resources due to seasonal operations* 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 Forebay aquatic weed removal

Few Southern DPS juvenile Green Sturgeon 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 from June 28 to August 31. Treatment could occur prior to June 28 at temperatures $\geq 25^{\circ}C$; however, Green Sturgeon would not be expected to occur at these temperatures. Treatment could also occur after August 31 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 on 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 Clifton Court Forebay, 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 SMSCG 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 SMSCG 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 (Verhille 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 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 Forebay 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 Clifton Court Forebay, but individuals are salvaged infrequently.

Potential changes to aquatic resources due to the San Joaquin Basin Steelhead telemetry study

The San Joaquin Basin Steelhead Telemetry Study would not have effects on Green Sturgeon.

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 on 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 previously in place as a result of the NMFS (2009) SWP/CVP BO's RPA (which is no longer the current BO). Based on the same reasoning applied to the analysis of Alternative 2, Alternative 3 could result in potential negative effects on 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 (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 temperature control device improvements

Improvement of the Shasta temperature control device 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 on 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 on 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 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 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 component of Alternative 3. This action would hydrologically connect the Sacramento River with the ship channel 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 ship channel. Estimates of salmonid survival in the Sacramento Deepwater Ship Channel are not available to compare with rates in the Sacramento River route. However, if survival rates are similar, fish entering the ship channel 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 Sacramento Deepwater Ship Channel could potentially attract adult Winter-Run Chinook Salmon. If the connection is maintained, there would likely not be impacts on 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 from December to 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 from December to 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 on 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 on 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 DCC. 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 CO_2 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 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 F.2.7, F.2.8, and F.2.9 in Appendix AB, Attachment F of the ROC LTO BA) (Reclamation 2019). 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 AB, Attachment F of the ROC LTO BA) (Reclamation 2019).

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 on 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 Clifton Court Forebay could reduce pre-screen loss of juvenile Chinook Salmon entrained into Clifton Court Forebay. 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 out-migrating 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. The NEPA process for the facility (Horizon Water and Environment 2017) indicates 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 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 enter the Sacramento Deepwater Ship Channel. There are potential benefits to Spring-Run Chinook Salmon from this action. Fish entering the ship channel 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 Sacramento Deepwater Ship Channel 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 on 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 DCC 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 DCC 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 the Tracy fish facility, including installing a CO_2 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 AB, Attachment F of the ROC LTO BA*:* WR_salvage_unclipped_date, WR_salvage_clipped_date, and WR_salvage_clipped_CWT_race) (Reclamation 2019). 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 out-migrating 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. The NEPA process for the facility (Horizon Water and Environment 2017) indicates 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 action. This action would hydrologically connect the Sacramento River with the ship channel 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 ship channel. Estimates of salmonid survival in the Sacramento Deepwater Ship Channel are not available to compare with rates in the Sacramento River route. However, fish entering the ship channel 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 (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).

Potential changes to aquatic resources from the predator hot spot removal program

Predator hot spot removal is primarily focused on providing positive effects on 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 DCC 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 DCC 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 AB, Attachment F of the ROC LTO BA) (Reclamation 2019). 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 on 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 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 from the small screen program

Although there may be moderate overlap of Fall-Run and 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-Run or Late Fall–Run Chinook Salmon rearing and out-migrating in the Bay-Delta are expected to be exposed to the effects of construction of screens on water diversion

intakes. Juvenile Sacramento River Fall-Run and 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. The NEPA process for the facility (Horizon Water and Environment 2017) indicates 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.3.8.2.6 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 conservation measure under Alternative 3. This conservation measure would hydrologically connect the Sacramento River with the ship channel 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 Sacramento Deepwater Ship Channel. Estimates of salmonid survival in the Sacramento Deepwater Ship Channel are not available to compare with rates in the Sacramento River route. However, fish entering the ship channel 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 Central Valley Steelhead 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 on 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 from December to 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 on 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 from August to 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 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 from August to 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 CO_2 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 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 Clifton Court Forebay could reduce pre-screen loss of juvenile Central Valley Steelhead entrained into Clifton Court Forebay, thereby 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 life stage in the same ways described above. Juvenile Central Valley Steelhead out-migrating 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. The NEPA process for the facility (Horizon Water and Environment 2017) indicates 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 from August to 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 Sacramento Deepwater Ship Channel. Fish entering the ship channel 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 Sacramento Deepwater Ship Channel 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 on 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 on 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 Clifton Court Forebay, 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 Southern Resident Killer Whale

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, 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.

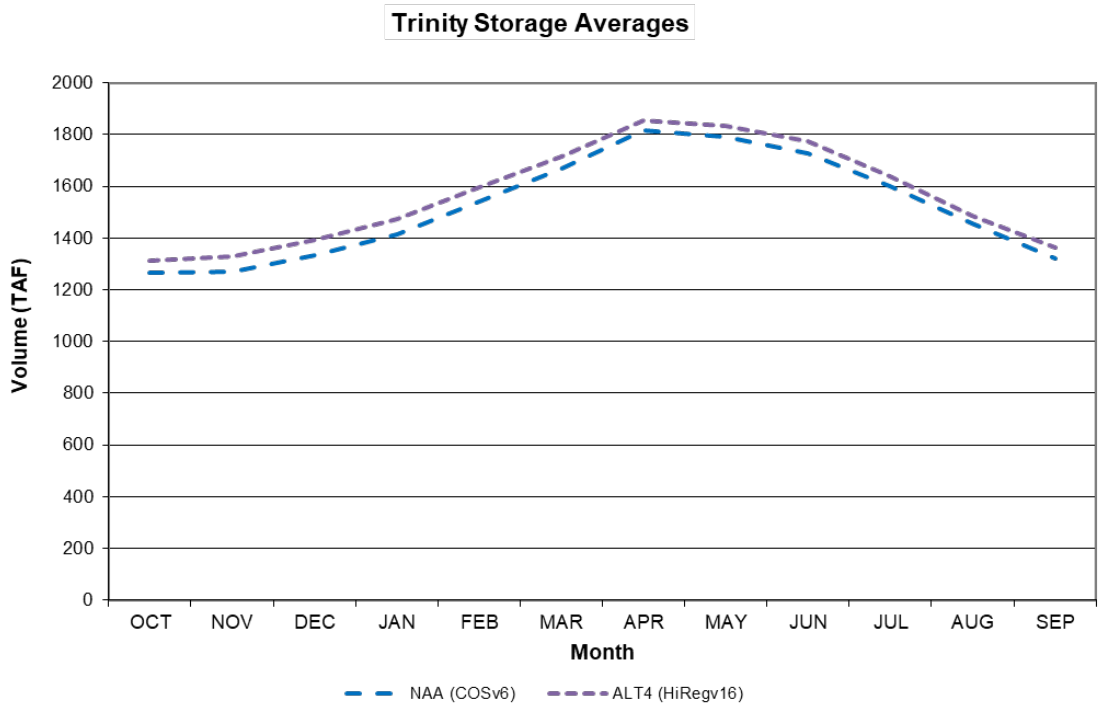


Figure O.3-129. Average Monthly Storage in Trinity Lake for the No Action Alternative and Alternative 4

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).

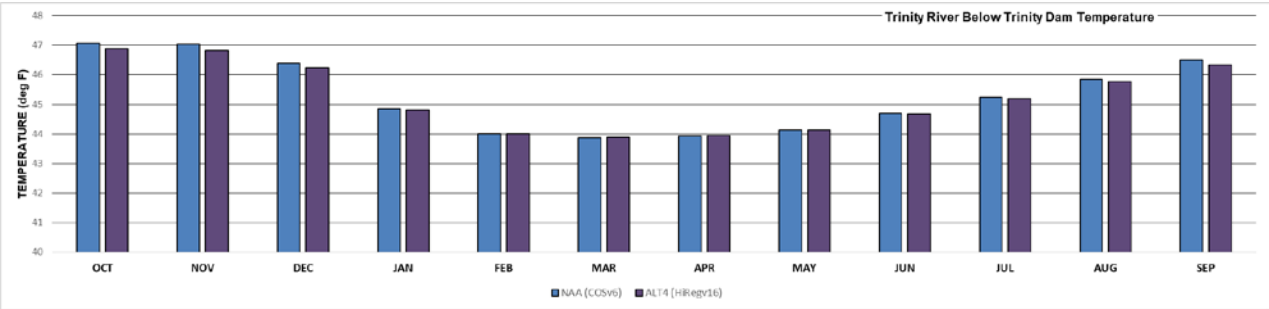


Figure O.3-130. Average Trinity River Water Temperatures below Trinity Dam for the period October to September, Average of All Water Year Types

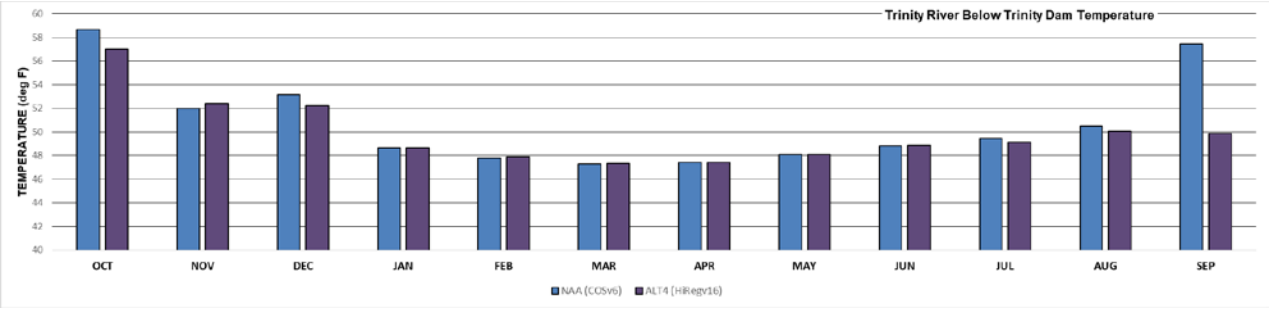


Figure O.3-131. Maximum Trinity River Water Temperatures below Trinity Dam for the Period October to September, Average of All Water Year Types

Reservoir Fish Species

Increased storage under Alternative 4 compared to the No Action Alternative would increase fish habitat, particularly for species that utilize margins, such as Black Bass (Figure O.3-131b and Table O.3-55b). Conversley, reservoir drawdown during May of some years could put some nests at risk of dewatering for basses, which spawn in relatively shallow lake areas when water warms to at least 50°F in late spring or summer. However, these species have rapid reproductive rates which can enable them to recover from episodic recruitment failures. Rainbow and Brown Trout, and Kokanee Salmon typically spawn in tributary streams, but they are capable of spawning in lakes if they are unable to access moving water. Increased stoarge during November may improve access to spawing areas for Brown Trout and Kokanee Salmon. Effects of Trinity Reservoir storage on fish in the Trinity River downstream of Lewiston Dam are described below.

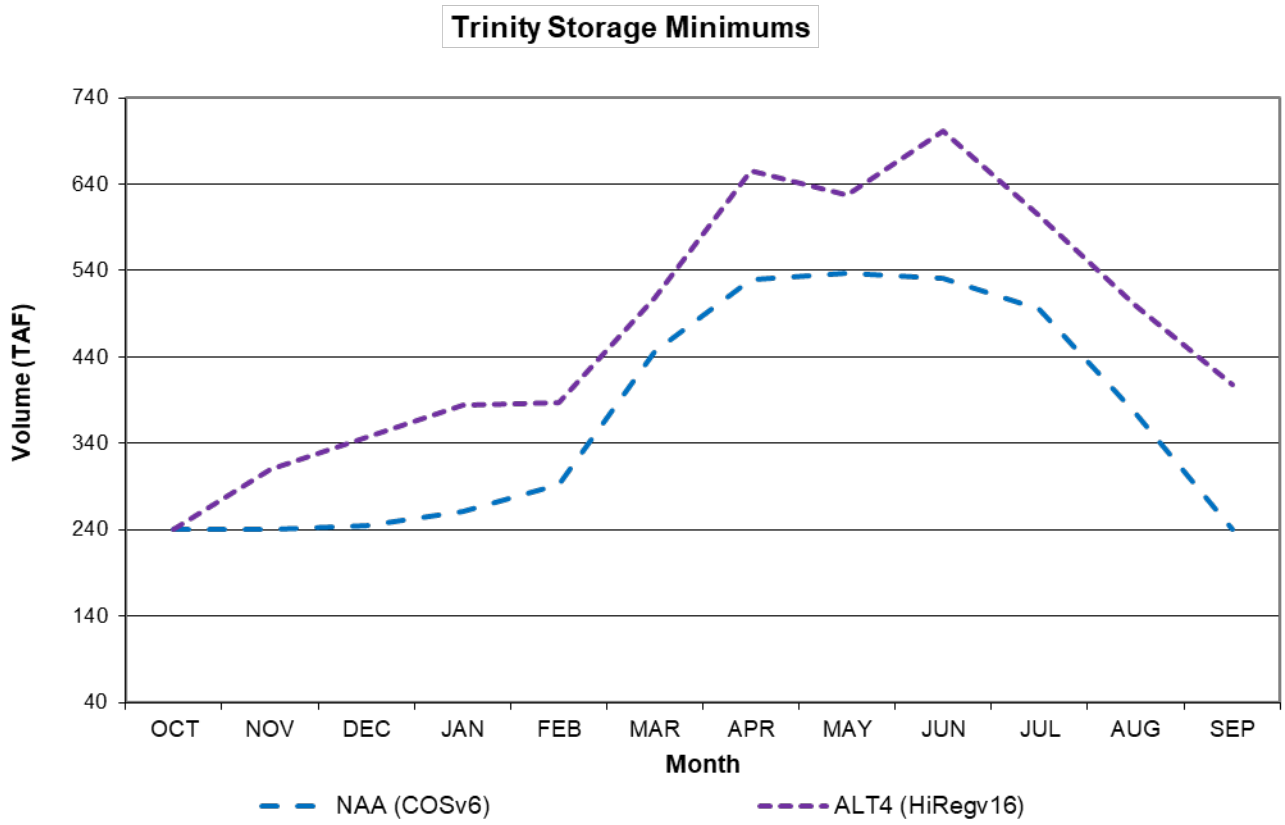


Figure O.3-131b. Modeled Trinity Lake Monthly Minimum Storage Volume under the No Action Alternative and Alternative 4 during All Water Year Types

Table O.3-55b. Modeled Differences in Trinity Lake Minimum Storage Volumes under Alternative 4 Relative to the No Action Alternative

Month	Change in Volume from No Action Alternative (TAF) Alt 4
October	1
November	70
December	102
January	123
February	95
March	62
April	126
May	90
June	171
July	109
August	124
September	168

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, based on water year type. In wet years, flows would increase by 7% to 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.

Under Alternative 4, diseases affecting salmon, such as *C. shasta* (Ich) and *columnaris*, could continue to have substantial impact on adult salmon, but the conditions would be improved compared to the No Action Alternative. Alternative 4 continues to consider 10 years of additional TRRP projects (through 2030), which would also be expected to reduce the threat of disease outbreaks. Nonetheless, disease pressures could change and there is uncertainty in how disease prevalence will affect future conditions under this alternative.

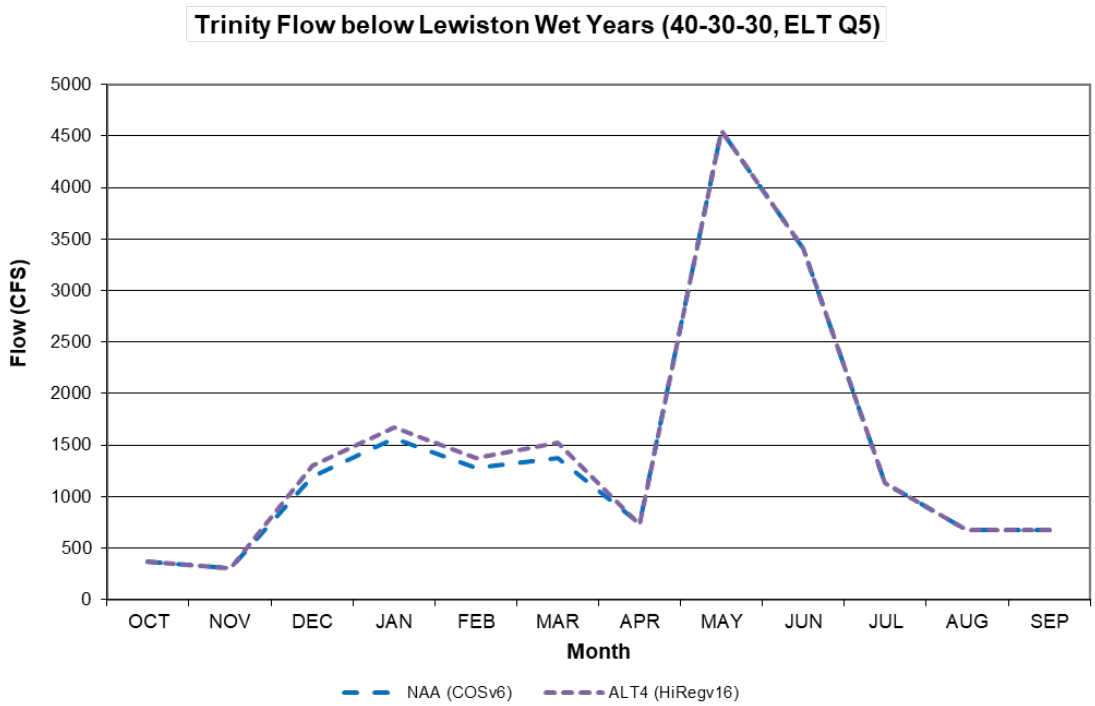


Figure O.3-132. Average Monthly Flow in the Trinity River downstream of Lewiston Dam for the No Action Alternative and Alternative 4 during Wet Years.

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 is not expected to result in redd scour based on previous studies in the Trinity River which reported sand and gravel substrates became mobile at flows of around 2,700 cfs or greater (McBain and Trush 1997). The flow increase could decrease available Coho fry and rearing habitat by approximately 20% to 25% during February based on WUA reported in USFWS et al. 1999. Habitat improvements and increased flows under Alternative 4 would also be expected to reduce the threat of disease outbreaks for Coho Salmon, although there is uncertainty in how disease prevalence will affect future conditions.

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 is not expected to result in redd scour based on previous studies in the Trinity River which reported sand and gravel substrates became mobile at flows of around 2,700 cfs or greater (McBain and Trush 1997). The flow increase could decrease available Spring-Run Chinook Salmon fry and juvenile rearing habitat by approximately 20% to 25% based on WUA reported in USFWS et al. 1999. Habitat improvements and increased flows under Alternative 4 would also be expected to reduce the threat of disease outbreaks for Spring-Run Chinook Salmon, although there is uncertainty in how disease prevalence will affect future conditions.

Fall-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 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 is not expected to result in redd scour based on previous studies in the Trinity River which reported sand and gravel substrates became mobile at flows of around 2,700 cfs or greater (McBain and Trush 1997). The flow increase could decrease available Fall-Run Chinook Salmon fry and juvenile rearing habitat by approximately 20% to 25% during February based on WUA reported in USFWS et al. 1999. Habitat improvements and increased flows under Alternative 4 would also be expected to reduce the threat of disease outbreaks

for Fall-Run Chinook Salmon, although there is uncertainty in how disease prevalence will affect future conditions.

Steelhead (Winter- and Summer-Run)

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 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. Habitat improvements and increased flows under Alternative 4 would be expected to reduce the threat of disease outbreaks for Steelhead. Although Steelhead remain resistant to these diseases, there is also uncertainty in how disease prevalence will affect future conditions.

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.

Eulachon

Eulachon are only found in the lower Klamath River. Water temperature and habitat conditions within the Lower Klamath River downstream of the confluence with the Trinity River are heavily influenced by several large tributaries that enter the Trinity River as well the Klamath River itselft. 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 Eulachon.

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).

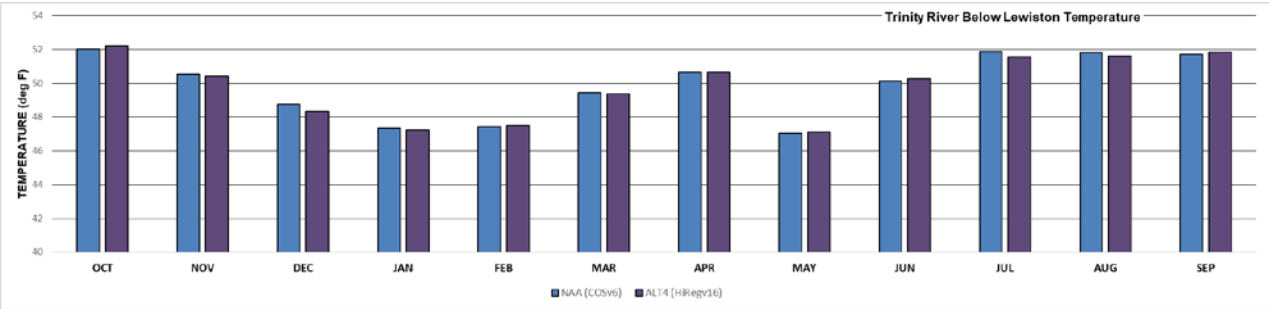


Figure O.3-133. Average Trinity River Water Temperatures below Lewiston Dam for the Period October to September, Average of All Water Year Types

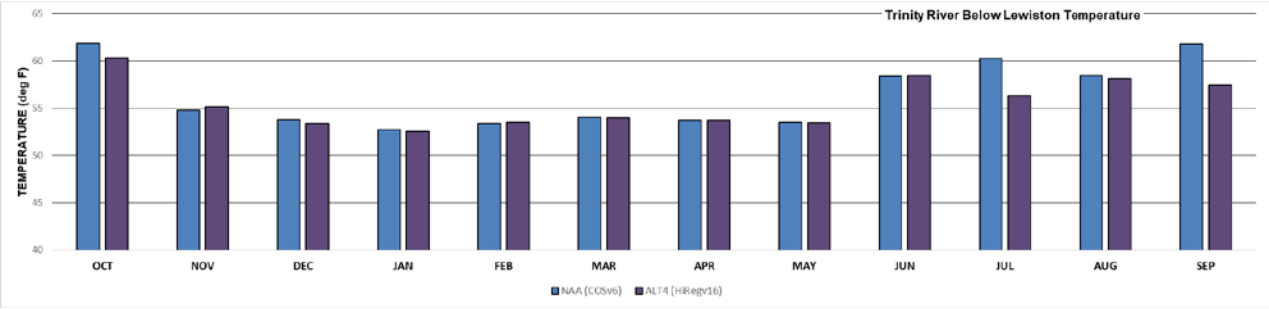


Figure O.3-134. Maximum Trinity River Water Temperatures below Lewiston Dam for the Period October to September, Average of All Water Year Types

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 from October to 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.

Eulachon

Eulachon are only found in the lower Klamath River. Water temperature and habitat conditions within the Lower Klamath River downstream of the confluence with the Trinity River are heavily influenced by several large tributaries that enter the Trinity River as well the Klamath River itselft. 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 Eulachon.

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 Grass Valley Creek 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 feet; and (2) the outlet channel, which receives a constant flow of 6 cfs to 10 cfs that travels approximately 2,300 feet to its confluence with the spillway outlet.

Grass Valley Creek is an important spawning tributary for Coho Salmon, Steelhead, and Pacific Lamprey in the upper Trinity River basin. Restoration of the upstream 800 feet of outlet channel was performed in 2012 to enhance spawning and rearing within the outlet reach of Grass Valley Creek. 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 feet from March 1 to 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 foot depth at riffle crests in the outlet channel for 600 feet downstream from the outlet works and a ≥10 cfs flow increase at USGS gage 11525630, located near the mouth of Grass Valley Creek.

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 Grass Valley Creek 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

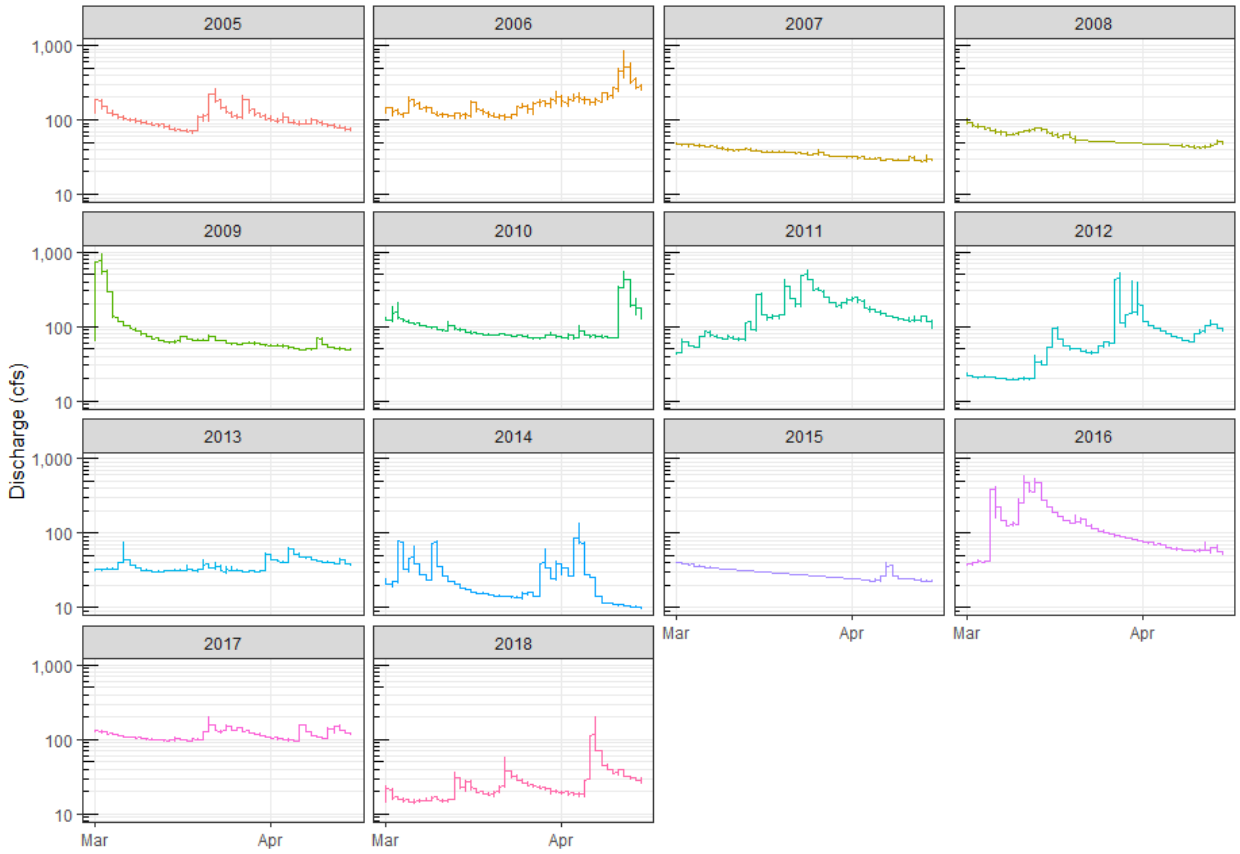


Figure O.3-135. Discharge (cfs) in Grass Valley Creek at USGS Gage 11525630 from March 1 through April 15, 2005 to 2018

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 Grass Valley Creek 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 Grass Valley Creek (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 Grass Valley Creek 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 Grass Valley Creek; however, the intake for the outlet works is located approximately 58 feet below the spillway crest, providing cooler than surface water temperatures. Overall, no effect on water temperature in Grass Valley Creek 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

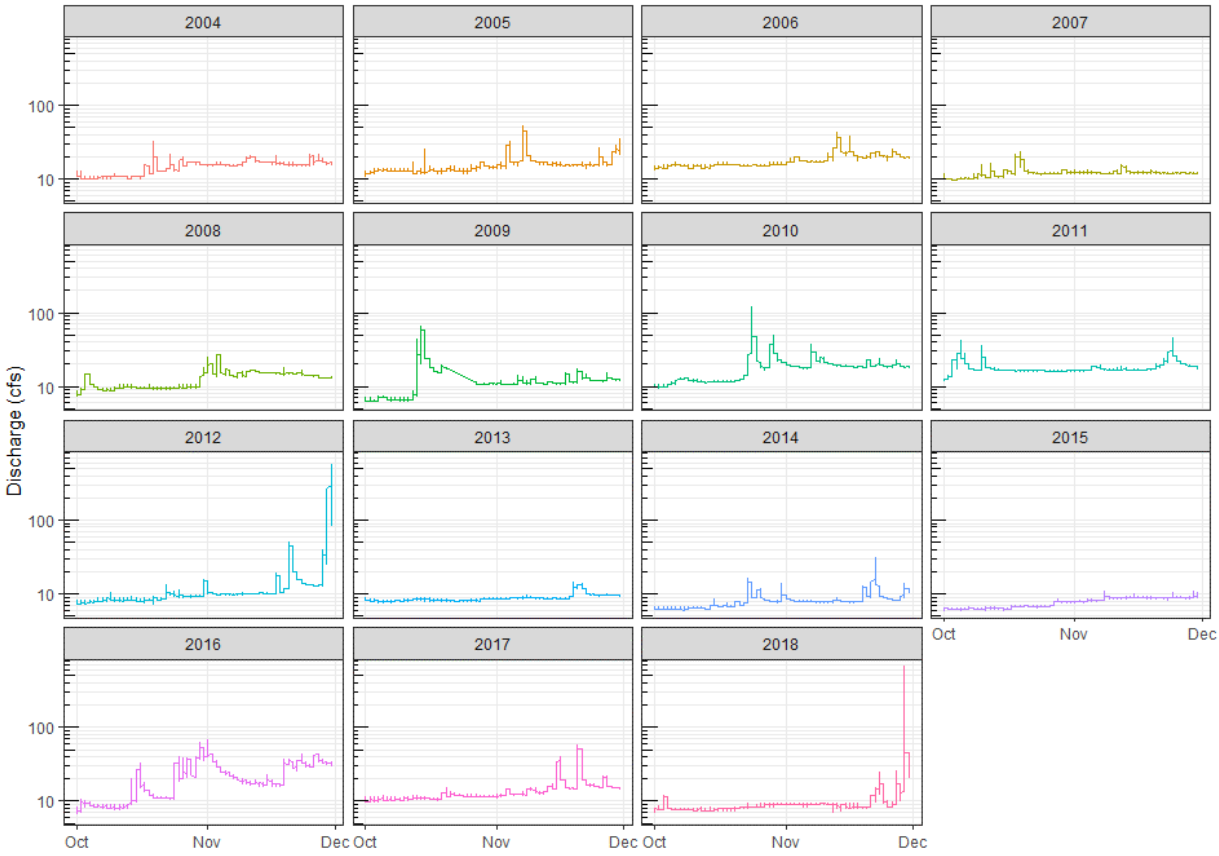


Figure 3. Discharge (cfs) in Grass Valley Creek at USGS Gage 11525630 from October through November, 2004–2018

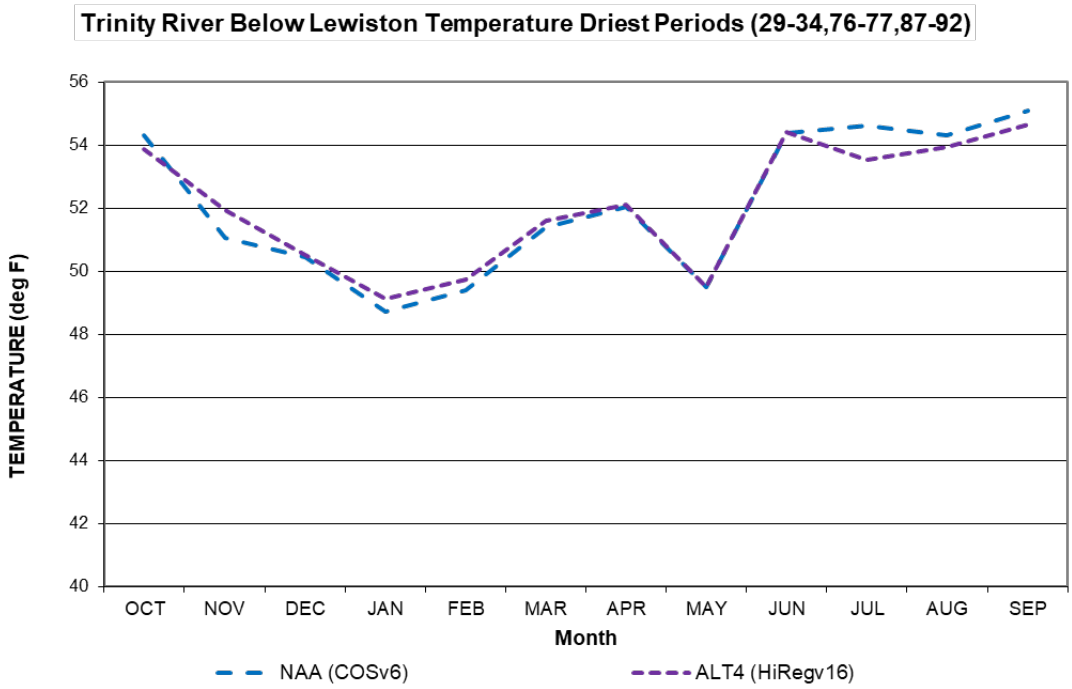


Figure O.3-137. Water Temperature in the Trinity River below Lewiston Dam during the Driest Periods of the Year under the No Action Alternative and Alternative 4.

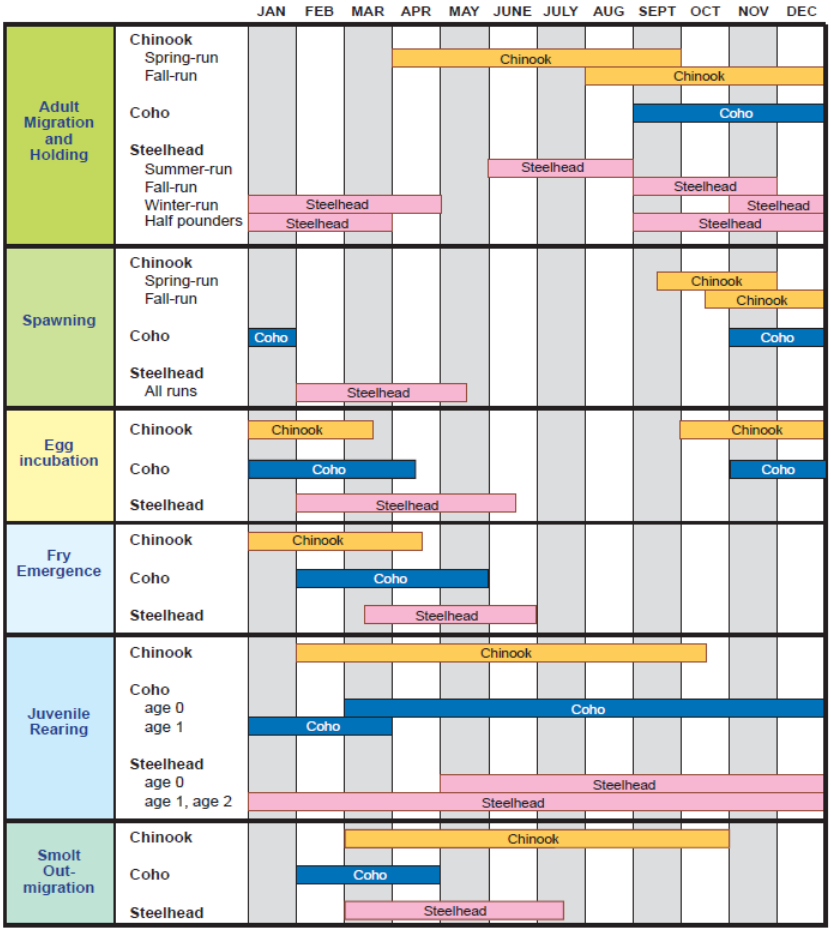
Potential changes to aquatic resources due to changes in pulse flows in Grass Valley Creek

Coho Salmon

Under Alternative 4, juvenile Coho Salmon in the Grass Valley Creek 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 feet 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 Grass Valley Creek are proposed under Alternative 4 but not the No Action Alternative. These releases are anticipated to be beneficial to adult Coho Salmon in Grass Valley Creek, as they would provide a depth ≥ 0.6 foot 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 Grass Valley Creek 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 Grass Valley Creek from its confluence with the Trinity River upstream 7.5 miles (Baldwin 2002). Spring-Run Chinook Salmon are not present in Grass Valley Creek, 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 Grass Valley Creek, 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 on 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 Grass Valley Creek, 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 Grass Valley Creek from its confluence with the Trinity River upstream to the outlet channel pool, located immediately downstream of the outlet works (Baldwin 2002). Grass Valley Creek is one of the most productive Winter-Run Steelhead tributaries in the upper Trinity River (Hill 2010). Summer-Run Steelhead are not present in Grass Valley Creek, 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 Grass Valley Creek, 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 Grass Valley Creek compared with the No Action Alternative.

Pacific Lamprey

Ammocoetes (juvenile lamprey) of potential Pacific Lamprey and Pit-Klamath Brook Lamprey have been recorded in Grass Valley Creek; however, without genetic testing ammocoetes of these two species cannot be differentiated. Based on habitat characteristics of Grass Valley Creek and species distribution, Pacific Lamprey are suspected to occur in Grass Valley Creek 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 Grass Valley Creek 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 action 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 cold water 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, and Fall-Run 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 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 1.0ºF to 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]	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]	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]	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]	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[1,2,3]	**Monthly Temperature (°F)**											
Water Year Type[4]	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
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]	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]	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 0.9ºF 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 (degrees 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 4 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 4 than under the No Action Alternative, the flows under Alternative 4 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 4 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. 2001a, 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 4, 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 4, 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 4, 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 4 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 to 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 4 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 4 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 RBDD. Under Alternative 4, 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 4, 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 differences 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 2011b: 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 August 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 critical 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-significant 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 2017c). 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. 2013). 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

Central Valley 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

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

Central Valley 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 4 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. 2017). 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. 2017). 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. 2017) concluded that the optimal range for normal embryo development of Southern DPS Green Sturgeon is 53°F 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°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.3-61 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°F 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 for Alternative 1 in Section O.3.3, *Alternative 1—Project-Level Effects*, 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. 2017). The upstream limit is the Cow Creek confluence. Green Sturgeon juveniles rear in the Sacramento River from about May through December (NMFS 2017c). 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 in Section O.3.3, 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. 2017). 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. 2017).

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 ºF 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°F, 63°F, 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 in the Sacramento River from July to 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 (USFWS 2003, 2005b).

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 in the Sacramento River from July to 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 RBDD, 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 4 are not likely to have significant effects on spawning adults, eggs, and alevins relative to the No Action Alternative.

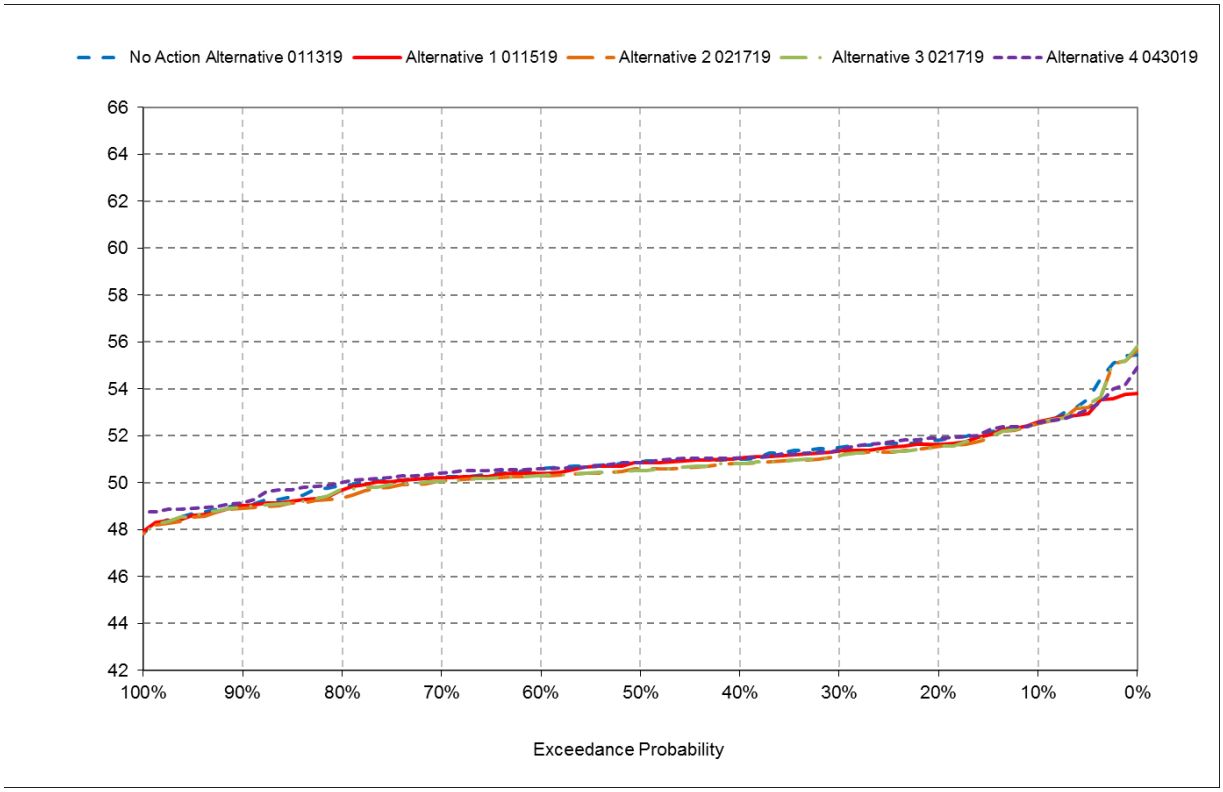


Figure O.3-139. HEC-5Q Sacramento River Water Temperatures at Clear Creek Confluence under the No Action Alternative, Alternative 1, Alternative 2, Alternative 3, and Alternative 4; May

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 2005a), 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 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.3.3.2, *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.3.3.2, *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 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. 2007a; 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 foot), 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 year-round 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 (macropthalmia) 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 year-round 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 prelarvae 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-significant 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 Wilkins 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 Central 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°F to 68°F and spawning ceases at about 70°F (Moyle 2002). The eggs can withstand temperatures of about 54°F to 75°F, with the optimum being about 64°F (Emmett et al. 1991). Larvae tolerate temperatures of 50°F to 77°F, but optimal temperatures for survival are 59°F to 72°F (Emmett et al. 1991). The adults appear to prefer water temperatures ranging from about 68°F to 75°F (Emmett et al. 1991) and juveniles prefer rearing temperatures of 61°F 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°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). Larval shad are planktonic for about 4 weeks, after which they metamorphose to actively swimming juveniles. Juveniles spend the next several months in fresh water, 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 2002b, 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°F 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°F to 70°F, although spawning is generally observed over a range of 55°F to 79°F (Stuber et al. 1982). Eggs hatch 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°F 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 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. 2009b). 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 4 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 4 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 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°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 cold water 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) from November to 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.

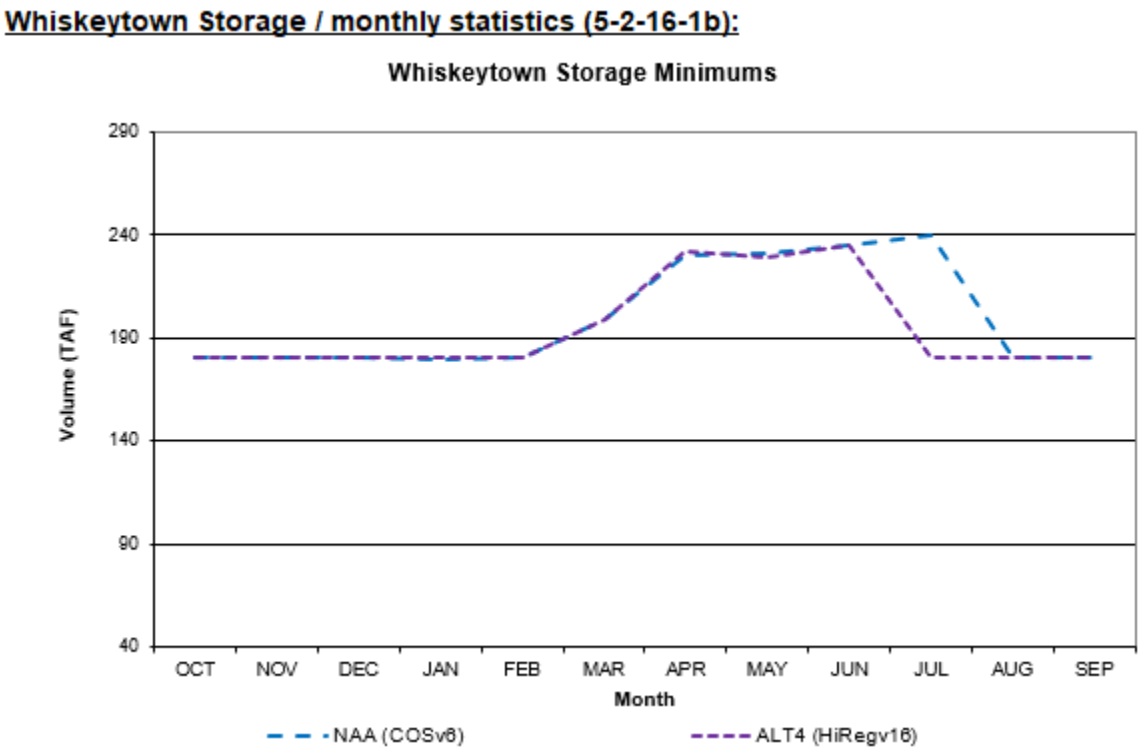


Figure O.3-140. Modeled Whiskeytown Lake Monthly Minimum Storage Volume under the No Action Alternative and Alternative 4 during all Water Year Types

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 on 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).

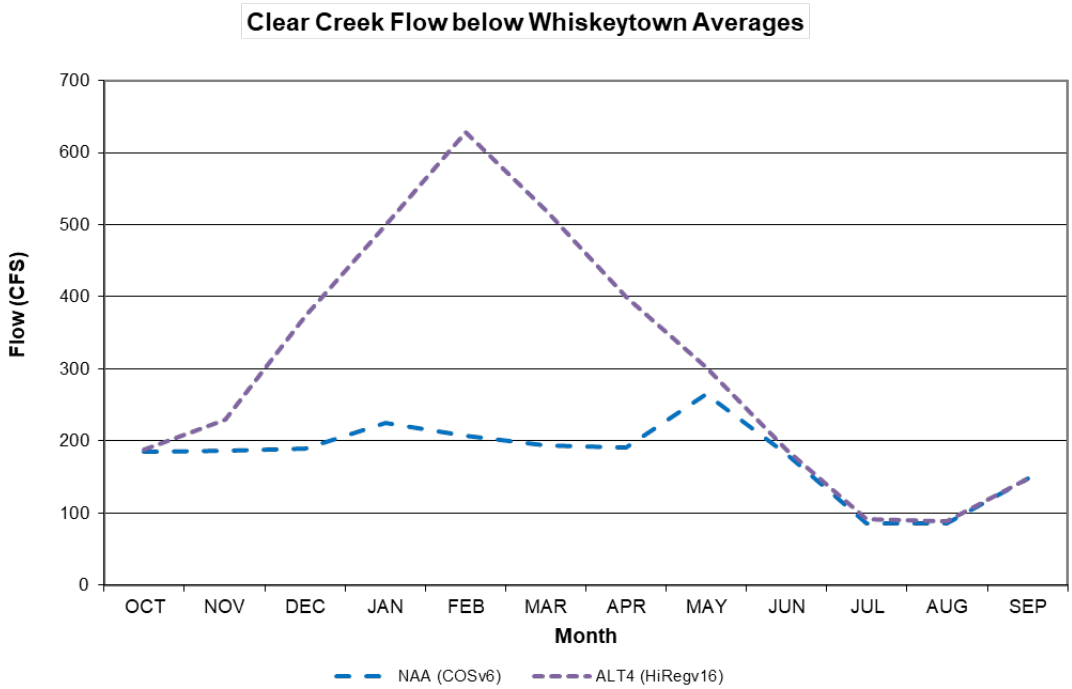


Figure O.3-141. CalSim II Estimates of Average Flow below Whiskeytown under the No Action Alternative and Alternative 4.

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 out-migrating 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 out-migrating 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 out-migrating 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 out-migrating 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).

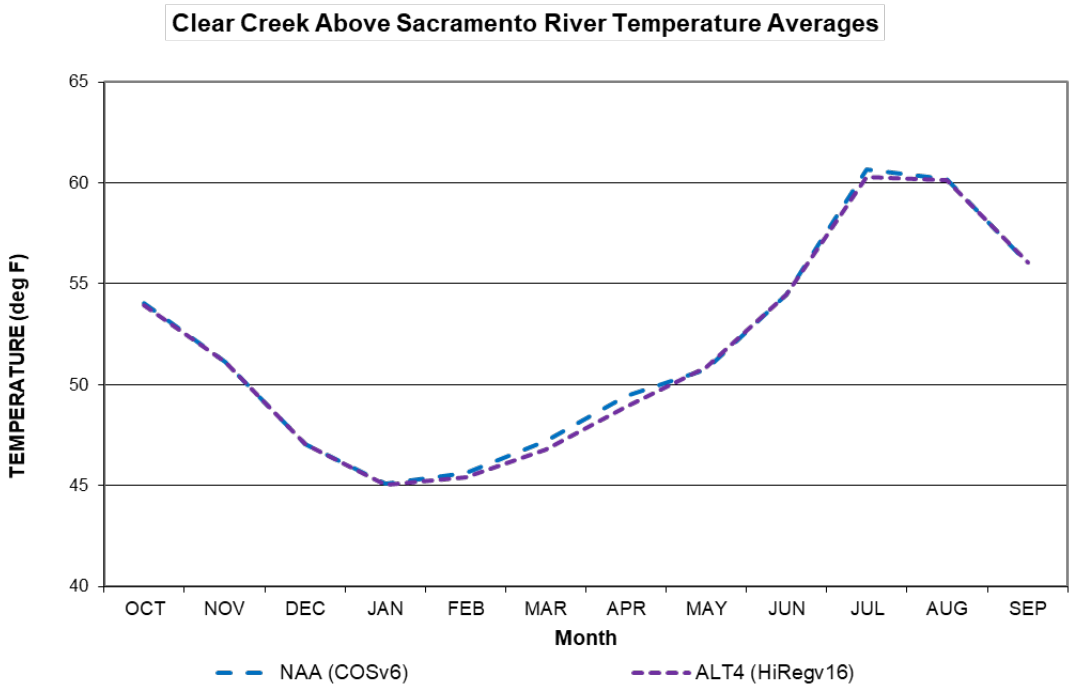


Figure O.3-142. Average Modeled Water Temperatures in Clear Creek above the Sacramento River under the No Action Alternative and Alternative 4.

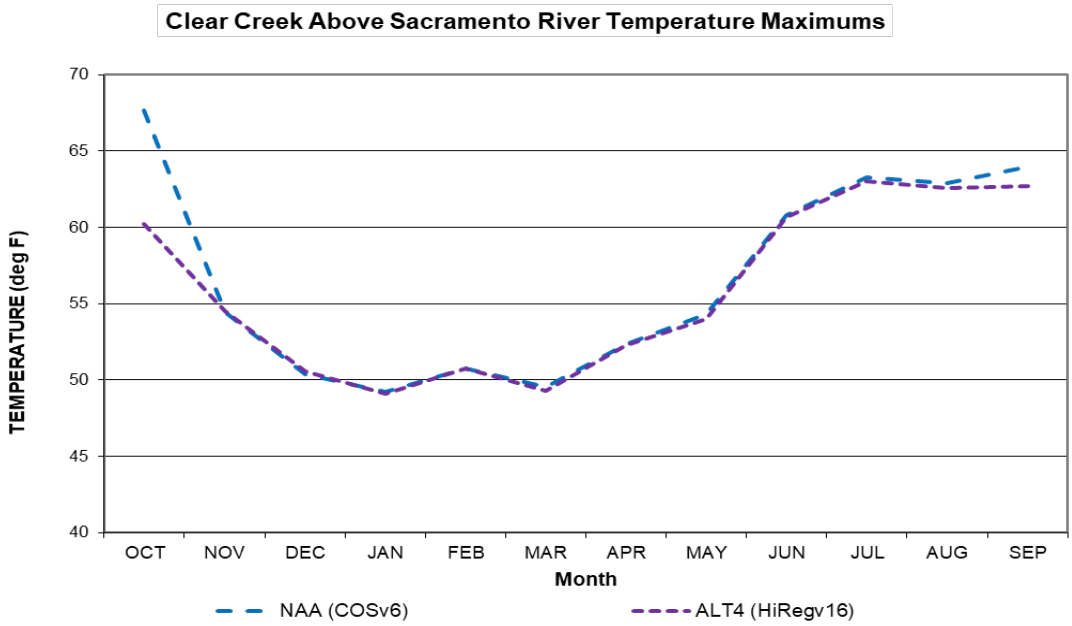


Figure O.3-143. Maximum Modeled Water Temperatures in Clear Creek above the Sacramento River under the No Action Alternative and Alternative 4.

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.

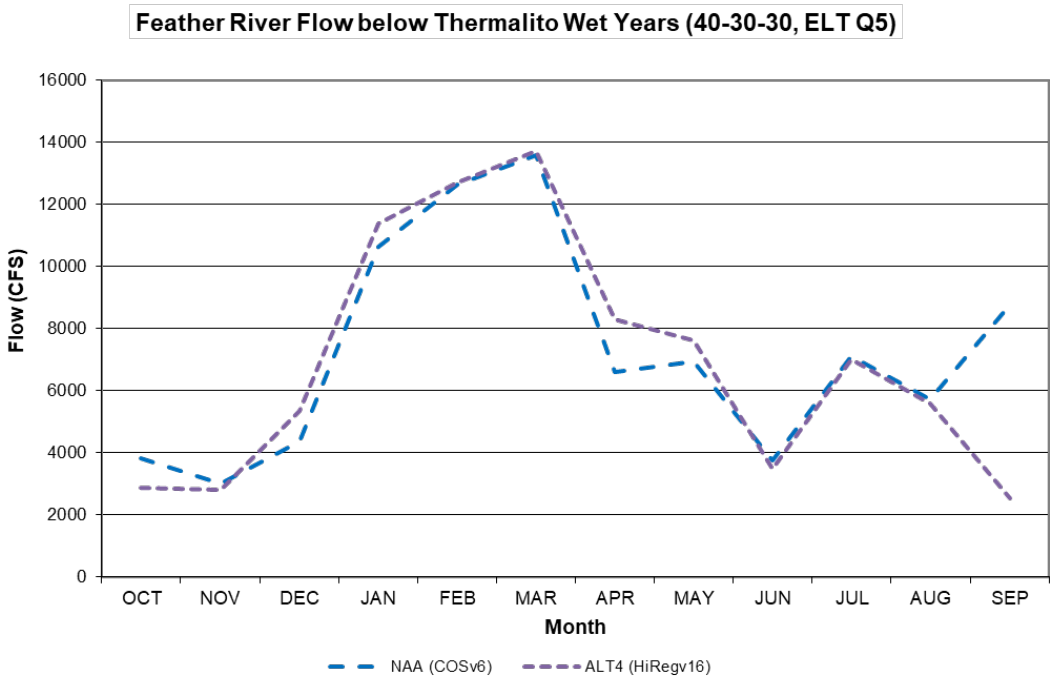
Under the No Action Alternative, DWR would operate Oroville Dam in accordance with ongoing management policies, criteria, and regulations, including water right permits and licenses issued by the SWRCB and operational requirements of the 2008 USFWS BO and the 2009 NMFS BO. Under the No Action Alternative, DWR typically releases water from Lake Oroville to meet the requirements of instream flows and D-1641.

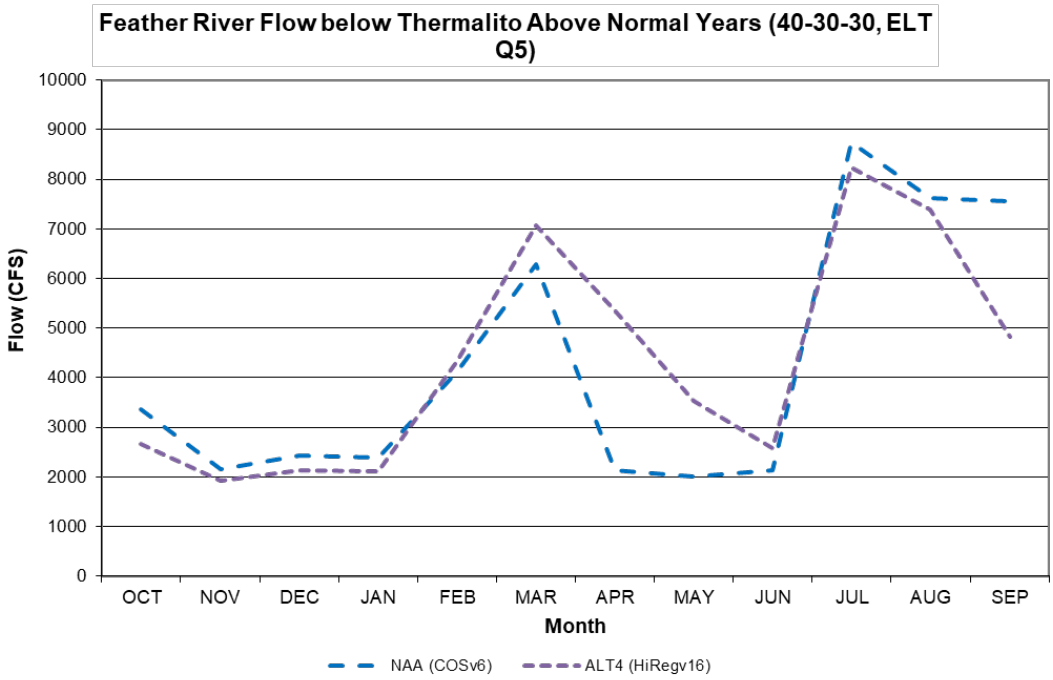
Table O.3-72. Feather River HFC Minimum Instream Flow Requirements

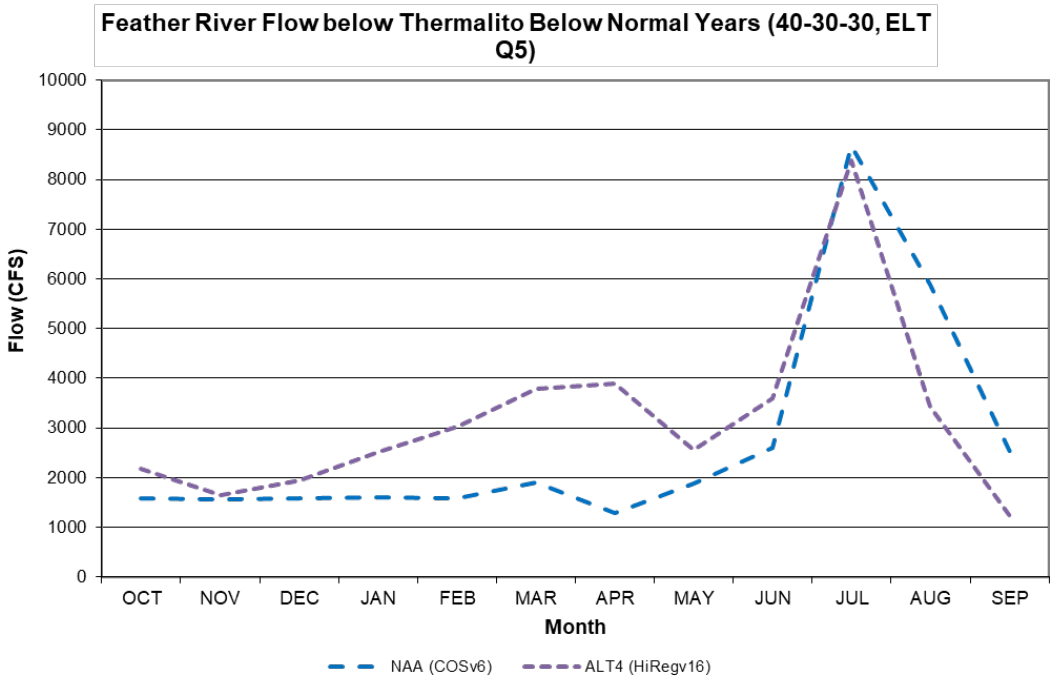
Preceding April to July Unimpaired Runoff (Percent of Normal)	Oct to Feb Minimum Instream Flow (cfs)	March Minimum Instream Flow (cfs)	April to Sept Minimum Instream Flow (cfs)
55% or greater	1,700	1,700	1,000
Less than 55%	1,200	1,000	1,000

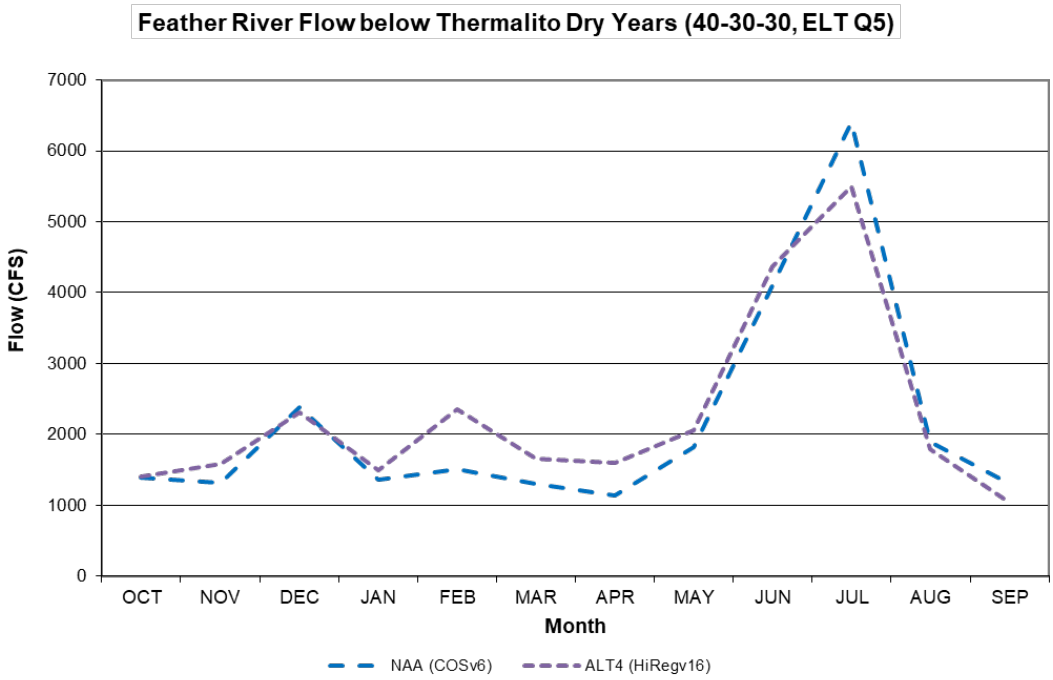
Potential changes to aquatic resources in the Feather River due to seasonal variation in flow

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)



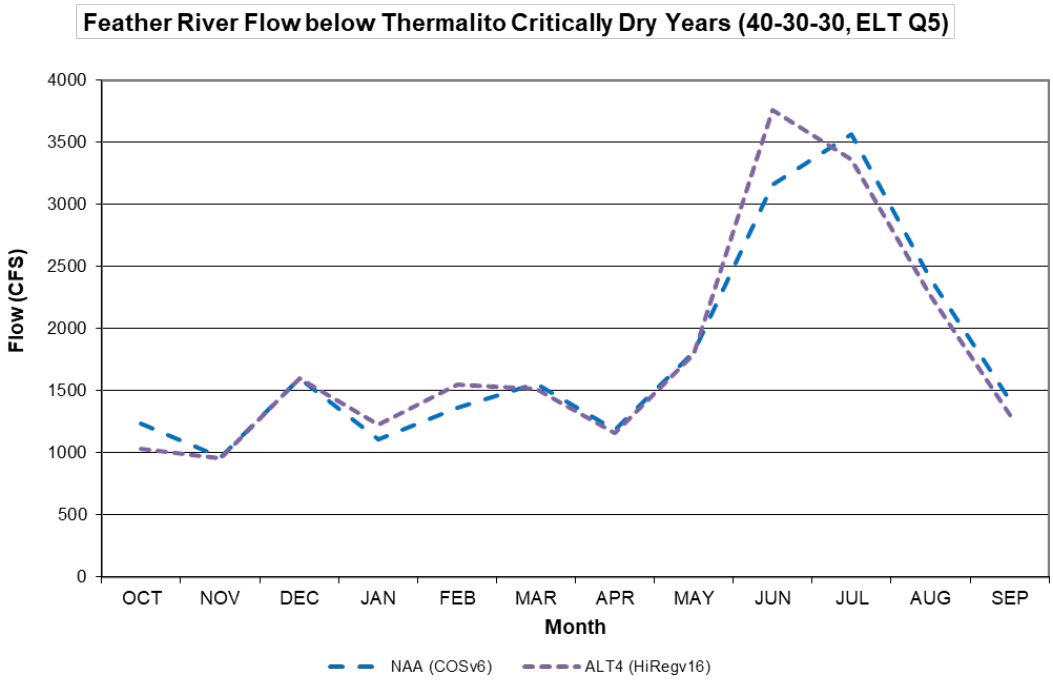


Figure O.3-144. CalSim II Estimates of Feather River Long-Term Average Flow below Thermalito, All Scenarios in Wet, Above Normal, Below Normal, Dry, and Critically Dry Water Years.

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 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 from January to April; juveniles out-migrating year-round with peaks from January to April and August to November; and holding and migrating adults occurring from April to 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 dissolved oxygen 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 dissolved oxygen 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

Period	Temperature (°F)
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).

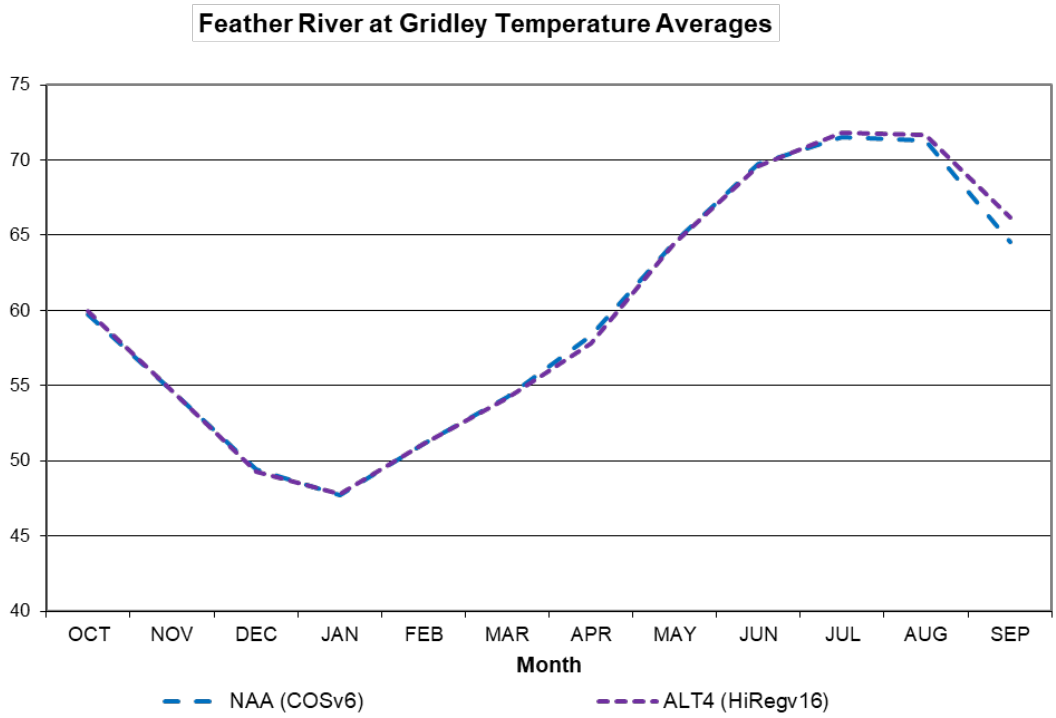


Figure O.3-145. RecTemp Average Feather River Water Temperatures at Gridley Bridge under the No Action Alternative and Alternative 4 Scenarios

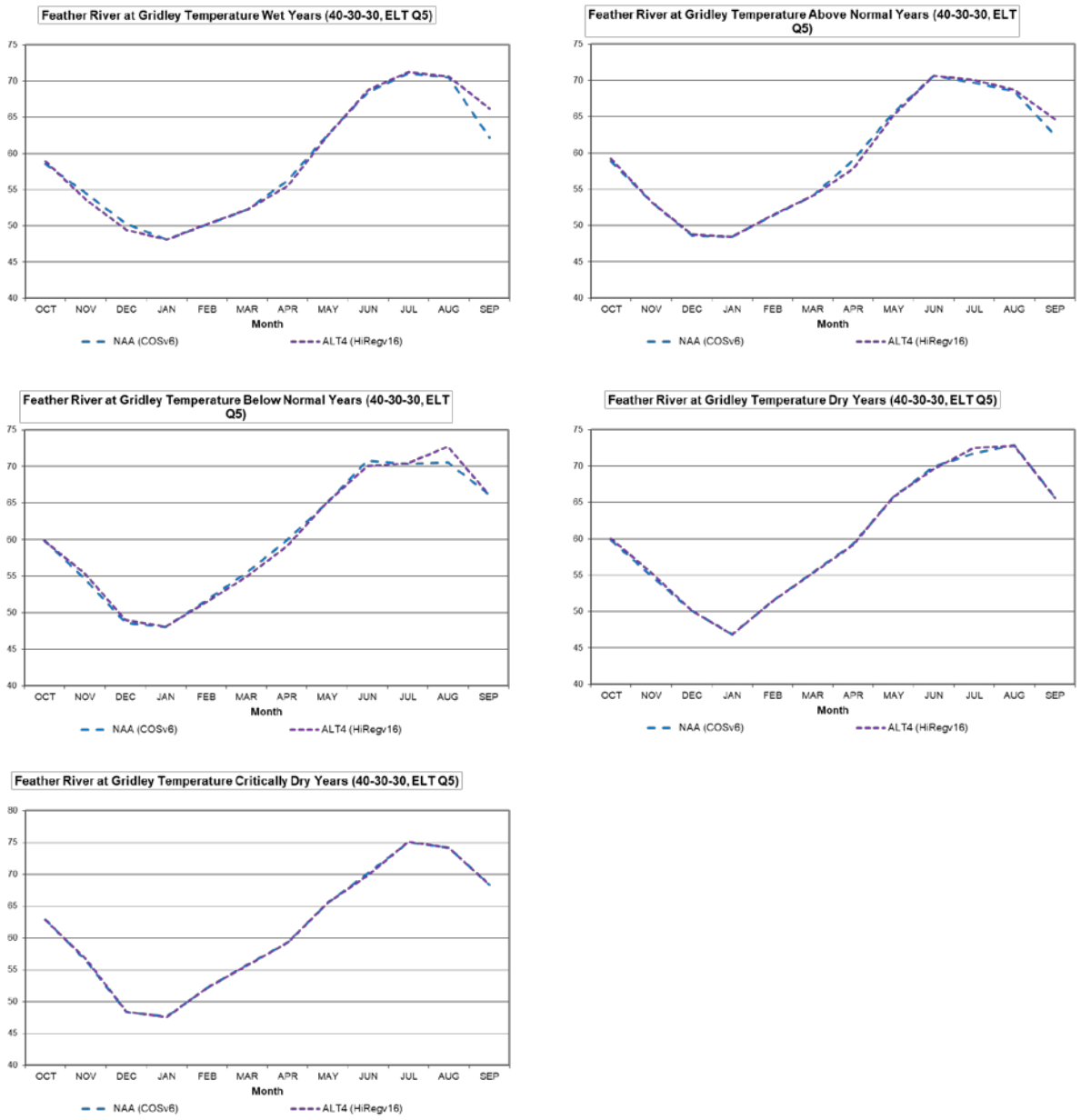


Figure O.3-146. RecTemp Average Estimated Feather River Water Temperatures at Gridley Bridge in Wet and Below Normal Water Year Types under the No Action Alternative and Alternative 4 Scenarios

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 4 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 during 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 cold water 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 4 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 4 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.3.3.6.

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 4. 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 D, Attachment 3-2, Figures 40-9 through 40-11). For larval/juvenile Delta Smelt in spring (March to June), effects may generally be similar to or slightly lesser or greater than effects of the the No Action Alternative, reflecting OMR flows (Appendix D, Attachment 3-2, Figures 40-12 through 40-15 of the ROC LTO BA). 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 D, Attachment 3-2, Figures 32-9 through 32-15 of the ROC LTO BA). Related to predation risk from Silversides, March to May south Delta exports would be less under Alternative 4 than the No Action Alternative (Appendix D, Attachment 3-3, Table 53-4 of the ROC LTO BA), as generally would be June to September Delta inflow (as represented largely by Freeport flow; Appendix D, Attachment 3-2, Table 29-4 of the ROC LTO BA) which could give greater predation risk under Alternative 4, based on the correlative analysis described in the ROC LTO BA. 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 D, Attachment 3-2, Figures 25-2 through 25-6 of the ROC LTO BA). 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 to October/November) period of potential harmful algal bloom occurrence (as reflected by OMR flows, for example: Appendix D, Attachment 3-2, Figures 40-7 and 40-8, 40-15 through 40-18 of the ROC LTO BA), 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 on 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 Forebay 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 D, Attachment 3-2, Table 41-2 of the ROC LTO BA), 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 D, Attachment 3-2, Figures 40-8 through 40-14 of the ROC LTO BA) 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 (2009c) 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. Mitigation measure AQUA-16 will monitor the presence of Longfin Smelt under Alternatives 1 through 4.

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 Forebay aquatic weed and algal bloom management

Potential changes to Longfin Smelt from changes to Suisun Marsh facilities

O.3.9.8.3 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 from October to 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 CAMT SST. The SST completed a thorough review of this subject and defined a 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.

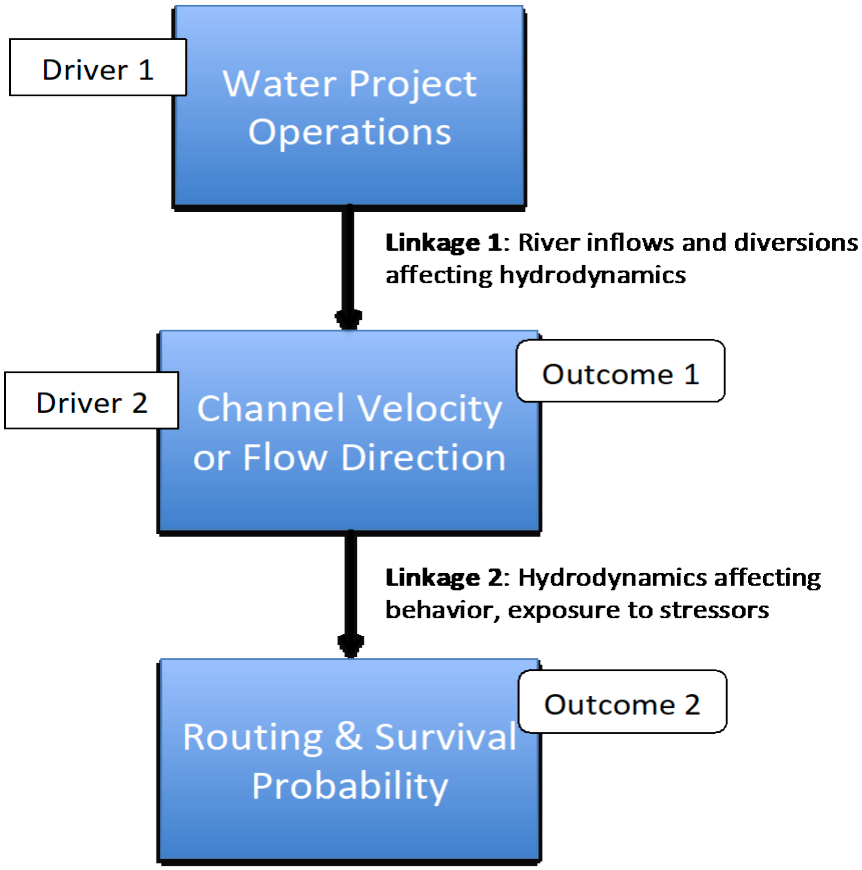


Figure O.3-147. Conceptual Model for Far-field Effects of Water Project Operations on Juvenile Salmonids in the Delta. This CM is a Simplified Version of the Information Provided by the CAMT SST.

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 (December to February and

March to May) in each water year (1922 to 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-Run, Late Fall–Run and Fall-Run Chinook Salmon. These data represent 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 from November to 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 from December to 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 DCC 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% to 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 out-migrating 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 due to OMR management

See the section above, *Potential changes to aquatic resources due to seasonal operations*, which integrates 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, 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, 2017c; USFWS 1993, 2000, 2007, 2010, 2017; CDFG 1994, 2009a; 58 FR 12854–12864) 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 2017d), 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 2017d, 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 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 2017d). From 1999 to 2009, the 11 years prior to construction of the Rock Slough Fish Screen, CCWD's Fish Monitoring Program collected no juvenile or adult Winter-Run Chinook Salmon at the Rock Slough Headworks (Reclamation 2016; NMFS 2017d).

Since construction of the Rock Slough Fish Screen, 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 to 2018, 47 salmon were recovered at the fish screen (Reclamation 2016: Appendix A; Tenera Environmental 2018a), but none of the captured fish were identified as Winter-Run Chinook Salmon (NMFS 2017d).

NMFS issued a biological opinion in 2017 (NMFS 2017d) that considered improvements to the Rock Slough Fish Screen facility including the hydraulic rake cleaning system, operation and maintenance of the fish screen and associated appurtenances, and administrative actions such as the transfer of operation and maintenance activities from Reclamation to CCWD. NMFS determined that operation and maintenance of Rock Slough Fish Screen 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 fish screen monitoring (NMFS 2017d). The incidental take provided in NMFS 2017d 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 2019a).

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 (2017c), 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 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 OMR 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, but varies depending on the tidal stage from approximately 56,000 square feet (at low tide and low San Joaquin River flow) to 68,000 square feet (at high tide and high San Joaquin River flow) as shown in Figure O.3-148.

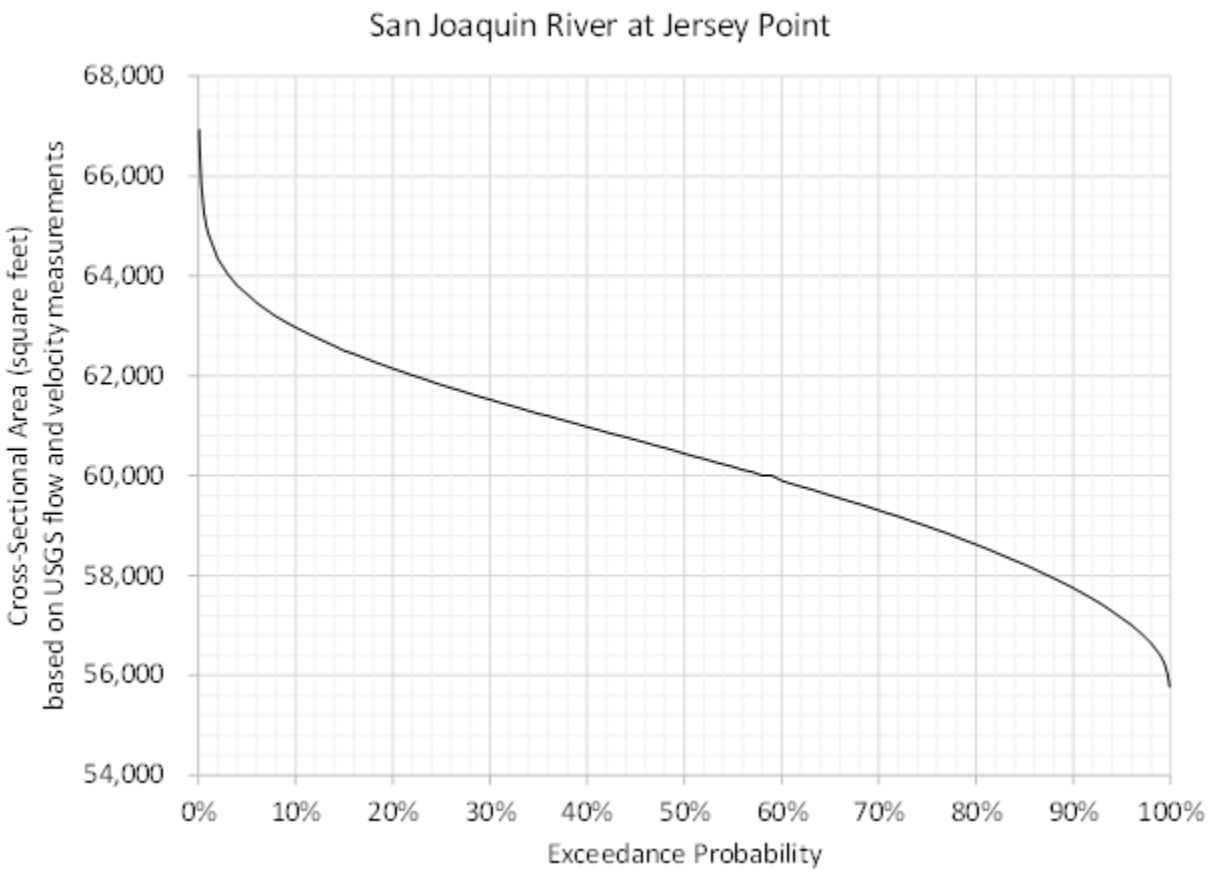


Figure O.3-148. Cross-sectional area of the San Joaquin River at Jersey Point (Station: 11337190) Calculated from USGS Measurements of Flow and Velocity every 15 Minutes for Water Years 2014 through 2018.

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 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 feet 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 feet 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 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 are available at https://www.wildlife.ca.gov/Regions/3). There should be no discernable effect on 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 Forebay 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 from December to May with a peak in March and 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 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 Clifton Court Forebay.

As discussed in Appendix D, *Alternatives Development Technical Memorandum*, treatment of harmful algal blooms with peroxide-based algaecide is proposed to occur as needed, year-round, but there are no anticipated impacts on 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 CO_2 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 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 F.2.7, F.2.8, and F.2.9 in Appendix AB, Attachment F of the ROC LTO BA) (Reclamation 2019). 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 AB, Attachment F of the ROC LTO BA) Reclamation 2019).

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 on 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 Clifton Court Forebay could reduce pre-screen loss of juvenile Chinook Salmon entrained into Clifton Court Forebay. 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 SWRCB 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 SMSCG 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 RRDS 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/sec, so that juvenile Winter-Run Chinook Salmon would be excluded from entrainment.

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, its unlikely juvenile Winter-Run Chinook Salmon will be entrained into the water distribution system, since Winter-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 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 from June to September. Therefore, no effects would occur as a result of actions for Delta Smelt summer-fall habitat.

Potential changes to aquatic resources due to changes from Clifton Court Forebay predator management

Clifton Court Forebay predator management efforts could reduce predation on listed fishes following entrainment into Clifton Court Forebay, reducing pre-screen loss.

Potential changes to aquatic resources due to the San Joaquin Basin Steelhead Telemetry Study

The San Joaquin Basin Steelhead Telemetry Study would not have effects on the Winter-Run Chinook Salmon population.

Potential changes to aquatic resources due to reintroduction changes from the Fish Conservation and Culture Laboratory

Reintroduction changes from the Fish Conservation and Culture Laboratory would not have effects on the Winter-Run Chinook Salmon population.

Potential changes to aquatic resources from monitoring

A number of monitoring activities described in ROC LTO BA 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 on 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 on 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 Section O.3.9.8.3, *Sacrament River Winter-Run Chinook Salmon*, for more detail concerning "far-field" and "near-field."

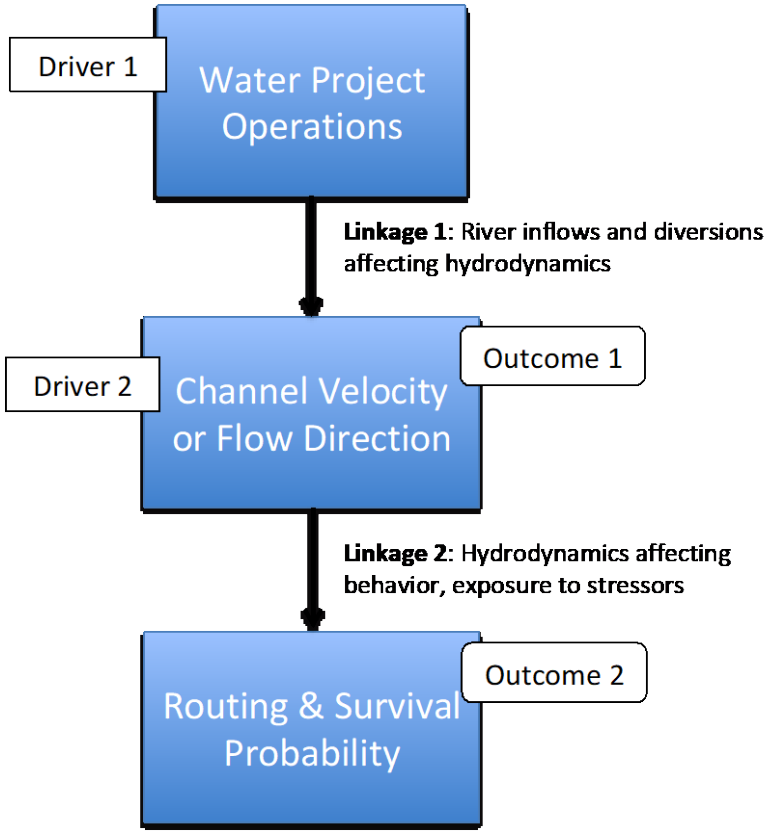


Figure O.3-149. Conceptual model for far-field effects of water project operations on juvenile salmonids in the Delta. This CM is a simplified version of the information provided by the CAMT SST.

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 juvenile Fall-Run 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 Section O.3.9.8.3, *Sacramento River Winter-Run Chinook Salmon*, 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 from November to 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 DCC 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 from November to 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 due to OMR management

See the section above, *Potential changes to aquatic resources due to seasonal operations*, which integrates OMR management.

Potential changes to aquatic resources due to Delta Cross Channel operations

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. 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 of 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 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 et al. 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, 2017c; USFWS 1993, 2000, 2007, 2010, 2017; CDFG 1994, 2009a; 58 FR 12854–12864). Therefore, CCWD's operation, including operation of the Rock Slough Intake, for Alternative 4 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 2017d), 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 2017d, 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 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 2017d). From 1999 to 2009, the 11 years prior to construction of the Rock Slough Fish Screen, 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 2017d) and 4 juvenile Central Valley Spring-Run at Pumping Plant #1 (CCWD 2019a). No adult Spring-Run were collected in the vicinity of the Rock Slough Intake from 1994 through 2009 (CDFG 2002c; Reclamation 2016; NMFS 2017d). 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 Rock Slough Fish Screen, 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 to 2018, 47 salmon were recovered at the fish screen (Reclamation 2016: Appendix A;

Tenera Environmental 2018a), but none of the captured fish were identified as Spring-Run Chinook Salmon (NMFS 2017d).

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 2019a).

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 (2017c), 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 Section O.3.9.8.3, *Sacramento River Winter-Run Chinook Salmon*, 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 Section O.3.9.8.3, the diversions at the Rock Slough Intake could move a neutrally buoyant particle in the San Joaquin River at Jersey Point approximately 540 feet 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 feet 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 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 are available at https://www.wildlife.ca.gov/Regions/3). The North Bay Aqueduct is located within designated critical habitat for Spring-Run Chinook Salmon. There should be no discernable effect on 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 4 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).

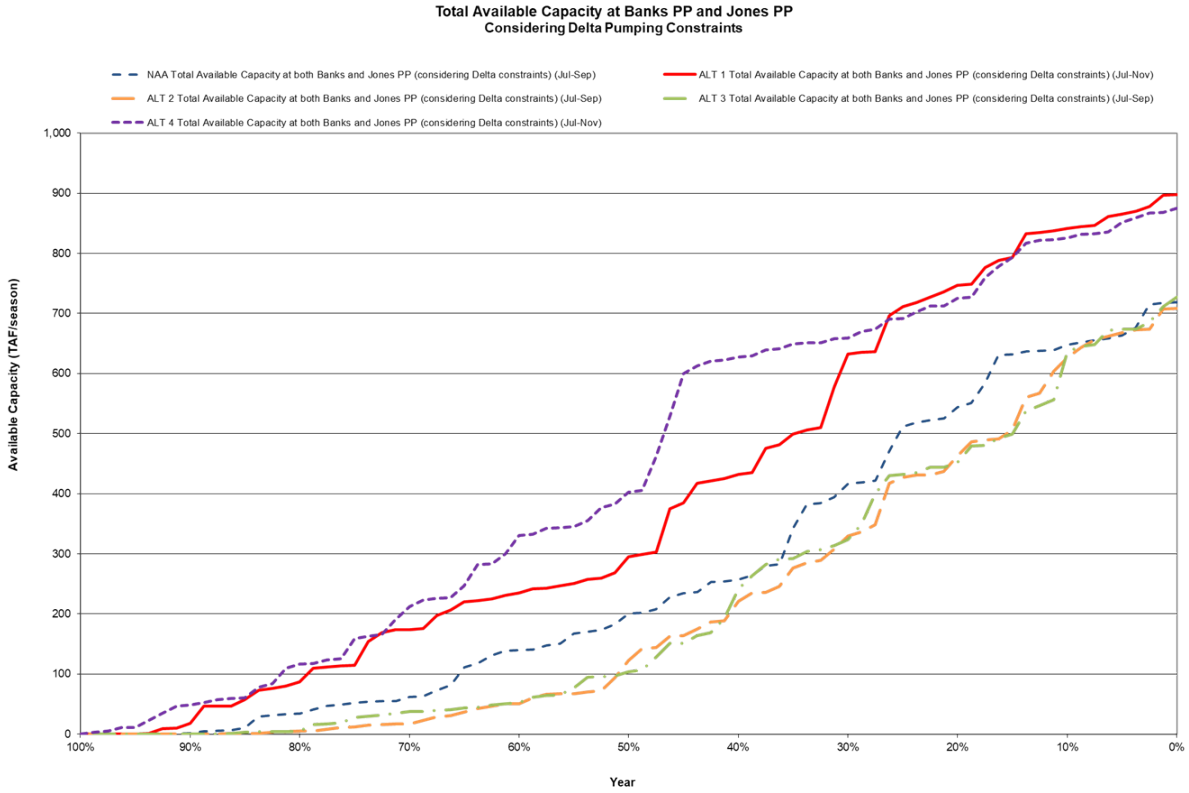


Figure O.3-150. Exceedance of Available Capacity for Transfers at Jones and Banks under the Alternative 4 and No Action Alternative

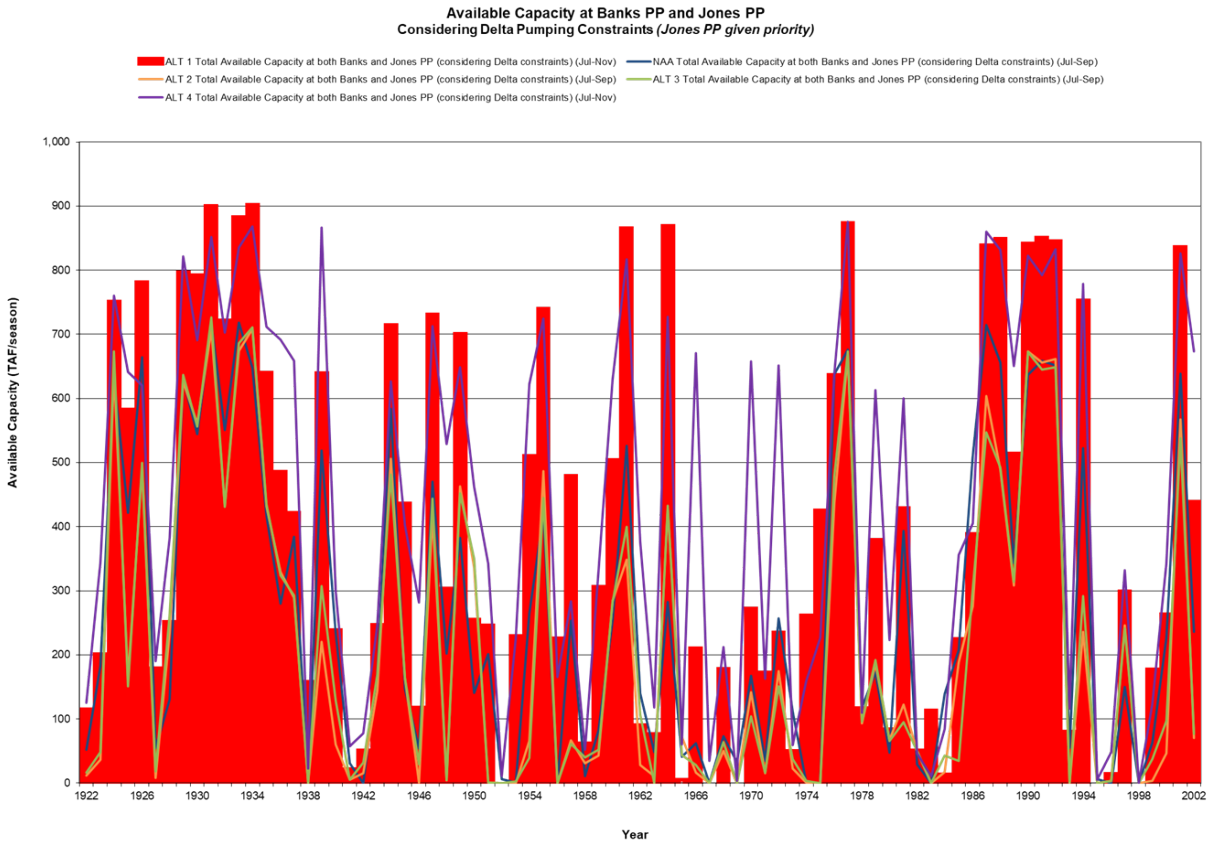


Figure O.3-151. Modeled Annual Maximum Available Capacity for Transfers under Alternative 4 and No Action Alternative, CalSim Period of Record (1922–2003)

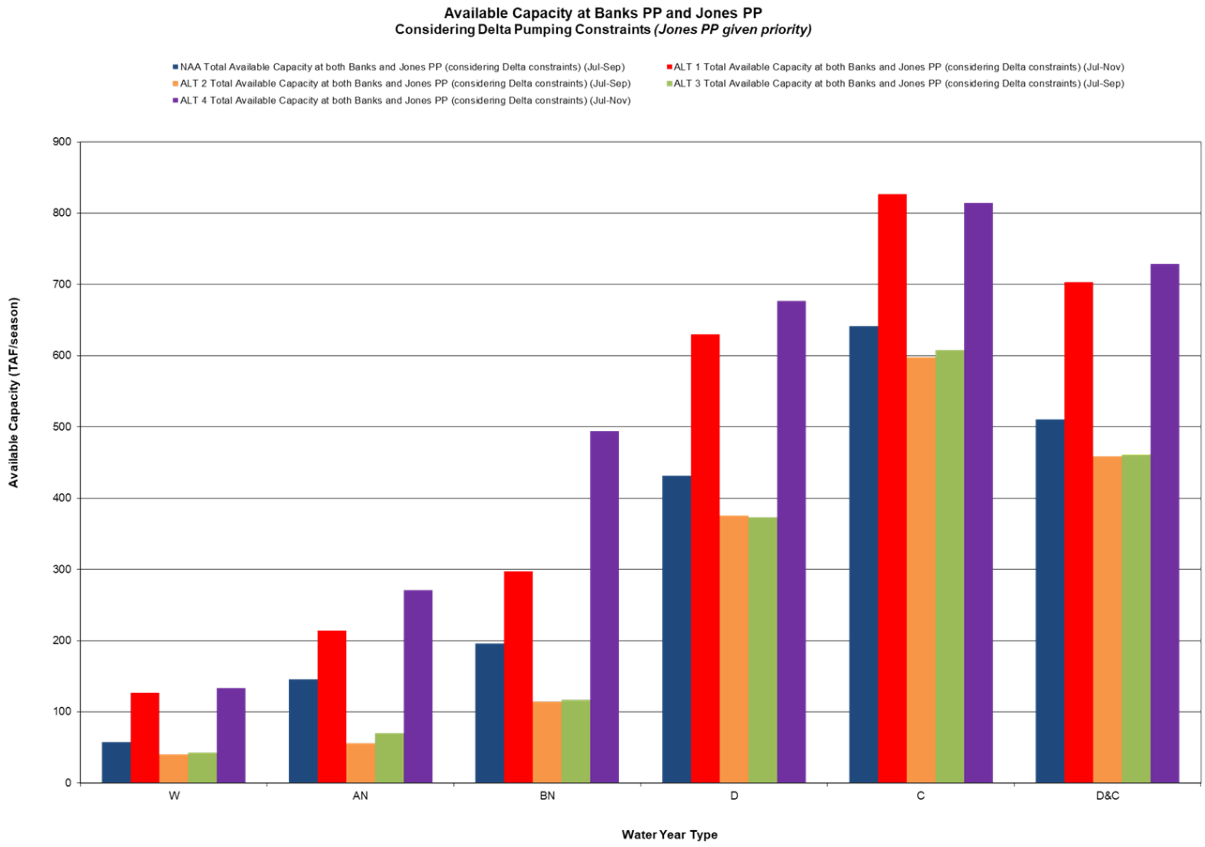


Figure O.3-152. Water Year Type average available capacity at Jones and Banks Pumping Plants

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 from December to 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 the *Potential changes to aquatic resources due to seasonal operations* 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 Forebay 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 from mid-November to 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, *Alternatives Development Technical Memorandum*, treatment of harmful algal blooms with peroxide-based algaecide is proposed to occur as needed, year-round, but there are no anticipated impacts on 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 the Tracy fish facility, including installing a CO_2 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 AB, Attachment F of the ROC LTO BA: WR_salvage_unclipped_date, WR_salvage_clipped_date, and WR_salvage_clipped_CWT_race) (Reclamation 2019). 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 SWRCB 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 SMSCG 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 RRDS 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/sec, so that juvenile Spring-Run Chinook Salmon would be excluded from entrainment.

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, 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 from June to September. Therefore, no effects would occur as a result of actions for Delta Smelt summer-fall habitat.

Potential changes to aquatic resources due to changes from Clifton Court Forebay 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

The San Joaquin Basin Steelhead Telemetry Study would not have effects on the Spring-Run Chinook Salmon population.

Potential changes to aquatic resources due to reintroduction changes from the Fish Conservation and Culture Laboratory

Reintroduction changes from the Fish Conservation and Culture Laboratory would not have effects on the Spring-Run Chinook Salmon population.

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 on 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 CAMT SST. The SST completed a thorough review of this subject and defined a 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.

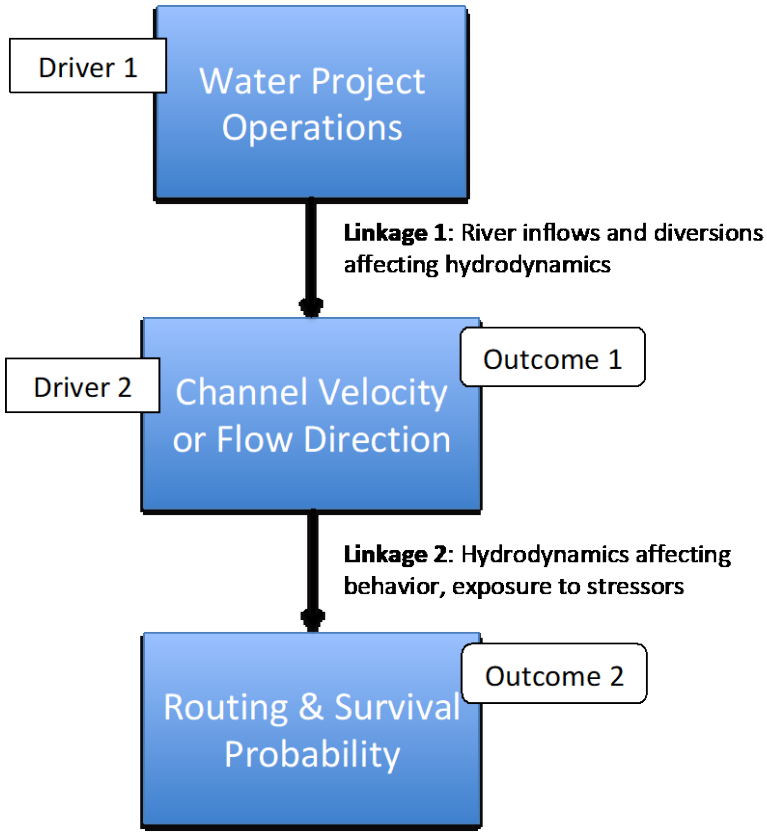


Figure O3-153. Conceptual model for far-field effects of water project operations on juvenile salmonids in the Delta. This CM is a simplified version of the information provided by the CAMT SST.

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, 2012, 2015; Michel et al. 2012).

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 (December to February and March to May) in each water year (1922 to 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 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. These data are extremely useful because they represent 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–Run Chinook Salmon 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 from February to May, and Late Fall–Run are present in the Delta from November to 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 DCC 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 during the March to May period, overlap between Alternative 4 and No Action Alternative was moderate in most water year types (55% to 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 due to OMR management

See the section above, *Potential changes to aquatic resources due to seasonal operations*, which integrates OMR management.

Potential changes to aquatic resources due to Delta Cross Channel operations

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 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 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 et al. 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, 2017c; USFWS 1993, 2000, 2007, 2010, 2017; CDFG 1994,

2009a; 58 FR 12854–12864). Therefore, CCWD's operations, including operation of the Rock Slough Intake, under Alternative 4 would remain unchanged from the current operations.

Fish monitoring prior to the construction of the Rock Slough Fish Screen indicates the timing and magnitude of Fall-Run and Late Fall–Run Chinook Salmon presence near the Rock Slough Intake. From 1999 to 2011, the 11 years prior to construction of the Rock Slough Fish Screen, CCWD's Fish Monitoring Program collected 23 juvenile Fall-Run and 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 or 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 or Late Fall–Run Chinook Salmon at CCWD's Old River Intake or Middle River Intake (CCWD 2019a).

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 and Late Fall–Run are not likely to be in the vicinity of the Rock Slough Intake. However, according to NMFS (2017c), 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 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 the 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 Section O.3.9.8.3, *Sacramento River Winter-Run Chinook Salmon*, 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 and 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 Section O.3.9.8.3, the diversions at the Rock Slough Intake could move a neutrally buoyant particle in the San Joaquin River at Jersey Point approximately 540 feet 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 feet 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 Forebay 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 from mid-November to 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 on 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 (Reclamation 2019). NMFS (2009) determined that operation of the SMSCG 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 RRDS 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/sec (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 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 in 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 due to changes from Clifton Court Forebay 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

The San Joaquin Basin Steelhead Telemetry Study would not have effects on the Fall-Run Chinook Salmon population.

Potential changes to aquatic resources due to reintroduction changes from the Fish Conservation and Culture Laboratory

Reintroduction changes from the Fish Conservation and Culture Laboratory would not have effects on the Fall-Run Chinook Salmon population.

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 from 2003 to 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 composed 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 during March to 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 from November to 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 due to OMR management

See the section above, *Potential changes to aquatic resources due to seasonal operations*, which integrates 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 on this life stage when compared to the No Action Alternative.

Potential changes to aquatic resources due to the Temporary Barriers Project

The 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 on 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, 2017c; USFWS 1993, 2000, 2007, 2010, 2017; CDFG 1994, 2009a; 58 FR 12854–12864). Therefore, CCWD's operations, including operation of the Rock Slough Intake, under Alternative 4 would remain unchanged from the current operations.

Fish monitoring prior to the construction of the Rock Slough Fish Screen 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 Rock Slough Fish Screen, 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 2019a).

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 (2017c), 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 4 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 the 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 Section O.3.9.8.3, *Sacramento River Winter-Run Chinook Salmon*, 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 Section O.3.9.8.3, the diversions at the Rock Slough Intake could move a neutrally buoyant particle in the San Joaquin River at Jersey Point approximately 540 feet 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 feet 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 North Bay Aqueduct's Barker Slough Pumping Plant relative to current operations. Juvenile Central Valley Steelhead could occur in the vicinity of the Barker Slough Pumping Plant; 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 were 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 Forebay aquatic weed removal

Under Alternative 4, the application of aquatic herbicide to the waters of Clifton Court Forebay will occur during the summer months of July and August. Juvenile Central Valley Steelhead abundance in the Delta peaks from March to 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 on 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 from August to 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 CO_2 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.

Skinner fish facility improvements under Alternative 4 to reduce predation on listed fishes following entrainment into Clifton Court Forebay could reduce pre-screen loss of juvenile Central Valley Steelhead entrained into Clifton Court Forebay, thereby 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 SMSCG is unlikely to impede migration of juvenile salmonids or produce conditions that support unusually high numbers of predators.

Under Alternative 4, the RRDS 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/sec (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 Forebay predator management

Clifton Court predator management under Alternative 4 could reduce pre-screen loss of juvenile Central Valley Steelhead entrained into Clifton Court Forebay, 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

The San Joaquin Basin Steelhead Telemetry Study would not have effects on Central Valley Steelhead.

Potential changes to aquatic resources due to reintroduction changes from the Fish Conservation and Culture Laboratory

Reintroduction changes from the Fish Conservation and Culture Laboratory would not have effects on Central Valley Steelhead.

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, Delta, and San Francisco 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 on 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 on 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 months) 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 months) 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 out-migrating 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 out-migrating 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 due to OMR management

See the section above, *Potential changes to aquatic resources due to seasonal operations*, which integrates 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 of the TBP are included in Alternative 4 and consist 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), out-migrating Chinook Salmon passage past the agricultural barrier was improved (DWR 2018). It could be inferred that passage of out-migrating 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, 2017c; USFWS 1993, 2000, 2007, 2010, 2017; CDFG 1994, 2009a; 58 FR 12854–12864). Therefore, CCWD's operations, including operation of the Rock Slough Intake, for Alternative 4 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 2017d), 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 40ºF in winter (December and January) to over 70ºF beginning in May and continuing through October (NMFS 2017d).

A review of the 24 years of fish monitoring data (1994 to 2018) near the Rock Slough Intake both pre- and post-construction of the Rock Slough Fish Screen showed that Southern DPS Green Sturgeon have never been observed in Rock Slough (CDFG 2002c; Reclamation 2016; NMFS 2017d; 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 2019a).

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 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 *Potential changes to aquatic resources due to water transfers* section in Section O.3.9.8.4, *Central Valley Spring-Run Chinook Salmon*, 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 *Potential changes to aquatic resources due to seasonal operations* 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 Forebay aquatic weed removal

Few Southern DPS juvenile Green Sturgeon 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 on 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 Tracy fish facility 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 Tracy fish facility 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 on 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 Clifton Court Forebay, 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 SMSCG 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 SMSCG 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 (Verhille 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 Forebay 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 Clifton Court Forebay, but individuals are salvaged infrequently.

Potential changes to aquatic resources due to the San Joaquin Basin Steelhead telemetry study

The San Joaquin Basin Steelhead Telemetry Study would not have effects on Green Sturgeon.

Potential changes to aquatic resources due to reintroduction changes from the Fish Conservation and Culture Laboratory

Reintroduction changes from the Fish Conservation and Culture Laboratory would not have effects on Green Sturgeon.

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 on 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 on 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 Section O.3.9.1, *Trinity River*, Section O.3.9.2, *Sacramento River*, Section O.3.9.3, *Clear Creek*, Section O.3.9.4, *Feather River*, Section O.3.9.5, *American River*, Section O.3.9.6, *Stanislaus River*, Section O.3.9.7, *San Joaquin River*, and Section O.3.9.8, *Bay Delta*. These analyses suggest that Alternative 4 may result in some potential positive and negative effects on 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 temperature control device improvements

Improvement of the Shasta temperature control device 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 Longfin Smelt

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 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 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 component of Alternative 4. This action would hydrologically connect the Sacramento River with the ship channel 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 Sacramento Deepwater Ship Channel. Estimates of salmonid survival in the ship channel are not available to compare with rates in the Sacramento River route. However, if survival rates are similar, fish entering the ship channel 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 Sacramento Deepwater Ship Channel could potentially attract adult Winter-Run Chinook Salmon. If the connection is maintained, there would likely not be impacts on 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 from December to 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 from December to 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 on 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 on 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 DCC. 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 CO_2 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 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 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 on 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 Clifton Court Forebay could reduce pre-screen loss of juvenile Chinook Salmon entrained into Clifton Court Forebay. 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 out-migrating 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. The NEPA process for the facility (Horizon Water and Environment 2017) indicates 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 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 Sacramento Deepwater Ship Channel. There are potential benefits to Spring-Run Chinook Salmon from this action. Fish entering the ship channel 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 Sacramento Deepwater Ship Channel 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 on 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 DCC 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 DCC 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 the Tracy fish facility, including installing a CO_2 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 out-migrating 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. The NEPA process for the facility (Horizon Water and Environment 2017) indicates 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 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 action. This action would hydrologically connect the Sacramento River with the ship channel 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 Sacramento Deepwater Ship Channel. Estimates of salmonid survival in the ship channel are not available to compare with rates in the Sacramento River route. However, fish entering the ship channel 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 (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 on 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 DCC 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 DCC 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 on 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 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 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-Run or Late Fall–Run Chinook Salmon rearing and out-migrating in the Bay-Delta are expected to be exposed to the effects of construction of screens on water diversion intakes. Juvenile Sacramento River Fall-Run and 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. The NEPA process for the facility (Horizon Water and Environment 2017) indicates 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 conservation measure under Alternative 4. This conservation measure would hydrologically connect the Sacramento River with the ship channel 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 Sacramento Deepwater Ship Channel. Estimates of salmonid survival in the ship channel are not available to compare with rates in the Sacramento River route. However, fish entering the Sacramento Deepwater Ship Channel 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 on 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 from 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 on 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 from August to 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 from August to 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 CO_2 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.

Skinner fish facility improvements under Alternative 4 to reduce predation on listed fishes following entrainment into Clifton Court Forebay could reduce pre-screen loss of juvenile Central Valley Steelhead entrained into Clifton Court Forebay, thereby 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 out-migrating 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. The NEPA process for the facility (Horizon Water and Environment 2017) indicates 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 from August to 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 Sacramento Deepwater Ship Channel. Fish entering the ship channel 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 Sacramento Deepwater Ship Channel 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 on 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 Tracy fish facility 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 on 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 Clifton Court Forebay, 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).

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).

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

on 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 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.
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.

Number	Title	Summary
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-15	Delta Smelt Monitoring	Continue to monitor Delta Smelt as coordinated with the Interagency Ecological Program (IEP).
MM-AQUA-16	Longfin Smelt Monitoring	Continue to monitor Longfin Smelt as coordinated with the Interagency Ecological Program (IEP).

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 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 n.d.). 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 on 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.

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 (Title 40 CFR Part 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 Part 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 Part 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 Part 112.7(a)(3)(iii)*).
- Methods of disposal of recovered materials will comply with applicable legal requirements (*40 CFR Part 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 on 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 on 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 in the *Qualifications of Fish Rescue Personnel* section. 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 (*Contingency Plans* section). Dewatering activities will also conform to the guidelines specified below (*Dewatering* section).

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 the *Electrofishing* section, 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 the *Electrofishing* section. 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 food web 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 food web, 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 2010a) 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 2010b 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.

Mitigation Measure AQUA-15 Delta Smelt Monitoring

Reclamation will continue to monitor longfin smelt as coordinated with the Interagency Ecological Program (IEP).

Mitigation Measure AQUA-16 Longfin Smelt Monitoring

Reclamation will continue to monitor longfin smelt as coordinated with the Interagency Ecological Program (IEP).

O.3.12 Summary of Impacts

Table O.3-76, Summary of Aquatic Resources Impacts, 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 flows resulting in decreased salmonid fry and rearing habitat in February of above normal water years	
	Alternative 2	Possible minimal, negative effect due to increased flows resulting in decreased salmonid fry and rearing habitat in February of above normal water years	

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
	Alternative 3	Possible minimal, negative effect due to increased flows resulting in decreased salmonid fry and rearing habitat in February of above normal water years	
	Alternative 4	Possible minimal, negative effect due to increased flows resulting in decreased salmonid fry and rearing habitat in February of above normal water years	
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 even though there may be negative impacts for one or more aquatic species/resources during specific periods (e.g., months) and water year types	
	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	No Action	Likely beneficial effect on habitat conditions	

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
restoration actions under the Trinity ROD	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 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	

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
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	
	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	

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
	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	
	Alternative 1	Potential increases in survival of winter-run and spring-run eggs and alevins from improved water temperature management and temperature control device; 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	

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
	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)	
	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	

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
	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	
	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	

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
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	
	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.	

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
	Alternative 4	Not included in this alternative	
Potential changes to aquatic resources due to Shasta temperature control device 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	
	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.	

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
	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	
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		

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
	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	
	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	

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
	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	
	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			

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
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 No Action.	
	Alternative 2	No change from current conditions	
	Alternative 3	No change from current conditions	
	Alternative 4	Under average conditions, there would be little difference in flood control storage under Alt 4 in comparison to No Action 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 No Action.	
	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	Minor changes would occur and vary by water year type and month. Similar flows in average and wet years compared to No Action. 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	
	Alternative 1	Similar to the no action alternative. May be slightly cooler in summer months compared to No Action.	
	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 No Action. Minor short-term impacts due to construction such as sediment or erosion addressed through mitigation measure.	

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
	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 No Action. Minor short-term impacts due to construction such as sediment or erosion addressed through mitigation measure.	
	Alternative 4	No change from current conditions	
Stanislaus River			
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 No Action. Very minor differences.	
	Alternative 2	Decreased flows would occur primarily from 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 Alternative 1 would result in larger cold water pool and potentially offset warming or delay warming water due to greater reserves of stored cold water.	
	Alternative 2	Reduced flows may result in warmer water conditions primarily from March through May. Potential limited negative effects.	

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
	Alternative 3	No specific temperature objective, but change not expected to current conditions due to same flow schedule as N.	
	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 7 mg/L of DO. Overall, similar conditions to No Action.	
	Alternative 2	Reduced flows may lower the amount of available dissolved oxygen 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 short-term 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 short-term impacts due to construction such as sediment or erosion addressed through mitigation measure.	
	Alternative 4	No change from current conditions	
San Joaquin River			

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
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	
	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	MM-AQUA-15

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
	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	
Potential changes to Delta 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 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	
	No Action	No change from current conditions	

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
Potential changes to Delta Smelt from North Bay Aqueduct operations (Project-Level)	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 Delta Smelt from water transfers (Project-Level)	No Action	No change from current conditions	
	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 Forebay 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 (CO_2 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)	MM-AQUA-15
	Alternative 3	Potential minor increase in salvage efficiency from reduced predation at Tracy (CO_2 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)	
	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 from Suisun Marsh facilities (Project-Level)	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
	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	
	No Action	Not included in this alternative	

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
Potential changes to Delta Smelt from the San Joaquin Basin Steelhead Telemetry Study (Project-Level)	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	
	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 on salvage efficiency	
	Alternative 2	Not included in this alternative	

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
	Alternative 3	Minor positive effect on 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	
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	MM-AQUA-16
	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	MM-AQUA-16

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
	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	MM-AQUA-16
	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	MM-AQUA-16
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	MM-AQUA-16
	Alternative 2	Potential for slightly greater negative effects than No Action (e.g., near-field predation), although limited by low presence in south Delta	MM-AQUA-16
	Alternative 3	Potential for slightly greater negative effects than No Action (e.g., near-field predation), although limited by low presence in south Delta	MM-AQUA-16
	Alternative 4	Potential for slightly less negative effects than No Action (e.g., near-field predation), although limited by low presence in south Delta	MM-AQUA-16
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.	MM-AQUA-16
	Alternative 2	Similar to No Action	

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
	Alternative 3	Similar to No Action, with potential additional limited negative effect from sediment and aquatic weed removal.	MM-AQUA-16
	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	
Potential changes to Longfin Smelt from Clifton Court Forebay 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 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 (CO_2 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	MM-AQUA-16
	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	MM-AQUA-16
	Alternative 3	Potential minor increase in salvage efficiency from reduced predation at Tracy (CO_2 device), but potential increase in salvage loss as described for Alternative 2, although low proportional loss expected	MM-AQUA-16
	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	MM-AQUA-16
Potential changes to Longfin Smelt due to changes from	No Action	No change from current conditions	
	Alternative 1	Similar to No Action	
	Alternative 2	Similar to No Action	

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
Suisun Marsh facilities (Project-Level)	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 MM-AQUA-1
	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 MM-AQUA-16
	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 MM-AQUA-16
	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 MM-AQUA-16
	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 MM-AQUA-16
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	MM-AQUA-16
	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	

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
	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	MM-AQUA-16
	Alternative 2	Not included in this alternative	
	Alternative 3	Potential limited negative effects from hybridization, reduced by risk management strategies	MM-AQUA-16
	Alternative 4	Not included in this alternative	
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)	No Action	Not included in this alternative	
	Alternative 1	Limited effects given Longfin Smelt distribution mostly downstream	MM-AQUA-16
	Alternative 2	Not included in this alternative	
	Alternative 3	Limited effects given Longfin Smelt distribution mostly downstream	MM-AQUA-16
	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 on salvage efficiency, although low proportional occurrence expected	
	Alternative 2	Not included in this alternative	
	Alternative 3	Minor positive effect on 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	

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
	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	MM-AQUA-16
	Alternative 2	Not included in this alternative	
	Alternative 3	Potential limited negative effects from hybridization, reduced by risk management strategies	MM-AQUA-16
	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	MM-AQUA-16
	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.	

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
	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.	
	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	

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
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	
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 Forebay 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 (CO_2 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	

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
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	
Potential changes to aquatic resources from Clifton Court Forebay 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	No effect	
	Alternative 2	Not included in this alternative	
	Alternative 3	No effect	
	Alternative 4	No effect	

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
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 Sacramento Deepwater Ship Channel is not maintained	
	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	
	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	

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	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	
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 on 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	

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
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.	
	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.	

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
	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.	
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	

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
	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	
	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 Forebay 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 (CO_2 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	

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 actions for Delta Smelt summer-fall habitat (Project-Level)	No Action	Not included in this alternative	
	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 Forebay 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 monitoring (Project-Level)	No Action		
	Alternative 1	No effect	
	Alternative 2	Not included in this alternative	
	Alternative 3	No effect	
	Alternative 4	No effect	

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
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	
	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

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 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	
	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 on 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	

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
	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.	
	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	

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 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	
	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 Forebay 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	

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
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 (CO_2 device); larger proportions of Late Fall-Run Chinook Salmon lost so this action would have greater effect on this run.	
	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	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 Forebay 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	

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
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		
	Alternative 1		
	Alternative 2		
	Alternative 3		
	Alternative 4		
Potential changes to aquatic resources from monitoring (Project-Level)	No Action		
	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 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	

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
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
	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	

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
	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 on 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	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.	

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
	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	
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	

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
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 Forebay aquatic weed removal (Project-Level)	No Action	No change from current conditions.	
	Alternative 1	Similar to No 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 (CO_2 device)	

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 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 Forebay 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		
	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		

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
	Alternative 4		
Potential changes to aquatic resources from monitoring (Project-Level)	No Action		
	Alternative 1	No effect	
	Alternative 2	Not included in this alternative	
	Alternative 3	No effect	
	Alternative 4	No effect	
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	
	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

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
	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 on 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 offset by positive effects of reduced entrainment	MM AQUA-7

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-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	
	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	

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
	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	
	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	

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
	Alternative 4	Similar to No Action	
Potential changes to aquatic resources from Clifton Court Forebay 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	
Potential changes to aquatic resources from Clifton Court Forebay 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	

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
	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	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 the Sacramento Deepwater Ship Channel food study (Program-Level)	No Action		
	Alternative 1	Potential effect from entrainment in the Sacramento Deepwater Ship Channel, 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	

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 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
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	

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 on 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	
	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	

Impact	Alternative	Magnitude and Direction of Impacts	Potential Mitigation Measures
	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	
	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 action 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, illegal marijuana cultivation, and other management actions, water uses, and land uses. Many of 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. Other activities have contributed to cumulative effects by degrading habitat in the mainstem Trinity River and tributaries, increasing competition and predation on listed and sensitive fishes and altering population genetics of listed salmonids.

Several management components have been established to mitigate for the adverse effects of dam construction on the Trinity River and are included in the 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. Components including sediment management and channel rehabilitation are focused on the 40-mile section of the Trinity River from Lewiston Dam to the confluence with the North Fork Trinity River (TRRP 2014). The effects of other components, including instream flow management, are intended to extend throughout the mainstem Trinity River downstream of Lewiston Dam. 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), 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 <u>Whiskeytown Reservoir Operations</u>

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 by 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-Run 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), 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 Chinook 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 cold water 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 temperature control device 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 salmonids 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 cold water 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 cold water pool storage in the following year. In addition to seasonal operations, such trade-offs are a central feature of Shasta cold water pool management, fall and winter refill and redd maintenance, spring pulse flows, 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 gage 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 above 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, and Fall-Run and Late Fall–Run Chinook Salmon 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 positive and negative effects. The cumulative projects include actions that affect the timing and magnitude 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 beneficial effects from the Shasta Dam Raise Project would be to increase the volume of the Shasta Reservoir cold water 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 spawning 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, *Summary of Impacts*). 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.

Green and White Sturgeon

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 Sturgeon 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 magnitude 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 beneficial effects from the Shasta Dam Raise Project would be to increase the volume of the Shasta Reservoir cold water 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 3.12, *Summary of Impacts*).

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: Sacramento 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. 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-Run 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 cold water 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, only 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 on 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 Delta Smelt

The following are the main potential effects on 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 Fish 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 on 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 on 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 4 also would not substantially contribute to cumulative effects.

O.3.13.8.3 Sacramento River Winter-Run Chinook Salmon

The following are the main potential effects on 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 on 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 on Central Valley Spring-Run Chinook Salmon 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 on 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 on 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 on 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 on 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 California Central Valley 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 California Central Valley 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 on California Central Valley 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 California Central Valley 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 on 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 on 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 Southern Resident Killer Whale

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 on 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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