— BUREAU OF —
RECLAMATION

Long-Term Operation – Initial Alternatives

Appendix K – Summer and Fall Delta Outflow and Habitat

Central Valley Project, California

Interior Region 10 – California-Great Basin

U.S. Department of the Interior September 2022

Mission Statements

The U.S. Department of the Interior protects and manages the Nation's natural resources and cultural heritage; provides scientific and other information about those resources; honors its trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated Island Communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

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Contents

1. Introduction

Operation of Central Valley Project (CVP) and State Water Project (SWP) facilities changes flows entering, moving through, and exiting the Delta and the flow-related habitat characteristics for Delta smelt. The summer and fall may represent a seasonal bottleneck for juvenile Delta smelt as freshwater flows reach their annual nadir and access to seaward habitat (e.g., Suisun Marsh) is lost, particularly during droughts (Hammock et al. 2022). The degree to which Delta smelt use these areas depends on salinity, temperature, and turbidity (Nobriga et al. 2008; Feyrer et al. 2011; Sommer and Mejia 2013). Other factors may affect their summer distribution such as Microcystis presence, prey density, bathymetric features, or other water quality constituents (Sommer and Mejia 2013). Summer and fall Delta outflow and habitat action is intended to increase the spatial overlap of key Delta smelt habitat attributes through moving the low salinity zone habitat westward by releases from reservoirs and limitations on exports, and by routing of freshwater flows for habitat connectivity and food web productivity.

Reclamation's management questions for the formulation of an alternative include:

- Does the area of suitable habitat increase given salinity, turbidity, temperatures, and/or contaminants?
- Does summer and fall habitat action increase food resources in historical Delta smelt summer and fall habitats from production and/or food transport?
- Does summer and fall habitat action support migration of Delta smelt to areas of improved suitable habitat?
- Are effects different between habitat actions from Suisun Marsh Salinity Control Gate (SMSCG) operations, export reductions, or reservoir releases?
- What are the effects on different Delta smelt life history strategies (i.e., freshwater, migratory, brackish water)?
- Does this improve population recruitment and viability?

This component includes the operation of the SMSCG at times in addition to those required by the Suisun Marsh Preservation Agreement as well as Delta outflow for the location of two parts per thousand (ppt) isohaline water with the Delta. X2 refers to this location scaled as the distance in kilometers (km) from the Golden Gate Bridge.

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2. Performance Metrics

Performance metrics describe criteria that can be measured, estimated, or calculated relevant to informing trade-offs for alternative management actions.

2.1 Biological

Biological metrics consider direct observations and environmental surrogates including:

- Abiotic Habitat (turbidity, salinity, current speed, temperature)

  Various field-occupancy and laboratory studies have demonstrated Delta smelt association with a set of abiotic conditions such as turbidity, salinity, current speed, and temperature (Feyrer et al. 2011; Bever et al. 2016; Hasenbein et al. 2016; Davis, Cocherell et al. 2019a). Consequently, suitable physical habitat for Delta smelt can be modeled based on appropriate ranges of these variables. Increase of suitable habitat was the basis of the fall X2 action where the low salinity zone is moved further downstream of the Delta. Operation of the SMSCG during the summer and fall is expected to increase suitable habitat in the marsh by lowering salinity (Sommer et al. 2020). However, food subsidy actions are not expected to have any measurable impact on the physical habitat of Delta smelt.

  A habitat suitability index can include both physicochemical and biological conditions that support Delta smelt. One way to accomplish this is to calculate a weighted food availability score by multiplying the average zooplankton biomass in each region/month for a scenario by the habitat suitability index (California Department of Water Resources 2022). Including both physical habitat and zooplankton prey in a single index more directly evaluates the potential benefit of actions like the SMSCG, which should result in favorable changes in zooplankton species composition by altering salinity.

- Food Availability (zooplankton abundance, biomass, and community composition)

  The availability and quality of zooplankton prey has been identified as limiting juvenile and subadult Delta smelt growth and survival during the summer and fall (Figures 1 and 2; Slater and Baxter 2014; Hammock et al. 2015). One of the objectives of the Summer-Fall Habitat Action is to create greater overlap between suitable physical habitat and sufficient, high quality zooplankton prey through flow actions that alter salinity or enhance zooplankton production and biomass and influence species composition (i.e., freshwater versus marine/brackish species). Diet composition and gut fullness differ across salinities. The freshwater zooplankton *Pseudodiaptomus forbesi* is an important prey item in both fresh water and the low-salinity zone (Slater et al. 2019). Gut fullness has been shown to differ along a salinity gradient (Slater et al. 2019) with evidence for relatively higher gut fullness in fresh water and the low-salinity zone during summer and fall, respectively (Hammock et al. 2017). Monitoring data has been used alone and in combination with modeling to predict and evaluate the effects of individual summer-fall habitat actions on zooplankton prey biomass and species composition (e.g., Hassrick et al. 2021; see Section 3.1, *Datasets*, and Section 3.3, *Models*). However, the ability to statistically detect the effects of actions on zooplankton biomass tends to be limited by high variability in zooplankton abundances resulting in the need for large numbers of samples (Brandon et al. 2022). The regional focus of these actions is primarily the Suisun (i.e., Suisun Bay, Grizzly Bay, Suisun Marsh) and Cache Slough areas.

- Population Abundance

  Delta smelt growth and survival have historically relied upon monitoring surveys (Section 3.1, *Datasets*) for analysis of the population abundance. Fish collected in monitoring surveys have subsequently been processed in laboratory studies of health (Hammock et al. 2022) and growth (Xieu et al. 2021). However, continued decline in the population has made the capture of wild Delta smelt rare and made modeling a more resilient management tool for this performance metric. Delta smelt life cycle models, population models, and growth models (Section 3.3, *Models*) are used to model changes in Delta smelt growth and survival under different management actions. Data and model output generated to evaluate the habitat suitability and zooplankton prey performance metrics can be incorporated into some of these models to predict individual (e.g., Delta smelt bioenergetics) and population-level (e.g., Delta Smelt Individual-Based Model) responses to different summer-fall habitat action scenarios.

2.2 Water Supply

Water supply metrics consider the multi-purpose beneficial uses of CVP Reservoir including:

- North-of-Delta agricultural deliveries (average and critical/dry years)
- South-of-Delta agricultural deliveries (average and critical/dry years)

2.3 NEPA Resources

Analysis of the range of alternatives as required by the National Environmental Policy Act is anticipated to describe changes in the multiple resources areas. Key resources are anticipated to include surface water supply, water quality, aquatic resources, regional economics, socioeconomics, land use and agricultural resources, cultural resources, environmental justice, climate change, and power.

3. Methods

In the spring of 2022, Reclamation solicited input for the knowledge base paper *Summer and Fall Habitat Management Actions - Smelt Growth and Survival*, included as Attachment K. Knowledge base papers compile potential datasets, literature, and models for analyzing potential effects from the operation of the CVP and SWP on species, water supply, and power generation. The methods for this appendix considered the knowledge base papers and determined the most relevant approach for Reclamation to answer management questions and evaluate options for potential alternatives.

Since implementation of the Record of Decision (ROD) and Incidental Take Permit (ITP), summer-fall actions have not been implemented due to repeated dry conditions (2020–2022); however, baseline monitoring, models, and synthesis have been conducted. As a result of these activities and in coordination with the summer-fall habitat action Delta Coordination Group (DCG), Reclamation and California Department of Water Resources (DWR) have developed multiple documents that are being used to understand and monitor the effects of these actions, identify science and monitoring needs, identify relevant models and datasets, and guide structured decision-making (SDM). Documents include the following: Science and Monitoring Plan, updated annually; action-specific operations and science plans, updated every 1 to 3 years; summer-fall seasonal reports; SDM process document and performance measure information sheets (California Department of Water Resources 2022 Appendix B); and a 2022 Action Plan (California Department of Water Resources 2022). These documents can serve as key references that collate information for the Summer and Fall Delta Outflow and Habitat action.

3.1 Datasets

Abiotic and biotic data used to assess summer and fall habitat under baseline conditions and in response to actions include publicly available monitoring data as well as data collected specifically for each action. In addition to the SDWSC, SMSCG, and NDFS studies, the Directed Outflow Project is designed to evaluate the effects of X2 actions on the quantity and quality of habitat and food for Delta smelt and on Delta smelt growth and health indices. Datasets include sample site geolocation data.

Multiple agencies collect continuous and discrete abiotic data including DWR and United States Geologic Survey. Continuous abiotic (e.g., hydrologic, temperature, turbidity) data are publicly available in real time on Bay Delta Live, DWR’s California Data Exchange Center, and the U.S. Geological Survey and San Francisco Estuary Institute’s Data Integration Portal. Discrete water quality data are publicly available on Environmental Data Initiative (EDI) and Bay Delta Live. Suisun Marsh Monitoring Program Channel Water Salinity Reports are available on the California Natural Resources Agency website, under Data and Resources.

Lower trophic (i.e., phytoplankton, zooplankton, benthic invertebrate) data are collected by multiple agencies and monitoring programs, including DWR and California Department of Fish and Wildlife (CDFW). Data are publicly available on Bay Delta Live, EDI, and the CDFW FTP site. CDFW and USFWS monitor Delta smelt and longfin smelt throughout the year using multiple gear types. CDFW's 20-mm, summer townet, and fall midwater trawl surveys and USFWS's Enhanced Delta Smelt Monitoring (EDSM) program are the most relevant datasets for summer-fall habitat effects on Delta smelt. Data are publicly available on EDI and the CDFW FTP site and are available upon request from the agencies. Daily and weekly EDSM data are available on USFWS's Lodi website library. Many of these datasets can be integrated into a single dataset using the R package Zooper (Bashevkin et al. 2022)

Long-term abiotic and biotic monitoring datasets and action-specific data used to evaluate the SMSCG and NDFS actions are described in their action plans (Table 5 in Hartman et al. 2022; Table 3-3 in Twardochleb et al. 2021). SDWSC data include abiotic data (e.g., depth, nutrients, water quality parameters, Chlorophyll a) and biotic data (e.g., zooplankton, fish observed via video, eDNA) and are available from Reclamation (Bureau of Reclamation and California Department of Water Resources 2022 Appendix C). Data collected by the Directed Outflow Project include abiotic (e.g., physical, chemical) and lower trophic (e.g., phytoplankton, mesozooplankton, macrozooplankton) data collected simultaneously with USFWS's EDSM monitoring (Bureau of Reclamation and California Department of Water Resources 2022 Appendix E). Any Delta smelt collected by EDSM are then processed for diet contents, growth and life history strategy, and histological indices of health. Data is available upon request from Reclamation or University of California (UC) Davis.

3.2 Literature

3.2.1 Delta Smelt

The San Francisco Bay-Delta's Mediterranean climate means that in a typical year, Delta smelt experiences wet conditions (i.e., high precipitation and flows) during the winter and spring months, and dry and low flow conditions in the summer-fall months. Delta smelt occurs primarily in the low salinity and freshwater portions of the San Francisco Bay-Delta. Historically, the center of distribution of Delta smelt closely followed the location of the low salinity zone (as approximated by X2) (Sommer et al. 2011). However, in more recent years, there is growing recognition that a substantial portion of the Delta smelt population can reside year-round in the perennially freshwater Cache Slough Complex (Mahardja et al. 2019; Hobbs et al. 2019).

During the summer-fall period, sub-adult Delta smelt primarily rear in the west Delta, Suisun Bay, and Cache Slough Complex (Merz et al. 2011; Sommer and Mejia 2013; IEP MAST 2015) (see Figures 1 and 2). Note that while Delta smelt used to occur in the central and south Delta during the summer-fall months, this is no longer the case (Nobriga et al. 2008). The degree to which Delta smelt use these areas depends on salinity, temperature, and turbidity (Nobriga et al. 2008; Feyrer et al. 2011; Sommer and Mejia 2013); other factors may affect their summer distribution such as *Microcystis* presence, prey density, bathymetric features, or other water quality constituents (Sommer and Mejia 2013). Periods of low outflow are thought to be stressful for Delta smelt because the volume of physically suitable habitat becomes restricted by encroaching salinity (Feyrer et al. 2011) and reduced subsidies of important, freshwater prey items such as *P. forbesi* (Kimmerer et al. 2019). As such, the summer-fall period may represent a seasonal bottleneck for the species as freshwater flows reach their annual nadir and access to seaward habitat (e.g., Suisun Marsh) is lost, particularly during droughts (Hammock et al. 2022).

Overall, the Delta smelt Summer-Fall Habitat Action is intended to increase the spatial overlap of key Delta smelt habitat attributes, and in the past had a focus on X2, Suisun Marsh, and experimental enhancements of prey supply from the Cache Slough Complex. Moving X2 downstream during the summer-fall period is expected to generally benefit Delta smelt because under most conditions, it would:

1. Maintain low salinity habitat in Suisun Marsh and Grizzly Bay when water temperatures are suitable;
2. Manage the low-salinity zone (LSZ) to overlap with turbid water and available food supplies; and
3. Establish contiguous fresh water- low salinity habitat from Cache Slough Complex to the Suisun Marsh

Meanwhile, operation of the SMSCG during the summer-fall months has the potential to provide an increase in LSZ habitat for endangered Delta smelt, and to allow them to more frequently occupy Suisun Marsh, one of their most important rearing habitats (Sommer et al. 2020; Figure 3).

The Delta Smelt Summer-Fall Habitat Action also includes consideration of food enhancement actions, such as the North Delta Food Subsidies Action/Study (Frantzich et al. 2021), Sacramento Deep Water Ship Channel Food Web Study (Loken et al. 2022), and the Suisun Marsh managed wetland and Roaring River Distribution System Food Subsidies studies (Figure 3).

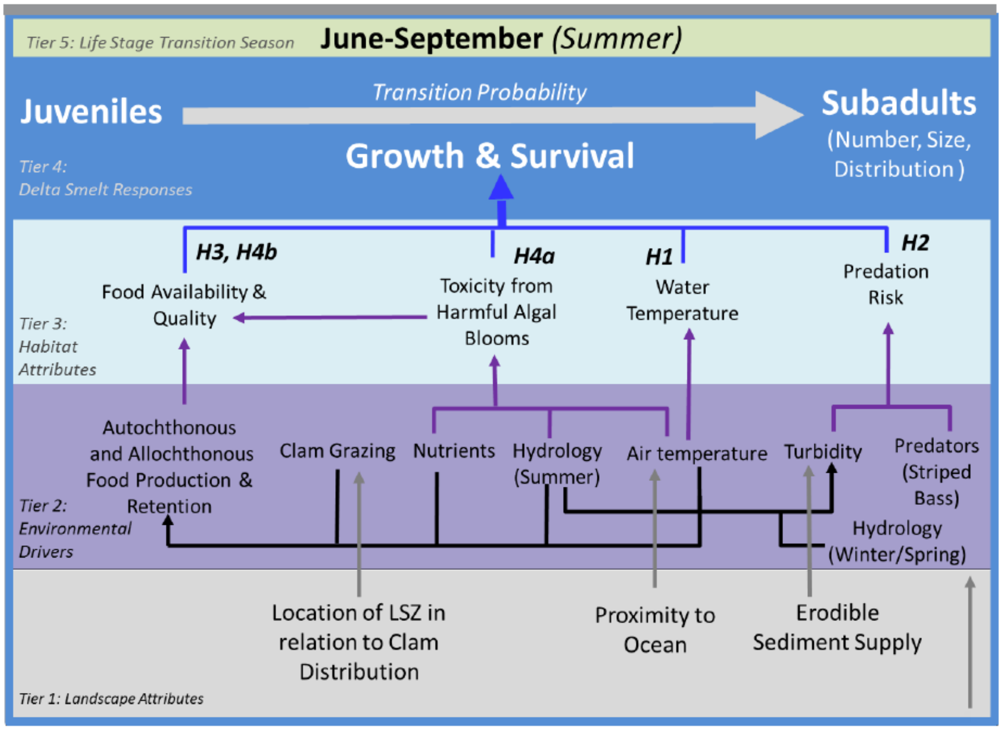

Figure 1. Conceptual Model of Drivers That Affect Delta Smelt during the Summer Transition from the Juvenile to Subadult Stage (IEP MAST 2015)

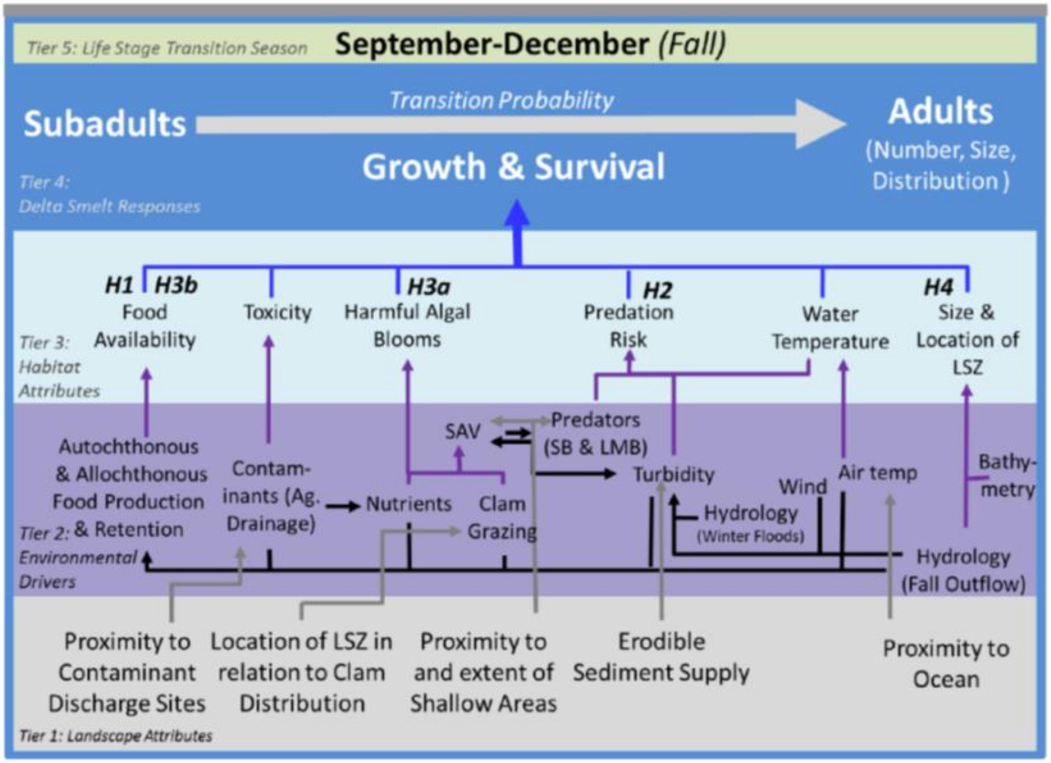

Figure 2. Conceptual Model of Drivers That Affect Delta Smelt during the Fall Transition from the Subadult to Adult Stage (IEP MAST 2015)

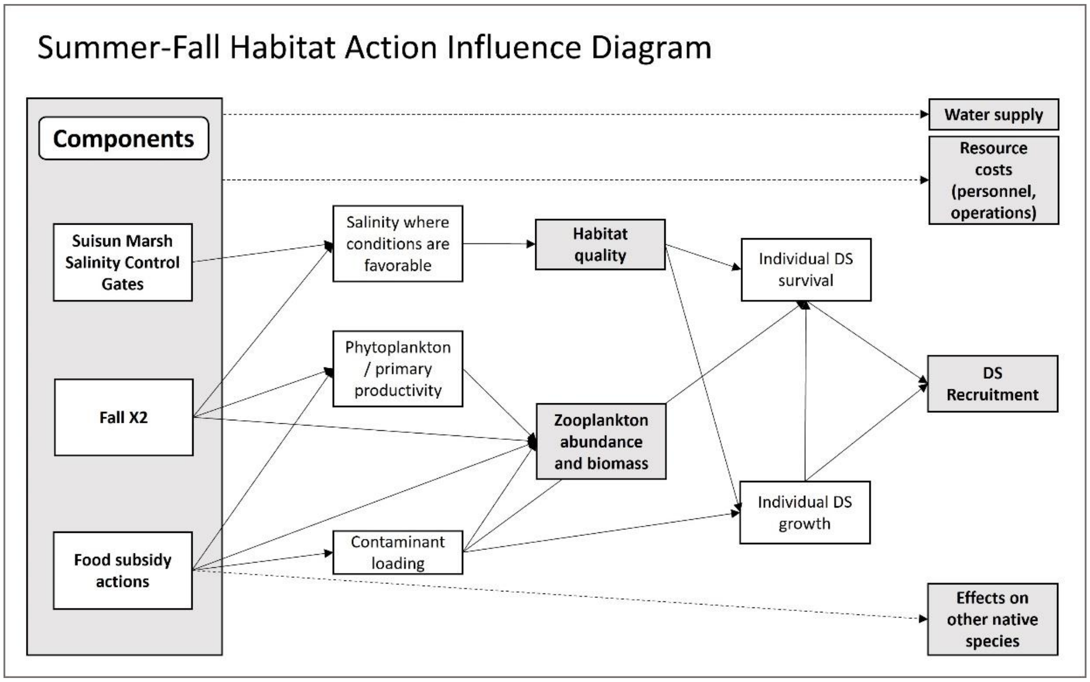

Figure 3. Summer-Fall Habitat Action Influence Diagram (modified from California Department of Water Resources 2022). The diagram shows causal links between the actions and the performance metrics.

3.2.2 Longfin Smelt

Water temperature can similarly affect longfin smelt. The critical thermal maximum is 24.8°C for larvae and 25.6°C for juveniles, and low densities of longfin smelt greater than 21-22°C indicates low field tolerance for these temperatures (Figure 4; Jeffries et al. 2016; Pasparakis, unpublished; Rosenfield 2010). The sublethal effects exhibited by longfin smelt are similar to those of Delta smelt. At temperatures of 20°C and above, juvenile longfin smelt have exhibited changes in gene expression associated with muscle function and growth and skeletal development and changes in gene expression associated with ion regulation, and pronounced cellular stress response, indicating acute thermal stress (Jeffries et al. 2016). Water temperatures also influence the initiation of spawning, and the duration of the spawning window, which occurs between 8°C–14°C (Grimaldo et al. 2017; Wang 2007). In lab studies, embryos and yolk-sac larvae experience reduced hatch success, length, growth rates, and earlier mass mortality at temperatures of 15°C compared with at 9°C and 12°C, thus indicating an optimal temperature of 9-12°C for culturing longfin smelt (Yanagitsuru et al. 2021). The distribution of juvenile longfin smelt tends to follow X2 closely (Figure 4), with a small percentage occupying Suisun Bay during the summer and early fall (Baxter et al. 2010). Greater outflow can support upstream subsidization of zooplankton in Suisun Bay (Kimmerer et al. 2019), which could benefit the individuals that occupy this area. Adult longfin smelt begin to enter the Delta in November or December and are unlikely to be impacted by the SFHA.

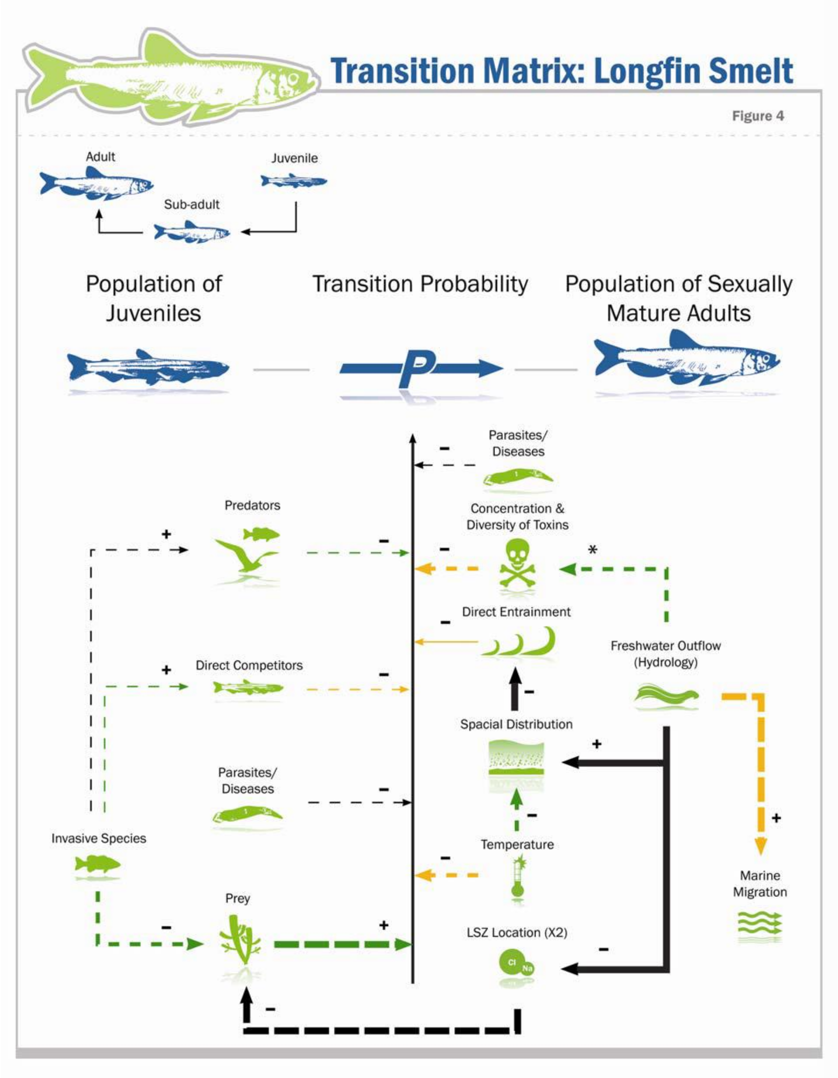

Figure 4. Proposed Conceptual Model for Longfin Smelt Transition from the Juvenile to Adult Stage (Rosenfield 2010).

3.3 Models

3.3.1 Delta Smelt Life Cycle Models

- Hamilton and Murphy (2018) limiting factors model
- Maunder and Deriso (2011) state-space model
- Polansky et al. (2020) state-space model
- Smith et al. (2021) state-space model with entrainment

3.3.2 Delta Smelt Population Models

- Kimmerer and Rose (2018): Individual-Based Modeling of Delta Smelt Population Dynamics in the Upper San Francisco Estuary III. Effects of Entrainment Mortality and Changes in Prey
- Rose et al. (2013a, 2013b): Individual-Based Modeling of Delta Smelt Population Dynamics in the Upper San Francisco Estuary I and II

3.3.3 Delta Smelt Growth

- Bioenergetics-Based Habitat Suitability, from the Individual-Based Model in R (IBMR) (Rose et al. 2013a, 2013b; Smith 2021)
- Delta Smelt Individual Based Model in R (Rose et al. 2013a, 2013b; Smith 2021)
- Bioenergetics-Based Growth Model (Fujiwara et al. 2015)

3.3.4 Delta Smelt Habitat and Food

- Hamilton and Murphy Smelt Habitat Model (Hamilton and Murphy 2020)
- Habitat Suitability Model (Bever et al. 2016)
- Feyrer and Manly Models (Three models very similar, with spatial differences; Feyrer et al. 2011, 2016; Manly et al. 2015).
- Nobriga Presence-Absence Model (Nobriga et al. 2008)
- DSM2 Water Cost Model (DWR Delta Modeling Section Reporting)
- Bay-Delta SCHISM (Ateljevich et al. 2014; Chao et al. 2017a, 2017b; Zhang et al. 2008, 2016, 2020).
    - Zhang, Y. and A.M. Baptista 2008. SELFE: A semi-implicit Eulerian- Lagrangian finite-element model for cross-scale ocean circulation, Ocean Modelling, 21(3-4), 71-96.
    - Zhang, Y., Ye, F., Stanev, E.V., and S. Grashorn. 2016. Seamless cross-scale modeling with SCHISM, Ocean Modelling, 102, 64-81.
- RMA Bay-Delta Model, RMA San Francisco Estuary UnTRIM Model (https://dshm.rmanet.app/overview/rma_calibration_reports/USBR_LTO_Summer _Fall_ Delta_Smelt_Habitat.pdf)
- Kimmerer Copepod Box Model (Kimmerer et al. 2018)

- RMA Copepod BPUE Model (Calanoid copepod analysis addendum; https://dshm.rmanet.app/overview/rma_calibration_reports/USBR_LTO_copepod_addendum.pdf)
- Bayesian Network Relative Risk Model for Contaminant Toxicity on Delta Smelt (Landis 2021)
- Soil and Water Assessment Tool (SWAT) for contaminant fate (Chen et al. 2017; https://swat.tamu.edu/).

3.3.5 Habitat

The Habitat Suitability Index (HSI) for Delta smelt was calculated using a method derived from Bever et al. (2016), RMA (2021) and Bay-Delta SCHISM output (see Section 3.3, Models; California Department of Water Resources 2022 Appendix B). The index represents spatially and temporally averaged suitability of habitats within the San Francisco Bay-Delta. Spatial averaging was performed both vertically over depth and horizontally over the area of each subregion defined by Rose et al. (2013). The temporal averaging was performed monthly from July to September. Habitat suitability was assessed only over the below normal years involving SMSCG actions.

To incorporate physical conditions and zooplankton availability into a weighted food availability index, regional, mean zooplankton biomass was multiplied by the habitat suitability index per month (June–October). Values were then summed across regions to develop a single index score for different action scenarios (California Department of Water Resources 2022 Appendix B). Another approach for integrating physical and biological habitat components into a single index is currently being explored using boosted regression tree analysis and environmental and biological survey data.

3.3.6 Zooplankton

The SMSCG action is aimed at expanding the low salinity zone in Suisun Marsh and portions of Grizzly Bay in order to provide Delta smelt access to high quality habitat. To evaluate this action, the Zooper package was used to integrate data during June-October from 2000–2020 across multiple zooplankton monitoring programs. A “baseline” for expected zooplankton biomass of each taxon included in the IBMR was determined for different water year types by region and month. Generalized additive models were used to predict the change in zooplankton biomass in Suisun Marsh for each taxon in response to salinity and, subsequently, predict the expected change in zooplankton biomass for scenarios when the action is versus isn’t implemented (California Department of Water Resources 2022 Appendix B).

The North Delta Food Subsidy (NDFS) action diverts either Sacramento River water or Colusa Drain Basin agricultural return water through the Yolo Toe Drain and through Cache Slough in order to restore positive net flow of water seaward. The goal is to transport and subsidize the lower food web (i.e., phytoplankton and zooplankton) in Cache Slough and the lower Sacramento River. Hypothesized impacts of this action on zooplankton were based on a combination of conceptual models, the RMA Copepod BPUE model (see Section 3.3, *Models*), and expert opinion to generate estimates of percent change in biomass across zooplankton taxa (California Department of Water Resources 2022 Appendix B).

3.3.7 Delta Smelt Growth

The impacts of actions on Delta smelt growth were evaluated using a modified version of the bioenergetics portion of the Delta smelt IBMR (See Models) to calculate the cumulative growth increment of Delta smelt occupying a given region. The model estimated potential growth (mm total length) using physical habitat conditions generated by the Bay-Delta SCHISM output and the percent change in zooplankton biomass generated as described above and in California Department of Water Resources 2022 (Appendix B) for different action scenarios. Potential growth was compared to an expected average rate of growth determined by fitting a von Bertalanffy growth model to size at age of wild Delta smelt California Department of Water Resources 2022 Appendix B).

Measurements of Delta smelt otolith microstructure can also be used to back-calculate growth (Xieu et al. 2021) in different regions and under different environmental conditions (Lewis et al. 2021). Lewis et al. (2021) quantified growth rates from the otoliths of Delta smelt collected during late-summer and fall from 2011–2019 and related them to age and environmental factors (i.e., salinity, temperature, water clarity, and region).

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4. Lines of Evidence

4.1 Habitat Modeling and Analysis

The area of suitable habitat for Delta smelt increases by increasing the low salinity zone's physical area through pushing X2 further downstream in the wider areas (Grizzly Bay) than the confluence of the Sacramento and San Joaquin Rivers (Feyrer et al. 2011; Bever et al. 2016; Hobbs et al. 2019). This should increase connectivity between the more turbid downstream waters with low salinity fresh waters upstream. However, this relationship is based primarily on the expected salinity change to the system and to some extent, turbidity and water velocity (Bever et al. 2016). Delta smelt do not appear to persist upstream of Jersey Point (Polansky et al. 2018), likely because habitat is inhospitable in the San Joaquin River and fish can be advected to water export facilities (Kimmerer 2008, 2011).

While increased flow or lower X2 in the summer-fall may increase turbidity, the erodible sediment pool from rivers has been depleted, resulting in sudden clearing in the early 2000s (Schoellhamer 2011). Furthermore, the expansion of invasive submersed aquatic vegetation in the Delta has caused an even further decline in turbidity within the Delta (Hestir et al. 2016).

Operation of the SMSCG decreases salinity and increases physical habitat suitability in Suisun Marsh. Bay-Delta SCHISM output for a below normal water year type was used to calculate the HSI for two different gate operation schedules to achieve 4 ppt at Belden's Landing and for a scenario in which the gates are not operated for the summer and fall habitat action. On a scale of 0 to 1, HSI increased 13%–40% from 0.36 when gates aren't operated to between 0.41-0.5, depending on operation schedule.

The relationship between summer-fall outflow and water temperature is even less clear. While there is a negative correlation between fall Delta inflow and water temperature (i.e., higher flow is associated with cooler temperature), the causal link for this relationship is not well understood (Bashevkin and Mahardja 2022). Moreover, summer and fall water temperatures have been increasing due to climate change (Bashevkin et al. 2022) and will progressively get warmer (Dettinger et al. 2016). Region-specific summer-fall actions (e.g., NDFS, SMSCG) for Delta smelt may not be successful if the water temperature becomes unsuitably warm at these locations in the near future.

Contaminant loading may fluctuate under high flow conditions, as pollutants are mobilized and transported downstream within waterways. However, there is a lot of uncertainty regarding the effects of flow on contaminants and the associated risk to aquatic resources including Delta smelt (Stillway et al. 2021). For instance, complex biogeochemical processes (e.g., photo-redox, absorption by phytoplankton, adsorption/desorption, complexation…) control the speciation and partitioning of some trace metals or organic contaminants between the dissolved, colloidal and particulate fractions (Bourg 1987; Rogers 1993; Turner 1996; Turner and Millward 2002; Abdou et al. 2022) and thus their availability through direct or trophic pathways. Because flow affects a number of biotic and abiotic drivers (e.g., salinity, suspended sediments, particulate and dissolved organic matter, phytoplankton production and concentration) involved both in those processes and in controlling the distribution, abundance, growth, survival, and reproductive success of aquatic organisms, its potential impacts on individual contaminants (or interactive effects of contaminant mixtures), their bioavailability and toxicity, go beyond direct hydrological effects such as mobilization, transport or dilution and are challenging to predict. Connon et al. (2019) recognize some of those sources of uncertainty, knowledge gaps and challenges in the current state of ecotoxicological monitoring and regulatory frameworks. They offer recommendations to integrate the latest research and technology advances into enhanced monitoring programs that should provide actionable information to guide management and mitigate risk to Bay-Delta aquatic resources, including Delta smelt.

4.2 Flow-Food Relationships During Summer and Fall

The steep decline in zooplankton abundance due to the introduction of invasive clams in the 1980s has been purported to be one of the main drivers of Delta smelt decline (Kimmerer and Rose 2018). The clam species is an indirect competitor to Delta smelt, consuming zooplankton prey and the phytoplankton resources needed for zooplankton. However, the distribution of the clam is restricted to the more saline portions of the estuary (Thompson and Parchaso 2010). Although the distribution of Delta smelt has been severely restricted in recent years, Delta smelt were known to reside in fresh water year-round within the North Delta region, especially during dry years (Sommer et al. 2011; Mahardja et al. 2019; Lewis et al. 2022). Phytoplankton blooms occurred in the North Delta during the summer-fall period of 2011 and 2012 following flow pulses through the Yolo Bypass Toe Drain, leading to the idea of using such flow pulses to augment zooplankton/food for Delta smelt (i.e., the NDFS action; Frantzich et al. 2018). The NDFS actions showed consistent increases in phytoplankton and chlorophyll; however, these effects have been mostly localized and only occasionally followed by a subsequent increase in zooplankton (Davis et al. 2022). A larger food web response from the NDFS action has been somewhat inconsistent, and preliminary results from the Delta smelt individual-based modeling effort showed little effect on the growth and survival of Delta smelt even under the most ideal scenarios (Resources Management Associates 2021; California Department of Water Resources 2022). For example, increases in Delta smelt growth increment under different NDFS implementation scenarios ranged from 0.21-0.63 mm when modeled for a below normal water year type (California Department of Water Resources 2022). However, the NDFS action may have led to a large-scale zooplankton increase in 2016 and it is thought that the timing and type of water used for the NDFS action (agricultural return water vs. river water) can largely affect the type of phytoplankton and zooplankton response (Frantzich et al. 2021). Furthermore, flow pulse actions in other areas in the San Francisco Bay-Delta (e.g., Sacramento Deep Water Ship Channel, Roaring River), along with managed flooding and drainage of wetlands in Suisun Marsh are being studied and considered as other ways to augment food for the increasingly rare Delta smelt.

4.3 Delta Smelt Behavior, Distribution, and Habitat Analysis

The distribution of larval Delta smelt is primarily driven by the flows in the region in which they hatched until they grow to approximately 20 mm TL, when they become free swimming and can retain their position in the estuary (IEP MAST 2015). A large portion of the population exhibits a migratory life history in which they are transported or actively migrate towards the low salinity zone, while some remain and complete their life cycle in fresh water (Hobbs et al. 2019). Delta smelt in the low salinity zone or brackish habitat remain there until environmental cues trigger them to move upstream towards fresh water for spawning. Because of its timing, the summer-fall habitat action is most relevant to the rearing juvenile and subadult life stage of Delta smelt.

Based on observed relationships between salinity, temperature, and turbidity with the probability of catching Delta smelt (Nobriga et al. 2008; Feyrer et al 2007), the intrusion of salinity along with changes in water clarity and rising temperatures in the Delta may limit access to otherwise supportive habitat. Summer and fall habitat actions aim to alleviate this constriction in action years by increasing the physical extent of lower salinity conditions in areas with higher turbidity, lower temperatures, and other favorable characteristics (e.g., complex bathymetry, sufficient prey availability). Thus, Delta juveniles and subadults may have access to more suitable habitat in areas including Suisun Marsh and Grizzly Bay than if no action was taken. By December and January, Delta smelt conduct their spawning migration using tidal movement (Bennett and Burau 2015). There is some uncertainty whether Delta smelt can exhibit this tidal surfing behavior to access more suitable habitat in the summer-fall months; however, evidence so far suggests that Delta smelt can indeed track the low salinity zone in fall months (Sommer et al. 2011) and that some Delta smelt were able to access Suisun Marsh in 2018 when the first SMSCG action was conducted (Sommer et al. 2020).

4.4 Are effects on water supplies different between habitat actions from gate operations, export reductions, or reservoir releases?

See Attachment K.1.

4.5 Habitat Use and Delta Smelt Life History Strategies

Using otolith isotope chemistry, three different life history strategies have been generally identified for Delta smelt (Hobbs et al. 2019): migratory, freshwater resident, and brackish water resident life histories. Some relationships between environmental factors and the prevalence of these life histories have been proposed. Lewis et al. (2022) observed freshwater residents as most abundant during cool and dry conditions while migratory and brackish residents were more commonly observed in warm and wet years. These observations of life history in the context of the habitat and population dynamics have implications for resilience that are further complicated by the near extirpation of wild Delta smelt and subsequent experimental releases. Therefore, if and how summer fall habitat actions affect fish expressing any of the three life histories is currently difficult to assess. However, we can surmise that if the summer-fall habitat actions offer benefits to Delta smelt, the X2 and SMSCG actions would primarily affect the migratory and brackish water resident portion of the population, while the NDFS action (if beneficial) would likely affect the freshwater resident portion of the population.

4.6 Does the summer and fall habitat action improve Delta smelt population recruitment and viability?

Hammock et al. (2022) observed that Delta smelt hepatosomatic index and condition factor are typically the lowest during the fall period and therefore fall may represent a seasonal bottleneck for Delta smelt. Delta smelt growth and survival in the summer-fall months are expected to increase based on anticipated increases in zooplankton prey abundance, possible changes in the zooplankton community composition to more nutritious prey, and greater suitable habitat area that connects different regions of the Delta (Feyrer et al. 2011; Kimmerer and Rose 2018). This was recently supported by a correlation between greater pelagic productivity and increases in hepatosomatic index and condition factor in fish collected in the fall (Hammock et al. 2022). Greater survival and growth in the summer-fall period should generally lead to higher fecundity and therefore recruitment in the subsequent spring. However, the magnitude of positive impacts from these actions with respect to the distribution and movement of Delta smelt at the population level will depend on the magnitude (i.e., spatial extent and temporal duration) of the summer-fall actions. For summer-fall actions to produce a measurable benefit to the Delta smelt population, it would also require the actions to be successful in their intended objectives (e.g., food subsidy action produces food) and not compromised by other limiting factors (e.g., warm water temperatures, low spring-summer survival, etc.).

5. Initial Options Analysis

5.1 Increased Delta Outflow

- Reservoir releases vs Reservoir releases in combination with export reductions
    - Moving the location of X2 downstream takes a considerable amount of freshwater and can be achieved in various ways. The primary means by which the summer-fall X2 action can be achieved is through reservoir releases because summer-fall months are generally dry. However, increasing Delta outflow can also be achieved with a combination of reservoir releases and reductions in export of water from the Delta. No evidence to date suggests that the response of Delta smelt to increase Delta outflow would differ based on how it is achieved. The current Delta Coordination Group is considering through the SDM process potential lagged impacts of reservoir releases to achieve increased Delta outflow in one year and on winter-run salmon survival in the following year. We generally expect that increased Delta outflow achieved with a combination of reservoir releases and export reductions would reduce the risk of negative impacts on winter-run salmon in a subsequent dry year.
- X2 location: 80/81 in AN water years; 80/74 in W water years
    - If X2 is located at 80–81 km, the daily average of depth-averaged salinity should be between 4 and 5 ppt in Suisun Marsh and most of Suisun Bay, resulting in that area falling within the LSZ at least 96% of a given day (Delta Modeling Associates 2014).

5.2 Additional Operation of the Suisun Marsh Salinity Control Gate

- 4 ppt vs. 6 ppt
    - Delta smelt prefer salinities less than 6 ppt (Sommer and Mejia 2013). Delta smelt habitat quantity and quality has been related to overlap of the LSZ and favorable water velocity, water clarity conditions, and bathymetry, particularly in important rearing habitats including Suisun Marsh (Bever et al. 2016). The operation of the SMSCG during summer and fall is aimed at providing this overlap by maintaining low salinities within Montezuma Slough with Suisun Marsh and Grizzly Bay. The salinity monitored at Belden's Landing has been used as the reference for meeting the salinity target.
- Number of days operating in dry year (30 days vs. 60 days)
    - The initiation and duration of gate operations influence how effective the SMSCG action is at maintaining a target salinity at Belden's Landing. Effectiveness can be

    defined as keeping the salinity as close to the target concentration as possible throughout the summer and fall or as achieving a maximum number of days below the target concentration during that time frame.

- Temperature off-ramp in response to unsuitable temperatures
    - Water temperature can affect Delta smelt in several ways, from gene response to mortality. Delta smelt occurrence in the field is almost non-existent at temperatures > 25° C (Nobriga et al. 2008), growth is hampered at >20° C (Lewis et al. 2021), and stress behaviors are also exhibited at 21° C (Davis, Hansen et al. 2019b). These studies indicate that high temperature may be a limiting factor during the summer-fall period and reduce or erase the positive benefits conferred by flow actions, such as the SMSCG.
    - Lab studies have determined a range of Delta smelt critical thermal maxima and chronic lethal thermal maxima (25.4°C–28.5°C) depending on acclimation temperatures and other study conditions (Swanson et al. 2000; Komoroske et al. 2014; Davis et al. 2019a). Meanwhile, observations from field survey data have found that Delta smelt are generally found below 22°C (Bennett 2005). Lab studies conducted across multiple life stages found that upper critical temperatures (CTmax) generally decreased with ontogenetic stage, with larval fish exhibiting higher CTmax, and post-spawning adults exhibiting lower CTmax (Komoroske et al. 2014). When CTmax was compared with corresponding temperatures experienced during each life stage, juveniles were least tolerant for warming conditions because they develop during the summer, when temperatures are warmest (Komoroske et al. 2014). Delta smelt can also experience sublethal effects from water temperature below their tolerances. At temperatures of 20°C and above, juvenile Delta smelt have exhibited an increase in oxygen consumption, as well as changes in genes associated with muscle function and growth and skeletal development, and changes in gene expression associated with ion regulation, and thus potentially osmoregulation (Jeffries et al. 2016). Warmer temperatures will also likely decrease the duration of the maturation window for juveniles, which could negatively affect reproductive potential, and the duration of the spawning window (15°C–20°C), which would result in smaller cohorts of adult Delta smelt (Brown et al. 2016; Bennett 2005).

5.3 Food Web Enhancement Actions

- With vs. without food web enhancement actions
    - Directed, more localized flow pulses have the potential to be used to transport nutrients, phytoplankton, and zooplankton from more productive to less productive areas. Actions such as the North Delta Food Subsidies Study subsidize less productive areas from more productive freshwater regions, whereas an action such as the Sacramento River Deep Water Ship Channel would move artificially nutrient-enriched (i.e., fertilized) water to areas with favorable Delta smelt habitat conditions (e.g., the maximum turbidity zone). The impact of these actions at a

population level are unknown and likely will depend on the distribution of Delta smelt, potential movement of Delta smelt to subsidized areas, the temporal and spatial extent of the action, and the resulting magnitude of prey subsidy.

- The North Delta Food Subsidies Study creates a flow pulse with coordinated releases of agricultural drainage from the Colusa Drain Basin or diversion of Sacramento River water into the Yolo Toe Drain. This highly productive water is then transported downstream to subsidize Cache Slough. However, the source of water (agricultural drainage versus Sacramento River) may influence the effectiveness of the action. For example, agricultural drainage water contains higher concentrations of contaminants than Sacramento River water (Davis et al. 2022).

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6. Conclusions

Does the area of suitable habitat increase given salinity, turbidity, temperatures, and/or contaminants?

The degree to which habitat is suitable for Delta smelt depends on the overlap of salinity, temperature, and turbidity. The area of suitable Delta smelt habitat, based solely on salinity, increases when X2's physical area is located downstream of the confluence of the Sacramento and San Joaquin Rivers near Grizzly Bay. Operation of the SMSCG also decreases salinity and increases physical habitat suitability in Suisun Marsh. Turbidity has been demonstrated to be a key determinant factor in the occurrence and abundance of Delta smelt in the field. Turbidity within the Delta is driven by tidal currents. Increased Delta outflow results in a greater overlap between X2 and the naturally turbid waters of the Suisun and Grizzly Bays. Water temperature greater than 25°C is a limiting factor for Delta smelt. The relationship between Delta outflow and water temperatures in the summer and fall is unclear. Contaminant loading may fluctuate under high flow conditions, as pollutants are mobilized and transported downstream within waterways but diluted by flow. There is much uncertainty regarding the effects of flow on contaminants and its relationship to other habitat attributes.

Does the summer and fall habitat action increase food resources in historical Delta smelt summer and fall habitats from production and/or food transport?

While food enhancement actions have been observed to cause localized increases in chlorophyll and phytoplankton, large scale food web responses have been inconsistent (only observed in 2016) and modeling efforts show little effect on growth and survival. Studies of managed flooding and drainage are ongoing in multiple locations in the Delta.

Does the summer and fall habitat action support migration of Delta smelt to areas of improved suitable habitat?

A large portion of the population exhibits a migratory life history in which they are transported or actively migrate between the low salinity zone and freshwater habitats of Cache Slough Complex and the Sacramento River Deep Water Shipping Channel. Summer and fall habitat actions may increase the physical extent of favorable characteristics (e.g., lower salinity conditions in areas with higher turbidity, lower temperatures, access to complex bathymetry, sufficient prey availability) between these geographical areas.

Are effects on water supply different between habitat actions from SMSCG operations, export reductions, or reservoir releases?

IA1 wet year fall X2 requirements cost the CVP an extra 400 TAF in exports, cuts and storage withdrawals over the NAA, and the SWP contributes an additional 63 TAF. The summer and fall operations in IA2 and IA3 have little effect on storage and deliveries.

What are the effects on different Delta smelt life history strategies (i.e., freshwater, migratory, brackish water)?

Three life histories of Delta smelt (i.e., freshwater, brackish, and migratory) have been identified, but assessing the impact of summer and fall habitat actions is difficult due to the current small population size of Delta smelt. If the Summer-Fall Habitat actions offer benefits to Delta smelt, the X2 and SMSCG actions would primarily affect the migratory and brackish water resident portion of the population, while the NDFS action (if beneficial) would likely affect the freshwater resident portion of the population.

Does the summer and fall habitat action improve population recruitment and viability?

Greater survival and growth in the summer-fall period should generally lead to higher fecundity and therefore recruitment for Delta smelt in the subsequent spring. However, the spatial extent and temporal duration of the actions are expected to influence the scale of measurable benefits and may be confounded by limiting factors such as climate change.

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K.1 Attachment 1. Summer and Fall Delta Outflow and Habitat CalSim Analysis

K.1.1 Assumptions

In addition to the No Action Alternative (NAA), there are three initial alternatives: Initial Alternative 1 (IA1), Initial Alternative 2 (IA2), and Initial Alternative 3 (IA3).

K.1.1.1 No Action Alternative

The NAA is described as Revised Alternative 1 in Appendix F1 of the 2019 *Final Environmental Impact Statement for Reinitiation of Consultation on Long-Term Operation of the Central Valley Project and State Water Project* (Bureau of Reclamation 2019) with additional SWP operations for implementing the 2020 ITP. The NAA uses hydrology projected at 2035 (2035 Central Tendency). Information on the updated modeling can be found on the CalSim Model Maintenance Management repository at github.com/usbr/cm3. In addition, full Sacramento River Settlement Contractors contract amounts were assumed and there are no daily components to the Wilkin’s Slough flow requirement.

K.1.1.2 Initial Alternative 1

IA1 includes the management of X2 with the following criteria:

- Fall X2 requirement of 80 km in above normal (AN) water years and 74 km in wet (W) water years. This option reflects the requirement from the 2020 ROD in AN water years and the requirement of 74 km from the 2008 Delta Smelt Biological Opinion in W water years.
- To meet the Fall X2 target, CVP prioritizes reducing exports over storage withdrawals to build storage in Shasta except for high Shasta conditions in fall (if it’s likely to spill), whereas SWP does not follow such preference and the model relies more often on storage withdrawals.
- No SMSCG operations from June through September.
- It is important to note that in the NAA, the 2020 ITP actions are implemented; however, in the initial alternatives, ITP actions other than the Old and Middle River (OMR) action (ITP Conditions of Approval 8.17-8.19, including San Joaquin River I/E and increased Delta outflow actions as summarized in Figure K.1-1) are turned off. To discern incremental changes from the NAA, a mid-step “NAA without ITP actions” model is included in relevant sections.

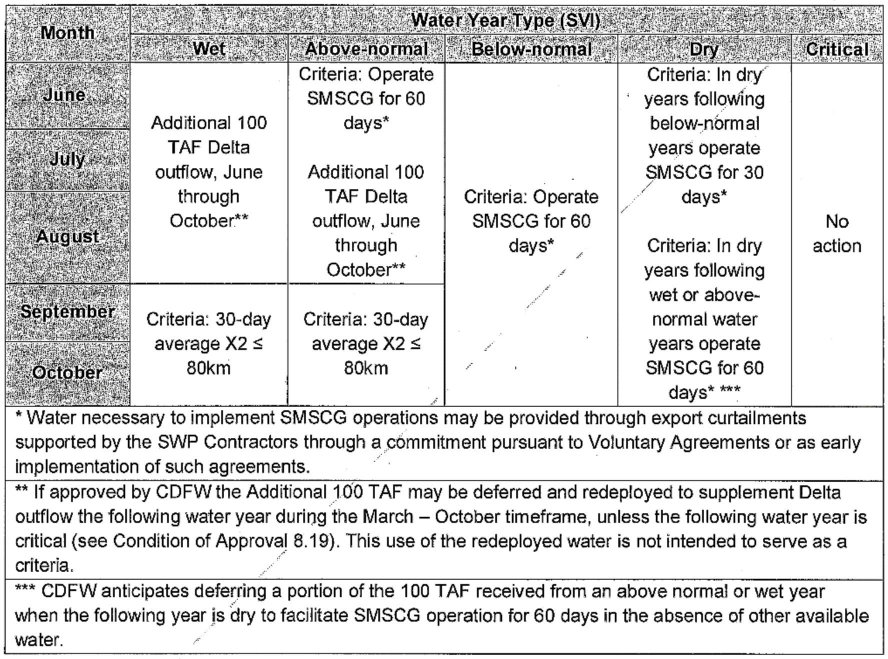
K.1.1.3 Initial Alternative 2

IA2 includes the development of habitat connectivity through operation of the Suisun Marsh Salinity Control Gates (SMSCG) with the following criteria.

- Fall X2 requirement of 81 km in AN water years and 80 km in W water years. This option has the less restrictive above normal year requirement from the 2008 BiOp and the Shasta storage measures from the 2020 ROD.
- To meet the Fall X2 target, CVP prioritizes reducing exports over storage withdrawals to build storage in Shasta except for high Shasta conditions in fall (if it’s likely to spill),

whereas SWP does not follow such preference and the model relies more often on storage withdrawals.

- SMSCG operations for salinity of 4 parts per thousand (ppt) at Belden's Landing from June through September. Sixty days of operations in W, AN, and below normal (BN) water years.
- The cost of SMSCG operations is split between the CVP and SWP.
- Projects are assumed to contribute equally to meet additional Delta outflow needed with the operation of the SMSCG.
- It is important to note that in the NAA, the 2020 ITP actions are implemented; however, in the IA alternatives, ITP actions other than the OMR action (ITP Conditions of Approval 8.17-8.19, including San Joaquin River I/E and increased Delta outflow actions as summarized in Figure K.1-1) are turned off. To discern incremental changes from the NAA, a mid-step "NAA without ITP actions" model is included in relevant sections.



Month	Water Year Type (SVI)				
	Wet	Above-normal	Below-normal	Dry	Critical
June	Additional 100 TAF Delta outflow, June through October**	Criteria: Operate SMSCG for 60 days* Additional 100 TAF Delta outflow, June through October**	Criteria: Operate SMSCG for 60 days*	Criteria: In dry years following below-normal years operate SMSCG for 30 days* Criteria: In dry years following wet or above-normal water years operate SMSCG for 60 days* ***	No action
July					
August					
September	Criteria: 30-day average X2 ≤ 80km	Criteria: 30-day average X2 ≤ 80km			
October					

* Water necessary to implement SMSCG operations may be provided through export curtailments supported by the SWP Contractors through a commitment pursuant to Voluntary Agreements or as early implementation of such agreements.

** If approved by CDFW the Additional 100 TAF may be deferred and redeployed to supplement Delta outflow the following water year during the March – October timeframe, unless the following water year is critical (see Condition of Approval 8.19). This use of the redeployed water is not intended to serve as a criteria.

*** CDFW anticipates deferring a portion of the 100 TAF received from an above normal or wet year when the following year is dry to facilitate SMSCG operation for 60 days in the absence of other available water.

Source: Table 9-A in California Department of Fish and Wildlife 2020:115.

Figure K.1-1. Criteria Required To Be Met through Implementation of the Summer-Fall Action to Benefit DS [Delta smelt] Habitat by Water Year

K.1.1.4 Initial Alternative 3

IA3 includes the real-time implementation of gate operations and food web actions with the following criteria:

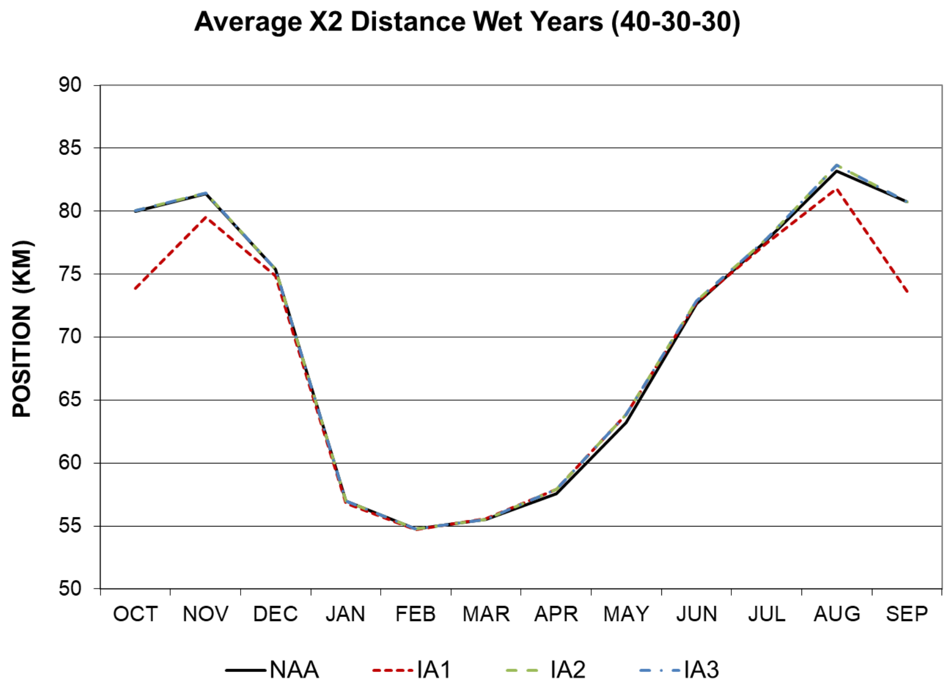
- Fall X2 requirement 80 km in both AN and W water years.

- To meet the Fall X2 target, CVP prioritizes reducing exports over storage withdrawals to build storage in Shasta except for high Shasta conditions in fall (if it’s likely to spill), whereas SWP does not follow such preference and the model relies more often on storage withdrawals.
- SMSCG operations for salinity of 4 ppt at Belden’s Landing from June through September. Sixty days of operations in W, AN, and below normal (BN) water years and 30 days of operations in dry water years.
- The cost of SMSCG operations is split between the CVP and SWP.
- Projects are assumed to contribute equally to meet additional Delta outflow needed with the operation of the SMSCG.
- It is important to note that in the NAA, the 2020 ITP actions are implemented; however, in the IA alternatives, ITP actions other than the OMR action (ITP Conditions of Approval 8.17-8.19, including SJR I/E and increased Delta outflow actions as summarized in Figure K.1-1) are turned off. To discern incremental changes from the NAA, a mid-step “NAA without ITP actions” model is included in relevant sections.

K.1.2 Results

K.1.2.1 Fall X2

Fall X2 requirements occur from September through October in W and AN water year types; where August serves as a “ramp up” month. Despite no X2 requirement in August, a slight freshening (or reduction in X2 distance) may be observed in August in order to meet the X2 requirement in September.



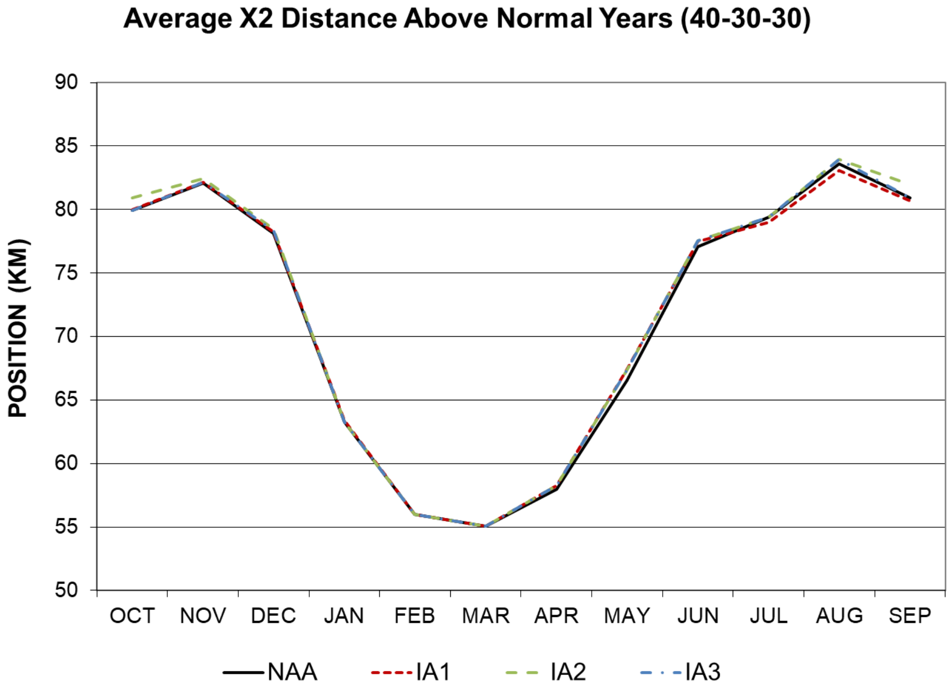
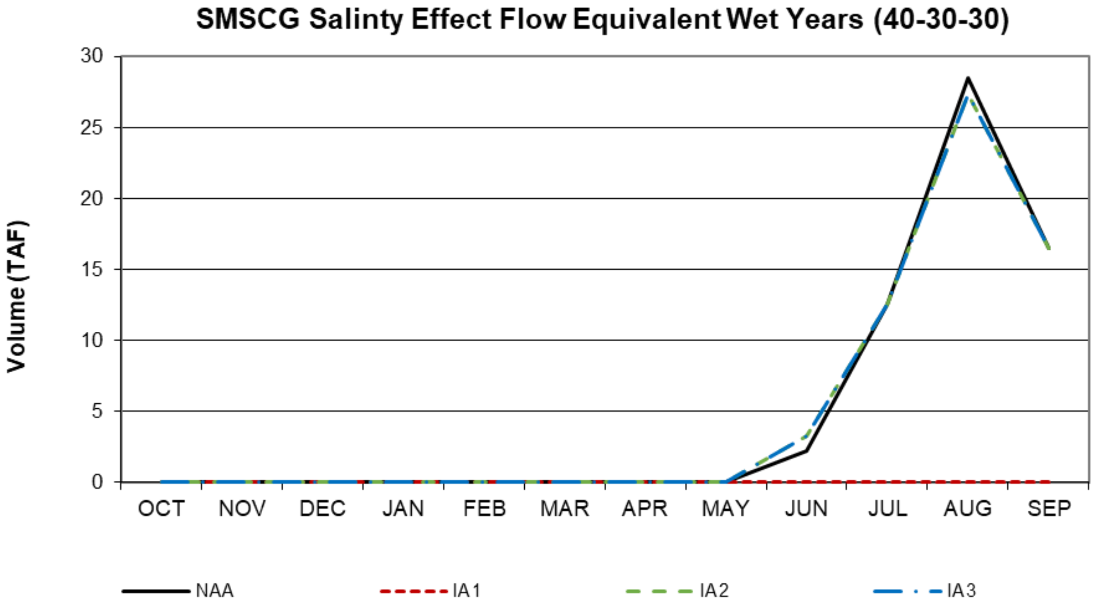


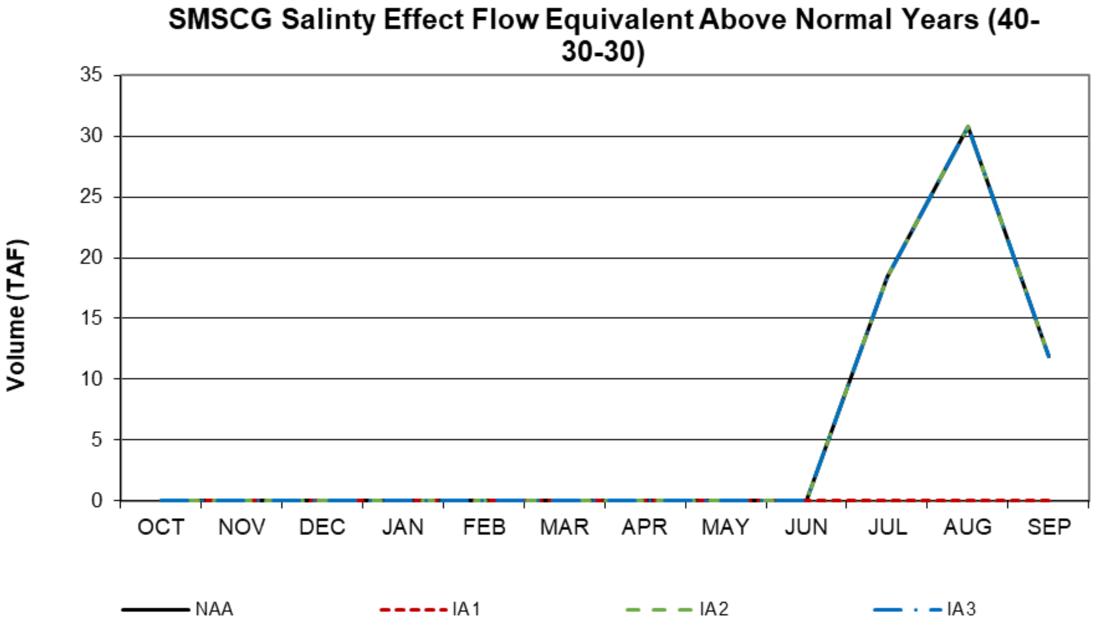
Figure K.1-2: Average Monthly Pattern of X2 Distance in AN and Wet Water Years (DSM2)

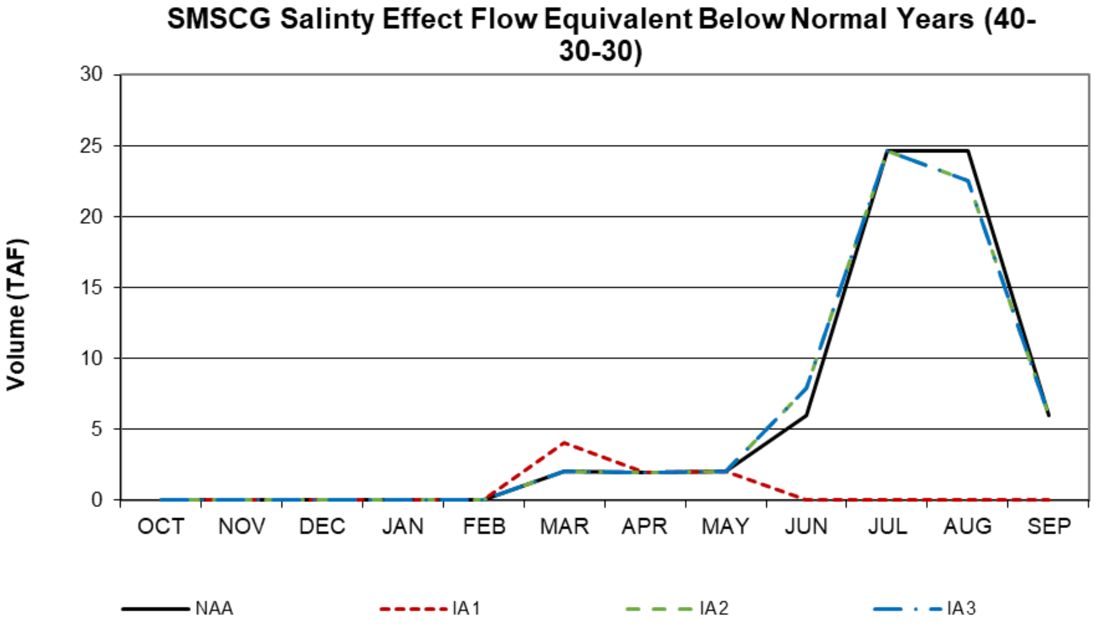
The X2 results (from DSM2) are shown in Figure K.1-2. This figure demonstrates the variation X2 from August through October in AN and W water years due to the difference in X2 requirements in the NAA, IA1, IA2 and IA3. All alternatives have a similar X2 distance throughout the rest of the year.

K.1.2.2 Suisun Marsh Salinity Control Gate

In the NAA, the cost of SMSCG operations in June through September in wet, above normal, and below normal years is shared by the CVP and SWP per the Coordinated Operations Agreement, while the dry year operation is an ITP action supported by the SWP. In the initial alternatives, the cost of all SMSCG operations is split evenly between the CVP and SWP. In CalSim, the cost of SMSCG Operations is accounted for within the salinity ANN. It has been estimated that the reduction of exports and storage is about 30 TAF/month in months that SMSCG operations occur.




SMSCG Salinty Effect Flow Equivalent Above Normal Years (40-30-30)
Volume (TAF)
35
30
25
20
15
10
5
0
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
NAA
IA1
IA2
IA3


SMSCG Salinty Effect Flow Equivalent Below Normal Years (40-30-30)
Volume (TAF)
30
25
20
15
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0
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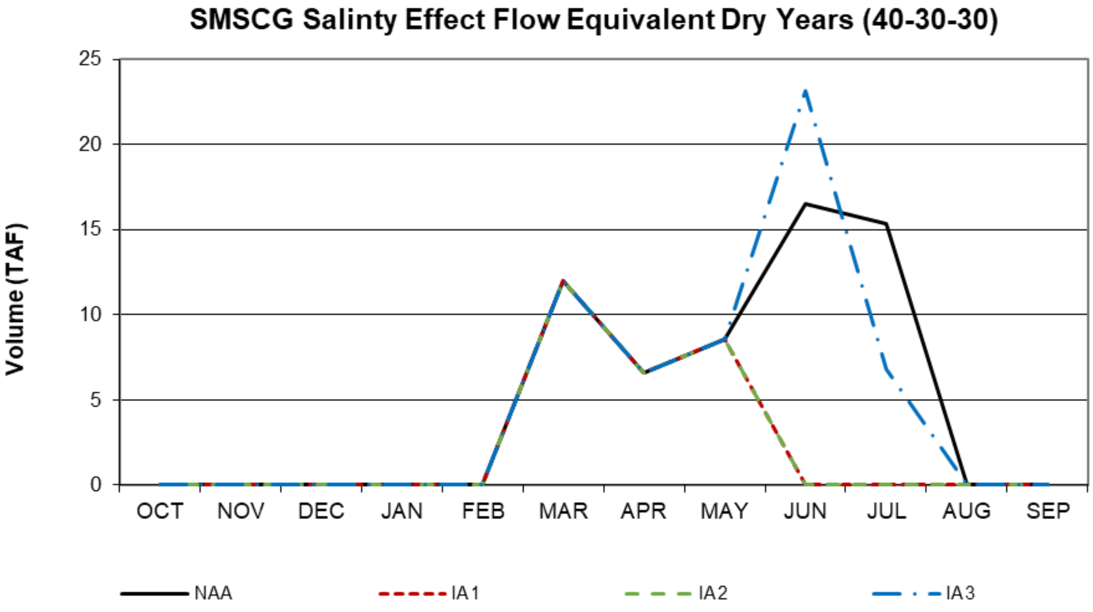


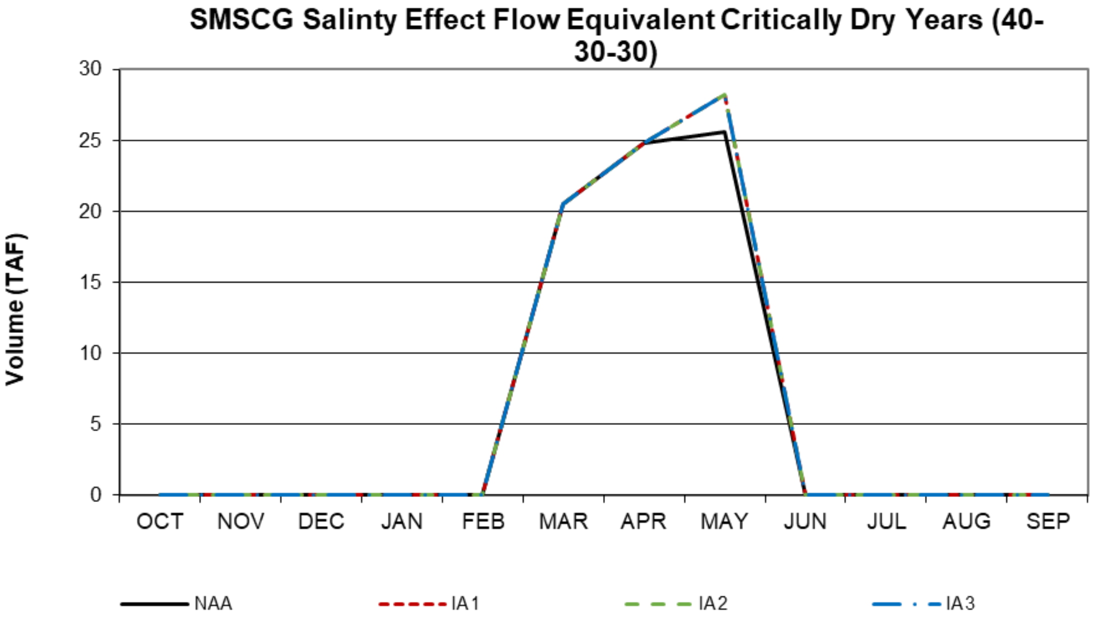


Figure K.1-3: Estimated Cost of Suisun Marsh Salinity Control Gate Operations by Watery Year Type

Figure K.1-3 shows that the estimated water cost of SMSCG operations primarily varies after May. IA1 does not have SMSCG operations in these months. In wet, AN, BN water years, the resulting water cost is similar across the other three alternatives. In dry water years, SMSCG operations occur for a 60-day period after May in the NAA and only a 30-day period after May in IA3. Finally, there are no SMSCG operations after May for critically dry years.

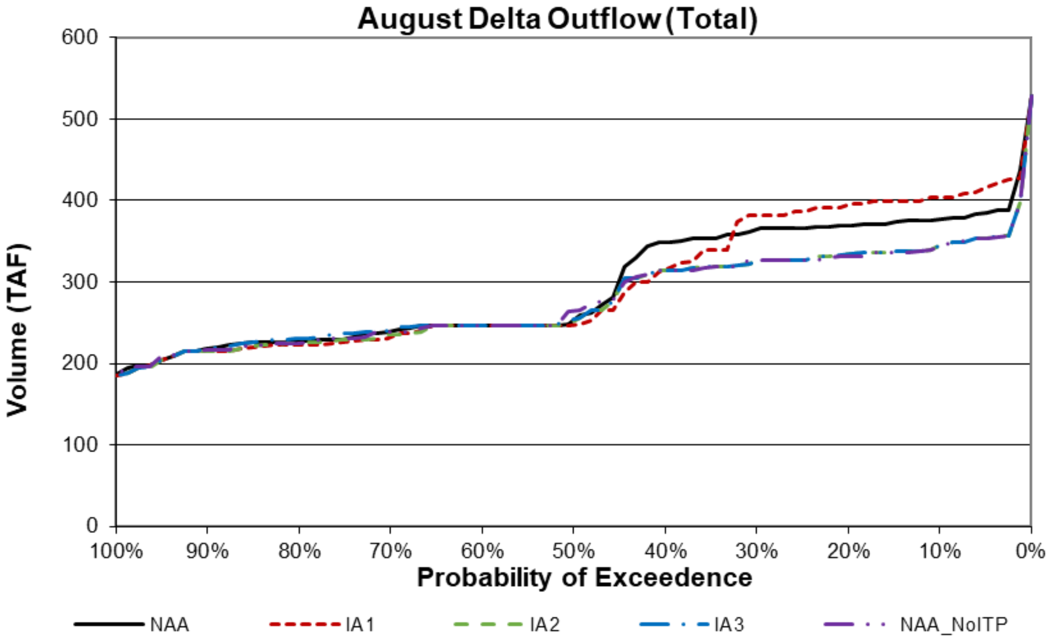
K.1.2.3 Delta Outflow

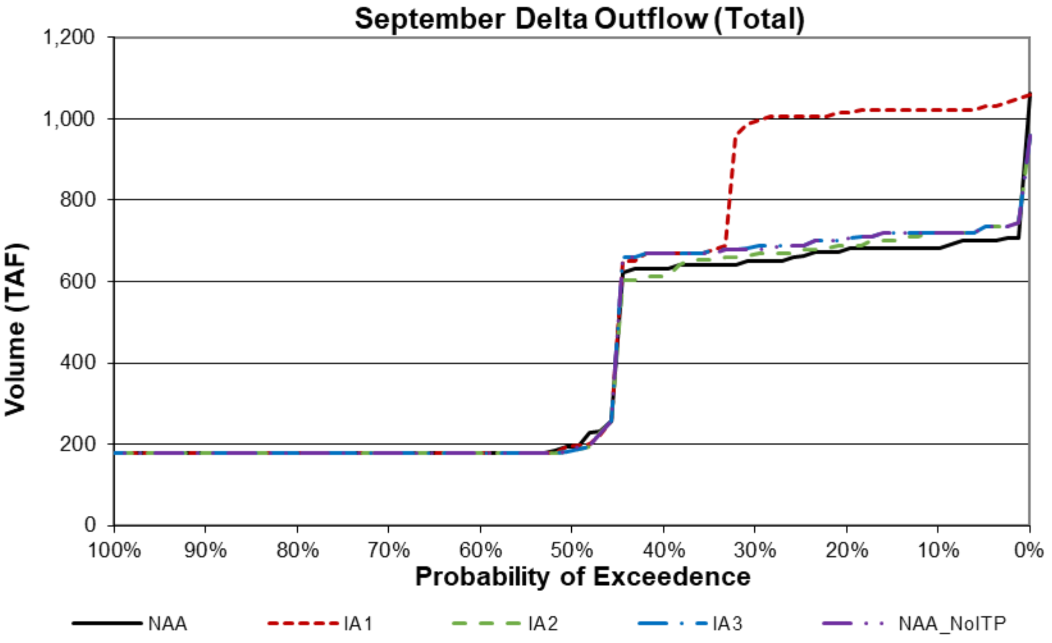
A lower Fall X2 target means that X2 needs to be pushed westward towards the Golden Gate Bridge, and therefore, it requires more Delta outflow. When there is not enough excess Delta outflow available, exports are reduced and/or stored water releases are made to achieve the Fall X2 target. SMSCG operations also affect the volume of water needed to meet salinity levels in the Delta. When SMSCG is open, fresh(er) water from the Delta moves into the Suisun Marsh and therefore more Delta outflow is needed to keep salinity at desired levels.

Table K.1-1: Annual Delta Outflow by Water Year Type in TAF (Mar – Feb)

	Average	Wet	Above Normal	Below Normal	Dry	Critically Dry
NAA	16,711	23,809	17,109	15,699	12,415	8,152
IA1	16,671	23,962	16,855	15,536	12,316	8,080
IA2	16,585	23,646	16,897	15,580	12,337	8,093
IA3	16,591	23,644	16,960	15,577	12,343	8,084

Table K.1-1 shows Annual Delta outflow for the NAA and alternatives by water year type. Except for IA1 in wet years, the alternatives have lower annual Delta outflows relative to the NAA.





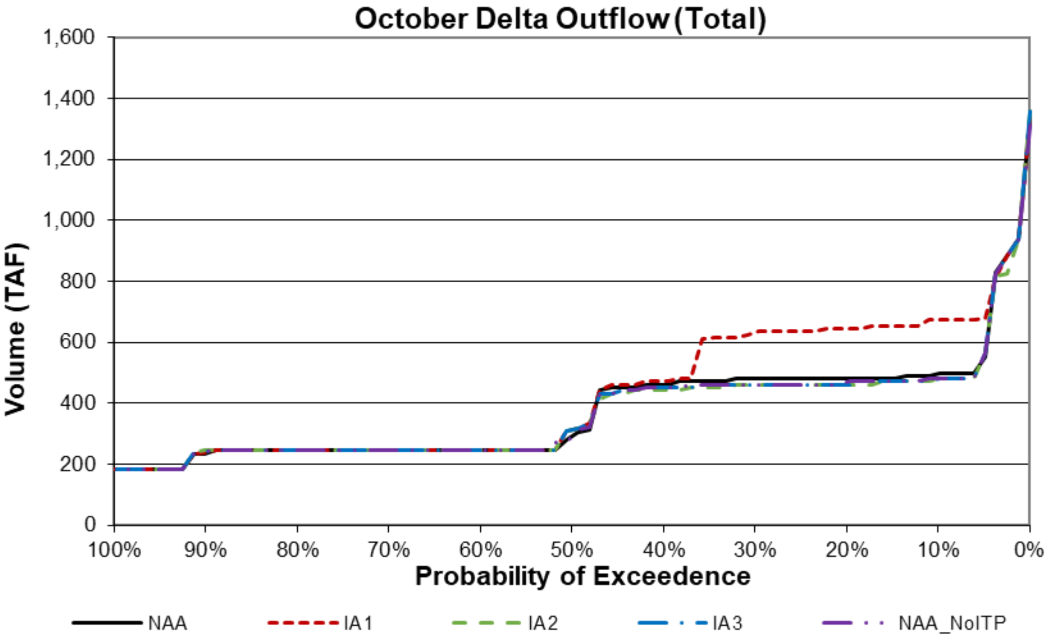


Figure K.1-4: Monthly Exceedance of Delta Outflow (Aug – Oct)

The differences between the alternatives in Figure K.1-4 are primarily driven by the Fall X2 requirement. In August, there is a gradual ramping to the final X2 requirement in September and October (Shown in Table 1). In W water years, IA1 has a Fall X2 requirement 4 - 6 km closer to the Golden Gate Bridge than the other alternatives, and therefore requires more Delta outflow. On average, IA1 requires 65 TAF more in August, 309 TAF more in September, and 79 TAF more in October of W water years when compared to the NAA without ITP actions. In AN water years, the alternatives have similar Fall X2 requirements which result in similar Delta outflows.

In the NAA, SWP exports are further reduced in August as a result of the additional Delta outflow actions of the SWP ITP; which results in higher Delta outflow.

K.1.2.4 Exports

Increasing Delta outflow for Fall X2 requirements or as a result of SMSCG operations is accomplished in the alternatives by reducing exports and/or increasing additional releases from storage. For CVP, most of the time, reducing exports is prioritized over stored water releases to reserve Shasta storage.

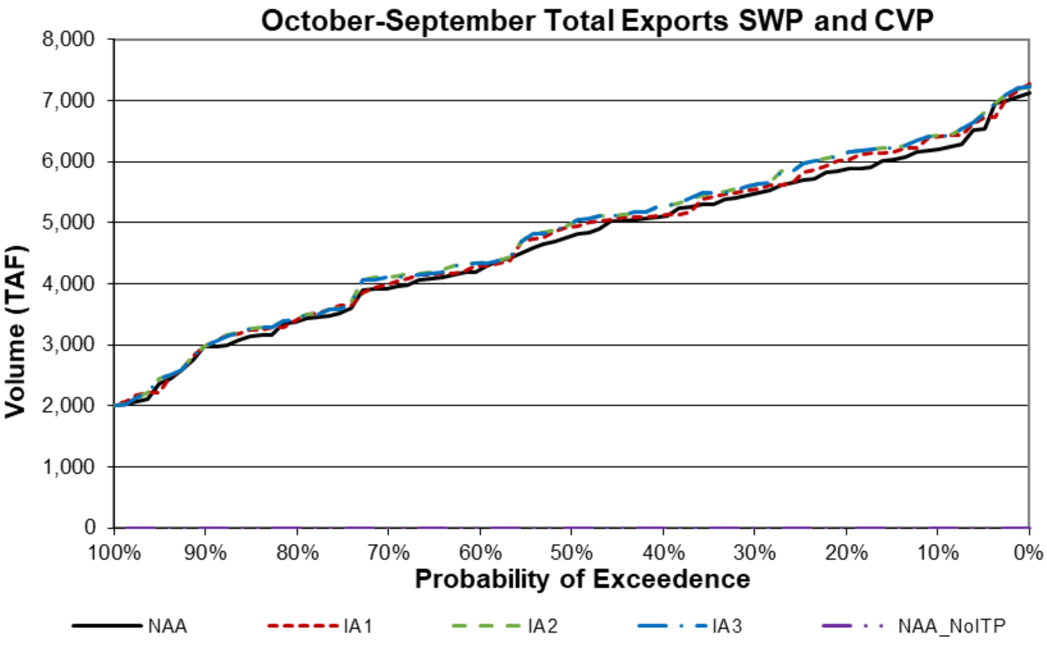
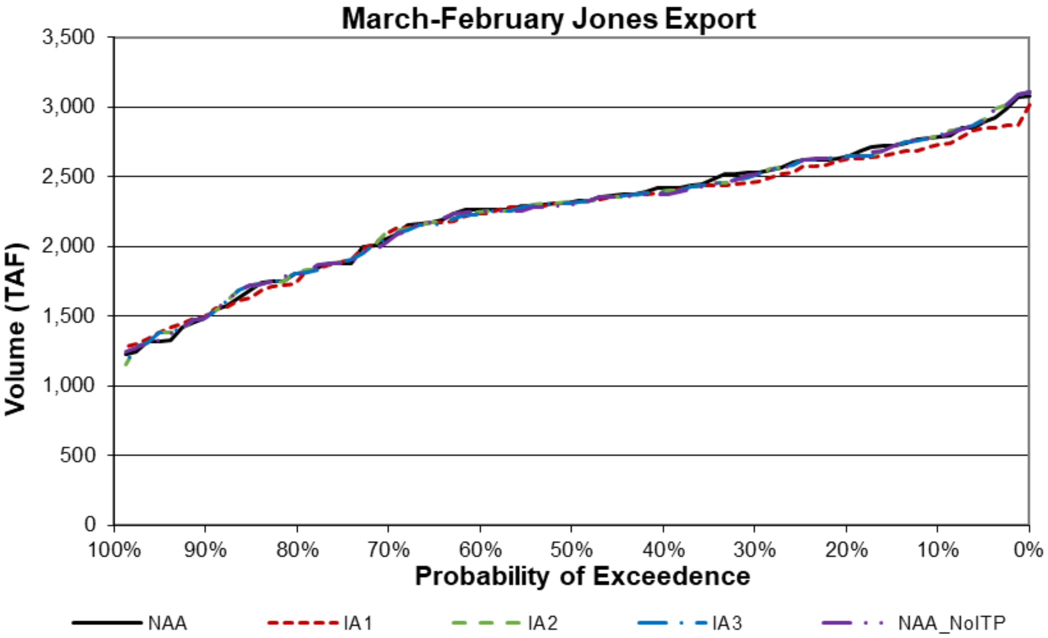


Figure K.1-5: Annual Exceedance of Total Exports



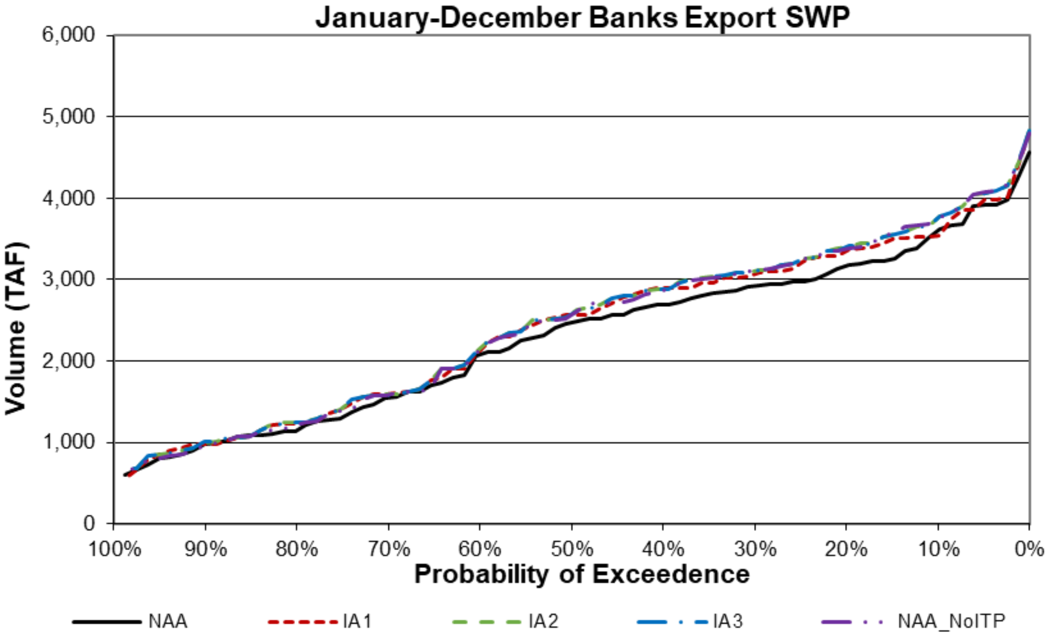


Figure K.1-6: Annual Exceedance of Jones (Above) and Banks (Below) Exports

When compared to the NAA without ITP actions, IA1 has less exports than the other alternatives because of higher export cuts to meet more demanding Fall X2 standards. The other alternatives have similar exports, despite having different SMSCG operations.

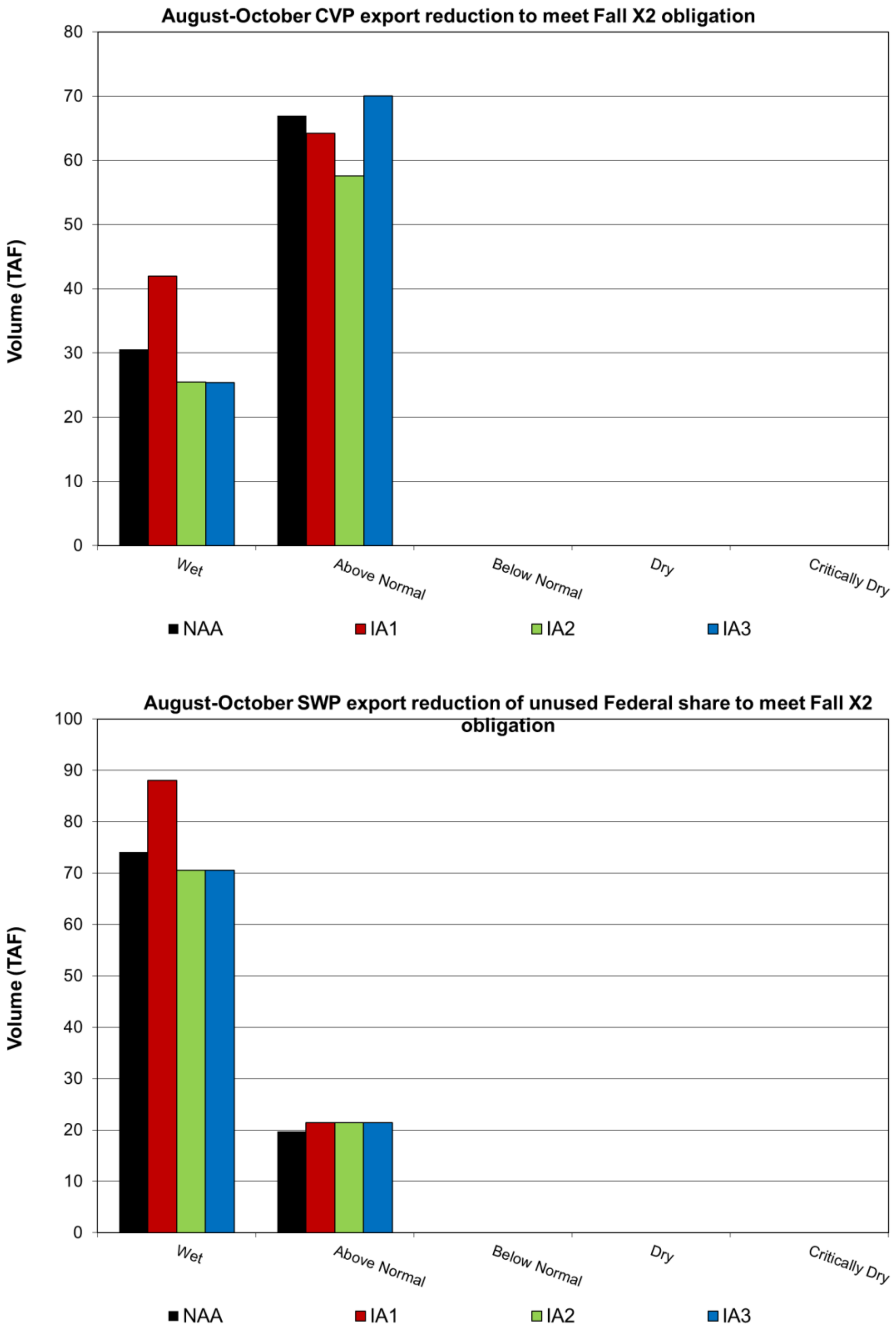
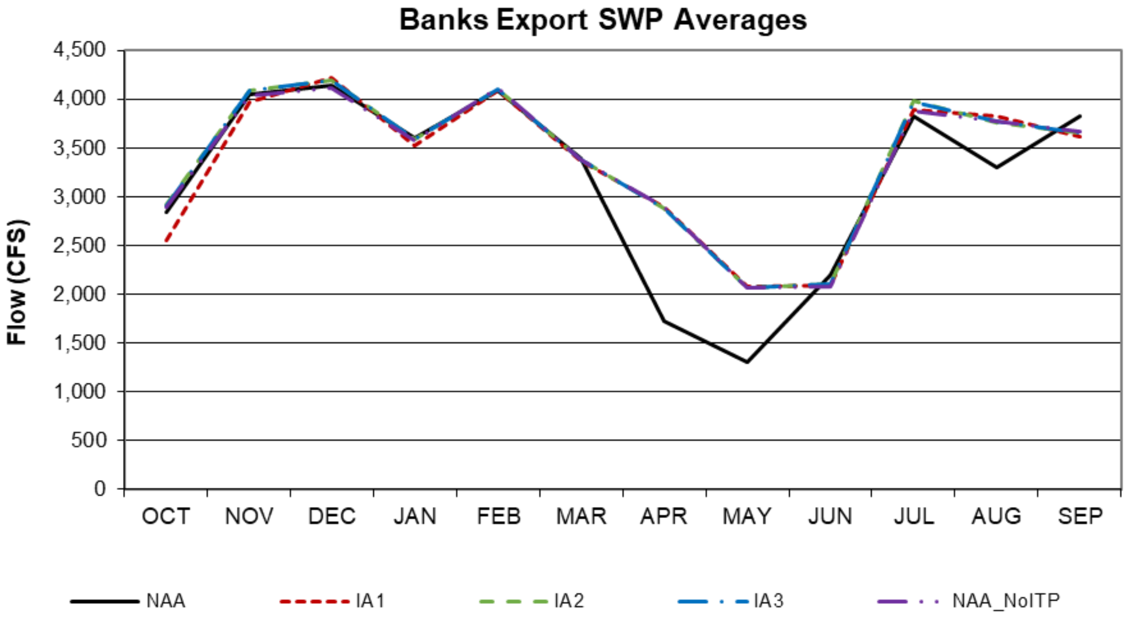
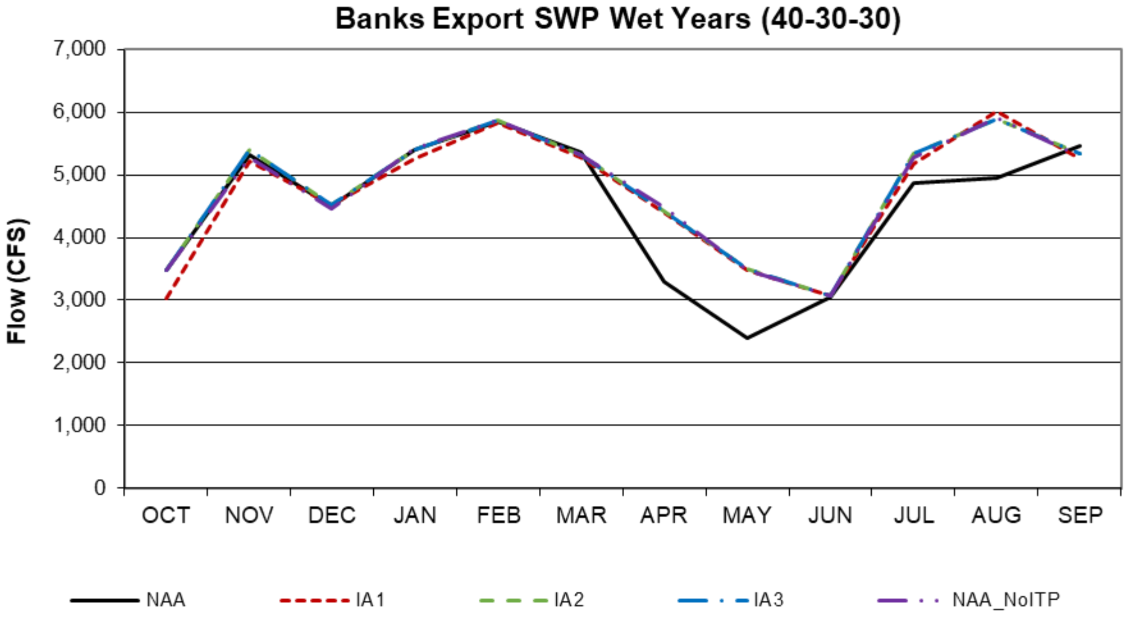
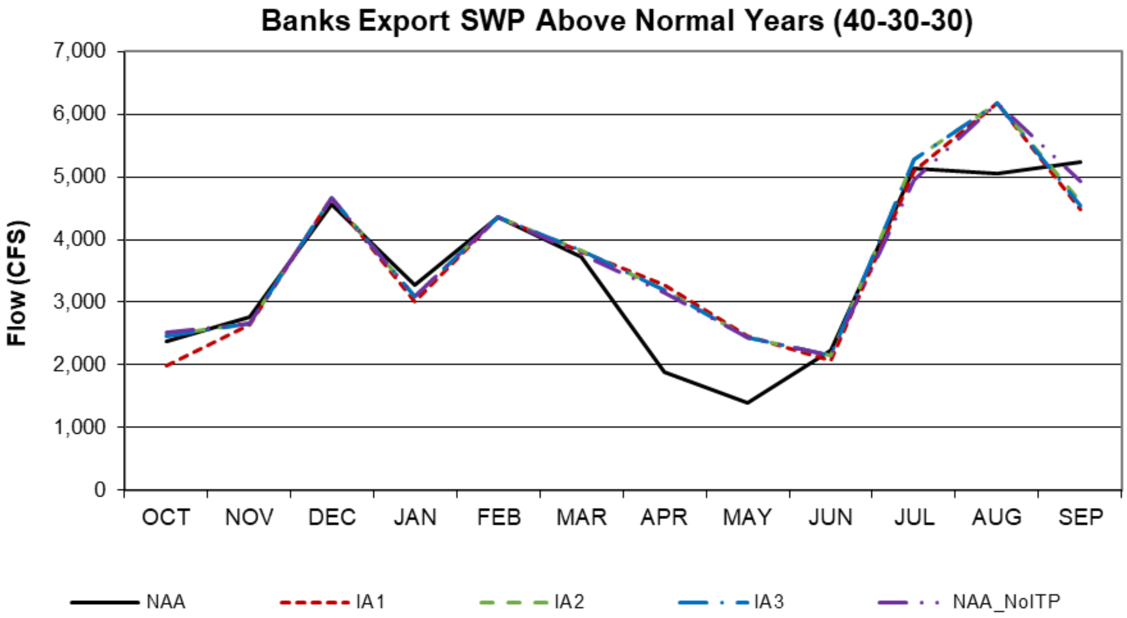


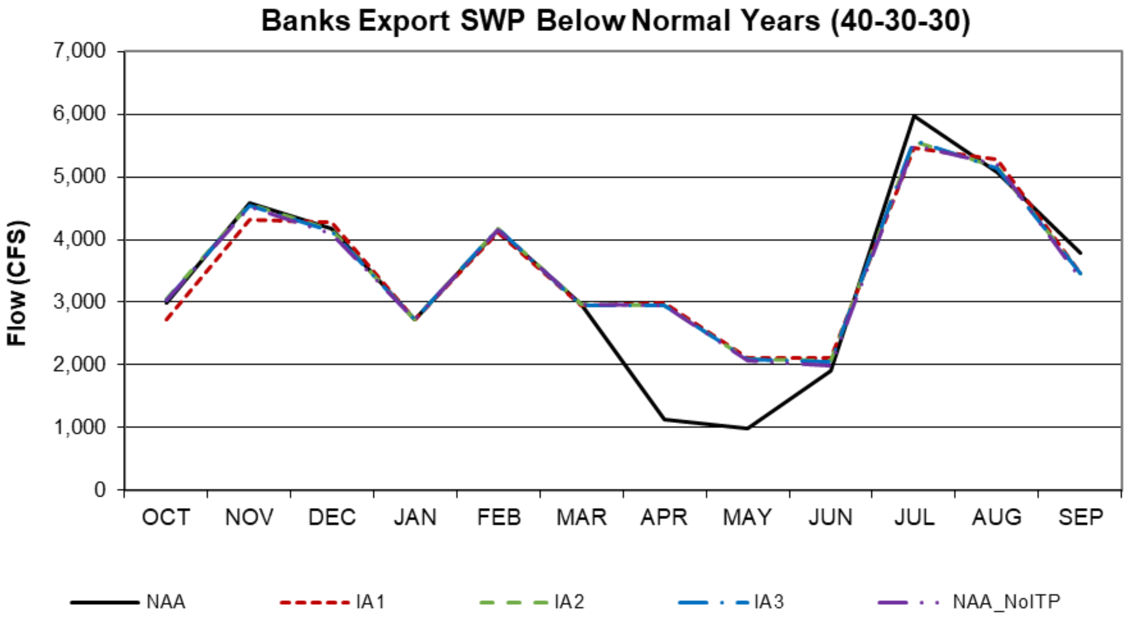
Figure K.1-7: Annual Reduction in CVP Exports (Above) and Unused Federal Share (Below) to meet Fall X2 by Water Year Type

Figure K.1-7 shows that in W water years, CVP's share of the higher cost of Fall X2 in IA1 is supported with 14 TAF reduction in the SWP's export of unused federal share and 12 TAF of cuts to CVP exports. In AN water years, IA2 has a slightly less costly Fall X2 requirement, and therefore cuts CVP exports less than the other alternatives.






Banks Export SWP Above Normal Years (40-30-30)
Flow (CFS)
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
NAA
IA1
IA2
IA3
NAA_NoITP


Banks Export SWP Below Normal Years (40-30-30)
Flow (CFS)
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
OCT
NOV
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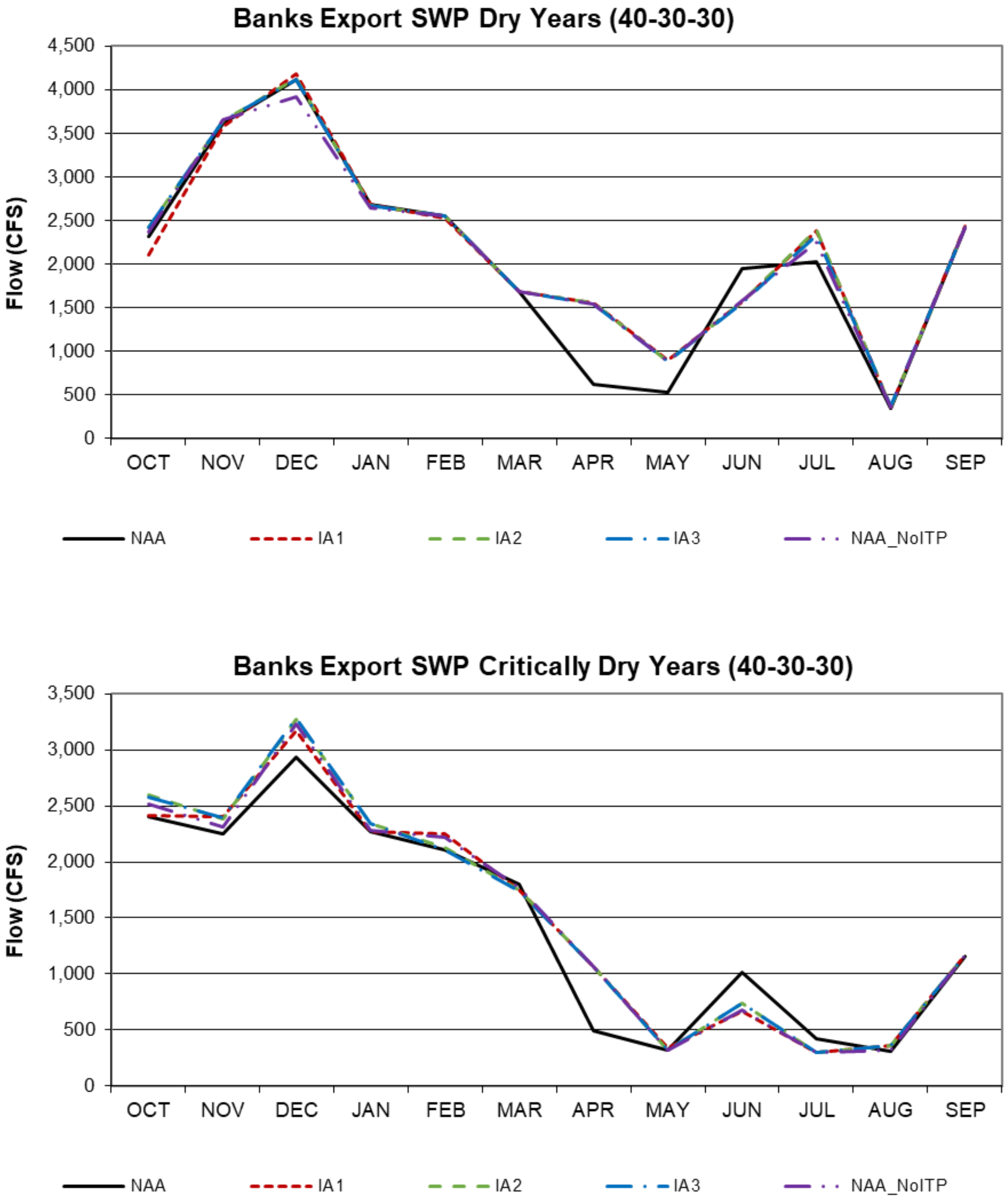

Figure K.1-8: Monthly Pattern of Banks Pumping by Water Year Type

For Banks exports, the initial alternatives should be compared to the NAA without ITP actions because other ITP actions outside of Fall X2 and SMSCG operations also affect exports. In wet and AN water years, IA1 has an annual reduction in Banks export of 101 TAF and 27 TAF respectively, when compared to the NAA without ITP actions. By comparison, IA2 and IA3 show little difference from the “NAA without ITP actions”.

K.1.2.5 Deliveries

The Fall X2 requirement and SMSCG operations affect south of Delta deliveries under the IA1 scenario, where Project deliveries remain similar in other scenarios.

Table K.1-2: Annual CVP NOD Deliveries by Water Year Type in TAF (Mar-Feb)

	Average	Wet	Above Normal	Below Normal	Dry	Critically Dry
NAA	2,424	2,530	2,562	2,505	2,390	2,044
IA1	2,418	2,528	2,557	2,494	2,372	2,038
IA2	2,424	2,529	2,560	2,501	2,391	2,040
IA3	2,423	2,529	2,560	2,497	2,388	2,039

Table K.1-3: Annual CVP NOD Settlement Contract Deliveries by Water Year Type in TAF (Mar - Feb)

	Average	Wet	Above Normal	Below Normal	Dry	Critically Dry
NAA	1,877	1,873	1,878	1,911	1,903	1,802
IA1	1,877	1,873	1,878	1,911	1,903	1,802
IA2	1,877	1,873	1,878	1,911	1,903	1,802
IA3	1,877	1,873	1,878	1,911	1,903	1,802

Table K.1-4: Annual CVP NOD Refuge Deliveries by Water Year Type in TAF (Mar - Feb)

	Average	Wet	Above Normal	Below Normal	Dry	Critically Dry
NAA	84	89	90	88	84	61
IA1	84	89	90	88	84	61
IA2	84	89	90	88	84	61
IA3	84	89	90	88	84	61

Table K.1-5: Annual CVP NOD Project Ag Deliveries by Water Year Type in TAF (Mar - Feb)

	Average	Wet	Above Normal	Below Normal	Dry	Critically Dry
NAA	247	326	348	276	198	31
IA1	242	326	344	267	186	28
IA2	246	326	347	273	199	29
IA3	245	326	347	270	197	28

Table K.1-6: Annual CVP NOD Project M&I Deliveries by Water Year Type in TAF (Mar - Feb)

	Average	Wet	Above Normal	Below Normal	Dry	Critically Dry
NAA	218	241	247	231	205	149
IA1	215	240	246	228	198	147
IA2	217	240	246	229	204	147
IA3	217	240	246	228	204	147

Tables K.1-2 – K.1-6 show that NOD CVP Settlement and Refuge deliveries are unaffected by differences in Fall X2 and SMSCG operations. There are only very minor differences in CVP Project Ag and M&I deliveries.

Table K.1-7: Annual CVP SOD Deliveries by Water Year Type in TAF (Mar – Feb)

	Average	Wet	Above Normal	Below Normal	Dry	Critically Dry
NAA	2,377	2,994	2,635	2,354	1,934	1,487
IA1	2,349	2,968	2,596	2,285	1,941	1,465
IA2	2,375	2,993	2,620	2,342	1,947	1,481
IA3	2,372	2,993	2,619	2,344	1,938	1,477

Table K.1-8: Annual CVP SOD Exchange Contract Deliveries by Water Year Type in TAF (Mar - Feb)

	Average	Wet	Above Normal	Below Normal	Dry	Critically Dry
NAA	855	875	875	875	864	757
IA1	855	875	875	875	864	757
IA2	855	875	875	875	864	757
IA3	855	875	875	875	864	757

Table K.1-9: Annual CVP SOD Refuge Deliveries by Water Year Type in TAF (Mar - Feb)

	Average	Wet	Above Normal	Below Normal	Dry	Critically Dry
NAA	271	278	278	278	273	237
IA1	271	278	278	278	273	238
IA2	271	278	278	278	271	238
IA3	271	278	278	278	272	238

Table K.1-10: Annual CVP SOD Project Ag Deliveries by Water Year Type in TAF (Mar - Feb)

	Average	Wet	Above Normal	Below Normal	Dry	Critically Dry
NAA	948	1,516	1,169	900	510	219
IA1	921	1,492	1,129	833	516	199
IA2	945	1,515	1,152	889	523	213
IA3	943	1,515	1,152	890	515	210

Table K.1-11: Annual CVP SOD Project M&I Deliveries by Water Year Type in TAF (Mar - Feb)

	Average	Wet	Above Normal	Below Normal	Dry	Critically Dry
NAA	120	141	131	117	104	90
IA1	119	140	131	115	105	88
IA2	120	142	131	116	105	89
IA3	120	142	131	117	104	89

Tables K.1-7 – K.1-11 show that CVP SOD Exchange and Refuge deliveries are similar across all the alternatives. IA1 has lower CVP SOD Project Ag and M&I deliveries because of export reductions and storage releases which meet the higher Fall X2 requirement.

Table K.1-12: Annual SWP Total Deliveries by Water Year Type in TAF (Jan - Dec)

	Average	Wet	Above Normal	Below Normal	Dry	Critically Dry
NAA	2,342	3,275	2,758	2,566	1,460	973
IA1	2,449	3,416	2,908	2,629	1,524	1,090
IA2	2,486	3,464	2,934	2,663	1,570	1,106
IA3	2,484	3,462	2,933	2,661	1,566	1,103
NAA_NoITP	2,468	3,453	2,927	2,650	1,540	1,072

Relative to the NAA without ITP, SWP deliveries have small differences. SWP obligations under the alternatives are largely supported by Oroville.

K.1.2.6 Reservoir Storage

For CVP, when export reductions are not enough to meet the Fall X2 requirement or the cost of SMSCG operations, additional storage withdrawals are made to meet them.

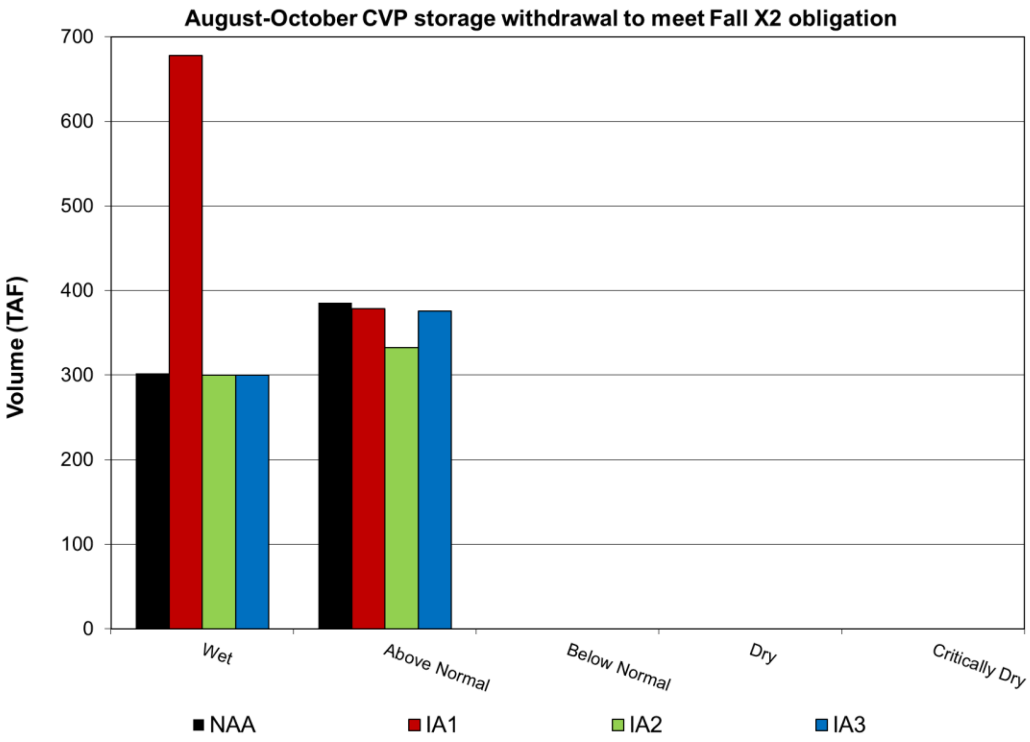

Figure K.1-9: Annual Storage Withdrawals to Meet the Fall X2 Requirement by Water Year Type

In W water years, IA1 has an increase of about 380 TAF in CVP storage withdrawal to meet Fall X2 when compared to the other alternatives. For AN water years, the Fall X2 requirement in IA2 is not as costly and therefore has an average reduction in CVP storage withdrawal of up to 60 TAF when compared to the other alternatives.

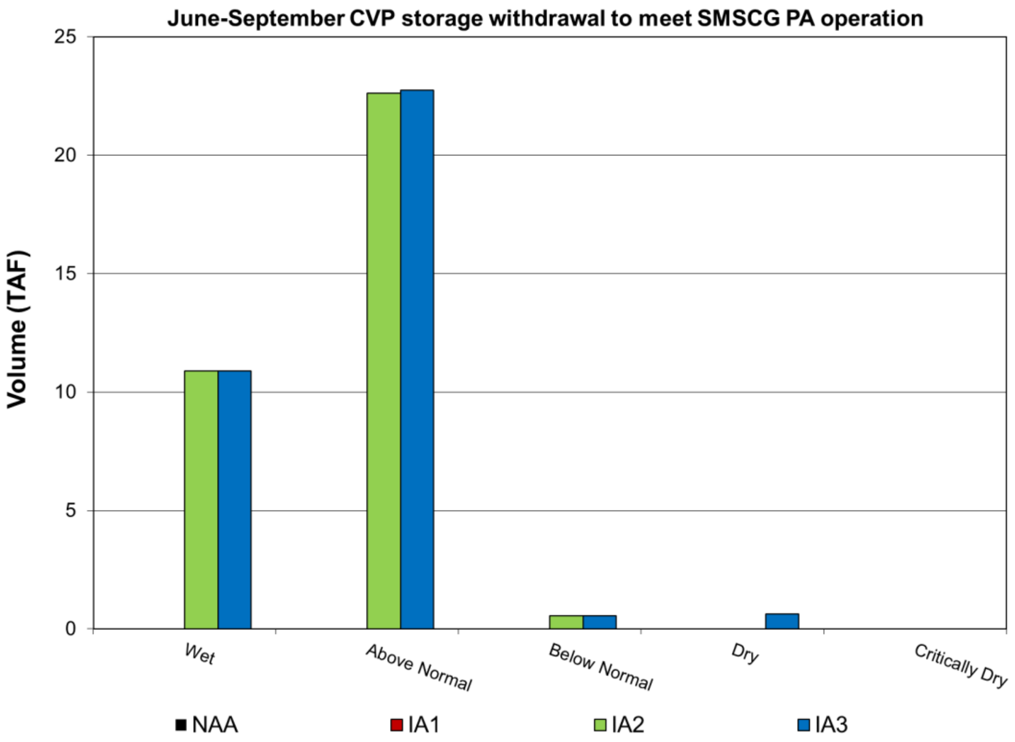

Figure K.1-10: Annual CVP Storage Withdrawal to Meet SMSCG PA Operations by Water Year Type

Figure K.1-10 shows average CVP stored water releases for SMSCG operations and little difference between IA2 and IA3 except in dry water years when only IA3 has the SMSCG operation.

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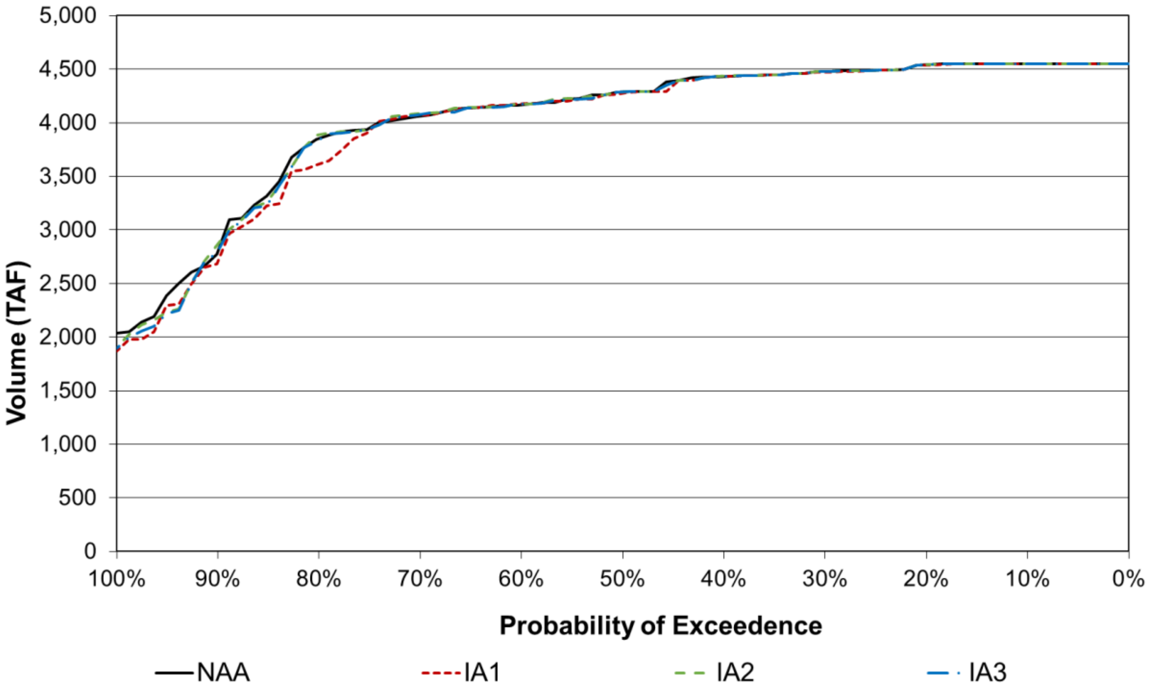

Figure K.1-2: Exceedance of End of April Shasta Storage

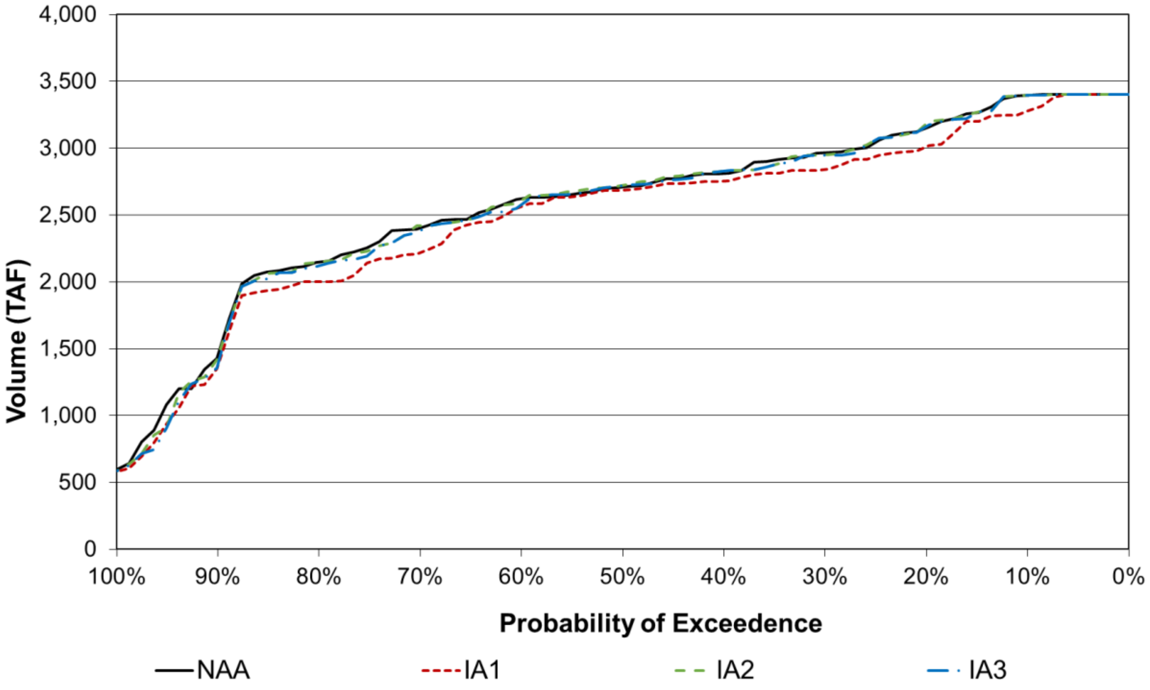

Figure K.1-3: Exceedance of End of September Shasta Storage

Figures K.1-11 – K.1-16 show the end of April (fill) and end of September (carryover) storage of the NOD CVP reservoirs: Shasta, Trinity, and Folsom. Lower storage in IA1 due to the higher cost of the Fall X2 requirement is seen clearly in Figure K.1-12, where IA1 has less Shasta carryover in all but the driest or wettest years. On the drier end of Figure K.1-11, Shasta shows some inability to recover storage in the fill season in IA1 after expending more storage to meet the Fall X2 requirement in previous years.

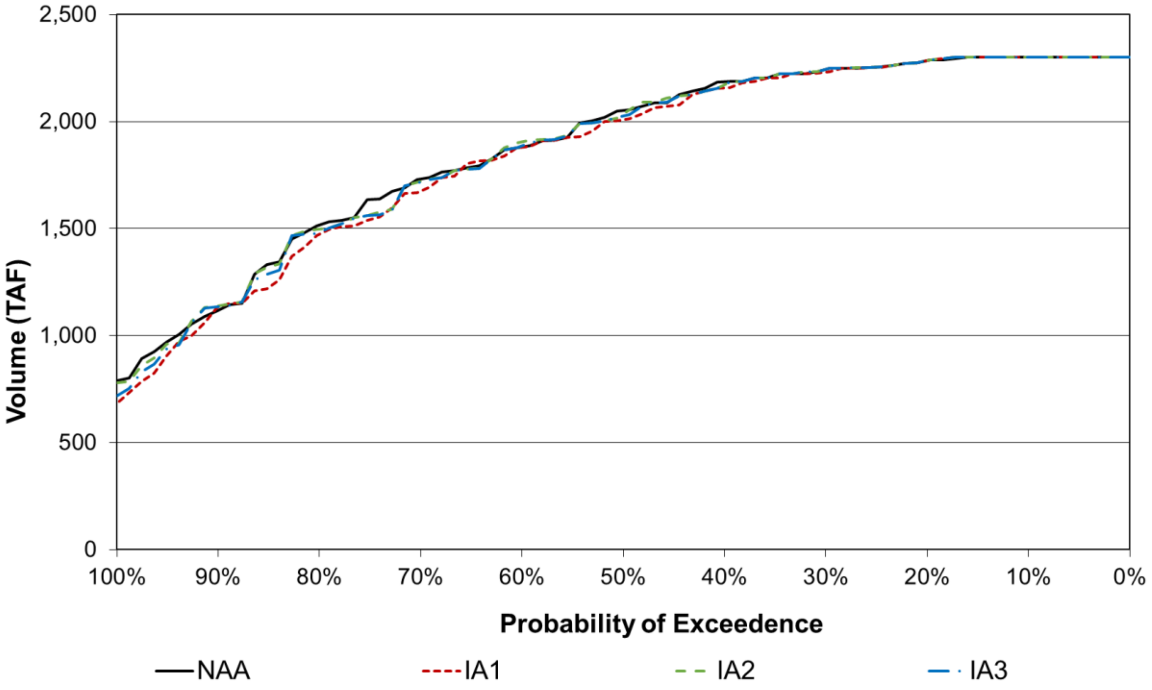

Figure K.1-4: Exceedance of End of April Trinity Storage

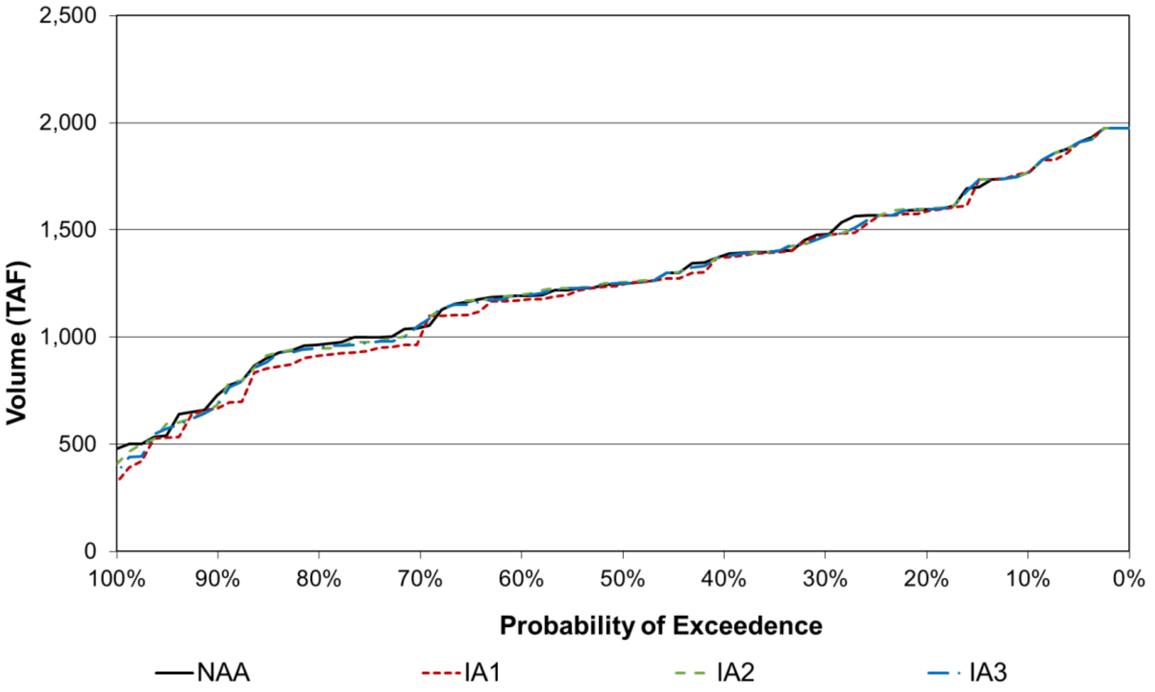

Figure K.1-5: Exceedance of End of September Trinity Storage

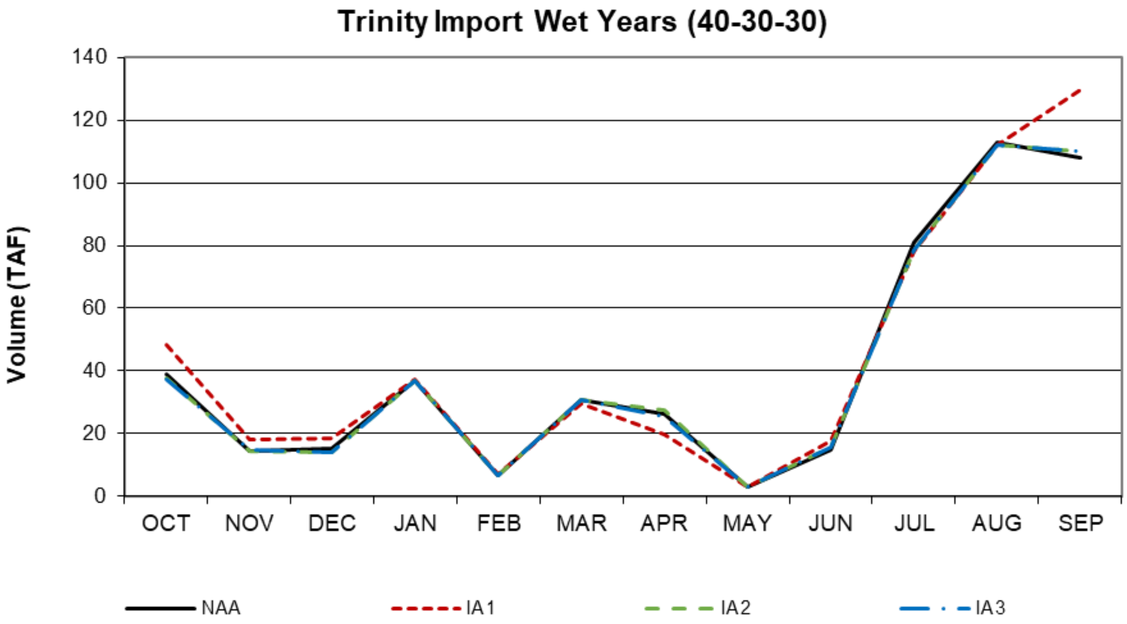

Figure K.1-6: Monthly Pattern of Trinity Imports in Wet Water Years

IA1 shows some decreased Fill and Carryover in Figures K.1-13 and K.1-14. Figure K.1-14 shows the Trinity contribution in September and October to the higher Fall X2 requirement in

IA1. November and December also have higher imports in IA1, affected by the Trinity/Shasta balance goals., additional imports are brought into the Sacramento Basin because Shasta storage is lower, and in CalSim, Trinity Imports are calculated partly as a function of balancing between Trinity and Shasta storage.

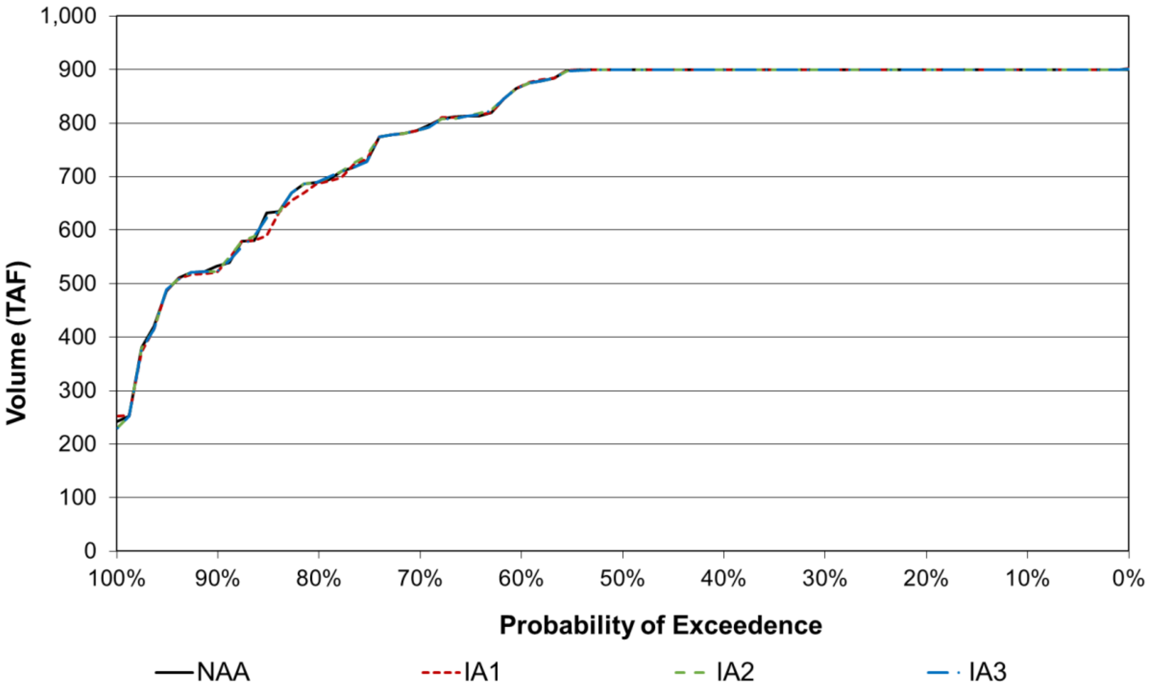

Figure K.1-7: Exceedance of End of April Folsom Storage

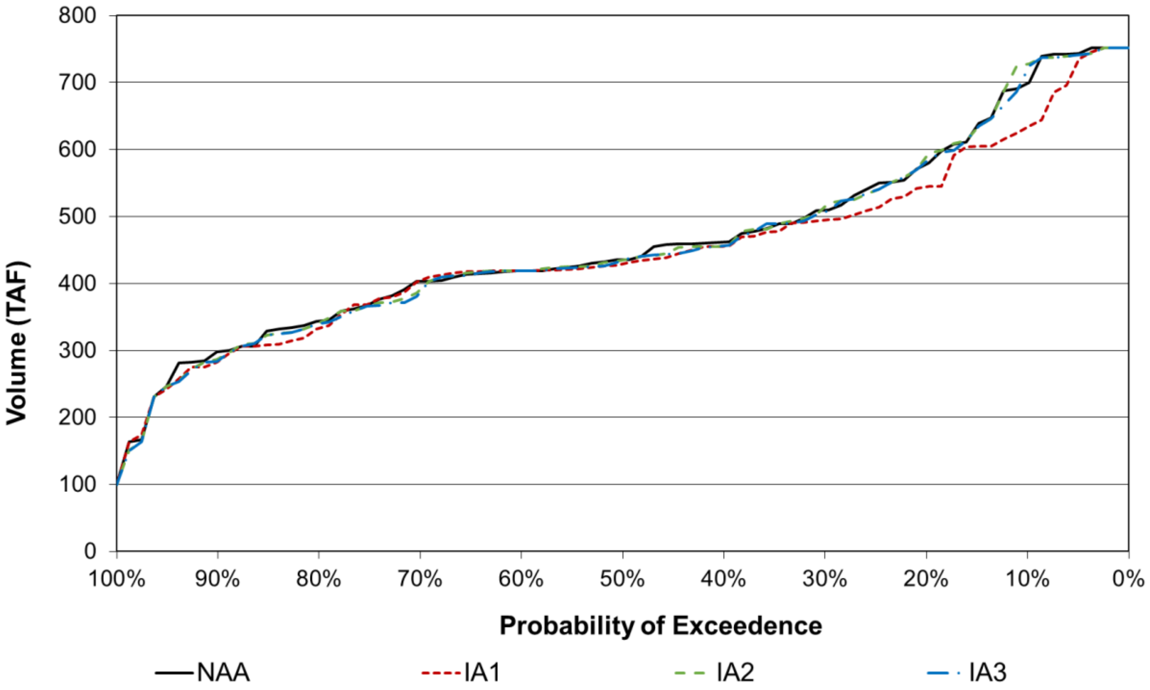

Figure K.1-8: Exceedance of End of September Folsom Storage

Figure K.1-17 shows that in Wet Water years when IA1 has a more costly Fall X2 requirement, Folsom carryover is reduced. However, Folsom refills more easily than Trinity or Shasta, so Figure K.1-16 shows that additional Folsom releases in IA1 rarely affects fill.

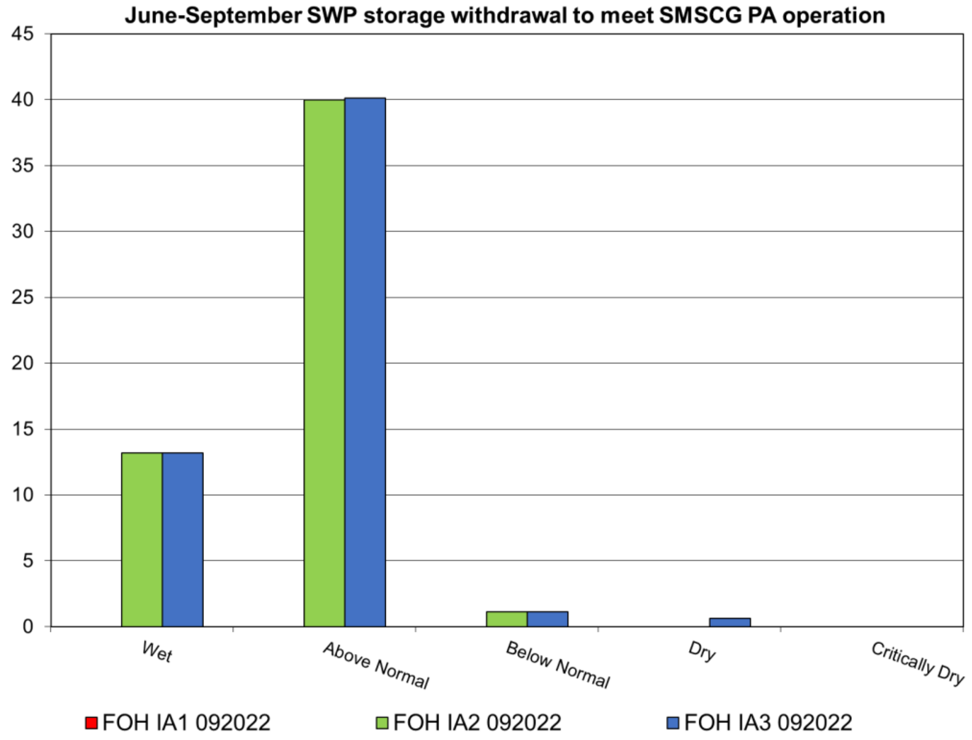

Figure K.1-9: Annual SWP Storage Withdrawal to Meet SMSCG PA Operations by Water Year Type

IA1 does include the SMSCG operations in June – September. IA2 and IA3 show a similar storage withdrawal to meet the cost of SMSCG operations in Figure K.1-18, except in Dry years where only IA3 has SCMSCG operations.

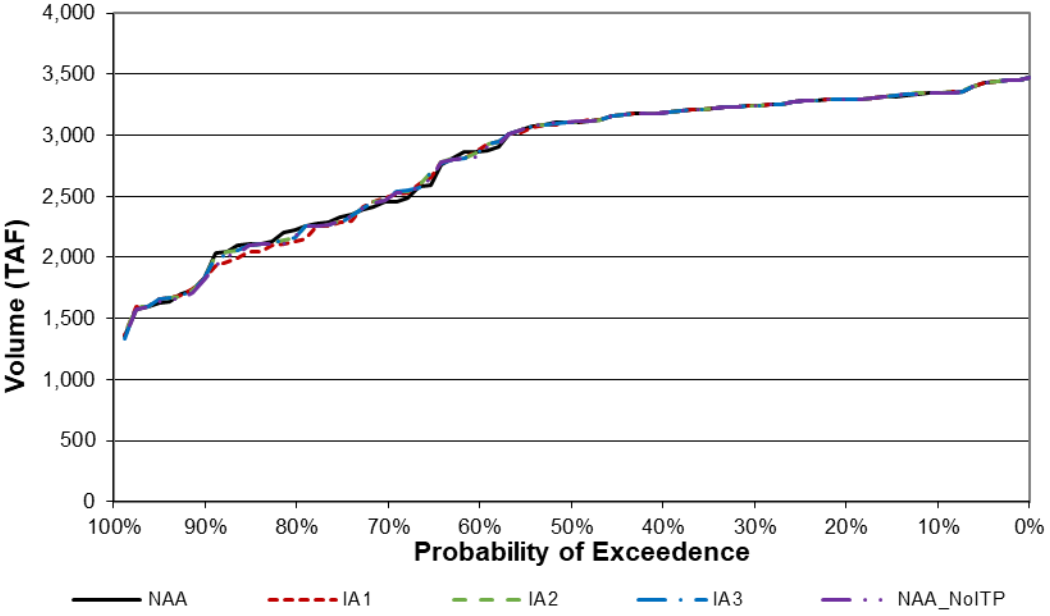

Figure K.1-10: Exceedance of End of April Oroville Storage

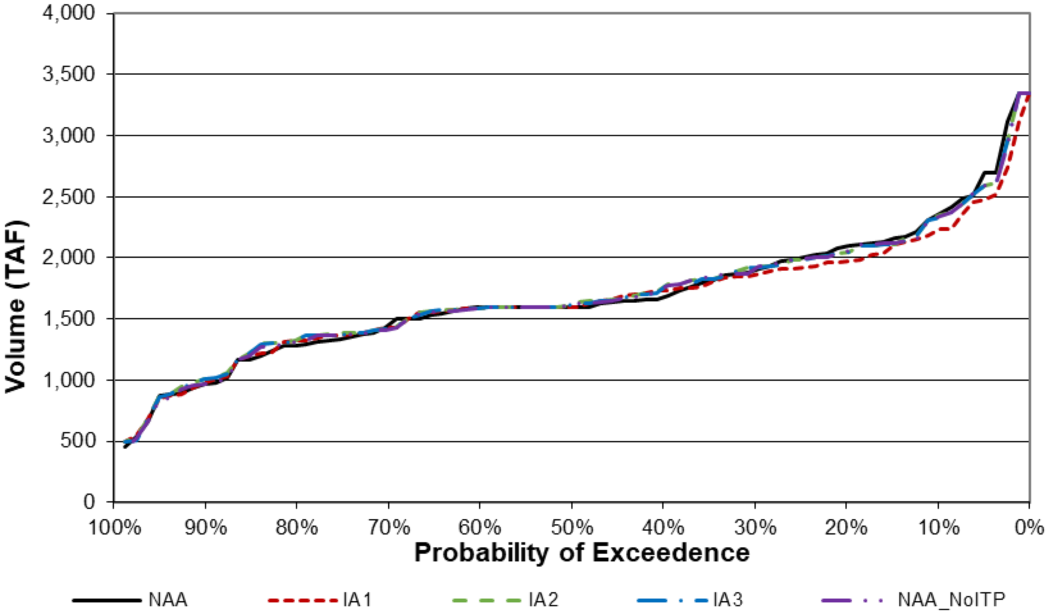

Figure K.1-11: Exceedance of End of September Oroville Storage

The effects of the higher IA1 Fall X2 requirement on Oroville storage is similar to Folsom. In wet water years, Figures K.1-19 and K.1-20 show lower carryover in wetter years due to Oroville releases for Fall X2, but mostly unaffected April fill.

K.1.2.7 Summary of Results

To address summer and fall Delta outflow and habitat, initial alternatives focused on Fall X2 requirements from August through October and SMSCG operations from June through September. IA1 wet year Fall X2 requirements cost the CVP an extra 400 TAF in exports, cuts and storage withdrawals over the NAA, and the SWP contributes an additional 63 TAF. The SMSCG summer and fall operations in IA2 and IA3 have smaller effect on storage and deliveries compared to the Fall X2.