5 Effects Analysis for Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale

5.1 Introduction

The potential effects of the proposed action (PA) on listed species under NMFS jurisdiction are evaluated in this section. Those species include the following.

- Chinook salmon, Sacramento River winter-run ESU
- Chinook salmon, Central Valley spring-run ESU[1]
- Steelhead, California Central Valley DPS
- Green sturgeon, southern DPS
- Killer whale, Southern Resident DPS

These species are evaluated with regard to the deconstructed effects of the PA, i.e. water facility construction, water facility maintenance, water facility operations, conservation measures, monitoring activities, and cumulative effects. Effects on southern resident killer whales are addressed qualitatively in a separate subsection from the other species because killer whales occur outside the Bay-Delta and would not be exposed to the direct effects of the action.

Scientific uncertainty exists with respect to the potential effects of the PA on listed fishes. As described in Section 3.4.7, *Collaborative Science and Adaptive Management Program*, of Chapter 3, the Collaborative Science and Adaptive Management Program will help to address scientific uncertainty by guiding the development and implementation of scientific investigations and monitoring for both permit compliance and adaptive management, and applying new information and insights to management decisions and actions.

Each subsection of this effects analysis also provides an analysis of effects on critical habitat for winter-run Chinook salmon, spring-run Chinook salmon, steelhead, and green sturgeon. For all four species, designated critical habitat is present in the Delta and adjacent areas, including upstream areas within the action area. The analysis includes, as necessary, potential effects on the following physical or biological features (PBFs)[2] of critical habitat for each species.

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[1] As described in Section 4.5.2 *Chinook Salmon, Central Valley Spring-Run ESU* of Chapter 4, *Action Area and Environmental Baseline*, this effects analysis includes consideration of San Joaquin River spring-run Chinook salmon, which are considered to represent both the population reintroduced as part of the San Joaquin River Restoration Program, and spring-running Chinook salmon observed in San Joaquin River tributaries in recent years.

[2] The designations of critical habitat for listed species have generally used the term primary constituent elements (PCEs). NMFS and USFWS' recently issued a final rule amending the regulations for designating critical habitat (81 FR 7414; February 11, 2016), which replaced the term PCEs with physical or biological features (PBFs). In addition, NMFS and USFWS recently issued a final rule revising the regulatory definition of "destruction or adverse modification" of critical habitat (81 FR 7214; February 11, 2016), which refers to PBFs, not PCEs. The shift in terminology does not change the approach used in conducting an analysis of the effects of the proposed action on

- Sacramento River Winter-run Chinook salmon
  - access from Pacific Ocean to spawning areas in the upper Sacramento River;
  - the availability of clean gravel for spawning substrate;
  - adequate river flows for successful spawning, incubation of eggs, fry development and emergence, and downstream transport of juveniles;
  - water temperatures for successful spawning, egg incubation, and fry development;
  - habitat areas and prey that are not contaminated;
  - riparian habitat that provides for successful juvenile development and survival; and
  - access downstream so that juveniles can migrate from spawning grounds to San Francisco Bay and the Pacific Ocean.
- Sacramento River spring-run Chinook salmon and California Central Valley steelhead
  - spawning habitat with water quantity and quality conditions and substrate supporting spawning, incubation and larval development;
  - freshwater rearing habitat with water quantity and quality, floodplain connectivity, forage, and natural cover supporting juvenile development, growth, mobility, and survival;
  - freshwater migration corridors free of obstruction and excessive predation with water quantity and quality conditions and natural cover supporting juvenile and adult mobility and survival; and
  - estuarine areas free of obstruction and excessive predation supporting mobility and survival, with water quantity, water quality, and salinity conditions supporting juvenile and adult physiological transitions between fresh and saltwater, and natural cover and forage supporting growth, maturation and survival.
- Green sturgeon (for freshwater riverine systems and estuarine habitats)
  - food resources for larval, juvenile, subadult, and adult life stages;
  - water flow regime with flow magnitude, duration, seasonality, and rate-of-change supporting growth, survival, and migration of all life stages;
  - water quality including temperature, salinity, oxygen content, and other chemical characteristics supporting growth and viability of all life stages;

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critical habitat, which is the same regardless of whether the original designation identified PCEs or PBFs. In this biological assessment, we use the term PBFs to include PCEs, as appropriate for the specific critical habitat.

- migratory corridor free of obstruction and excessive predation with water quantity and quality conditions supporting safe and timely passage of juveniles and adults within and between riverine, estuarine and marine habitats;
- water depth sufficient (>5 m) for holding pools supporting adults and subadults;
- substrate type or size (for freshwater riverine systems but not estuarine habitat) supporting egg deposition, egg and larval development, subadult and adult holding, and adult spawning; and
- sediment quality (*i.e*, chemical characteristics) supporting growth and viability of all life stages.

5.2 Effects of Water Facility Construction on Fish

5.2.1 Preconstruction Studies (Geotechnical Exploration)

Geotechnical investigations in open water at the proposed locations for the water conveyance facilities and alignments have the potential to affect listed salmonids and green sturgeon and their designated critical habitat. Approximately 100 over-water borings are currently proposed to collect geotechnical data at the proposed locations of the north Delta intakes, barge landings, tunnel alignment crossings, HOR gate, and CCF facilities (Table 3.2-4). Site-specific studies will investigate several geotechnical properties of these sites, including the stability of canal embankments and levees, liquefaction of soils, seepage through coarse-grained soils, settlement of embankments and structures, subsidence, and soil-bearing capacity. Specific field activities will include drilling of sample soil borings, cone penetration, and other *in situ* tests (slug tests, aquifer/pumping tests, and test pits) to evaluate subsurface conditions. In-water borings will be conducted using a mud rotary method in which a conductor casing will be pushed into the sediment to isolate the drilling area, drilling fluids (bentonite), and cuttings from the surrounding water. Drilling fluids and cuttings will be contained within the conductor casing and returned to a recirculation tank on the drill ship or barge where they will be transferred to drums for storage and disposal.

DWR plans to restrict in-water drilling to the approved in-water work window (August 1 to October 31) between the hours of sunrise and sunset. The duration of drilling at each location will vary depending on the number and depth of the holes, drill rate, and weather conditions, but activities are not expected to exceed 60 days at any one location. Overwater borings for the intake structures and river crossings for tunnels will be carried out by a drill ship and barge-mounted drill rigs. A number of AMMs are proposed to avoid or minimize potential turbidity, suspended sediment, and other water quality impacts (e.g., bentonite or contaminant spills) on listed species and aquatic habitat during geotechnical activities: *Worker Awareness Training; Construction Best Management Practices and Monitoring; Stormwater Pollution Prevention Plan (SWPPP); Erosion and Sediment Control Plan; Spill Prevention, Containment, and Countermeasure Plan (SPCCP); Hazardous Material Management Plan (HMMP);* and *Disposal and Reuse of Spoils, Reusable Tunnel Material, and Dredged Material; and Barge Operations Plan* (Appendix 3.F *General Avoidance and Minimization Measures*).

Restricting in-water geotechnical activities to August 1 to October 31 will avoid the primary migration and rearing seasons of juvenile salmonids and primary migration seasons of adults in the Delta with the exception of adult steelhead, which may peak in abundance during the late summer and fall months (September-October). There is some potential for winter-run juveniles (less than 60 mm in length) to occur in the lower Sacramento River and Delta in October but this is uncommon; typically, the earliest that juveniles would be expected to occur in the action area is November or December (del Rosario et al. 2013). The proposed in-water work window period will also avoid the peak upstream migration period of adult green sturgeon (late February to early May). However, post-spawning adults (returning downriver following spawning) and rearing juveniles may be present through the summer and fall and therefore subject to the potential effects of geotechnical activities during the in-water work window.

With containment of all in-water drilling activities to closed systems and implementation of the AMMs identified above, potential water quality effects of geotechnical drilling activities would be limited to temporary, localized increases in turbidity, suspended sediment, and noise during barge operations (e.g., anchoring of barges) and drilling activities (e.g., installation and removal of conductor casings) that will dissipate rapidly and return to baseline levels shortly after cessation of daily activities. If present, any listed salmonids or green sturgeon that may be present during the in-water work period would likely be large, active adults and juveniles that are capable of avoiding such disturbances with minimal harassment or risk of injury (see Section 5.2.2.4.3). Evidence suggests that young-of-the-year juvenile green sturgeon overwinter in upstream reaches of the Sacramento River before entering the Delta; based on the size distribution of juveniles observed at the export facilities in the southern Delta, most juveniles that occur in the action area of the proposed water conveyance facilities would be older juveniles >100 mm in length. Therefore, effects on steelhead and green sturgeon will likely be limited to harassment in response to temporary, localized increases in turbidity, suspended sediment, and noise.

Geotechnical activities may affect the designated critical habitat of listed salmonids and green sturgeon through suspension and deposition of sediment or direct disturbance of channel sediments and benthic food resources at the drilling sites. However, these effects are expected to be insignificant based on the low intensity, brief duration, and small areas affected; avoidance of vegetation and other potential sources of cover and food for fish (e.g., instream woody debris); and the general low quality of rearing habitat for juvenile salmonids and green sturgeon at the proposed facilities (see 6.1.1.3, North Delta Intakes. 6.1.1.4, Barge Landings, 6.1.1.5, Head of Old River Gate, and 6.1.1.6, Clifton Court Forebay). Consequently, with implementation of the proposed in-water work window and AMMs, geotechnical exploration is not likely to adversely affect the designated critical habitat of listed salmonids or green sturgeon.

5.2.2 North Delta Intakes

5.2.2.1 Deconstruct the Action

Three intakes will be constructed on the east bank of the Sacramento River between Clarksburg and Courtland at river miles (RMs) 41.1, 39.4, and 36.8 (Intakes 2, 3, and 5) (Appendix 3.A *Map Book for the Proposed Action*). Each intake will divert a maximum of 3,000 cfs from the Sacramento River. Each intake consists of an intake structure fitted with on-bank fish screens;

gravity collector box conduits extending through the levee to convey flow to the sedimentation system; a sedimentation system consisting of sedimentation basins to capture sand-sized sediment and drying lagoons for sediment drying and consolidation; a sedimentation afterbay providing the transition from the sedimentation basins to a shaft that will discharge into a tunnel leading to the Intermediate Forebay; and an access road, parking area, electrical service, and fencing (as shown in Appendix 3.C *Conceptual Engineering Report*, Volume 2, Sheets 11, 12, and 13). Additional details on the intake design, construction methods, and proposed construction schedule are described in Chapter 3.

Construction of each intake is projected to take approximately 4 to 5 years. All in-water activities will be restricted to June 1-October 31 to minimize exposure of listed fish species to construction-related impacts on water quality and other hazards. Constructing each intake will involve installing a sheet pile cofferdam in the river during the first construction season, which will isolate the in-water work area during the remaining years of construction and become permanent components of the intake structure. Following closure of the cofferdam, fish rescue and salvage activities will be performed to collect any stranded fish and return them to the river. Dewatering of the cofferdam will be performed using a screened intake to prevent entrainment of fish. Water pumped from within the cofferdams will be treated (removing all sediment), using settling basins or Baker tanks, and returned to the river. After the cofferdams are dewatered, dredging, foundation pile driving, and other construction activities will proceed within the confines of the cofferdams.

Clearing and grading of the waterside slope of the levee will be required prior to installing the sheetpile cofferdam and rock slope protection (riprap), depending on site conditions (e.g., presence of vegetation). Following cofferdam installation, an excavator operated from a barge and/or the top of the levee would be used to install riprap on the adjacent levee slope to provide permanent erosion protection to the levee, cofferdam, and intake facility.

It is assumed that after the intakes are completed, the area in front of each intake will need to be dredged to provide appropriate flow conditions at the intake entrance. Preliminary estimates of these areas are provided in Appendix 5.H *Construction Effects Tables for Salmonids and Green Sturgeon*; these are only approximate and are based on preliminary geotechnical data. If required, the dredging will occur during the approved in-water work window and will be minimized to the extent practicable. It is also assumed that periodic maintenance dredging may be needed to maintain appropriate flow conditions during operation of the intakes.

Construction of the intake facilities would result in permanent and temporary impacts on habitat in the Sacramento River. It is currently estimated that 6.6 acres of tidal perennial habitat and 1.02 linear miles of channel margin habitat would be permanently replaced by the intake structures (including foundation piles), transition walls, and riprap (Table 3.4-1). Temporary impacts, including water quality impacts and disturbance of benthic habitat associated with dredging and other in-water construction activities, is estimated to affect approximately 20.1 acres of tidal perennial habitat. Temporary impacts on channel margin habitat occur within the same footprint as permanent impacts.

Construction activities that could potentially affect winter-run Chinook salmon, spring-run Chinook salmon, steelhead, and green sturgeon include cofferdam installation, levee clearing and grading, riprap placement, dredging, and barge operations. All other construction activities, including construction of the sedimentation basins, intermediate forebay, and associated facilities, will be isolated from the Sacramento River and not result in effects to listed fish species or aquatic habitat in the Sacramento River.

5.2.2.2 Turbidity and Suspended Sediment

Construction activities that disturb the riverbed and banks within the footprints of the north Delta intake facilities may temporarily increase turbidity and suspended sediment levels in the Sacramento River. These activities include cofferdam installation and removal, levee clearing and grading, riprap placement, dredging, and barge operations. Potential turbidity and sediment impacts on listed fish species and aquatic habitat will be minimized by restricting in-water construction activities to June 1 through October 31. In addition, DWR proposes to implement a number of AMMs to avoid or minimize potential turbidity, suspended sediment, and other water quality impacts on listed species and aquatic habitat: *Worker Awareness Training; Construction Best Management Practices and Monitoring; Stormwater Pollution Prevention Plan (SWPPP); Erosion and Sediment Control Plan; Spill Prevention, Containment, and Countermeasure Plan (SPCCP); Hazardous Material Management Plan (HMMP); Disposal and Reuse of Spoils, Reusable Tunnel Material, and Dredged Material; and Barge Operations Plan* (Appendix 3.F *General Avoidance and Minimization Measures*).

Construction-related turbidity and suspended sediment may occur during winter and spring due to increased erosion and mobilization of sediment in runoff from disturbed levee surfaces. However, with implementation of the proposed erosion and sediment control measures (AMM4) and other BMPs to ensure the effectiveness of these measures (*AMM2, Construction Best Management Practices and Monitoring*), the potential for adverse water quality effects outside the in-water construction window will be insignificant.

5.2.2.2.1 Assess Species Exposure

5.2.2.2.1.1 Salmonids

The Sacramento River is the primary migration route utilized by adult winter-run Chinook salmon, spring-run Chinook salmon, and steelhead to access upstream spawning areas in the Sacramento River basin, and the primary migration route for juveniles entering the Delta and estuary from upstream spawning and rearing areas. Restricting impact pile driving to June 1 to October 31 avoids the primary migration periods of winter- and spring-run adults and juveniles, and the primary migration period of steelhead juveniles in the action area. In some years, a small proportion of the total number of winter-run (adults) and spring-run Chinook salmon (adults and juveniles) and steelhead (juveniles) migrating through the action area may occur as late as June and July although water temperatures frequently exceed suitable ranges by late June or early July. Steelhead adults are more likely to be exposed to construction-generated turbidity and sedimentation based on the timing of upstream migration, which generally extends from late summer through fall in the lower Sacramento River (August through November with a peak in September-October). There is some potential for winter-run juveniles (less than 60 mm in length) to occur in the lower Sacramento River and Delta in October but this is uncommon; typically, the earliest that juveniles would be expected to occur in the action area is November or December (del Rosario et al. 2013).

5.2.2.2.1.2 Green Sturgeon

The in-water construction period (June 1–October 31) avoids the peak upstream migration period of green sturgeon (late February to early May) although migration through the Delta may extend through June or July. However, adults may be present in the Delta throughout the year; following their migration and spawning in upstream reaches (April through early July), adults may hold for several months and then migrate back downstream in the fall or winter or move out of the river quickly during spring and summer (Heublein et al. 2009). Juvenile green sturgeon may be present in the Delta year-round and therefore may occur in the action area during in-water construction activities. Evidence suggests that young-of-the-year juvenile green sturgeon overwinter in upstream reaches of the Sacramento River before entering the Delta where they continue to rear for up to three years before entering the ocean (Kynard et al. 2005).

5.2.2.2.2 Assess Species Response

5.2.2.2.2.1 Salmonids

Depending on the level of exposure, suspended sediment can cause lethal, sublethal, and behavioral effects in fish (Newcombe and Jensen 1996). For salmonids, elevated suspended sediment has been linked to a number of behavioral and physiological responses indicative of stress (gill flaring, coughing, avoidance, and increase in blood sugar levels) (Bisson and Bilby 1982; Sigler et al. 1984; Berg and Northcote 1985; Servizi and Martens 1992). High suspended sediment levels can clog gill tissues, interfering with respiration and increasing physiological stress. Very high levels can directly damage gill tissues, resulting in physical injury and even death.

Migrating adults have been reported to avoid high silt loads or cease migration when avoidance is not possible (Cordone and Kelley 1961, as cited in Bjornn and Reiser 1991). Bell (1991) cited a study in which adult salmon did not move in streams where the sediment concentration exceeded 4,000 milligrams per liter (mg/L) (because of a landslide). Juveniles tend to avoid streams that are chronically turbid (Bisson and Bilby 1982; Lloyd 1987) or move laterally or downstream to avoid turbidity plumes (Sigler et al. 1984; Lloyd 1987; Servizi and Martens 1992). Juvenile coho salmon have been reported to avoid turbidities exceeding 70 NTU (Bisson and Bilby 1982) and cease territorial behavior when exposed to a pulse of turbidity of 60 NTU (Berg 1982). Such behavior could result in displacement of juveniles from preferred habitat or protective cover, which may reduce growth and survival by affecting foraging success or increasing their susceptibility to predation.

Laboratory studies have demonstrated that chronic or prolonged exposure to high turbidity and suspended sediment levels can lead to reduced growth rates. For example, Sigler et al. (1984) found that juvenile coho salmon and steelhead trout exhibited reduced growth rates and higher emigration rates in turbid water (25–50 NTU) compared to clear water. Reduced growth rates generally have been attributed to an inability of fish to feed effectively in turbid water (Waters 1995). Chronic exposure to high turbidity and suspended sediment also may affect growth and survival by impairing respiratory function, reducing tolerance to disease and contaminants, and causing physiological stress (Waters 1995).

During cofferdam installation, levee clearing and grading, riprap placement, dredging, and barge operations, turbidity and suspended sediment levels in the river are anticipated to exceed ambient river levels in the immediate vicinity of these activities, creating turbidity plumes that may extend several hundred feet downstream of construction activities. NMFS (2008a) reviewed observations of turbidity plumes during installation of riprap for bank protection projects along the Sacramento River and concluded that visible plumes are expected to be limited to only a portion of the channel width, extend no more than 1,000 feet downstream, and dissipate within hours of cessation of in-water activities. Based on these observations, NMFS concluded that turbidity levels produced by such activities could disrupt normal feeding and sheltering behavior of salmonids (National Marine Fisheries Service 2008a).

Although specific thresholds associated with behavioral, sublethal, and lethal effects are not available, it can be reasonably assumed that the effects of proposed in-water construction activities on listed fish species will be limited to brief exposures and likely avoidance of elevated turbidity and suspended sediment based on the limited spatial and temporal extent of turbidity plumes and proximity of unaffected habitat in the action area. Dredging will likely generate the most continuous sources of elevated turbidity and sedimentation but will affect a relatively small portion of the channel during daylight hours only, resulting in only minor disruptions in migration, holding, and rearing behavior. Adult salmonids would be expected to readily avoid high turbidity and suspended sediment and move to adjacent holding areas or continue their migration in deeper, offshore portions of the channel. Because of their small size and reliance on shallower, nearshore waters and associated cover, displacement of juvenile salmonids from these areas could increase their vulnerability to predators, potentially increasing mortality. However, utilization of nearshore areas by juvenile salmon and steelhead is generally reduced by June and July because most juveniles are large, actively migrating smolts that are known to move rapidly through the Delta and estuary during their seaward migration (Williams 2006).

In addition to the water quality impacts discussed above, increases in sediment loads in the Sacramento River can bury river substrates that support important food organisms (benthic invertebrates) for juvenile salmonids and green sturgeon. The natural channel substrate in this portion of the Sacramento River is dominated by fine sediment (sand and silt) that is frequently disturbed by high flows and human activities (e.g., boat wakes). Although suspended sediment generated by construction activities would be expected to cause some sedimentation of the channel downstream of the construction sites, potential reductions in abundance or production of benthic invertebrates would not be expected to affect the availability of food or foraging habitat for salmonids because of the localized, temporary nature of the disturbance, and adaptations of the local invertebrate fauna to sediment disturbance.

5.2.2.2.2.2 Green Sturgeon

No specific information is available to evaluate the potential responses of green sturgeon to increased turbidity and suspended sediment. Green sturgeon may be affected in similar ways to salmonids but may be less sensitive to high turbidity when foraging because of their greater reliance on touch and electroreception (versus sight) to locate prey. However, green sturgeon are potentially more sensitive to sedimentation impacts on benthic invertebrate communities due to their benthic forging behavior and year-round presence in the Delta.

5.2.2.2.3 Assess Risk to Individuals

5.2.2.2.3.1 Salmonids

Increases in turbidity and suspended sediment levels during in-water construction activities will be temporary and localized, and unlikely to reach levels causing direct injury to anadromous salmonids. Juvenile salmonids, if holding or rearing in the affected areas, are likely to respond by avoiding or moving away from affected shoreline areas, disrupting normal activities and increasing their exposure to predators. Such disruptions are expected to be brief and unlikely to adversely affect the growth of individual salmonids. However, there could be minor losses due to increased predation mortality.

5.2.2.2.3.2 Green Sturgeon

Based on the expected responses of green sturgeon to construction-related increases in turbidity and suspended sediment levels, the potential effects of increased turbidity and suspended sediment during construction of the proposed intakes are considered insignificant. Although green sturgeon are more sensitive to reductions in benthic food resources, the small spatial and temporal scale of impacts on these food resources is unlikely to affect access to food resources and individual foraging success.

5.2.2.2.4 Assess Effects on Designated Critical Habitat

5.2.2.2.4.1 Salmonids

Increases in turbidity and suspended sediment levels during construction of the proposed intakes will affect the PBFs or essential physical and biological features of the designated critical habitat of winter-run Chinook salmon, spring-run Chinook salmon, and steelhead. Elevated turbidity and suspended sediment generated by in-water construction activities would primarily affect the physical and biological features of freshwater rearing habitat and migration corridors through temporary degradation of water quality, increases in exposure to mod-channel predators, and potential sedimentation of potential food-producing areas. These effects will have only a localized and temporary effect on critical habitat in the action area.

5.2.2.2.4.2 Green Sturgeon

Increases in turbidity and suspended sediment levels during construction of the proposed intakes will affect the PBFs of designated critical habitat for southern DPS green sturgeon. These effects would be limited to localized, temporary degradation of the physical and biological features of water quality and potential sedimentation of food-producing areas. No long-term or permanent effects on critical habitat are expected.

5.2.2.3 Contaminants

Construction of the north Delta intakes poses an exposure risk to listed fish species from potential spills of hazardous materials from construction equipment, barges and towing vessels, and other machinery, and from potential mobilization of contaminated sediment. The risk of accidental spills of contaminants and other hazardous materials will exist throughout the construction period but will be highest during in-water construction activities due to the proximity of construction activities to the Sacramento River.

5.2.2.3.1 Accidental Spills

Construction of the north Delta intakes could result in accidental spills of contaminants, including oil, fuel, hydraulic fluids, concrete, paint, and other construction-related materials, resulting in localized water quality degradation and potential adverse effects on listed fish species. Potential effects of contaminants on fish include direct injury and mortality (e.g., damage to gill tissue causing asphyxiation) or delayed effects on growth and survival (e.g., increased stress or reduced feeding), depending on the type of contaminant, extent of the spill, and exposure concentrations. The risk of such effects is highest during in-water construction activities, including cofferdam installation, levee grading and armoring, and barge operations, because of the proximity of construction equipment to the Sacramento River.

Implementation of Appendix 3.F *General Avoidance and Minimization Measures,* AMM 5 *Spill Prevention, Containment, and Countermeasure Plan* and AMM14 *Hazardous Materials Management* is expected to minimize the potential for contaminant spills and guide rapid and effective response in the case of inadvertent spills of hazardous materials. With implementation of these and other required construction BMPs (e.g., AMM 3 *Stormwater Pollution Prevention Plan*), the risk of contaminant spills or discharges to the Sacramento River from in-water or upland sources would be effectively minimized.

5.2.2.3.2 Disturbance of Contaminated Sediments

Contaminants may also enter the aquatic environment through disturbance, resuspension, or discharge of contaminated soil and sediments from construction sites. Sediments act as a sink or source of contaminant exposure depending on local hydrologic conditions, habitat type, and frequency of disturbance. Sediment is a major sink for more persistent chemicals that have been introduced into the aquatic environment, with most organic and inorganic anthropogenic chemicals and waste materials accumulating in sediment (Ingersoll 1995). Thus, resuspension of contaminated sediments may have adverse effects on fish that encounter sediment plumes or come into contact with deposited or newly exposed sediment. Suspended sediment can also adversely affect fish by causing localized increases in chemical oxygen demand in waters in or near plumes.

The proposed intake sites are downstream of the City of Sacramento where sediments have been affected by historical and current urban discharges from the city. No information on sediment contaminants at these sites is currently available. Metals, PCBs, and hydrocarbons (typically oil and grease) are common urban contaminants that are introduced to aquatic systems via nonpoint-source stormwater drainage, industrial discharges, and municipal wastewater discharges. Many of these contaminants readily adhere to sediment particles and tend to settle out of solution relatively close to the primary source of contaminants. PCBs are persistent, adsorb to soil and organic matter, and accumulate in the food web. Lead and other metals also will adhere to particulates and can bioaccumulate to levels sufficient to cause adverse biological effects. Mercury is also present in the Sacramento River system and could be sequestered in riverbed sediments. Hydrocarbons biodegrade over time in an aqueous environment and do not tend to bioaccumulate or persist in aquatic systems.

Dredging has the potential to release contaminants from disturbed sediments into the water column during construction and maintenance dredging at the proposed intakes. Current estimates indicate the total dredging and channel disturbance would affect 12.1 acres of the riverbed adjacent to the cofferdams at the north Delta intakes. Measured sediment plumes from hydraulic dredging operations (Hayes et al. 2000) suggest that less than 0.1% of disturbed sediments and associated contaminants would likely be re-suspended during cutterhead dredging operations. In sediments, only a small fraction of the total amount of heavy metals and organic contaminants is dissolved. In the case of heavy metals, releases during dredging may be largely due to the resuspension of fine particles from which the contaminants may be desorbed, and in the case of organic contaminants, most of the chemicals released into the dissolved phase would be expected to be bound to dissolved organic matter. Therefore, the potential release of contaminants from suspended sediment is expected to be limited because many of the chemical constituents preferentially adsorb or attach to organically enriched or fine particles of sediment.

The potential for introduction of contaminants from disturbed sediments will be addressed through the implementation of specific measures addressing containment, handling, storage, and disposal of contaminated sediments, as described under AMM6 *Disposal of Spoils, Reusable Tunnel Material, and Dredged Material* in Appendix 3.F *General Avoidance and Minimization Measures*. These measures include the preparation and implementation of a pre-construction sampling and analysis plan (SAP) to characterize contaminants and determine appropriate BMPs to minimize or avoid mobilization of contaminated sediments during in-water construction activities. Because potential mobilization of contaminants is closely linked to sediment disturbance and associated increases in turbidity and suspended sediment, turbidity monitoring and control measures (e.g., silt curtains) to achieve compliance with existing Basin Plan objectives will be an important measures for limiting dispersal of contaminated sediments during dredging and other in-water construction activities.

5.2.2.3.3 Assess Species Exposure

Exposure to contaminated sediments, either through direct exposure (e.g., swimming through plumes of resuspended sediment) or foraging on contaminated food sources, may be deleterious to endangered and threatened salmon, steelhead, and green sturgeon. Toxic compounds can be absorbed through dermal contact, ingestion, or uptake through the gills. Point sources where discharge occurs and hydraulic conditions drop suspended sediment in specific areas may create “hot spots” of contaminants, which may contain contaminant levels significantly higher than ambient water levels (EPA 1994). Prolonged exposure of fish and their prey organisms, either through external contact or ingestion of contaminated food sources, can also lead to adverse effects through bioaccumulation.

5.2.2.3.3.1 Salmonids

The potential for contaminant spills would exist throughout the construction period with the highest risk occurring during in-water construction activities. The proposed in-water work window (June 1-October 31) will avoid the peak winter and spring migration and rearing periods of anadromous salmonids. Based on the general timing of migration of adult and juveniles in the action area, in-water work activities could overlap with the occurrence of winter-run Chinook salmon and spring-run Chinook salmon adults in June (possibly July for spring-run Chinook salmon), spring-run Chinook salmon and steelhead juveniles in June, and steelhead adults from August through October. These exposures are expected to be brief because most juveniles and adults are actively migrating through the action area during these months. However, exposure to contaminants may occur at other times of the year due to potential exposure of newly exposed sediment that will remain after dredging is completed.

5.2.2.3.3.2 Green Sturgeon

The in-water construction period (June 1–October 31) will avoid the peak upstream migration period of green sturgeon (late February to early May) although adults may be present in the action area during their outmigration in summer, fall, and winter. Juvenile green sturgeon may be present in the Delta year-round and therefore subject to exposure to contaminants during in-water construction activities (June 1-October 31) as well as other times of the year when they may encounter newly exposed sediment. Compared to salmonids, green sturgeon are more likely to be exposed to contaminated sediments and food sources because of their relatively long residence time (3-4 years for rearing juveniles) and prolonged contact with sediment both externally (e.g., resting and foraging on the bottom) and through ingestion of benthic food organisms.

5.2.2.3.4 Assess Species Response

5.2.2.3.4.1 Salmonids

The potential effects of contaminants on fish generally range from physiological stress, potentially resulting in delayed effects on growth, survival, and reproductive success, to direct mortality (acute toxicity) depending on the concentration, toxicity, solubility, bioavailability, and duration of exposure, as well as the sensitivity of the species and life stage. Studies have shown that dredging contaminated sediments increases particulate-bound contaminants in waters next to or near to the dredge, producing deleterious effects on species that occupy those areas. (Bellas et al. 2007; Bocchetti et al. 2008; Engwall et al. 1998; Sundberg et al. 2007; Sturve et al. 2005; Yeager et al. 2010). Heavy metals (Cd, Cu, Hg, Ni, Pb, Zn, Ag, Cr, As) and organic contaminants (PAHs, PCBx, pesticides) are of most concern. Generally, toxic metal and pesticide contamination can cause acute toxicity in aquatic organisms (as seen in some first flush events in urban creeks and streams) which may result in death from high concentrations, or chronic (sublethal) effects which reduces the organism's health and may lessen survival over time. Increased levels of heavy metals are detrimental because they interfere with metabolic functions through inhibition of enzyme activity, decrease neurological function, degrade cardiovascular output, and can act as mutagens, teratogens, or carcinogens to organisms that are exposed to them (Rand et al. 1995; Goyer 1996). Charged particles (metals like copper) can also interfere with ion exchange channels in sensitive membranes or structures like gills or olfactory rosettes. Lipophilic compounds in fine sediment, such as toxic polyaromatic hydrocarbons (PAHs) can be absorbed through lipid membranes of gill tissue, providing a pathway for exposure if fish swim through a sediment plume. Exposure to PAHs and other aromatic compounds typical of petroleum hydrocarbon contamination from industry, spills, and engine exhausts was shown to suppress immune responses in Chinook salmon (Varanasi et al. 1993; Arkoosh et al. 1998, 2001). Dredge plumes may also cause short lived changes in dissolved oxygen (DO), pH, hydrogen sulfide (H_2S), and ammonia (NH_3).

Toxic substances used at construction sites, including gasoline, lubricants, and other petroleum-based products, can also enter the aquatic environment as a result of accidental spills or leakage from machinery or storage containers. These substances can kill aquatic organisms through exposure to lethal concentrations or chronic exposure to non-lethal levels that cause physiological stress and increased susceptibility to other sources of mortality. In addition to the direct effects of exposure described above, contaminants can enter the aquatic food web and accumulate in fish through their diet, leading to lethal and sublethal effects, including effects on behavior, tissues and organs, reproduction, growth, and immune system (Connon et al. 2009).

5.2.2.3.4.2 Green Sturgeon

The potential effects of contaminants and general exposure mechanisms described above are generally applicable to green sturgeon. However, green sturgeon are more likely to be exposed to contaminated sediments and food sources because of their benthic behavior, diet, and relatively long residence of juveniles in the Delta (3-4 years). In addition, the relatively high metabolic oxygen requirements of green sturgeon (Mayfield and Cech 2004) increases their susceptibility to reductions in dissolved oxygen levels in bottom waters caused by dredging, which can adversely affect blood circulation, nervous system responses, food digestion, and other physiological functions.

5.2.2.3.5 Assess Risk to Individuals

5.2.2.3.5.1 Salmonids

Implementation of the proposed *Spill Prevention, Containment, and Countermeasure Plan* (AMM 5), *Hazardous Materials Management* (AMM6), and *Stormwater Pollution Prevention Plan* (AMM3) are expected to minimize the potential for spills or discharges of contaminants into the Sacramento River during construction of the proposed intakes. Adherence to all preventative, response, and disposal measures in the approved plans are expected to reduce the potential effects to listed fish species to discountable levels. No information is available on potential contaminant risks associated with disturbance and exposure of sediments resulting from dredging and other construction activities at the intake construction sites. However, this risk is expected to be minimized by developing and implementing a SAP to characterize contaminants and determine appropriate BMPs to minimize or avoid mobilization of contaminated sediments during in-water construction activities. While some exposure of listed salmonids to sediment-borne contaminants may be unavoidable, these exposures are expected to be brief because of the limited aerial extent of in-water construction areas (pile driving, dredging, and barge operations), implementation of BMPs to limit the extent of sediment plumes originating from these areas, and the relatively short periods of time that juveniles and adults are likely to spend in the affected areas.

5.2.2.3.5.2 Green Sturgeon

The proposed AMMs to minimize the potential for spills or discharges of contaminants into the Sacramento River during construction of the proposed intakes are also expected to be protective of green sturgeon. Compared to salmonids, however, green sturgeon are considered to be at higher risk of exposure to contaminated sediments because of their benthic orientation, diet, and relatively long residence of juveniles in the Delta (3-4 years). Although in-water pile driving, dredging, and barge operations at the water conveyance facilities will disturb a small fraction of the potential habitat available to juveniles in the Delta, the potential for harm or mortality of some individuals from contaminant exposures may be magnified by their year-round presence (including the in-water construction period) and potential for exposure at multiple construction sites (north Delta intakes, barge landings, CCF, and HOR gate) during their residence in the Delta.

5.2.2.3.6 Assess Effects on Designated Critical Habitat

5.2.2.3.6.1 Salmonids

The potential release of contaminants through spills or sediment disturbance could affect the PBFs of designated critical habitat for listed salmonids through adverse effects on water quality and food resources (reduced abundance of benthic invertebrates and consumption of contaminated benthic invertebrates).

5.2.2.3.6.2 Green Sturgeon

The potential release of contaminants through spills or sediment disturbance could affect the PBFs of designated critical habitat for green sturgeon through adverse effects on water quality and food resources (reduced abundance of benthic invertebrates and consumption of contaminated benthic invertebrates).

5.2.2.4 Underwater Noise

During construction of the north Delta intakes, activities that are likely to generate underwater noise include pile driving, riprap placement, dredging, and barge operations. Pile driving poses the greatest risk to fish because the levels of underwater noise produced by impulsive types of sounds often reach levels of sufficient intensity to injure or kill fish within a certain radius of the source piles (Popper and Hastings 2009). Other activities such as riprap placement, dredging, and barge operations generally produce more continuous, lower energy sounds below the thresholds associated with direct injury but may cause avoidance behavior or temporary hearing loss or physiological stress if avoidance is not possible or exposure is prolonged (Popper and Hastings 2009).

During construction of the north Delta intakes, underwater noise levels of sufficient intensity to cause direct injury or mortality of fish could occur over a period of 12-42 days during the proposed in-water work period (June 1-October 31) for up to 2 years at each intake location. Restriction of pile driving activities to June 1-October 31 will avoid the primary migration seasons of adult winter-run Chinook salmon, spring-run Chinook salmon, and sturgeon, and the primary juvenile rearing and migration seasons of winter-run Chinook salmon, spring-run Chinook salmon, and steelhead. However, because of the potential occurrence of salmonids and green sturgeon (see below) during pile driving activities, DWR 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 fish species (Appendix 3.F *General Avoidance and Minimization Measures*, AMM9 *Underwater Sound Control and Abatement Plan*). These measures include the use of vibratory methods or other non-impact driving methods (e.g., drill-shaft methods) to install the cofferdam sheet piles and foundation piles. The degree to which vibratory and non-impact driving methods can be performed is uncertain at this time (due to uncertain geologic conditions at the proposed intake sites) although reasonable assumptions are applied to sheet pile installation in the following analysis. If impact pile driving is required, DWR, in coordination with the USFWS, NMFS, and CDFW, will evaluate the feasibility of other protective measures including dewatering, physical devices (e.g., bubble curtains), and operational measures (e.g., restricting pile driving to specific times of the day) to limit the intensity and duration of underwater noise levels when listed fish species may be present. Coordination, implementation, and monitoring of these measures will be performed in accordance with the underwater sound control and abatement plan, which includes hydroacoustic monitoring to determine compliance with established objectives (e.g., distances to cumulative noise thresholds) and corrective actions to be taken should the thresholds be exceeded. These measures may include additional physical or operational measures to further limit the magnitude and/or duration of underwater noise levels.

5.2.2.4.1 Assess Species Exposure

5.2.2.4.1.1 Salmonids

The Sacramento River is the primary migration route utilized by adult winter-run Chinook salmon, spring-run Chinook salmon, and steelhead to access upstream spawning areas in the Sacramento River basin, and the primary migration route for juveniles entering the Delta and estuary from upstream spawning and rearing areas. Restricting impact pile driving to June 1 to October 31 avoids the primary migration periods of winter- and spring-run adults and juveniles, and the primary migration period of steelhead juveniles in the action area. In some years, a small proportion of the total number of winter-run and spring-run Chinook salmon (adults and juveniles) and steelhead (juveniles) migrating through the action area may occur as late as June and July although water temperatures frequently exceed suitable ranges by late June or early July. Steelhead adults may be exposed to pile driving noise to a greater extent based on the timing of upstream migration, which generally extends from late summer through fall in the lower Sacramento River (August through November with a peak in September-October). There is some potential for winter-run juveniles (less than 60 mm in length) to occur in the lower Sacramento River and Delta in October but this is uncommon; typically, the earliest that juveniles would be expected to occur in the action area is November or December (del Rosario et al. 2013).

5.2.2.4.1.2 Green Sturgeon

The in-water construction period (June 1–October 31) will avoid the peak upstream migration period of green sturgeon (late February to early May) although post-spawning adults may encounter pile driving noise during their outmigration in summer and fall. Juvenile green sturgeon are present in the Delta year-round and are therefore subject to pile driving noise during the in-water construction period. Although the timing of their downstream movements is unknown, the risk of juveniles encountering pile driving noise during construction of the north Delta intakes is relatively high because this route serves as the primary migration route for juveniles entering the Delta from natal rearing areas in the upper Sacramento River.

5.2.2.4.2 Assess Species Response

5.2.2.4.2.1 Salmonids

Pile driving and other sources of anthropogenic noise have the potential to disrupt fish hearing and adversely affect fish through a broad range of behavioral, physiological, or physical effects (McCauley et al. 2003, Popper and Hastings 2009). These effects may include behavioral responses, physiological stress, temporary and permanent hearing loss, tissue damage (auditory and non-auditory), and direct mortality depending on the intensity and duration of exposure. In salmonids and most other teleost fish, the presence of a swim bladder to maintain buoyancy increases their vulnerability to direct physical injury (i.e., tissue and organ damage) from underwater noise (Hastings and Popper 2005). Underwater noise may also damage hearing organs that may temporarily affect hearing sensitivity, communication, and ability to detect predators or prey (Popper and Hastings 2009). Underwater noise may also cause behavioral effects (e.g., startle or avoidance responses) that can disrupt or alter normal activities (e.g., migration, holding, or feeding) or expose individuals to increased predation risk.

Pile driving noise has received increasing attention in recent years because of its potential to cause direct injury or mortality of fish and other aquatic animals. Factors that may influence the magnitude of effects include species, life stage, and size of fish; type and size of pile and hammer; frequency and duration of pile driving; site characteristics (e.g., depth); and distance of fish from the source. Dual interim criteria representing the acoustic thresholds associated with the onset of physiological effects in fish have been established to provide guidance for assessing the potential for injury resulting from pile driving noise (Fisheries Hydroacoustic Working Group 2008) (Table 5.2-1). The dual criteria for impact pile driving are (1) 206 decibels (dB) for peak sound pressure level (SPL); and (2) 187 dB for cumulative sound exposure level (SEL) for fish larger than 2 grams, and 183 dB SEL for fish smaller than 2 grams. The peak SPL threshold is considered the maximum sound pressure level a fish can receive from a single strike without injury. The cumulative SEL threshold is considered the total amount of acoustic energy that a fish can receive from single or multiple strikes without injury. The cumulative SEL threshold is based on the total daily exposure of a fish to noise from sources that are discontinuous (in this case, noise that occurs up to 12 hours a day, with 12 hours between exposures). This assumes that the fish is able to recover from any effects during this 12-hour period. These criteria relate to impact pile driving only. Vibratory pile driving is generally accepted as an effective measure for minimizing or eliminating the potential for injury of fish from pile driving operations.

Table 5.2-1. Interim Criteria for Injury to Fish from Pile Driving Activities.

Interim Criteria	Agreement in Principle
Peak Sound Pressure Level (SPL)	206 dB re: 1µPa (for all sizes of fish)
Cumulative Sound Exposure Level (SEL)	187 dB re: 1µPa^2-sec—for fish size ≥ 2 grams 183 dB re: 1µPa^2-sec—for fish size < 2 grams

In the following analysis, the potential for injury to fish from exposure to pile driving sounds was evaluated using a spreadsheet model developed by NMFS to calculate the distances from the pile that sound attenuates to the peak or cumulative criteria. These distances define the area in which the criteria are expected to be exceeded as a result of impact pile driving. The NMFS spreadsheet calculates these distances based on estimates of the single-strike sound levels for each pile type (measured at 10 meters from the pile) and the rate at which sound attenuates with distance. In the following analysis, the standard sound attenuation rate of 4.5 dB per doubling of distance was used in the absence of other data. To account for the exposure of fish to multiple pile driving strikes, the model computes a cumulative SEL for multiple strikes based on the single-strike SEL and the number of strikes per day or pile driving event. The NMFS spreadsheet also employs the concept of “effective quiet”. This assumes that cumulative exposure of fish to pile driving sounds of less than 150 dB SEL does not result in injury.

Insufficient data are currently available to support the establishment of a noise threshold for behavioral effects (Popper et al. 2006). NMFS generally assumes that a noise level of 150 dB root mean square (RMS) is an appropriate threshold for behavioral effects. NMFS acknowledges this uncertainty in other BiOps but believes this noise level is appropriate for identifying the potential for behavioral effects of pile driving sound on fish until new information indicates otherwise (e.g., National Marine Fisheries Service 2015).

5.2.2.4.2.2 Green Sturgeon

The interim criteria in Table 5.2-1 are assumed to be applicable to green sturgeon based on general similarities in anatomy and physiology (e.g., presence of a swim bladder) to other fishes for which data are available.

5.2.2.4.3 Assess Risk to Individuals

Table 5.2-2 presents the extent, timing, and duration of pile driving noise levels predicted to exceed the interim injury and behavioral thresholds based on application of the NMFS spreadsheet model and the assumptions presented in Appendix 3.E *Pile Driving Assumptions for the Proposed Action*. This analysis considers only those pile driving activities that could generate noise levels sufficient to exceed the interim injury thresholds in the Sacramento River or other waters potentially supporting listed fish species. These activities include impact pile driving in open water, in cofferdams adjacent to open water, or on land within 200 feet of open water. For cofferdam sheet piles, it is assumed that approximately 70% of the length of each pile can be driven using vibratory pile driving, with impact driving used to finalize pile placement. For the intake structure foundation piles, the current design assumes the use of impact pile driving only. However, some degree of attenuation is expected assuming that the cofferdams can be fully dewatered. Therefore, predictions are shown for two scenarios, one in which dewatering results in a 5 dB reduction in reference noise levels, and one in which no attenuation is possible (no dewatering or other forms of attenuation). All computed distances over which pile driving sounds are expected to exceed the injury and behavioral thresholds assume an unimpeded sound propagation path. However, site conditions such as major channel bends and other in-water structures can reduce these distances by impeding the propagation of underwater sound waves.

Table 5.2-2. Extent, Timing, and Duration of Pile Driving Noise Levels Predicted to Exceed the Interim Injury and Behavioral Thresholds at the North Delta Intake Sites

Facility or Structure	Distance to 206 dB SPL Injury Threshold (feet)	Distance to Cumulative 187 dB SEL Injury Threshold[1, 2] (feet)	Distance to 150 dB RMS Behavioral Threshold[2] (feet)	Construction Season	Timing of Pile Driving	Duration of Pile Driving (days)
Intake 2						
Cofferdam	30	2,814	13,058	Year 8	Jun–Oct	42
Foundation (no attenuation)	46	3,280	32,800	Year 9	Jun–Oct	19
Foundation (with attenuation)	20	1,522	15,226	Year 9	June-Oct	19
Intake 3						
Cofferdam	30	2,814	13,058	Year 7	Jun–Oct	42
Foundation (no attenuation)	46	3,280	32,800	Year 8	Jun–Oct	14
Foundation (with attenuation)	20	1,522	15,226	Year 8	June-Oct	14
Intake 5						
Cofferdam	30	2,814	13,058	Year 5	Jun–Oct	42
Foundation (no attenuation)	46	3,280	32,800	Year 6	Jun–Oct	19
Foundation (with attenuation)	20	1,522	15,226	Year 6	June-Oct	19

[1] Computed distances to injury thresholds are governed by the distance to "effective quiet" (150 dB SEL). Calculation assumes that single strike SELs <150 dB do not accumulate to cause injury. Accordingly, once the distance to the cumulative injury threshold exceeds the distance to effective quiet, increasing the number of strikes does not increase the presumed injury distance.

[2] Distance to injury and behavioral thresholds assume an attenuation rate of 4.5 dB per doubling of distance and an unimpeded propagation path; on-land pile driving, non-impact driving methods, dewatering of cofferdams, and the presence of major river bends or other channel features can impede sound propagation and limit the extent of underwater sounds exceeding the injury and behavioral thresholds.

Sound monitoring data collected during similar types of pile driving operations indicate that single-strike peak SPLs exceeding the interim injury thresholds are expected to be limited to areas within 30 feet of the cofferdam sheet piles and 20-46 feet of the intake foundation piles, depending on whether cofferdams can be dewatered (Table 5.2-2).

Based on a cumulative (daily) threshold of 187 dB SEL, the risk of injury is calculated to extend up to 5,628 feet (2,814 x 2) during installation of the cofferdams and 6,560 feet (3,280 x 2) during installation of the foundation piles (3,044 feet if the cofferdams can be dewatered) assuming an unimpeded propagation path.[3] The predictions in Table 5.2-2 apply to one intake location; the current construction schedule indicates that pile driving in a given year would occur at one intake only with the exception of Year 8 in which cofferdam installation at Intake 2 may

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[3] Based on the estimated number of pile strikes per day, the computed distances to the injury thresholds are governed by the distance to "effective quiet" (150 dB SEL).

coincide with foundation pile installation at intake 3 (Appendix 3.D *Construction Schedule for the Proposed Action*). In this case, there would be no overlap in the potential noise impact areas although fish migrating through the action area could be potentially exposed to pile driving noise over two reaches totaling 12,188 feet. Based on the duration of pile driving activities, such conditions could occur for up to 14 days based on the duration of foundation pile installation.

The potential for behavioral effects would extend beyond the distances associated with potential injury. Based on a threshold of 150 dB RMS, the potential for behavioral effects is calculated to extend up to 13,058 feet away during cofferdam sheet pile installation, and 32,800 feet away during intake foundation pile installation (15,226 feet away if the cofferdams can be dewatered) assuming an unimpeded propagation path. However, the extent of noise levels exceeding the injury and behavioral thresholds would be constrained to varying degrees by major channel bends that range from approximately 1,500 to 12,000 feet away from each intake facility.

For each intake facility, the current construction schedule indicates that cofferdam sheet piles would be installed over a period of 42 days at each intake location within the in-water construction season (June 1-October 31; August 1-September 30 if feasible) followed by installation of the intake foundation piles over a period of 14-19 days during the following season.

5.2.2.4.3.1 Salmonids

Pile driving noise may adversely affect adult and juvenile salmonids that are holding, migrating, or rearing near the intake sites. During pile driving activities, underwater noise levels sufficient to cause injury or mortality would extend across the entire width of the river and up to 3,280 feet away from the source piles. As previously discussed, exposure of salmonids to pile driving noise during the in-water construction period would be limited to a small proportion of adult and juvenile Chinook salmon and steelhead that may be migrating downstream through the action area in June and July, and to a larger proportion of adult steelhead that may begin their upstream migration in the Sacramento River in late summer and peak in abundance in early fall (September-October). Peak SPLs exceeding the injury criteria would be limited to small areas immediately adjacent to source piles (20–46 feet) and thus would affect 3-10% of the total channel width available for adults and juvenile to pass (see Appendix 3.E *Pile Driving Assumptions for the Proposed Action*). However, the potential for injury still exists because migrating adults and juveniles would be faced with passing through channel reaches of up to 6,560 feet long in which noise levels are predicted to exceed the cumulative injury thresholds. During the in-water construction period, most adults and juveniles that are likely to encounter pile driving noise would be actively migrating through the affected reaches, thus minimizing the duration of their exposure to underwater noise levels sufficient in intensity to cause injury or mortality. At the maximum cruising speeds reported for adult Chinook salmon and steelhead (up to 4 feet per second, respectively [Bell 1986]), adults would be able to swim through reaches up to 6,560 feet long in less than one hour and thus avoid cumulative exposures associated with potential injury. Published and unpublished data from telemetry studies of acoustic-tagged young-of-year and yearling smolts (80-170 mm fork length) also indicate rapid downstream migration rates, ranging from approximately 9 to 29 miles per day for fish released at upstream locations and detected leaving the Delta (Michel et al. 2012; Jason Hassrick, personal communication).

As noted above, pile-driving noise can disrupt or alter the behavior of fish, resulting in adverse effects on survival, growth, and reproductive success. For migrating salmonids, pile driving noise can potentially delay or block migrations or result in avoidance responses that could increase their exposure to other stressors such as elevated water temperatures, predators, or increased metabolic demands associated with prolonged delays. Based on a threshold of 150 dB RMS, the potential for behavioral effects is predicted to extend up to 13,058 feet away during cofferdam sheet pile installation and 32,800 feet away during intake foundation pile installation (15,226 feet away if the cofferdams can be dewatered) assuming an unimpeded propagation path. While evidence suggests that pile-driving operations may disrupt normal migratory behavior in salmonids (Feist et al. 1996), the risk of adverse effects associated with such delays is expected to be low because of the rapid migration rates of juveniles and adults expected to occur in the action area at the time of pile driving, and daily opportunities for juveniles and adults to pass the affected areas at night (dusk to dawn) when pile driving activities will cease. Nevertheless, juvenile salmonids that may be holding, sheltering, or feeding in these areas following initiation of pile driving activities each day may be forced to leave protective cover or exhibit alarm responses that could make them more vulnerable to predators.

Although the potential exists for injury or mortality of listed salmonids to occur at the north Delta intake sites due to pile driving noise, several actions are proposed to minimize this risk. Restriction of pile driving activities to June 1 through October 31 will avoid the primary rearing periods for anadromous salmonids in the lower Sacramento River, which is considered the most sensitive life stage to pile driving noise. The extent to which vibratory and other non-impact pile driving methods (e.g., drilling) will be used is unknown at this time but would be expected to substantially reduce the extent, intensity, and duration of pile driving noise potentially encountered by listed fish species. Furthermore, implementation of *AMM9 Underwater Sound Control and Abatement Plan* includes the use of a number of coordination, mitigation, and monitoring measures to avoid and minimize potential impacts on listed fish species, including 1) coordination with NMFS, USFWS, and CDFW during the design process to communicate any changes in proposed pile driving methods as updated design and geotechnical information becomes available; 2) potential use of a number of physical attenuation devices, including pile caps, bubble curtains, air-filled fabric barriers, and isolation piles; 3) implementation of hydroacoustic monitoring and operational protocols to maintain pile driving noise levels within specified limits; 4) monitoring the in-water work area for stressed or injured fish and temporarily stopping work to determine appropriate actions if stressed or injured fish are observed; 5) initiating impact pile driving with a “soft-start” to provide fish an opportunity to move away from the area before the standard force is applied; and 6) managing the timing and duration of daily pile driving operations, including operation of multiple pile drivers, to provide opportunities for fish to pass or leave the affected areas with minimal exposure to potentially harmful noise levels.

5.2.2.4.3.2 Green Sturgeon

As discussed above, green sturgeon may be exposed to pile driving noise as adults during their downriver migration from spawning areas in the summer and fall, and as juveniles during their 3-4-year residence period in the Delta. Factors that may limit exposure of green sturgeon to the direct effects of pile driving noise at the north Delta intakes include an avoidance response to pile driving noise, as observed for Atlantic salmon (Krebs et al. 2016; see below), and the rapid migration rate of adults through the action area; recent telemetry studies indicate that adult green sturgeon migrate rapidly to and from spawning areas in the upper Sacramento River, traversing the lower Sacramento River and estuary in less than one week (Heublein et al. 2009); tag detections at Knights Landing (RM 145) and Rio Vista Bridge (RM 21) equated to average migration rates of 1-3 miles per hour (1.5-4.4 feet per second) for summer and fall outmigrants. Kelly and Klimley (2011) studied movements of adult green sturgeon in San Francisco Bay and reported an average swimming speed of 1.6-2 feet per second and a maximum recorded speed of 7 feet per second. The lower range of these swimming speeds are generally in the range of sustained swimming speeds reported for other sturgeon species (e.g., Peake 2006). At these swimming speeds, green sturgeon adults would be able to pass through the potential impact reaches (pile driving noise exceeding the cumulative threshold of 187 dB are predicted to extend 5,628 feet for cofferdam sheet piles and 3,044-6,560 feet for intake foundation piles) in 1.2 hours or less and thus avoid exposures associated with potential injury.

The potential for injury and mortality is higher for juvenile green sturgeon because of their year-round presence in the Delta and potential for encountering pile driving noise at multiple locations during their 3-4 residence period. Juveniles may be at higher risk of exposure in the north Delta because of their need to pass through this region during their downstream movement to estuarine rearing areas. The timing of these movements are unknown but could overlap with the proposed in-water construction period. Factors that may limit exposure of juveniles to pile driving noise include the relatively large size of juveniles residing in the Delta. Based on the size distribution of juveniles observed at the export facilities in the southern Delta, most juveniles potentially encountering pile driving noise at the proposed intakes would be actively swimming juveniles (>100 mm in length) capable of avoiding or swimming away from areas of elevated noise. Although no data are available for green sturgeon, monitoring of acoustically-tagged Atlantic sturgeon (*Acipenser oxyrhinchus*) in the immediate vicinity of test pile locations in the Hudson River indicated that sturgeon avoided these areas during active pile driving (impact driving of 1.2-, 2.4-, and 3.0-meter steel piles), and did not remain long enough in these areas to be exposed to cumulative levels of noise sufficient to cause physiological effects (Krebs et al. 2016). Such behavior may disrupt or delay the movements of juveniles attempting to move through the affected reaches although opportunities to pass will occur at night (dusk to dawn) when pile driving activities will cease.

NMFS has also expressed concern about the potential for adverse effects of noise from tunnel boring (TBM) operations on listed fish species in the Delta, noting that green sturgeon may be especially sensitive. Tunnel boring operations can generate groundborne vibrations and noise that may be detected by sturgeon and other fishes living on the bed or in the water column above active tunneling operations. There are no studies that specifically relate groundborne vibration to resulting underwater sound pressure levels, but the levels associated with tunnel boring operations are likely comparable to those produced by vibratory driving, boats, and other sources of continuous sounds. These sounds are not expected to exceed thresholds associated with injury or mortality although behavioral effects may occur. However, in Atlantic sturgeon, Krebs et al. (2016) found no evidence of an avoidance response to vibratory driving. Assuming this observation is generally applicable to green sturgeon, tunnel boring noise is not likely to adversely affect green sturgeon.

5.2.2.4.4 Assess Effects on Designated Critical Habitat

5.2.2.4.4.1 Salmonids

Underwater noise levels from pile driving and other construction activities will affect the designated critical habitat of winter-run Chinook salmon, spring-run Chinook salmon, and steelhead through temporary degradation of the PBFs of migratory habitat (i.e., unobstructed migratory pathways). Adverse effects on critical habitat would occur within areas subjected to noise levels associated with potential injury and behavioral effects, as described above. Underwater noise levels of sufficient intensity to cause direct injury or mortality of fish could occur over a period of 12-42 days during the proposed in-water work period (June 1-October 31) over a 2-year period at each intake location. Underwater noise levels will return to baseline levels following cessation of pile driving and other construction activities, and would not result in long-term impacts on critical habitat.

5.2.2.4.4.2 Green Sturgeon

The effects of underwater noise on the designated critical habitat of green sturgeon would be similar to that described for salmonids.

5.2.2.5 Fish Stranding

Installation of cofferdams in the Sacramento River has the potential to strand and subject fish to direct exposure to dewatering and other construction activities within the enclosed cofferdams. Sheet pile installation will be limited to the proposed in-water construction period (June 1-October 31) to avoid the peak abundance of listed fish species in the action area. When listed fish species may be present, DWR proposes to minimize potential stranding losses by implementing a fish rescue and salvage plan (Appendix 3.F *General Avoidance and Minimization Measures, AMM 8 Fish Rescue and Salvage Plan*). This plan will be submitted to the fish and wildlife agencies (NMFS, USFWS, CDFW) for review and approval prior to implementation. The plan will include detailed procedures for fish rescue and salvage, including collection, holding, handling, and release, that would apply to all in-water activities with the potential to strand fish. All fish rescue and salvage operations will be conducted under the guidance of a qualified fish biologist. The biologist, in consultation with a designated agency biologist, will determine the appropriate fish collection and relocation methods based on site-specific conditions and construction methods. For example, collection methods will likely vary depending on whether or to what extent (water depth) dewatering can be achieved.

5.2.2.5.1 Assess Species Exposure

5.2.2.5.1.1 Salmonids

Restriction of cofferdam construction and other in-water activities to June 1-October 31will avoid the primary migration and rearing periods of anadromous salmonids. Based on the general timing of migration of adult and juveniles in the action area, the potential for exposure of juvenile salmon and steelhead is relatively low. A higher risk of exposure exists for adult steelhead, especially in September and October when migration typically peaks in the Sacramento River.

5.2.2.5.1.2 Green Sturgeon

The in-water construction period (June 1–October 31) will avoid the peak upstream migration period of green sturgeon (late February to early May) although adults (including post-spawning adults) and rearing juveniles may be present in the Delta year-round and therefore subject to stranding during the proposed in-water construction period.

5.2.2.5.2 Assess Species Response

5.2.2.5.2.1 Salmonids

Most Chinook salmon and steelhead that are likely to be present in the action area at the time of cofferdam installation are likely to be large, migrating adults and juveniles that would be expected to avoid or move away from active construction areas, minimizing their risk of being stranded. Although present in low numbers, smaller, rearing juveniles would be at a higher risk of entrapment. Any stranded fish may experience stress and potential mortality in response to poor water quality (e.g., low dissolved oxygen) and would ultimately die as a result of dewatering or injuries caused by dredging or pile driving within the enclosed cofferdam.

5.2.2.5.2.2 Green Sturgeon

No specific information is available to evaluate the potential responses of green sturgeon to construction activities or their susceptibility to being stranded in cofferdams. However, most green sturgeon that are likely to be present in the action area at the time of cofferdam installation would be relatively large, highly mobile adults and juveniles that are capable of readily avoiding active construction areas.

5.2.2.5.3 Assess Risk to Individuals

5.2.2.5.3.1 Salmonids

With the implementation of a fish rescue and salvage plan (AMM8), the likelihood of stranding and subsequent injury or mortality of individual salmonids would be low. Although proposed fish rescue and salvage activities are expected to minimize these risks, some losses may still occur because of varying degrees of effectiveness of the collection methods and potential injury or mortality associated with capture, handling, and relocation of fish (Kelsch and Shields 1996, Reynolds 1996).

5.2.2.5.3.2 Green Sturgeon

The potential for injury or mortality of green sturgeon from stranding and fish rescue and salvage activities would be similar to that described for salmonids. Because of differences in size, behavior, and morphology of green sturgeon, alternative methods may be required to rescue and relocate any stranded individuals.

5.2.2.5.4 Assess Effects on Designated Critical Habitat

5.2.2.5.4.1 Salmonids

The potential for stranding during in-water construction activities would have a temporary adverse effect on the PBFs of the designated critical habitat of listed salmonids (e.g., safe and unobstructed migratory corridors).

5.2.2.5.4.2 Green Sturgeon

The potential for stranding during in-water construction activities would have a temporary adverse effect on the PBFs of the designated critical habitat of green sturgeon (safe and unobstructed migratory corridors).

5.2.2.6 Direct Physical Injury

During construction of the north Delta intakes, fish could be injured or killed by direct contact with equipment or materials that enter or operate within the open waters of the Sacramento River. Potential mechanisms include fish being crushed by falling rock (riprap), impinged by sheetpiles, entrained by dredges, or struck by propellers. In addition to the proposed work window (June 1-October 31), the potential for injury of listed fish species would be minimized to the extent practicable by limiting the duration of in-water construction activities and implementing the AMMs described in Appendix 3.F *General Avoidance and Minimization Measures*. Applicable AMMs include *Worker Awareness Training; Erosion and Sediment Control Plan; Disposal of Spoils, Reusable Tunnel Material, and Dredged Material; Barge Operations Plan; and Fish Rescue and Salvage Plan*.

5.2.2.6.1 Assess Species Exposure

5.2.2.6.1.1 Salmonids

Restriction of in-water activities to June 1-October 31 will avoid the primary migration and rearing periods of anadromous salmonids. Based on the general timing of migration of adult and juveniles in the action area, the potential for exposure for most species and life stages would be June and July although steelhead adults may also be present from August through October.

5.2.2.6.1.2 Green Sturgeon

Restriction of in-water activities to June 1-October 31 will avoid the peak upstream migration period of green sturgeon (late February to early May). However, a relatively high potential for exposure exists for adults (including post-spawning adults) and rearing juveniles that may be present in the Delta year-round and therefore subject to injury during the proposed in-water construction period.

5.2.2.6.2 Assess Species Response

5.2.2.6.2.1 Salmonids

As described above, most Chinook salmon and steelhead that are likely to be present in the action area during in-water construction activities are likely to be large, migrating adults and juveniles that would be expected to avoid or move away from active construction areas.

5.2.2.6.2.2 Green Sturgeon

Similarly, most green sturgeon that are likely to occur in the action area during in-water construction activities would be adults and large juveniles that are capable of avoiding active construction areas.

5.2.2.6.3 Assess Risk to Individuals

5.2.2.6.3.1 Salmonids

There is a low risk of injury or mortality of salmonids based on the likely response to active construction activities (See 5.2.2.4.3.1).

5.2.2.6.3.2 Green Sturgeon

There is a low risk of injury or mortality of green sturgeon based on the likely response to active construction activities.

5.2.2.6.4 Assess Effects on Designated Critical Habitat

5.2.2.6.4.1 Salmonids

The potential for injury during in-water construction activities would have a temporary adverse effect on the PBFs of the designated critical habitat of listed salmonids (safe and unobstructed migratory corridors).

5.2.2.6.4.2 Green Sturgeon

The potential for injury during in-water construction activities would have a temporary adverse effect on the PBFs of the designated critical habitat of listed salmonids (safe and unobstructed migratory corridors).

5.2.2.7 Loss/Alteration of Habitat

Construction of the proposed intake facilities would result in temporary to permanent losses or alteration of aquatic habitat on the Sacramento River. Temporary effects of construction activities on water quality, including turbidity and suspended sediment, underwater noise, and contaminants, were previously discussed. The following analysis focuses on longer-term to permanent losses or alteration of habitat associated with construction activities. These impacts total approximately 20.1 acres of tidal perennial habitat and 1.02 linear miles of channel margin habitat that encompass the in-water work areas and permanent footprints of intake structures. The footprint of each intake structure, including cofferdams, transition wall structures, and bank protection (riprap), would result in the permanent loss of approximately 6.6 acres of tidal perennial habitat and 1.02 linear miles of shoreline and associated riparian vegetation. At each intake location, these structures would encompass 1,600-2,000 linear feet of shoreline and 35 feet (5-7%) of the total channel width.

During construction activities, DWR will implement *AMM2 Construction Best Management Practices and Monitoring*, to protect listed fish, wildlife, and plant species, their designated critical habitat, and other sensitive natural communities (Appendix 3.F *General Avoidance and Minimization Measures*). These BMPs include a number of measures to limit the extent of disturbance of aquatic and riparian habitat during construction, and, following construction, to restore temporarily disturbed areas to pre-construction conditions. All construction and site restoration BMPs will be subject to an approved construction and post-construction monitoring plan to ensure their effectiveness.

DWR proposes to offset unavoidable impacts to the designated critical habitat of winter-run Chinook salmon, spring-run Chinook salmon, steelhead, and green sturgeon through restoration of tidal marsh and channel margin habitat (SRA cover) at an approved restoration site or the purchase of conservation credits at an approved conservation bank.

5.2.2.7.1 Assess Species Exposure

5.2.2.7.1.1 Salmonids

All migrating and/or rearing salmonids that occur in the action area during construction of the intake facilities would be potentially exposed to the physical alteration of channel margin habitat (i.e., changes in water depths, velocities, substrate, and cover conditions) and permanent losses of aquatic habitat within the footprints of the intake structures.

5.2.2.7.1.2 Green Sturgeon

All migrating and/or rearing green sturgeon that occur in the action area during construction of the intake facilities would be potentially exposed to the physical alteration of channel margin habitat (i.e., changes in water depths, velocities, substrate, and cover conditions) and permanent losses of aquatic habitat within the footprints of the intake structures.

5.2.2.7.2 Assess Species Response

5.2.2.7.2.1 Salmonids

The leveed, channelized reaches of the Sacramento River near the proposed intakes primarily function as a migration corridor for adult and juvenile salmonids. The PBFs of migration and rearing habitat for salmonids have been degraded from historical conditions, and are unlikely to support high densities of juvenile salmonids. The temporary and permanent footprints of the intake facilities are characterized by steep, riprap-armored levee slopes with low quantities of overhanging and instream woody cover. Vegetation densities are low and much of the levee slope is unshaded. About 98% of the shoreline has less than 25% overhead cover (primarily from overhanging vegetation), and about 23% of the shoreline has less than 5% overhead cover. Shallow water is limited to a narrow band along the steep levee slope and there is no off-channel or floodplain habitat.

During and following construction, no significant changes would be expected in passage conditions (water depths and velocities) for adults because of their use of deeper, offshore portions of the channel for holding and migration. Some reduction is expected in the quality of rearing and passage conditions for juveniles due to permanent losses of shallow water habitat, the structural and hydraulic changes associated with the presence of cofferdams and riprap, and removal of vegetation within the temporary and permanent footprints of the intake.

5.2.2.7.2.2 Green Sturgeon

The leveed, channelized reaches of the Sacramento River near the proposed intakes primarily function as a migration corridor for adult green sturgeon migrating to upstream spawning areas, post-spawning adults migrating downstream from spawning areas, and juveniles migrating downstream to the estuary. Potential impacts would be limited to potential reductions in low-quality foraging habitat (nearshore benthic habitat) for green sturgeon within the temporary and permanent footprints of the intakes.

5.2.2.7.3 Assess Risk to Individuals

5.2.2.7.3.1 Salmonids

Temporary and permanent losses or alteration of habitat at the proposed intake sites are expected to have insignificant effects on migrating adult salmonids; passage conditions for adults would remain unobstructed during and following the construction of the intake facilities. Although the proposed locations of the intakes currently provide low quality rearing habitat for juvenile salmonids, construction of the intakes would further degrade this habitat by eliminating shallow water habitat and adversely affecting associated rearing and refuge functions, including protection from predatory fish that occupy deeper offshore waters of the Sacramento River. In addition, cofferdams, riprap, and other artificial structures provide physical and hydraulic conditions that may attract certain predatory fish species (e.g., striped bass, largemouth bass, Sacramento pikeminnow) and potentially increase their ability to ambush juvenile salmonids and other fishes.

5.2.2.7.3.2 Green Sturgeon

Based on the largely migratory function of the channel reaches near the intake facilities, construction of the intake facilities is unlikely to adversely affect passage conditions or foraging habitat of adult and juvenile green sturgeon. The loss or alteration of potential foraging habitat within the temporary and permanent footprints of the intake facilities is unlikely to have a measurable effect on growth and survival of individuals because it represents a very small proportion of the total amount of habitat available to adults and juveniles during their residence in the Delta and estuary.

5.2.2.7.4 Assess Effects on Designated Critical Habitat

5.2.2.7.4.1 Salmonids

Impacts to the designated critical habitat of listed salmonids include temporary and permanent impacts on juvenile rearing and migration habitat, as described above. DWR proposes to offset impacts to the designated critical habitat of winter-run Chinook salmon, spring-run Chinook salmon, and steelhead through restoration of tidal perennial habitat and channel margin habitat at an approved restoration site and/or the purchase of conservation credits at an approved conservation bank (Table 3.4-1).

5.2.2.7.4.2 Green Sturgeon

Impacts to the designated critical habitat of southern DPS green sturgeon include temporary and permanent impacts on adult migration and juvenile rearing and migration habitat, as described above. DWR proposes to offset impacts to the designated critical habitat of green sturgeon through restoration of tidal perennial habitat at an approved restoration site and/or the purchase of conservation credits at an approved conservation bank (Table 3.4-1).

5.2.3 Barge Landings

5.2.3.1 Deconstruct the Action

Barge landings will be constructed at each of the TBM launch shaft sites for the loading and unloading of construction equipment, materials, fill, and tunnel spoils. A total of seven barge landings are currently proposed (Appendix 3.A *Map Book for the* Proposed Action) at the following locations:

- Snodgrass Slough north of Twin Cities Road (adjacent to proposed intermediate forebay)
- Little Potato Slough (Bouldin Island south)
- San Joaquin River (Venice Island south)
- San Joaquin River (Mandeville Island east at junction with Middle River)
- Middle River (Bacon Island north)
- Middle River (Victoria Island northwest)
- Old River (junction with West Canal at Clifton Court Forebay)

These locations are approximate but represent the general areas for these facilities based on their proximity to the launch shaft sites. Barge docks may also be needed, at contractors' discretion, at the Intake 3 and Intake 5 construction sites at the Staten Island TBM retrieval shaft, and at the Banks and Jones Connections construction sites. Additional details on the design, construction methods, and proposed construction schedule for the barge landings are described in Chapter 3.

Major construction elements of this action include barge landing construction, levee clearing and armoring (as necessary), and barge operations. The barge landings will be constructed over a period of 2 years. The specific design of the barge landings is unknown at this time. Docks supported by steel piles are currently proposed although floating barges will be used where possible to minimize in-water construction activities. Docks would each occupy an overwater area of approximately 300 by 50 feet (0.34 acre) spanning 5-9% of the total channel widths at the proposed locations. Some clearing and armoring of the levee may be required to provide access and protect the levee from wave erosion; such effects are included within the footprint estimate (30 acres total) for barge landings.

Following construction, these facilities will operate for 5-6 years serving the TBM launch and retrieval sites as well as other construction sites as needed. During construction of the tunnels and other water conveyance facilities, it is projected that up to 15,000 barge trips may be added to the daily vessel traffic in the action area. If these trips are divided evenly among the 7 proposed barge landings and spread over the number of days for 5.5 years, this corresponds conservatively to an average of 7.5 barge trips per day (1.1 per landing). To protect aquatic habitat and listed fish species, the barge operations plan (AMM7) will require barges and towing vessels to comply with standard navigation and operating rules to avoid or minimize physical disturbances and water quality impacts in the navigable waterways of the Delta. Where avoidance is not possible, the plan will include provisions to minimize effects as described in Appendix 3.F *General Avoidance and Minimization Measures*, Section 3.F.2.7.4 *Environmental Training* and Section 3.F.2.7.5 *Dock Approach and Departure Protocol*.

Construction of the barge landings would result in temporary impacts on water quality and permanent impacts on physical habitat within the footprints of the barge landings. The barge docks will affect a total of approximately 22.4 acres of tidal perennial habitat that includes the in-water work areas and docks, piers, and mooring structures. Each dock will be in use for the duration of construction activities (5-6 years) at the TBM shaft sites and other construction sites (e.g., north Delta intakes) as needed, and will be removed at the completion of construction. All piles will either be removed or cut at the mudline.

5.2.3.2 Turbidity and Sedimentation

Pile driving, riprap placement, and barge operations will be the principal sources of turbidity and suspended sediment during construction of the barge landings. These activities will result in disturbance of the channel bed and banks, resulting in periodic increases in turbidity and suspended sediment in the adjacent waterways. Barge operations will have temporary effects on turbidity and suspended sediment at the barge landings as well as along the routes that will be used to transport construction materials between the barge landings and existing commercial ports in the Delta and estuary.

Potential turbidity and sediment impacts on listed fish species and aquatic habitat will be minimized by restricting in-water construction activities to August 1 through October 31 at most locations[4]. In addition, DWR proposes to develop and implement a *Barge Operations Plan*, which includes specific measures to minimize bed scour, bank erosion, loss of submerged and emergent vegetation, and disturbance of benthic communities (Appendix 3.F *General Avoidance and Minimization Measures*). Other AMMs that are proposed to avoid or minimize potential turbidity, suspended sediment, and other water quality impacts include *Worker Awareness Training; Construction Best Management Practices and Monitoring; Stormwater Pollution Prevention Plan (SWPPP); Erosion and Sediment Control Plan; Spill Prevention, Containment, and Countermeasure Plan (SPCCP); Hazardous Material Management Plan; and Disposal and Reuse of Spoils, Reusable Tunnel Material, and Dredged Material* (Appendix 3.F *General Avoidance and Minimization Measures*).

Some potential exists for construction-related turbidity and suspended sediment to occur during winter and spring due to increased erosion and mobilization of sediment in runoff from disturbed levee surfaces. However, with implementation of the proposed erosion and sediment control measures (AMM4) and other BMPs to ensure the effectiveness of these measures (*AMM2, Construction Best Management Practices and Monitoring*), no adverse water quality effects are anticipated outside of the in-water construction season.

5.2.3.2.1 Assess Species Exposure

5.2.3.2.1.1 Salmonids

The proposed timing of in-water construction activities at the barge landings (August through October) avoids the peak winter and spring migration and rearing periods of listed salmonids in the Delta. However, this period overlaps with the upstream migration of adult steelhead, which may enter the Delta in late summer (August-September) and peak in abundance in the fall and winter months in the Sacramento and San Joaquin River (September through January).[5] Following construction, these facilities will be operated year-round as needed to serve the TBM launch sites and other construction sites. Consequently, the potential exists for exposure of listed salmonids to potential physical disturbances, noise, and water quality effects of barge operations at all times of the year.

5.2.3.2.1.2 Green Sturgeon

The in-water construction period (August 1–October 31) will avoid the peak upstream migration period of green sturgeon (late February to early May) although adults (post-spawning adults), subadults, and rearing juveniles may be present in the Delta year-round and therefore potentially exposed to increases in turbidity and suspended sediment during the in-water construction period and year-round barge operations.

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[4] In-water construction activities at the north Delta intakes (Intake 3 and 5) and CCF, which may include barge landings, will be conducted June 1-October 31 and July 1-November 30, respectively.

[5] See section 5.2.2.2.1 for potential exposure of listed fish species at the north Delta intakes.

5.2.3.2.2 Assess Species Response

5.2.3.2.2.1 Salmonids

Based on the timing of in-water construction activities, adult steelhead may encounter localized increases in turbidity and suspended sediment at the barge landings during pile driving, riprap placement, and barge operations. Increases in nearshore turbidity and suspended sediment levels are also expected along the barge routes used to transport construction materials between the barge landings and commercial ports in the Delta and estuary.

As described in Section 5.2.2.2.2.1 *Salmonids*, turbidity and suspended sediment levels that are likely to be generated by these activities are not expected to reach levels that would cause direct injury to listed salmonids. Increases in nearshore turbidity and suspended sediment levels from waves generated by passing tug boats and barges are expected by short lived and infrequent based on the average increase of 7.5 trips per day throughout the entire action area. With implementation of the proposed AMMs to avoid or minimize potential turbidity, suspended sediment, and other water quality impacts (see section 5.2.3.3, *Contaminants*) on listed species and aquatic habitat, these activities are expected to result in temporary, localized increases in turbidity and suspended sediment levels that dissipate rapidly with distance from the source and return to baseline levels following cessation of activities. The effects on adult steelhead would likely be limited to harassment of individuals that encounter turbidity plumes.

5.2.3.2.2.2 Green Sturgeon

No specific information is available to evaluate the potential responses of green sturgeon to increased turbidity and suspended sediment. Green sturgeon may be affected in similar ways to salmonids but may be less sensitive to high turbidity when foraging because of their greater reliance on touch and electroreception (versus sight) to locate prey. However, green sturgeon are potentially more sensitive to the effects of barge operations on benthic invertebrate communities because of their benthic foraging behavior. Wave erosion and deposition of resuspended sediment in nearshore areas from barges and tug boats operating at the barge landings or along the barge routes can reduce food availability by dislodging or burying benthic substrates.

5.2.3.2.3 Assess Risk to Individuals

5.2.3.2.3.1 Salmonids

Increases in turbidity and suspended sediment levels during in-water construction activities at the barge landings will be temporary and localized, and unlikely to reach levels causing direct injury to anadromous salmonids. Because of the temporary, localized nature of elevated turbidity and suspended sediment, any disruptions of the normal behavior are expected to be brief and have insignificant effects on individual salmonids.

5.2.3.2.3.2 Green Sturgeon

Based on their large sizes, mobility, and benthic feeding adaptations, green sturgeon are unlikely to be affected by increases in turbidity and suspended sediment during construction of the .barge landings. Potential effects on food availability at the barge landings and along the barge routes are unlikely to affect green sturgeon feeding success and growth because of the small amount of habitat potentially affected at the barge landings and minor increases in number and frequency of barges operating in the Delta.

5.2.3.2.4 Assess Effects on Designated Critical Habitat

5.2.3.2.4.1 Salmonids

Increases in turbidity and suspended sediment levels during construction of the barge landings will affect the PBFs of designated critical habitat of winter-run Chinook salmon, spring-run Chinook salmon, and steelhead. Elevated turbidity and suspended sediment generated by in-water construction activities and barge operations would primarily affect the PBFs of freshwater rearing habitat and migration corridors through temporary degradation of water quality and sedimentation of potential food-producing areas. As discussed above, water quality impacts will be localized and temporary and therefore the effect to the conservation value of rearing and migration habitat is insignificant. Increases in nearshore turbidity and suspended sediment levels from waves generated by passing tug boats and barges will extend the geographic area of effects on critical habitat but these effects are expected to be short-lived and infrequent based on the average daily increase in vessel trips throughout the entire action area.

5.2.3.2.4.2 Green Sturgeon

Increases in turbidity and suspended sediment levels during construction of the barge landings will affect the PBFs of designated critical habitat for southern DPS green sturgeon. . These effects would be limited to localized, temporary effects on the PBFs of freshwater riverine habitat through temporary degradation of water quality and sedimentation of potential food-producing areas. No long-term or permanent effects on critical habitat are expected.

5.2.3.3 Contaminants

Construction of the barge landings poses an exposure risk to listed fish species from potential spills of hazardous materials from construction equipment, barges and towing vessels, and other machinery, and from potential mobilization of contaminated sediment. The risk of accidental spills of contaminants and other hazardous materials during construction of the barge landings would be similar to that described for the north Delta intakes (section 5.2.2.3) due to the proximity of construction activities to the waters of the Delta. Implementation of Appendix 3.F *General Avoidance and Minimization Measures*, AMM 5 *Spill Prevention, Containment, and Countermeasure Plan* and AMM14 *Hazardous Materials Management* is expected to minimize the potential for introduction of contaminants into surface waters and guide rapid and effective response in the case of inadvertent spills of hazardous materials. These AMMs include the use of watertight forms and other containment structures to prevent spills or discharge of raw concrete, wash water, and other contaminants from entering surface waters and other sensitive habitats during casting of the barge decks and other overwater activities. With implementation of these and other required construction BMPs (e.g., AMM 3 *Stormwater Pollution Prevention Plan*), the risk of contaminant spills or discharges to Delta waters from in-water and overwater sources would be effectively minimized.

Contaminants may also enter the aquatic environment through disturbance, resuspension, or discharge of contaminated soil and sediments from construction sites. Because the barge landings would be constructed on Delta waterways adjacent to major agricultural islands, these sites are more likely to contain agricultural-related toxins such as copper and organochlorine pesticides. As described in Section 5.2.2.3 *Contaminants*, sediments act as a sink or source of contaminant exposure and resuspension of contaminated sediments may have adverse effects on fish that encounter sediment plumes or come into contact with newly exposed sediment.

The potential for introduction of contaminants from disturbed sediments will be addressed through the implementation of specific measures addressing containment, handling, storage, and disposal of contaminated sediments, as described under Appendix 3.F *General Avoidance and Minimization Measures*, AMM6 *Disposal of Spoils, Reusable Tunnel Material, and Dredged Material*. These measures include the preparation and implementation of a pre-construction sampling and analysis plan (SAP) to characterize contaminants and determine appropriate BMPs to minimize or avoid mobilization of contaminated sediments during in-water construction activities. Because potential mobilization of contaminants is closely linked to sediment disturbance and associated increases in turbidity and suspended sediment, turbidity monitoring and control measures (e.g., silt curtains) to achieve compliance with existing Basin Plan objectives will be an important measures for limiting dispersal of contaminated sediments during dredging and other in-water construction activities.

5.2.3.3.1 Assess Species Exposure

5.2.3.3.1.1 Salmonids

The potential for contaminant spills would exist throughout the construction period but the highest risk to listed fish species and aquatic habitat would occur during in-water construction activities. These activities will be restricted to the in-water work period (August 1–October 31) to avoid the peak winter and spring migration and rearing periods of anadromous salmonids. However, this period overlaps with the upstream migration of adult steelhead, which may enter the Delta in late summer (August-September) and peak in abundance in the fall and winter months in the Sacramento and San Joaquin Rivers (September through January). The potential also exists for all listed salmonids that occur in the action area during their seasonal migration and rearing periods to encounter elevated contaminant levels through direct exposure to newly exposed sediment or uptake via their food sources (benthic invertebrates).

5.2.3.3.1.2 Green Sturgeon

The in-water construction period (August 1–October 31) will avoid the peak upstream migration period of green sturgeon (late February to early May) although adults (including post-spawning adults) and rearing juveniles may be present in the Delta year-round and therefore potentially subject to contaminant exposure during the in-water work window as well as other times of the year when they may encounter newly disturbed or exposed sediment. In comparison to salmonids, green sturgeon are more likely to be exposed to contaminated sediments and food sources because of their relatively long residence time (3-4 years for rearing juveniles) and prolonged contact with sediment both externally (e.g., resting and foraging on the bottom) and through ingestion of benthic food organisms.

5.2.3.3.2 Assess Species Response

5.2.3.3.2.1 Salmonids

As described in section 5.2.2.3, the discharge of contaminants into the aquatic environment can cause direct or indirect effects on fish depending on the type, concentrations, and fate of contaminants. In addition to direct exposure from spills or re-suspension of contaminated sediments, contaminants can enter the aquatic food web and accumulate in fish through their diet, leading to lethal and sublethal effects, including effects on behavior, tissues and organs, reproduction, growth, and immune system (Connon et al. 2009).

5.2.3.3.2.2 Green Sturgeon

The potential effects of contaminants and general exposure mechanisms described above are also applicable to green sturgeon.

5.2.3.3.3 Assess Risk to Individuals

5.2.3.3.3.1 Salmonids

Implementation of the proposed *Spill Prevention, Containment, and Countermeasure Plan* (AMM 5), *Hazardous Materials Management* (AMM6), and *Stormwater Pollution Prevention Plan* (AMM3) is expected to minimize the potential for spills or discharges of contaminants into the Delta waterways during construction of the barge landings. Adherence to all preventative, response, and disposal measures in the approved plans are expected to reduce the potential effects to listed fish species to discountable levels. No information is available on potential contaminant risks associated with disturbance and exposure of sediments resulting from pile driving and barge operations. However, this risk is expected to be minimized by developing and implementing a SAP to characterize contaminants and determine appropriate BMPs to minimize or avoid mobilization of contaminated sediments during in-water construction activities. Some exposure of listed salmonids to sediment-borne contaminants or elevated contaminants in food organisms may be unavoidable because of the potential dispersal of contaminants during construction and continued disturbance of contaminated sediments during year-round barge operations. However, these exposures are expected to be minimized by the limited aerial extent of in-water construction areas (pile driving and barge operations), implementation of BMPs to limit the extent of sediment plumes originating from these areas, and the relatively short periods of time that juveniles and adults are likely to spend in the affected areas.

5.2.3.3.3.2 Green Sturgeon

The proposed AMMs to minimize the potential for spills or discharges of contaminants into the Delta waterways during construction of barge landings are also expected to protect green sturgeon. Compared to salmonids, however, green sturgeon are considered to be at higher risk of exposure to contaminated sediments because of their benthic orientation, diet, and relatively long residence of juveniles in the Delta (3-4 years). Although in-water pile driving and barge operations at the water conveyance facilities will disturb a small fraction of the potential habitat available to juveniles in the Delta, the potential for harm or mortality of some individuals from contaminant exposures may be magnified by their year-round presence and potential for exposure at multiple construction sites (north Delta intakes, barge landings, and HOR gate) during their residence in the Delta.

5.2.3.3.4 Assess Effects on Designated Critical Habitat

5.2.3.3.4.1 Salmonids

The potential release of contaminants through spills or sediment disturbance could affect the PBFs of designated critical habitat of listed salmonids through adverse effects on water quality and food resources (direct exposure to sediment-borne contaminants or through consumption of contaminated benthic invertebrates) (see Section 5.2.2.3). Because of the widespread distribution of the proposed barge landings and barge routes in the Delta, the critical habitat for all listed salmonids could be affected.

5.2.3.3.4.2 Green Sturgeon

The potential release of contaminants through spills or sediment disturbance could affect the PBFs of designated critical habitat of green sturgeon through adverse effects on water quality and food resources (reduced abundance of benthic invertebrates and consumption of contaminated benthic invertebrates).

5.2.3.4 Underwater Noise

During construction of the barge landings, activities that are likely to generate underwater noise include in-water pile driving, riprap placement, and barge operations. Pile driving conducted in or near open water poses the greatest risk to fish because the levels of underwater noise produced by impulsive types of sounds often reach levels of sufficient intensity to injure or kill fish within a certain radius of the source piles (Popper and Hastings 2009). Other activities such as riprap placement and barge operations generally produce more continuous, lower energy sounds below the thresholds associated with direct injury but may cause avoidance behavior or temporary hearing loss or physiological stress if avoidance is not possible or exposure is prolonged (Popper and Hastings 2009).

Impact pile driving at the barge landing sites would potentially produce underwater noise levels of sufficient intensity and duration to cause injury to fish. Currently, it is estimated that each barge landing would require vibratory and/or impact driving of 107 steel pipe piles (24-inch diameter) to construct the dock and connecting bridge. Based on the concurrent operation of 4 impact pile drivers at each site and an estimated installation rate of 60 piles per day, pile driving noise would be expected to occur over a period of 2 days at each barge landing.

DWR proposes to minimize the potential exposure of listed fish species to pile driving noise by conducting all pile driving between August 1 and October 31 when most species are least likely to occur in the action area. In addition, DWR 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 fish species (Appendix 3.F *General Avoidance and Minimization Measures*, AMM9 *Underwater Sound Control and Abatement Plan*). These measures include the use of vibratory and other non-impact driving methods as well as other physical and operational measures to limit the intensity and duration of underwater noise levels when listed fish species may be present. Where impact pile driving is required, hydroacoustic monitoring will be performed to determine compliance with established objectives (e.g., distances to cumulative noise thresholds) and identify corrective actions to be taken should the thresholds be exceeded.

5.2.3.4.1 Assess Species Exposure

5.2.3.4.1.1 Salmonids

Restricting impact pile driving to the in-water work period (August 1–October 31) will avoid the primary migration and rearing periods of anadromous salmonids. However, this period coincides with the initiation of adult steelhead migration in the Delta in late summer and increasing numbers through the fall. Based on the general timing of migration in the action area, adult steelhead could be exposed to pile driving at the barge landings throughout the in-water work period.

5.2.3.4.1.2 Green Sturgeon

Restricting pile driving to August 1-October 31 will avoid the peak upstream migration period of green sturgeon (late February to early May) although adults (including post-spawning adults) and rearing juveniles may be present in the Delta year-round and therefore subject to exposure to pile driving noise during this period.

5.2.3.4.2 Assess Species Response

5.2.3.4.2.1 Salmonids

As described in Section 5.2.2.4, the potential responses of fish to pile driving noise can range from behavioral effects to direct injury or mortality, depending on a number of biological, physical, and exposure variables. Sound exposure criteria currently in use by state and federal resource and transportation agencies in California, Oregon, and Washington to evaluate the potential for injury to pile driving activities are presented in Table 5.2-1. The peak SPL is considered the maximum sound pressure level a fish can receive from a single strike without injury. The cumulative SEL is considered the total amount of acoustic energy that a fish can receive from a single or multiple strikes without injury. Pile driving and other sources of construction noise may also cause behavioral responses that could disrupt or delay normal activities, potentially leading to adverse effects on survival, growth, and reproductive success. Insufficient data are currently available to support the establishment of a noise threshold for behavioral effects (Popper et al. 2006); however, it is generally assumed that 150 dB RMS is an appropriate threshold for behavioral effects.

5.2.3.4.2.2 Green Sturgeon

The interim criteria in Table 5.2-1 are assumed to be applicable to green sturgeon based on general similarities in anatomy and physiology (e.g., presence of a swim bladder) to other fishes for which data are available.

5.2.3.4.3 Assess Risk to Individuals

Table 5.2-3 presents the extent, timing, and duration of pile driving noise levels predicted to exceed the interim injury and behavioral thresholds at the barge landings based on application of the NMFS spreadsheet model and the assumptions presented in Appendix 3.E *Pile Driving Assumptions for the Proposed Action*. During installation of the dock piles, it is assumed that approximately 70% of the length of each pile can be driven using vibratory pile driving, with impact driving used to finalize pile placement.

Table 5.2-3. Extent, Timing, and Duration of Pile Driving Noise Levels Predicted to Exceed the Interim Injury and Behavioral Thresholds at the Barge Landing Sites.

Facility	Distance to 206 dB SPL Injury Threshold (feet)	Distance to Cumulative 187 dB SEL Injury Threshold[1, 2] (feet)	Distance to 150 dB RMS Behavioral Threshold[2] (feet)	Number of Construction Seasons	Timing of Pile Driving	Duration of Pile Driving (days)
Barge Landings						
Dock piles	46	1,774	9,607	1 (Year 1 or 2)	Aug–Oct	2

[1] Computed distances to injury thresholds are governed by the distance to "effective quiet" (150 dB SEL). Calculation assumes that single strike SELs <150 dB do not accumulate to cause injury. Accordingly, once the distance to the cumulative injury threshold exceeds the distance to effective quiet, increasing the number of strikes does not increase the presumed injury distance.

[2] Distance to injury and behavioral thresholds assume an attenuation rate of 4.5 dB per doubling of distance and an unimpeded propagation path; on-land pile driving, vibratory driving or other non-impact driving methods, dewatering of cofferdams, and the presence of major river bends or other channel features can impede sound propagation and limit the extent of underwater sounds exceeding the injury and behavioral thresholds.

Sound monitoring data collected during similar types of pile driving operations indicate that single-strike peak SPLs exceeding the interim injury thresholds are expected to be limited to areas within 46 feet of the source piles with no attenuation and 20 feet with attenuation (Table 5.2-3). Based on a cumulative (daily) threshold of 187 dB, the risk of injury is calculated to extend 1,774 feet away from the source piles without attenuation and 823 feet away from the source piles with attenuation.[6] Based on a threshold of 150 dB RMS, the potential for behavioral effects is calculated to extend 9,607 and 4,458 feet, respectively. However, the extent of noise levels exceeding the injury and behavioral thresholds would be constrained to varying degrees by major channel bends that typically occur within 700-8,500 feet of the barge landing sites. Pile driving activities at each site are projected to take place over a 2-day period during a single construction season. The current schedule indicates that pile driving at multiple sites would occur within the same construction season although the specific timing at individual sites is unknown (Appendix 3.D *Pile Driving*).

5.2.3.4.3.1 Salmonids

Restriction of pile driving activities to August 1 through October 31 will avoid the primary juvenile rearing and migration periods for anadromous salmonids in the Delta, which is considered the most sensitive life stage to underwater noise. Most salmonids that are likely to encounter pile driving noise would be upstream migrating adult steelhead. Peak SPLs exceeding the injury criteria would be limited to a radius of 20-46 feet around the source piles, affecting approximately 4-35% of the total channel width available for adults to pass (Appendix 3.E *Pile Driving Assumptions for the Proposed Action*). However, the potential for injury still exists because migrating adults would be faced with passing through channel reaches of up to 3,548 feet long (1,774 x 2) in which all or most of the channel width would be subjected to noise levels exceeding the cumulative injury thresholds. However, based on the reported maximum reported cruising speeds of adult steelhead (3-4 feet per second [Bell 1986]), adults would be capable of migrating through the affected reaches in less than 30 minutes, thus avoiding cumulative exposures associated with potential injury.to underwater noise levels. As discussed in section 5.2.2.4.3.1, pile driving noise can potentially delay or block migrations or result in avoidance

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[6] In this case, the distance to the injury thresholds are governed by the distance to "effective quiet" (150 cB SEL).

responses that could increase the exposure of adults to other stressors such as elevated water temperatures or increased metabolic demands associated with prolonged delays. However, the risk of adverse effects associated with such delays is expected to be low because of the rapid migration rates of adults, daily opportunities for adults to pass the affected areas at night (dusk to dawn), and the short duration of pile driving activities at each construction site (2 days).

To further minimize the risk of injury and mortality of steelhead from pile driving noise, DWR 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 fish species (Appendix 3.F *General Avoidance and Minimization Measures*, AMM9 *Underwater Sound Control and Abatement Plan*). These measures include the use of vibratory and other non-impact driving methods as well as other physical and operational measures to limit the intensity and duration of underwater noise levels when listed fish species may be present. Where impact pile driving is required, hydroacoustic monitoring will be performed to determine compliance with established objectives (e.g., distances to cumulative noise thresholds) and identify corrective actions to be taken should the thresholds be exceeded. In addition, DWR will work with contractors to minimize pile driving activities at barge landing facilities by using floating docks instead of pile-supported docks wherever feasible, considering the load requirements of the landings and site conditions.

5.2.3.4.3.2 Green Sturgeon

Green sturgeon are also at risk of being injured or killed by pile driving noise at the barge landings. Post-spawning adults migrating down the Sacramento River in summer and fall may enter the DCC, Georgiana Slough, and other routes potentially leading to the barge landing sites. Juveniles are considered at higher risk because of their year-round presence in the Delta and potential for encountering pile driving noise at multiple locations during their 3-4 residence period. As discussed in section 5.2.2.4.3.2, evidence exists for avoidance of pile driving noise in other sturgeon species. Although such behavior may disrupt or delay the movements or foraging activities of juveniles in proximity to the barge landings, the risk of adverse effects is expected to be limited by daily opportunities for juveniles to leave the affected areas at night (dusk to dawn) and the short duration of pile driving activities at each site (2 days). To further limit the potential magnitude of take, DWR will implement an underwater sound control and abatement plan (AMM9), and perform hydroacoustic monitoring to determine compliance with established objectives (e.g., distances to cumulative noise thresholds) and identify corrective actions to be taken should the thresholds be exceeded.

5.2.3.4.4 Assess Effects on Designated Critical Habitat

5.2.3.4.4.1 Salmonids

Underwater noise levels from pile driving and other construction activities will affect the designated critical habitat of winter-run Chinook salmon, spring-run Chinook salmon, and steelhead through temporary degradation of the PBFs of migratory habitat (i.e., unobstructed migratory pathways). Adverse effects on critical habitat would occur within areas subjected to noise levels associated with potential injury and behavioral effects, as described above. These effects would occur for up to 2 days at each barge landing site. Underwater noise levels will return to baseline levels following cessation of pile driving and other construction activities, and would not result in long-term impacts on critical habitat.

5.2.3.4.4.2 Green Sturgeon

The effects of underwater noise on the designated critical habitat of green sturgeon would be similar to that described for salmonids.

5.2.3.5 Fish Stranding

No actions are proposed at the barge landings that could result in stranding of fish or require fish rescue and salvage activities.

5.2.3.6 Direct Physical Injury

During construction of barge landings, fish could be injured or killed by direct contact with equipment or materials that are operated or placed in open waters of the adjacent Delta channels. Potential mechanisms include fish being crushed by falling rock (riprap), impinged by dock piles, and struck or entrained by vessels or propellers. In addition to the proposed work window (August 1-October 31), the potential for injury of listed fish species would be minimized by limiting the duration of in-water construction activities to the extent practicable and implementing the following AMMs: *General Avoidance and Minimization Measures*. Applicable AMMs include *Worker Awareness Training; Erosion and Sediment Control Plan; Disposal of Spoils, Reusable Tunnel Material, and Dredged Material; Barge Operations Plan; and Fish Rescue and Salvage Plan* (Appendix 3.F *General Avoidance and Minimization Measures*).

Operational effects of barge operations, including effects that could take place during transits of the Delta between barge loading and unloading facilities, include propeller entrainment and wave-induced shoreline impacts (e.g., dewatering, loss of benthic food organisms).

5.2.3.6.1 Assess Species Exposure

5.2.3.6.1.1 Salmonids

Restriction of pile driving to August 1-October 31will avoid the primary winter and spring migration and rearing periods of anadromous salmonids. However, this period overlaps with the upstream migration of adult steelhead, which may enter the Delta in late summer (August-September) and peak in abundance in the fall and winter months in the Sacramento and San Joaquin Rivers (September through January). Barge operations would continue year-round for 5-6 years following construction, potentially affecting all listed species of salmonids occurring in the Delta during their rearing and migration life stages.

5.2.3.6.1.2 Green Sturgeon

Restriction of in-water activities to August 1-October 31 will avoid the peak upstream migration period of green sturgeon (late February to early May) although adults (including post-spawning adults) and rearing juveniles may be present in the Delta year-round and therefore subject to injury during construction and operation of the barge landings.

5.2.3.6.2 Assess Species Response

5.2.3.6.2.1 Salmonids

Most anadromous salmonids that are likely to be present in the action area during construction of the barge landings are likely to be large, migrating adult steelhead that would be expected to avoid active construction areas and thus avoid injury. However, year-round barge operations could affect all listed species of salmonids occurring in the Delta during their rearing and migration life stages. These potential effects include direct injury or mortality of fish from entrainment into tug boat propellers. Although there are few direct observations of fish being seriously injured or killed by boat traffic (Rosen and Hales, 1980; Gutreuter et al. 2003), there is general agreement that the shear stresses caused by propellers result in mortality to early life stages (eggs and larval stages of fish), and that juvenile and adult fish are much less susceptible to entrainment because of their greater swimming capability (Morgan II et al., 1976; Holland, 1986; Killgore et al., 2001; Wolter and Arlinghaus 2003).

The potential effects of vessel traffic also include wave-induced disturbances or dewatering of nearshore (littoral) areas (Wolter and Arlinghaus 2003). The magnitude of these forces is related to channel morphology and vessel size and speed, but can result in significant disturbance to nearshore (littoral) communities, including juvenile fishes which can suffer from disorientation and stranding in nearshore areas during vessel passage, potentially leading to reduced survival and growth (Wolter and Arlinghaus 2003).

5.2.3.6.2.2 Green Sturgeon

The discussion above is assumed to generally apply to green sturgeon. Although green sturgeon are assumed to have a lower risk of interactions with vessels because of their use of deep water and benthic habitat, sturgeon in general may be susceptible to vessel interactions because of their surface-oriented behavior (e.g., breaching) as observed for white sturgeon, and anecdotal evidence of vessel interactions for other sturgeon species (NMFS 2014).

5.2.3.6.3 Assess Risk to Individuals

5.2.3.6.3.1 Salmonids

During construction of the barge landings, there is a low risk of injury of adult steelhead based on their likely response to noise, turbidity, and other construction-related disturbances at the barge landing sites (see 5.2.2.2.2 and 5.2.2.4.3). No information exists on the characteristics of vessels that are most likely to interact with listed salmonids or the rates of these interactions. Although implementation of the barge operations plan (AMM7) is expected to minimize potential interactions, the frequency of such interactions will likely increase and result in an elevated risk of direct injury (e.g., propeller strikes) of juvenile and adult salmonids. Year-round barge traffic will also increase the frequency of wave-induced shoreline disturbances, which could adversely affect rearing juveniles that depend on shallow nearshore areas for resting, feeding, and protection from predators. However, an average increase of 7.5 trips per day over the entire action area suggests that any increases in injury or harassment of listed salmonids would be expected to be small.

5.2.3.6.3.2 Green Sturgeon

Similar to salmonids, there is a low risk of injury of green sturgeon during construction of the barge landings based on their likely response to noise, turbidity, and other construction-related disturbances. Green sturgeon are also at risk of direct injury from increases in vessel traffic at the barge landings and along the routes that will be used to transport construction materials between the barge landings and existing commercial ports in the Delta and estuary. Although green sturgeon are assumed to have a lower risk of interactions with vessels because of their use of deep water and benthic habitat, sturgeon in general may be susceptible to vessel interactions because of their surface-oriented behavior (e.g., breaching) as observed for white sturgeon, and anecdotal evidence from other sturgeon species (NMFS 2014).

5.2.3.6.4 Assess Effects on Designated Critical Habitat

5.2.3.6.4.1 Salmonids

The potential for injury during in-water construction activities would have an adverse effect on the PBFs of the designated critical habitat of listed salmonids (safe and unobstructed migratory corridors).

5.2.3.6.4.2 Green Sturgeon

The potential for injury during in-water construction activities would have an adverse effect on the PBFs of the designated critical habitat of southern DPS green sturgeon (safe and unobstructed migratory corridors).

5.2.3.7 Alteration/Loss of Habitat

Construction of the barge landings and the operation of barges during and after construction would result in temporary to permanent losses or alteration of aquatic habitat in several channels of the east, south, and north Delta that are within the designated critical habitat of Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, California Central Valley steelhead, and southern DPS green sturgeon. Temporary effects of construction activities on water quality, including turbidity and suspended sediment, underwater noise, and contaminants, were previously discussed. The following analysis focuses on longer-term to permanent losses or alteration of habitat associated with construction activities. These impacts encompass a total of approximately 22.4 acres of tidal perennial habitat that include the in-water work areas and permanent footprints of docks, mooring structures, and other in-water and overwater structures. The aquatic footprints of the individual barge landings would encompass 0.34 acre of overwater structures, encompassing approximately 300 linear feet of shoreline and 5-19% of the total width of the river or slough. This is considered a permanent alteration of habitat that would exist throughout the construction period (7-8 years).

During construction activities, DWR will implement AMM2, *Construction Best Management Practices and Monitoring*, to protect listed fish, wildlife, and plant species, their designated critical habitat, and other sensitive natural communities (Appendix 3.F *General Avoidance and Minimization Measures*). These BMPs include a number of measures to limit the extent of disturbance of aquatic and riparian habitat during construction, and, following construction, to restore temporarily disturbed areas to pre-construction conditions. All construction and site restoration BMPs will be subject to an approved construction and post-construction monitoring plan to ensure their effectiveness. To further minimize adverse effects to aquatic habitat associated with barge operations, DWR also proposes to implement a *Barge Operations Plan*, which includes specific measures to minimize bed scour, bank erosion, loss of submerged and emergent vegetation, and disturbance of benthic communities (Appendix 3.F *General Avoidance and Minimization Measures*). DWR proposes to offset unavoidable impacts to the designated critical habitat of CCV steelhead and southern DPS green sturgeon through restoration of aquatic and channel margin habitat at an approved restoration site and/or the purchase of conservation credits at an approved conservation bank.

5.2.3.7.1 Assess Species Exposure

5.2.3.7.1.1 Salmonids

All migrating and/or rearing salmonids that occur in the action area during construction and operation of the barge landings would be potentially exposed to the physical alteration of channel margin habitat (i.e., changes in water depths, velocities, substrate, and cover conditions) and permanent losses of aquatic habitat within the footprints of the docks, mooring structures, and other in-water and overwater structures.

5.2.3.7.1.2 Green Sturgeon

All migrating and/or rearing green sturgeon that occur in the action area during construction and operation of the barge landings would be potentially exposed to the physical alteration of channel margin habitat (i.e., changes in water depths, velocities, substrate, and cover conditions) and permanent losses of aquatic habitat within the footprints of the docks, mooring structures, and other in-water and overwater structures.

5.2.3.7.2 Assess Species Response

5.2.3.7.2.1 Salmonids

Habitat conditions for anadromous salmonids in the vicinity of the proposed barge landings are degraded from historical conditions and the habitat likely functions primarily as a migration corridor for adults migrating to upstream spawning areas and juveniles migrating downstream to the estuary. The PBFs supporting the migration and rearing of steelhead in the action area have been degraded by altered flow patterns, levee construction, extensive riprapping, and loss of natural wetland and floodplain habitat. Because the barge landings will likely be sited in areas with steep levees, deep nearshore areas, and minimal obstructions to barge access and operations, it is unlikely that the construction and operation of the barge landings will substantially degrade the PBFs of critical habitat relative to current conditions. During and following construction, no measurable changes would be expected in channel widths or passage conditions (water depths and velocities) for adults because of their use of deeper, offshore portions of the channel for holding and migration. Some reductions are expected in the quality of passage and rearing conditions for juveniles due to the removal of aquatic and riparian vegetation, the addition of riprap to the levee slope, and the installation of artificial in-water and overwater structures within the permanent footprints of the barge landings. These actions would generally result in loss of cover, benthic food resources, and changes in physical and hydraulic conditions that may increase exposure of migrating juveniles to predation.

As previously discussed, adult and juvenile salmonids would likely avoid the barge landing sites during active periods of construction due to increased turbidity and suspended sediment, noise, and other construction-related disturbances (see 5.2.2.2.2.1 and 5.2.2.4.3.1). Although these sites lack high-quality rearing habitat, the addition of artificial in-water and overwater structures could further degrade the suitability of the sites for juvenile rearing and migration. Docks, piles, and barges provide shade and cover that may attract certain predatory fish species (e.g., striped bass, largemouth bass, Sacramento pikeminnow) and potentially increase their ability to ambush juvenile salmonids and other fishes. These structures may also improve predation opportunities for piscivorous birds (e.g., gulls, terns, cormorants) by providing perch sites immediately adjacent to open water. In addition, the elimination or disturbance of benthic habitat and associated invertebrate communities due to pile installation and scour would result in localized reductions in benthic food production that would likely persist for the duration of barge operations. This represents a permanent alteration of habitat that would exist throughout the construction period (2 years) and continue during operation of the barge landings (5-6 years).

5.2.3.7.2.2 Green Sturgeon

Habitat conditions for green sturgeon near the proposed barge landings are degraded from historical conditions and likely functions primarily as a migration corridor for adults migrating to upstream spawning areas and as foraging habitat for juveniles. Based on the expected changes in habitat conditions resulting from the construction of the barge landings, impacts to the PBFs of green sturgeon critical habitat would primarily be caused by the loss of foraging habitat within the permanent footprints of the barge landings.

5.2.3.7.3 Assess Risk to Individuals

5.2.3.7.3.1 Salmonids

Temporary and permanent losses or alteration of habitat at the proposed barge landing site are expected to have insignificant effects on migrating adult salmonids; passage conditions for adults would remain unobstructed throughout the construction period. Although the proposed barge landing sites currently provide low quality rearing habitat for juvenile salmonids, construction of the barge landings would further degrade this habitat by removing any existing vegetation from the levee slope and nearshore areas, placing riprap on the levee slope, and installing artificial in-water and overwater structures within the temporary and permanent footprints of the barge landings. These actions will generally result in loss of cover, benthic food resources, and changes in physical and hydraulic conditions that may increase predation opportunities. This is unlikely to significantly affect the growth of juvenile salmonids because of the low quality of existing habitat for rearing salmonids. However, the lack of cover for juvenile fish and presence of structural and overhead cover for predators may increase the risk of predation by increasing the amount of predator habitat and/or susceptibility of juvenile salmonids to predation.

5.2.3.7.3.2 Green Sturgeon

Similar to Section 5.2.3.1 construction of the barge landings is unlikely to adversely affect adult sturgeon, and would have minimal effects on rearing and passage conditions for juveniles. The primary effects would be similar to that of salmonids above on critical habitat of green sturgeon, with the loss of potential foraging habitat (benthic habitat) within the temporary and permanent footprints of the barge landings. This is unlikely to have a measurable effect on growth and survival of juvenile green sturgeon because it represents a very small proportion of the total amount of habitat available to juveniles during their residence in the Delta and estuary.

5.2.3.7.4 Assess Effects on Designated Critical Habitat

5.2.3.7.4.1 Salmonids

Impacts to the designated critical habitat of listed salmonids include permanent impacts on adult migration and juvenile rearing and migration habitat, as described above. DWR proposes to offset impacts to the designated critical habitat of winter-run Chinook salmon, spring-run Chinook salmon, and steelhead through restoration of tidal perennial habitat at an approved restoration site[7] and/or the purchase of conservation credits at an approved conservation bank (Table 3.4-1).

5.2.3.7.4.2 Green Sturgeon

Impacts to the designated critical habitat of green sturgeon include permanent impacts on adult migration and juvenile rearing and migration habitat, as described above. DWR proposes to offset impacts to the designated critical habitat of green sturgeon through restoration of tidal perennial habitat at an approved restoration site and/or the purchase of conservation credits at an approved conservation bank (Table 3.4-1).

5.2.4 Head of Old River Gate

5.2.4.1 Deconstruct the Action

An operable gate (Head of Old River [HOR] gate) will be constructed at the HOR to prevent migrating juvenile salmonids (San Joaquin River-origin steelhead, spring-run Chinook salmon, and fall-run Chinook salmon) from entering Old River from the San Joaquin River, and thereby minimize their exposure to the CVP/SWP pumping facilities. The gate will be located in Old River approximately 400 feet downstream of the junction of Old River with the San Joaquin River (Appendix 3.A *Map Book for the Proposed Action*). The gate will be 210 feet long and 30 feet wide, with a top elevation of +15 feet (Appendix 3.C *Conceptual Engineering Report*, Volume 2, Sheets 11, 12, and 13), and include seven bottom-hinged gates, fish passage structure, boat lock, control building, boat lock operator's building, and communications antenna. Additional details on the design, construction methods, and proposed construction schedule for the HOR gate are described in Chapter 3.

Construction of the HOR gate is expected to take 2 years. The HOR gate will be constructed in two phases using cofferdams to isolate and dewater half the channel during the first phase and the other half during the second phase. All in-water construction work, including cofferdam installation, riprap placement, dredging, and barge operations, would be restricted to August 1-November 30 to minimize or avoid potential effects on listed fish species. In addition, all pile driving requiring the use of an impact pile driver in or near open water (cofferdams and foundation piles) will be restricted to the in-water work period to avoid or minimize exposure of listed species to potentially harmful underwater noise levels. Construction of the HOR gate will require dredging of approximately 500 feet of channel (150 feet upstream to 350 feet downstream from the proposed gate) and removal of up to 1,500 cubic yards of material with a barge-mounted hydraulic or a sealed clamshell dredge. The need for additional clearing and grading of the site for construction, staging, and other support facilities is expected to be minimal because of the presence of existing access roads and staging areas that have been used in the past for installation of a temporary rock barrier.

Construction of the HOR gate will result in temporary impacts on water quality and permanent impacts on physical habitat within the footprint of the gate and channel reaches that would be

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[7] Some combination of channel margin and tidal perennial habitat, sited and designed in coordination with NMFS and CDFW, may be targeted to achieve these benefits, consistent with restoring south Delta historical habitat function and processes (see 3.4.3.1.3).

affected by dredging. These impacts encompass a total of approximately 2.9 acres of tidal perennial habitat that includes the permanent footprint of the gate, fish passage structure, and boat lock.

5.2.4.2 Turbidity and Suspended Sediment

Construction activities would result in disturbance of the channel bed and banks, resulting in temporary increases in turbidity and suspended sediment levels in Old River and potentially the San Joaquin River. These activities include cofferdam construction (sheet pile installation), dredging, levee clearing and grading, riprap placement, and barge operations. All other sediment-disturbing activities will be outside or isolated from the active channel and would not result in the discharge of sediment to the river. Water pumped from the cofferdams will be treated (removing all sediment) using settling basins or Baker tanks, and returned to the river. In addition to the in-water work window, a number of AMMs are proposed to avoid or minimize potential impacts on water quality and listed fish species during construction of the HOR gate. These AMMs include *Worker Awareness Training; Construction Best Management Practices and Monitoring; Stormwater Pollution Prevention Plan (SWPPP); Erosion and Sediment Control Plan; Spill Prevention, Containment, and Countermeasure Plan (SPCCP); Hazardous Material Management Plan;* and *Disposal and Reuse of Spoils, Reusable Tunnel Material, and Dredged Material* (Appendix 3.F *General Avoidance and Minimization Measures*).

5.2.4.2.1 Assess Species Exposure

5.2.4.2.1.1 Salmonids

Restriction of these activities to the in-water work period (August 1–November 30) will avoid the primary winter and spring migration and rearing periods of anadromous salmonids. However, this period overlaps with the upstream migration of adult steelhead in October and November and the downstream migration of juvenile steelhead (yearling and older smolts) in November. San Joaquin River (SJR)-basin spring-run Chinook salmon (yearling smolts) may also be present in November, assuming juveniles exhibit similar emigration patterns to Sacramento River spring-run populations

5.2.4.2.1.2 Green Sturgeon

Both adult and juvenile green sturgeon are known to occur in the lower reaches of the San Joaquin River and Delta. The risk of exposure of adults to construction activities at the HOR may be lower than other regions of the Delta because of the location and timing of construction activities relative to the primary migration route (Sacramento River) and timing of upstream migration (late February to early May). Juvenile green sturgeon may be present year-round and therefore could be exposed to in-water construction activities and associated increases in turbidity, suspended sediment, and other construction-related disturbances during the proposed in-water construction period.

5.2.4.2.2 Assess Species Response

5.2.4.2.2.1 Salmonids

As described in section 5.2.2.2, turbidity and suspended levels typically generated by in-water construction activities are not expected to reach levels that would cause direct injury to salmonids. All steelhead and spring-run Chinook salmon that are likely to be present in the action area during the in-water work window would be expected to be large, actively migrating adults and juveniles (yearling or older smolts) that are known to move rapidly through the Delta during their upstream and downstream migrations (see 5.2.2.4.3.1). With implementation of the AMMs, in-water construction activities would result in temporary, localized increases in turbidity and suspended sediment that dissipate rapidly with distance from the source and return to baseline levels following cessation of activities. The effects on adult and juvenile steelhead would likely be limited to harassment of individuals that encounter turbidity plumes.

Increases in suspended sediment during in-water construction activities may result in localized sediment deposition in the vicinity of the HOR gate, potentially degrading food-producing areas by burying benthic substrates that support important food organisms (benthic invertebrates) for juvenile salmonids. Because of the localized nature of these effects and brief exposure of migrating juveniles to reduced food availability, no measurable effect on growth or survival of juveniles is expected.

5.2.4.2.2.2 Green Sturgeon

No specific information is available to evaluate the potential responses of green sturgeon to increased turbidity and suspended sediment. Green sturgeon may be affected in similar ways to salmonids although green sturgeon may be less sensitive to short-term increases in suspended sediments or turbidity because of their use of olfactory cues as opposed to vision to locate prey. Any reductions in the availability of foraging habitat and food availability due to sedimentation of benthic habitat may force green sturgeon to seek alternative foraging areas but this would likely have no measurable effects on growth or survival because the affected area represents a very small proportion of the total amount of foraging habitat available to green sturgeon in the Delta and estuary.

5.2.4.2.3 Assess Risk to Individuals

5.2.4.2.3.1 Salmonids

Based on the expected responses of salmonids to construction-related increases on turbidity and suspended sediment, any disruptions of the normal behavior are expected to be brief, but may potentially increase predation on juveniles.

5.2.4.2.3.2 Green Sturgeon

Based on the expected responses of green sturgeon to construction-related increases in turbidity and suspended sediment levels, the potential effects of increased turbidity and suspended sediment during construction of the HOR gate is expected to be insignificant. Although green sturgeon are more sensitive to reductions in benthic food resources, the small spatial and temporal scale of impacts on these food resources is unlikely to affect access to food resources and individual foraging success.

5.2.4.2.4 Assess Effects on Designated Critical Habitat

5.2.4.2.4.1 Salmonids

Increases in turbidity and suspended sediment levels during construction of the HOR gate will affect the PCEs of the designated critical habitat of CCV steelhead. Elevated turbidity and suspended sediment generated by in-water construction activities would primarily affect the PCEs of freshwater rearing habitat and migration corridors through temporary degradation of water quality and potential sedimentation of potential food-producing areas. These effects will be localized and temporary and therefore unlikely to significantly affect the conservation value of rearing and migration habitat in the action area.

5.2.4.2.4.2 Green Sturgeon

Increases in turbidity and suspended sediment levels during construction of the HOR gate will affect the PBFs of the designated critical habitat for southern DPS green sturgeon. These effects would be limited to localized, temporary degradation of the PBFs of water quality and potential sedimentation of food-producing areas. No long-term or permanent effects on critical habitat are expected.

5.2.4.3 Contaminants

Construction of the HOR gate poses an exposure risk to listed fish species from potential spills of hazardous materials from construction equipment, barges and towing vessels, and other machinery, and from potential mobilization of contaminated sediment. The risk of accidental spills of contaminants and other potentially hazardous materials would be similar to that described for the north Delta intakes (section 5.2.2.3) due to the proximity of construction activities to the waters of the Delta. Implementation of AMM 5, *Spill Prevention, Containment, and Countermeasure Plan,* and AMM14 *Hazardous Materials Management* (see Appendix 3.F *General Avoidance and Minimization Measures*) is expected to minimize the potential for introduction of contaminants into surface waters and guide rapid and effective response in the case of inadvertent spills of hazardous materials. With implementation of these and other required construction BMPs (e.g., AMM 3, *Stormwater Pollution Prevention Plan*), the risk of contaminant spills or discharges to Delta waters from in-water or upland sources would be effectively minimized.

Contaminants may also enter the aquatic environment through disturbance, resuspension, or discharge of contaminated soil and sediments from construction sites. As described in section 5.2.2.3, sediments act as a sink or source of contaminant exposure, and resuspension of contaminated sediments may have adverse effects on fish that encounter sediment plumes or come into contact with deposited or newly exposed sediment. Contaminated sediments may be present in Old River and within the footprint of the proposed HOR gate because of the proximity of the site to major municipal, industrial, and agricultural areas. The potential for introduction of contaminants from disturbed sediments will be addressed through the implementation of specific measures addressing containment, handling, storage, and disposal of contaminated sediments, as described under AMM6 *Disposal of Spoils, Reusable Tunnel Material, and Dredged Material* in Appendix 3.F *General Avoidance and Minimization Measures*. These measures include the preparation and implementation of a pre-construction sampling and analysis plan (SAP) to characterize contaminants and determine appropriate BMPs to minimize or avoid mobilization of contaminated sediments during in-water construction activities. Because potential mobilization of contaminants is closely linked to sediment disturbance and associated increases in turbidity and suspended sediment, turbidity monitoring and control measures (e.g., silt curtains) to achieve compliance with existing Basin Plan objectives will be an important measures for limiting dispersal of contaminated sediments during dredging and other in-water construction activities.

5.2.4.3.1 Assess Species Exposure

5.2.4.3.1.1 Salmonids

The potential for contaminant spills or releases would exist throughout the construction period but the highest risk would occur during in-water construction activities. The timing of in-water construction activities (August 1–November 30) overlaps with the upstream migration of adult steelhead starting in October and November and the downstream migration of juvenile steelhead (yearling and older smolts) in November. SJR-basin spring-run Chinook salmon (yearling smolts) may also be present in November, assuming juveniles exhibit similar emigration patterns to Sacramento River spring-run populations. Potential exposure to contaminant spills during in-water construction activities is expected to be brief because most adult and juvenile salmonids that may be present will be actively migrating through the action area during these months. However, exposure to contaminants may occur at other times of the year due to potential exposure of newly exposed sediment that will remain after construction is completed.

5.2.4.3.1.2 Green Sturgeon

The risk of exposure of adult green sturgeon to potential contaminant spills at the HOR may be lower than other regions of the Delta because of the location and timing of construction activities relative to the primary migration route (Sacramento River) and timing of upstream migration (late February to early May). Juvenile green sturgeon may be present year-round and therefore could be exposed to potential contaminant spills as well as potential contaminants in newly exposed sediment throughout the year. In comparison to salmonids, green sturgeon are more likely to be exposed to contaminated sediments and food sources because of their relatively long residence time (3-4 years for rearing juveniles) and prolonged contact with sediment both externally (e.g., resting and foraging on the bottom) and through ingestion of benthic food organisms.

5.2.4.3.2 Assess Species Response

5.2.4.3.2.1 Salmonids

As described in Section 5.2.2.3, the discharge of contaminants into the aquatic environment can cause direct or indirect effects on fish depending on the type, concentrations, and fate of contaminants. In addition to direct exposure from spills or re-suspension of contaminated sediments, contaminants can enter the aquatic food web and accumulate in fish through their diet, leading to lethal and sublethal effects, including effects on behavior, tissues and organs, reproduction, growth, and immune system (Connon et al. 2009).

5.2.4.3.2.2 Green Sturgeon

The potential effects of contaminants and general exposure mechanisms described above are also applicable to green sturgeon.

5.2.4.3.3 Assess Risk to Individuals

5.2.4.3.3.1 Salmonids

Implementation of the proposed *Spill Prevention, Containment, and Countermeasure Plan* (AMM 5), *Hazardous Materials Management* (AMM6), and *Stormwater Pollution Prevention Plan* (AMM3) is expected to minimize the potential for spills or discharges of contaminants into Old River. Adherence to all preventative, response, and disposal measures in the approved plans are expected to reduce the potential effects to listed fish species to discountable levels. No information is available on potential contaminant risks associated with disturbance and exposure of sediments resulting from pile driving and barge operations. However, this risk is expected to be minimized by developing and implementing a SAP to characterize contaminants and determine appropriate BMPs to minimize or avoid mobilization of contaminated sediments during in-water construction activities. Some exposure of listed salmonids to sediment-borne contaminants or elevated contaminants in food organisms may be unavoidable because of the potential dispersal of contaminants during construction and continued disturbance and exposure of sediments during construction and maintenance dredging.

5.2.4.3.3.2 Green Sturgeon

The proposed AMMs to minimize the potential for spills or discharges of contaminants into Old River during construction of the HOR gate are also expected to protect green sturgeon. Compared to salmonids, however, green sturgeon are considered to be at higher risk of exposure to contaminated sediments because of their benthic orientation, diet, and relatively long residence of juveniles in the Delta (3-4 years). Although in-water pile driving, dredging, and barge operations will disturb a small fraction of the potential habitat available to juveniles in the Delta, the potential for harm or mortality of some individuals from contaminant exposures may be magnified by their year-round presence and potential for exposure at multiple construction sites (north Delta intakes, barge landings, and CCF) during their residence in the Delta.

5.2.4.3.4 Assess Effects on Designated Critical Habitat

5.2.4.3.4.1 Salmonids

The potential release of contaminants through spills or sediment disturbance could affect the PBFs of the designated critical habitat of CCV steelhead and SJR basin spring-run Chinook salmon through adverse effects on water quality and food resources (reduced abundance of benthic invertebrates and consumption of contaminated benthic invertebrates).

5.2.4.3.4.2 Green Sturgeon

The potential release of contaminants through spills or sediment disturbance could affect the PBFs of the designated critical habitat of green sturgeon through adverse effects on water quality and food resources (reduced abundance of benthic invertebrates and consumption of contaminated benthic invertebrates).

5.2.4.4 Underwater Noise

During construction of the HOR gate, activities that are likely to generate underwater noise include in-water pile driving, riprap placement, dredging, and barge operations. Pile driving conducted in or near open water poses the greatest risk to fish because the levels of underwater noise produced by impulsive types of sounds often reach levels of sufficient intensity to injure or kill fish within a certain radius of the source piles (Popper and Hastings 2009). Other activities such as riprap placement, dredging, and barge operations generally produce more continuous, lower energy sounds below the thresholds associated with direct injury but may cause avoidance behavior or temporary hearing loss or physiological stress if avoidance is not possible or exposure is prolonged (Popper and Hastings 2009).

Impact pile driving at the barge landing sites would potentially produce underwater noise levels of sufficient intensity and duration to cause injury to fish. Currently, it is estimated that the HOR gate would require the installation of 550 temporary sheet piles (275 piles per season) to construct the cofferdams and 100 14-inch steel pipe or H-piles (50 piles per season) to construct the foundation. Based on an assumed installation rate of 15 piles per day, pile driving would be expected to occur up to 19 days per season during installation of the sheet piles, and up to 4 days per season during installation of the foundation piles. DWR proposes to minimize the potential exposure of listed fish species to pile driving noise by conducting all in-water construction activities between August 1 and November 30. In addition, DWR proposes to minimize the risk of injury to fish by using vibratory methods or other non-impact driving and attenuation methods to the extent feasible. Sheet piles will be installed starting with a vibratory hammer, then switching to impact hammer if refusal is encountered before target depths. For the purposes of the following analysis, it is assumed that approximately 70% of the sheet piles can be driven using a vibratory hammer, followed by an estimated 210 strikes to drive the sheet piles to the final depth using an impact hammer. For the foundation piles, the current design assumes the use of impact pile driving only. However, some degree of attenuation is expected assuming that the cofferdams can be fully dewatered. Therefore, predictions are shown for two scenarios, one in which dewatering results in a 5 dB reduction in reference noise levels, and one in which no attenuation is possible (no dewatering or other forms of attenuation). It is possible that cast-in-drilled-hole concrete piles will be used to construct the foundation depending on the results of geotechnical evaluations and final design. Based on the potential for injury of listed fish species, DWR may also implement other protective measures on accordance with an underwater sound control and abatement plan (Appendix 3.F *General Avoidance and Minimization Measures, AMM9 Underwater Sound Control and Abatement Plan*).

5.2.4.4.1 Assess Species Exposure

5.2.4.4.1.1 Salmonids

Based on the in-water work window of August 1-November 30, pile driving activities overlap with the upstream migration of adult steelhead in October and November and the downstream migration of juvenile steelhead (yearling and older smolts) in November. SJR-basin spring-run Chinook salmon (yearling smolts) may also be present in November, assuming juveniles exhibit similar emigration patterns to Sacramento River spring-run populations.

5.2.4.4.1.2 Green Sturgeon

Both adult and juvenile green sturgeon are known to occur in the lower reaches of the San Joaquin River and Delta. The risk of exposure of adult green sturgeon to pile driving noise at the HOR gate may be lower than other regions of the Delta because of the location and timing of construction activities relative to the primary migration route (Sacramento River) and timing of upstream migration (late February to early May). Juvenile green sturgeon may be present year-round and therefore could be exposed to pile driving noise during the proposed in-water construction period.

5.2.4.4.2 Assess Species Response

5.2.4.4.2.1 Salmonids

As described in Section 5.2.2.4, the potential responses of fish to pile driving noise can range from behavioral effects to direct injury or mortality, depending on a number of biological, physical, and exposure variables. Sound exposure criteria currently in use by state and federal resource and transportation agencies in California, Oregon, and Washington to evaluate the potential for injury to pile driving activities are presented in Table 5.2-1. The peak SPL is considered the maximum sound pressure level a fish can receive from a single strike without injury. The cumulative SEL is considered the total amount of acoustic energy that a fish can receive from a single or multiple strikes without injury. Pile driving and other sources of construction noise may also cause behavioral responses that could disrupt or delay normal activities, potentially leading to adverse effects on survival, growth, and reproductive success. Insufficient data are currently available to support the establishment of a noise threshold for behavioral effects (Popper et al. 2006); however, it is generally assumed that 150 dB RMS is an appropriate threshold for behavioral effects.

5.2.4.4.2.2 Green Sturgeon

The interim criteria in Table 5.2-1 are assumed to be applicable to green sturgeon based on general similarities in anatomy and physiology (e.g., presence of a swim bladder) to other fishes for which data are available.

5.2.4.4.3 Assess Risk to Individuals

Table 5.2-2 presents the extent, timing, and duration of pile driving noise levels predicted to exceed the interim injury and behavioral thresholds at the HOR gate based on application of the NMFS spreadsheet model and the assumptions presented in Appendix 3.E *Pile Driving Assumptions for the Proposed Action*.

Table 5.2-4. Extent, Timing, and Duration of Pile Driving Noise Levels Predicted to Exceed the Interim Injury and Behavioral Thresholds at the Head of Old River Gate.

Facility	Distance to 206 dB SPL Injury Threshold (feet)	Distance to Cumulative 187 and 183 dB SEL Injury Threshold[1] (feet)	Distance to 150 dB RMS Behavioral Threshold[1] (feet)	Number of Construction Seasons	Timing of Pile Driving	Duration of Pile Driving per Season (days)
Head of Old River Gate						
Cofferdams	30	2,063	13,058	2	Aug–Nov	19
Foundation (no attenuation)	46	1,774[2]	9,607	2	Aug–Nov	4
Foundation (with attenuation)	20	823[2]	4,458	2	Aug–Nov	4

[1] Distance to injury and behavioral thresholds assume an attenuation rate of 4.5 dB per doubling of distance and an unimpeded propagation path; on-land pile driving, vibratory driving or other non-impact driving methods, dewatering of cofferdams, and the presence of major river bends or other channel features can impede sound propagation and limit the extent of underwater sounds exceeding the injury and behavioral thresholds.

[2] Computed distances to injury thresholds are governed by the distance to “effective quiet” (150 dB SEL). Calculation assumes that single strike SELs <150 dB do not accumulate to cause injury. Accordingly, once the distance to the cumulative injury threshold exceeds the distance to effective quiet, increasing the number of strikes does not increase the presumed injury distance..

Sound monitoring data collected during similar types of pile driving operations indicate that single-strike peak SPLs exceeding the interim injury thresholds are expected to be limited to areas within 30 feet of the cofferdam sheet piles and 20-46 feet of the foundation piles, depending on whether cofferdams can be dewatered (Table 5.2.4). Based on a cumulative (daily) threshold of 187 dB SEL, the risk of injury is calculated to extend up to 4,126 feet (2,063 x 2) during installation of the cofferdams and 3,548 feet (1,774 x 2) during installation of the foundation piles (1,646 feet if the cofferdams can be dewatered) assuming an unimpeded propagation path. Based on a threshold of 150 dB RMS, the potential for behavioral effects is calculated to extend up to 13,058 feet away during cofferdam sheet pile installation, and 9,607 feet away during foundation pile installation (4,458 feet away if the cofferdams can be dewatered) assuming an unimpeded propagation path. However, the extent of noise levels exceeding the injury and behavioral thresholds would be constrained by major channel bends or levees located approximately 1,500 feet downstream of the proposed construction site in Old River, and approximately 700 feet upstream where levees at the junction of the San Joaquin River and Old River which would create a major impediment to sound propagation. The potential for effects could occur during two construction seasons (August 1-November 30) for up to 19 days during cofferdam installation and 4 days during foundation pile installation.

5.2.4.4.3.1 Salmonids

Pile driving activities from August 1 through November 30 may overlap with the upstream migration of adult steelhead in October and November and the downstream migration of juvenile steelhead and spring-run Chinook salmon (yearling or older smolts) in November. During cofferdam and foundation pile installation, peak SPLs exceeding the injury criteria would be limited to areas immediately adjacent to the source piles (20-46 feet), affecting approximately 27-61% of the total channel width available for adults to pass (75 feet). However, adults and juveniles passing the construction site during active pile driving operations would be potentially subject to cumulative noise exposures exceeding 187 dB SEL over areas extending across the entire width of Old River and upstream and downstream up to 2,063 feet away. Consequently, underwater noise levels capable of causing injury could affect adults and juveniles attempting to pass the construction site in Old River or migrating in the San Joaquin River and attempting to pass the Old River junction. However, the distances over which these levels would occur would likely be constrained by a major channel bend located approximately 1,500 feet downstream of the proposed construction site in Old River, and by levees at the junction of the San Joaquin River and Old River approximately 700 feet upstream of the site. Based on the general migration rates and reported swimming speeds of migrating adults and juvenile salmonids (smolts) (see Section 5.2.2.4.3), adult and juvenile steelhead within the range of sizes that are likely to occur in Old River and the San Joaquin River during pile driving activities would be capable of swimming through the affected reaches within a few hours and thus avoid or minimize their exposure to potentially harmful levels of underwater noise. Similarly, any delays in migration due to avoidance behavior are expected to be minor because of the rapid migration rates of juveniles and adults and daily opportunities for juveniles and adults to pass the affected areas at night when pile driving activities will cease. Nevertheless, juvenile salmonids that may be holding, sheltering, or feeding in these areas following initiation of daily pile driving activities may be forced to leave protective cover or exhibit alarm responses that could make them more vulnerable to predators.

Thus, the potential exists for some injury and mortality of steelhead and juvenile salmon to occur from pile driving noise during the proposed in-water construction period at the HOR gate. To minimize this risk, DWR 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 fish species (Appendix 3.F *General Avoidance and Minimization Measures*, AMM9 *Underwater Sound Control and Abatement Plan*). These measures include the use of vibratory and other non-impact driving methods as well as other physical and operational measures to limit the intensity and duration of underwater noise levels when listed fish species may be present. Where impact pile driving is required, hydroacoustic monitoring will be performed to determine compliance with established objectives (e.g., distances to cumulative noise thresholds) and identify corrective actions to be taken should the thresholds be exceeded.

5.2.4.4.3.2 Green Sturgeon

Potential exposure of adult green sturgeon to pile driving noise at the HOR gate is lower than other regions of the Delta because of the timing of pile driving relative to the spring spawning migration of adults and the distance of the HOR gate from their principal migration corridor. Juveniles are considered at higher risk because of their year-round presence in the Delta and potential for encountering pile driving noise at multiple locations during their 3-4 residence period. As discussed in section 5.2.2.4.3.2, evidence exists for avoidance of pile driving noise in other sturgeon species. Although such behavior may disrupt or delay the movements or foraging activities of juveniles in proximity to the Old River gate, the risk of adverse effects is expected to be reduced by daily opportunities for juveniles to leave the affected areas at night (dusk to dawn). This risk will be further reduced by implementing an underwater sound control and abatement plan (AMM9), and performing hydroacoustic monitoring to determine compliance with established objectives (e.g., distances to cumulative noise thresholds) and identify corrective actions to be taken should the thresholds be exceeded.

5.2.4.4.4 Assess Effects on Designated Critical Habitat

5.2.4.4.4.1 Salmonids

During construction of the HOR gate, underwater noise levels from pile driving and other construction activities will affect the designated critical habitat of CCV steelhead through temporary degradation of the PBFs of migratory habitat (i.e., unobstructed migratory pathways). Adverse effects on critical habitat would occur within areas subjected to noise levels associated with potential injury and behavioral effects, as described above. These effects would occur for approximately 19 days during installation of the sheet piles, and 4 days during installation of the foundation piles. Underwater noise levels will return to baseline levels following cessation of pile driving and other construction activities, and would not result in long-term impacts on critical habitat.

5.2.4.4.4.2 Green Sturgeon

The effects of underwater noise on the designated critical habitat of green sturgeon would be similar to that described for salmonids.

5.2.4.5 Fish Stranding

Installation of cofferdams to isolate construction areas for the HOR gate has the potential to strand and subject fish to direct exposure to dewatering and construction activities within the enclosed cofferdams. Sheet pile installation will be limited to the proposed in-water construction period (August 1-November 30) to avoid the peak abundance of listed fish species in the action area. When listed fish species may be present, DWR proposes to minimize potential stranding losses by implementing a fish rescue and salvage plan (Appendix 3.F *General Avoidance and Minimization Measures, AMM8 Fish Rescue and Salvage Plan*). The plan will be submitted to the fish and wildlife agencies (NMFS, USFWS, CDFW) for review and approval prior to implementation. The plan will include detailed procedures for fish rescue and salvage, including collection, holding, handling, and release, that would apply to all in-water activities with the potential to entrap fish. All fish rescue and salvage operations will be conducted under the guidance of a qualified fish biologist. The biologist, in consultation with a designated agency biologist, will determine the appropriate fish collection and relocation methods based on site-specific conditions and construction methods. For example, collection methods will likely vary depending on whether or to what extent (water depth) dewatering can be achieved.

5.2.4.5.1 Assess Species Exposure

5.2.4.5.1.1 Salmonids

Closure of the cofferdams and potential stranding of fish may overlap with the upstream migration of adult steelhead in October and November and the downstream migration of juvenile steelhead (yearling and older smolts) in November. SJR-basin spring-run Chinook salmon (yearling smolts) may also be present in November, assuming juveniles exhibit similar emigration patterns to Sacramento River spring-run populations.

5.2.4.5.1.2 Green sturgeon

Both adult and juvenile green sturgeon are known to occur in the lower reaches of the San Joaquin River and Delta. The risk of stranding of adult green sturgeon in cofferdams at the HOR gate may be lower than other regions of the Delta because of the location and timing of construction activities relative to the primary migration route (Sacramento River) and timing of upstream migration (late February to early May). Juvenile green sturgeon may be present year-round and therefore subject to stranding during the proposed in-water construction period.

5.2.4.5.2 Assess Species Response

5.2.4.5.2.1 Salmonids

Stranding of adult steelhead and juvenile steelhead and spring-run Chinook salmon in the cofferdams is considered unlikely because migrating adults and yearling or older smolts would be expected to avoid active construction areas (see 5.2.2.2.2 and 5.2.2.4.3).

5.2.4.5.2.2 Green Sturgeon

No specific information is available to evaluate the potential responses of green sturgeon to construction activities or their susceptibility to being stranded in cofferdams. However, most green sturgeon that are likely to be present in the action area at the time of cofferdam installation would be relatively large, highly mobile adults and juveniles that are capable of readily avoiding active construction areas.

5.2.4.5.3 Assess Risk to Individuals

5.2.4.5.3.1 Salmonids

With implementation of a fish rescue and salvage plan (AMM8), the likelihood of stranding and subsequent injury or mortality of individual salmonids would be low. Although proposed fish rescue and salvage activities are expected to minimize these risks, some losses may still occur because of varying degrees of effectiveness of the collection methods and potential injury or mortality associated with capture, handling, and relocation of fish (Kelsch and Shields 1996, Reynolds 1996).

5.2.4.5.3.2 Green Sturgeon

The potential for stranding of green sturgeon is similar to that described for salmonids.

5.2.4.6 Direct Physical Injury

During construction of the HOR gate, fish could be injured or killed by direct contact with equipment or materials that are operated or placed in open waters of Old River. Potential mechanisms include fish being impinged by sheetpiles, entrained by dredges, or struck by propellers during barge operations. DWR proposes to minimize the potential for injury of listed fish species by conducting all in-water construction activities between August 1 and November 30. In addition to the proposed work window (August 1-November 30, the potential for injury of listed fish species would be minimized to the extent practicable by limiting the duration of in-water construction activities and implementing the AMMs described in Appendix 3.F *General Avoidance and Minimization Measures*. Applicable AMMs include *Worker Awareness Training; Erosion and Sediment Control Plan; Disposal of Spoils, Reusable Tunnel Material, and Dredged Material; Barge Operations Plan; and Fish Rescue and Salvage Plan*.

5.2.4.6.1 Assess Species Exposure

5.2.4.6.1.1 Salmonids

During in-water construction activities of the HOR gate, the potential for injury of listed salmonids would exist in October and November for adult steelhead and November for juvenile steelhead and (yearling and older smolts). SJR-basin spring-run Chinook salmon (yearling smolts) may also be present in November, assuming juveniles exhibit similar emigration patterns to Sacramento River spring-run populations.

5.2.4.6.1.2 Green Sturgeon

Both adult and juvenile green sturgeon are known to occur in the lower reaches of the San Joaquin River and Delta. Potential exposure of adult green sturgeon to in-water construction activities at the HOR gate may be lower than other regions of the Delta because of the location and timing of construction activities relative to the primary migration route (Sacramento River) and timing of upstream migration (late February to early May). Juvenile green sturgeon may be present year-round and therefore could be exposed to in-water construction activities and potential injury during the proposed in-water construction period.

5.2.4.6.2 Assess Species Response

5.2.4.6.2.1 Salmonids

Most salmonids that are likely to be present in the action area at the time in-water construction activities are likely to be large, migrating adults and juveniles that would be expected to avoid or move away from active construction areas.

5.2.4.6.2.2 Green Sturgeon

Similarly, most green sturgeon that are likely to occur in the action area are likely to be large, actively swimming adults and juveniles that are capable of avoiding active construction areas.

5.2.4.6.3 Assess Risk to Individuals

5.2.4.6.3.1 Salmonids

There is a low risk of injury of salmonids based on the likely response to active construction activities.

5.2.4.6.3.2 Green Sturgeon

There is a low risk of injury of green sturgeon based on the likely response to active construction activities.

5.2.4.6.4 Assess Effects on Designated Critical Habitat

5.2.4.6.4.1 Salmonids

The potential for injury during in-water construction activities would have a temporary adverse effect on the PBFs of the designated critical habitat of CCV steelhead and juvenile steelhead and SJR-basin spring-run Chinook salmon (safe and unobstructed migratory corridors).

5.2.4.6.4.2 Green Sturgeon

The potential for injury during in-water construction activities would have a temporary adverse effect on the PBFs of the designated critical habitat of southern DPS green sturgeon (safe and unobstructed migratory corridors).

5.2.4.7 Loss/Alteration of Habitat

Construction of the HOR gate would result in temporary and permanent losses or alteration of aquatic habitat in Old River. Temporary effects of construction activities on water quality, including turbidity and suspended sediment, underwater noise, and contaminants, were previously discussed (Sections 5.2.4.2, 5.2.4.3, and 5.2.4.4). The following analysis focuses on longer-term to permanent impacts on physical habitat associated with construction activities. These impacts are estimated to encompass approximately 2.9 acres of tidal perennial habitat within the footprint of the cofferdams, permanent structures (gate, fish passage structure, and boat lock), and upstream and downstream channel areas that will be dredged. During the construction period (2 years), the cofferdams will affect up to 100 feet of the channel length and 75 feet (50%) of the channel width. No additional impacts associated with construction staging, access, or levee clearing/armoring are anticipated because of the presence of existing roads, staging areas, and riprap that have been used in recent years to install the temporary rock barrier.

During construction activities, DWR will implement Appendix 3.F *General Avoidance and Minimization Measures*, *AMM2 Construction Best Management Practices and Monitoring*, to protect listed fish, wildlife, and plant species, their designated critical habitat, and other sensitive natural communities. These BMPs include a number of measures to limit the extent of disturbance of aquatic and riparian habitat during construction, and, following construction, to restore temporarily disturbed areas to pre-construction conditions. All construction and site restoration BMPs will be subject to an approved construction and post-construction monitoring plan to ensure their effectiveness. DWR proposes to offset unavoidable impacts to the designated critical habitat of CCV steelhead, SJR-basin spring-run Chinook salmon and southern DPS green sturgeon through restoration of aquatic and channel margin habitat at an approved restoration site and/or the purchase of conservation credits at an approved conservation bank.

5.2.4.7.1 Assess Species Exposure

5.2.4.7.1.1 Salmonids

All migrating or rearing salmonids that occur in the action area during construction of the HOR gate would be potentially exposed to the physical alteration of aquatic and channel margin habitat within the footprints of the cofferdams, permanent structures, and dredged areas.

5.2.4.7.1.2 Green Sturgeon

All migrating or rearing green sturgeon that occur in the action area during construction of the HOR gate would be potentially exposed to the physical alteration of aquatic and channel margin habitat within the footprints of the cofferdams, permanent structures, and dredged areas.

5.2.4.7.2 Assess Species Response

5.2.4.7.2.1 Salmonids

Old River in the action area of the HOR gate is within the designated critical habitat of CCV steelhead. Habitat conditions for anadromous salmonids in the action area of the HOR gate are degraded from historical conditions and the habitat likely functions primarily as a migration corridor for adults migrating to upstream spawning areas and juveniles migrating downstream to the estuary and ocean. The PBFs supporting the migration and rearing of steelhead in the action area have been degraded by altered flow patterns, levee construction, extensive riprapping, and loss of natural wetland and floodplain habitat. Because of these conditions and past disturbance associated with the annual installation of a temporary rock barrier at the site, it is unlikely that the construction of the HOR gate will substantially degrade the PBFs of critical habitat relative to current conditions. During construction, fish passage past the construction site would be maintained by constructing half the structure in one year and the remaining half in the following year. Increased water velocities resulting from constriction of the flow may result in delays in migration and increased energy expenditure by adults to pass the site but these effects are not expected to significantly affect migration timing or the condition of migrating adults based on the strong swimming abilities of adults and the distances over which potentially higher velocities would be encountered (up to 100 feet).

Some reductions is expected in the quality of passage and rearing conditions for juvenile salmonids due to changes in hydraulic conditions associated with the cofferdams, potential bed scour adjacent to the cofferdams, and dredging both upstream and downstream of the proposed barrier. Potential impacts to the PBFs of critical habitat for CCV steelhead would generally result in loss of shallow water habitat, instream cover, benthic food resources, and altered hydraulic conditions that may increase exposure of migrating juveniles to predation. The installation of cofferdams in Old River may attract predator fish species (e.g., striped bass) and potentially increase their ability to ambush juvenile salmonids and other fishes. In addition, the constriction of flow and increases in water velocities and turbulence at the interface of the cofferdams and the river may concentrate and disorient juvenile salmonids, further enhancing the risk of predation. In addition, the elimination or disturbance of benthic habitat and associated invertebrate communities due to pile installation, scour, and dredging would result in localized reductions in benthic substrates that support important food organisms (benthic invertebrates) for juvenile salmonids. This represents a permanent alteration of habitat that would exist throughout the construction period (3 years).

5.2.4.7.2.2 Green Sturgeon

Old River in the action area of the HOR gate is within the designated critical habitat of southern DPS green sturgeon. Based on the degraded status of habitat in Old River near the HOR gate, this area likely functions primarily as a migration corridor for adult green sturgeon and low-quality foraging habitat for juveniles. Based on the expected changes in habitat conditions resulting from the construction of the HOR gate, impacts to the PCEs of green sturgeon critical habitat would primarily be caused by the loss of foraging habitat within the footprints of the cofferdams, permanent structures, and channel areas upstream and downstream of the structure that will be dredged. Because of their benthic nature and strong swimming abilities, green sturgeon would likely be unaffected by the changes in hydraulic conditions described above..

5.2.4.7.3 Assess Risk to Individuals

5.2.4.7.3.1 Salmonids

Changes in physical and hydraulic conditions during construction of the HOR gate are expected to have insignificant effects on migrating adult salmonids; suitable passage conditions for adults would be maintained throughout the construction period by limiting construction to half the channel width during each year of construction. Although the proposed construction site currently provides low quality habitat for juvenile salmonids, the installation of the in-channel structures and dredging would further degrade this habitat by altering hydraulic conditions and eliminating shallow water habitat, instream cover, and benthic food resources within these areas. This is unlikely to affect the growth of juvenile salmonids because of the low quality and likely minimal use of this habitat by rearing salmonids under existing conditions. However, the lack of cover for juvenile fish and the structural and hydraulic changes associated with the presence of the cofferdams may increase the risk of predation by increasing the amount of predator habitat and/or susceptibility of juvenile salmonids to predation as they pass the construction site.

5.2.4.7.3.2 Green Sturgeon

Based on the degraded status of habitat in Old River near the HOR gate, construction of the HOR gate is unlikely to adversely affect adult sturgeon, and would have minimal effects on rearing and passage conditions for juveniles. The primary effect of construction on the critical habitat of Southern DPS green sturgeon is the loss of potential foraging habitat (benthic habitat) within the footprints of the permanent in-channel structures and dredged area. This is unlikely to have a measurable effect on growth and survival of green sturgeon because it represents a very small proportion of the total amount of habitat available to juveniles during their residence in the Delta and estuary.

5.2.4.7.4 Assess Effects on Designated Critical Habitat

5.2.4.7.4.1 Salmonids

Impacts to the designated critical habitat of CCV steelhead include permanent impacts on juvenile migration and rearing habitat, as described above. DWR proposes to offset impacts to the designated critical habitat of steelhead through restoration of tidal perennial habitat at an approved restoration site and/or the purchase of conservation credits at an approved conservation bank (Table 3.4-1).

5.2.4.7.4.2 Green Sturgeon

Impacts to the designated critical habitat of green sturgeon include permanent impacts on juvenile migration and rearing habitat, as described above. DWR proposes to offset impacts to the designated critical habitat of green sturgeon through restoration of tidal perennial habitat at an approved restoration site and/or the purchase of conservation credits at an approved conservation bank (Table 3.4-1).

5.2.5 Clifton Court Forebay

5.2.5.1 Deconstruct the Action

Construction activities at Clifton Court Forebay (CCF) that may potentially affect listed salmonids and green sturgeon include expansion and dredging of SCCF, construction of divider wall and east/west embankments, dewatering and excavation of NCCF, construction of NCCF outlet canals and siphons, and construction of a SSCF intake structure and NCCF emergency spillway. The estimated 7-year construction period will be phased, beginning with expansion of SCCF (Phases 1, 2, and 3); construction of the divider wall between NCCF and SCCF (Phase 4); construction of the west and east embankments (Phase 5); and construction of the NCCF east, west, and north side embankments (Phases 6, 7, and 8). Details on the design, construction methods, and proposed construction schedule for CCF are described in Chapter 3.

Permanent impacts on aquatic habitat include the loss of an estimated 258 acres of tidal perennial habitat in CCF that would be replaced by permanent fill and structures associated with the new CCPP, perimeter and divider embankments, outlet canals and siphons, and intake structure and spillway (Mapbook M3.A).

5.2.5.2 Turbidity and Suspended Sediment

In-water construction activities at CCF would result in elevated turbidity and suspended sediment levels in CCF and Old River. The principal sources of increased turbidity and suspended sediment are dredging, cofferdam construction (sheet pile installation and removal), levee clearing and grading, and riprap placement. Minor increases in turbidity and suspended sediment in CCF and Old River are also expected during construction of the CCPP, embankments, outlet canal and siphons, SSCF intake structure, and North CCF (NCCF) emergency spillway. All other sediment-disturbing activities within cofferdams, upland areas, or non-fish-bearing waters pose little or no risk to listed fish species or aquatic habitat.

The potential for adverse effects of elevated turbidity and suspended sediment on listed fish species would be minimized by restricting all in-water construction to July1-November 30, limiting the duration of these activities to the extent practicable, and implementing the AMMs described in Appendix 3.F *General Avoidance and Minimization Measures* to protect listed fish species from water quality impairment. These measures include *Worker Awareness Training; Construction Best Management Practices and Monitoring; Stormwater Pollution Prevention Plan (SWPPP); Erosion and Sediment Control Plan; Spill Prevention, Containment, and Countermeasure Plan (SPCCP);* and *Hazardous Material Management Plan, and Disposal and Reuse of Spoils, Reusable Tunnel Material, and Dredged Material Plan*.

Dredging of CCF will result in the suspension of large volumes of sediment and potential secondary effects on water quality, including potential re-suspension of contaminants and reductions in dissolved oxygen levels associated with the decomposition of vegetation and organic material in disturbed sediments. In addition to implementing the AMMs listed above, DWR proposes to limit the potential exposure of listed species to water quality impacts by restricting the timing, extent, and frequency of major sediment-disturbing events. For example, DWR proposes to limit the extent of dredging impacts in CCF by restricting daily operations to two dredges operating for 10-hour periods (daylight hours) within 200-acre cells enclosed by silt curtains (representing approximately 10% of total surface area of CCF). In addition, dredging will be monitored and regulated through the implementation of the *Disposal and Reuse of Spoils, Reusable Tunnel Material, and Dredged Material Plan*, which includes preparation of a sampling and analysis plan, compliance with NPDES and SWRCB water quality requirements during dredging activities, and compliance with applicable in-water work windows established by CDFW, NMFS, and USFWS.

Some potential exists for construction-related turbidity and suspended sediment to occur during winter and spring due to increased erosion and mobilization of sediment in runoff from disturbed levee surfaces. However, with implementation of the proposed erosion and sediment control measures (AMM4) and other BMPs to ensure the effectiveness of these measures (*AMM2, Construction Best Management Practices and Monitoring*), no adverse water quality effects are anticipated outside of the in-water construction season.

5.2.5.2.1 Assess Species Exposure

5.2.5.2.1.1 Salmonids

The timing of in-water construction activities (July 1–November 30) will avoid the sensitive winter and spring migration, spawning, and early rearing periods of listed fish species in the Delta. However, based on continued operation of CCF and potential entrainment of listed fish species into CCF during construction activities, in-water construction activities may affect adult steelhead which may be present in the Delta in late summer or fall (starting as early as August for Sacramento River steelhead). In addition, extending in-water construction activities into November results in the potential exposure of juvenile steelhead (yearling and older smolts), spring-run Chinook salmon (yearling smolts), and winter-run Chinook salmon (young-of-the year). SJR-basin spring-run Chinook salmon juveniles may also be present in November, assuming juveniles exhibit similar emigration patterns to Sacramento River spring-run populations.

5.2.5.2.1.2 Green Sturgeon

Both adult and juvenile green sturgeon are known to occur in the lower reaches of the San Joaquin River and Delta. The in-water construction period (July 1–November 30) will avoid the peak upstream migration period of green sturgeon (late February to early May) although adults (post-spawning adults) and juveniles may be present in the Delta year-round and therefore potentially exposed to increases in turbidity and suspended sediment in CCF during the in-water construction period. Salvage of green sturgeon generally peaks in the summer although few are generally encountered at the Skinner and Tracy salvage facilities in recent years (NMFS 2015).

5.2.5.2.2 Assess Species Response

5.2.5.2.2.1 Salmonids

As described for the north Delta intakes, turbidity and suspended levels typically generated by in-water construction activities are not expected to reach levels that would cause direct injury to salmonids. All steelhead that may be present in CCF and Old River during the in-water work window would be large, actively migrating adults and juveniles (smolts) that are capable of avoiding active construction areas. With implementation of the AMMs, in-water construction activities would result in temporary, localized increases in turbidity and suspended sediment that dissipate rapidly with distance from the source and return to baseline levels following daily in-water activities. The effects on adult and juvenile steelhead would likely be limited to harassment of individuals that encounter turbidity plumes.

Increases in suspended sediment during in-water construction activities may result in localized sediment deposition in CCF and Old River, potentially degrading food-producing areas by burying benthic substrates that support important food organisms (benthic invertebrates) for juvenile salmonids. However, CCF and the adjacent south Delta channels have been highly altered for the purpose of water conveyance and lack many of the attributes of functional migration and rearing habitat. Therefore, the potential effects of sedimentation on food production would likely have little or no effect on juvenile steelhead growth or survival due to the temporary, localized nature of these effects and low quality of existing habitat.

5.2.5.2.2.2 Green Sturgeon

No specific information is available to evaluate the potential responses of green sturgeon to increased turbidity and suspended sediment. Green sturgeon may be affected in similar ways to salmonids although green sturgeon may be less sensitive to short-term increases in suspended sediments or turbidity because of their use of olfactory cues as opposed to vision to locate prey. Any reductions in the availability of foraging habitat and food due to sedimentation of benthic habitat would likely have little or no effect on growth or survival due to the temporary, localized nature of these effects and low quality of existing habitat in CCF and adjacent south Delta channels.

5.2.5.2.3 Assess Risk to Individuals

5.2.5.2.3.1 Salmonids

Based on the expected responses of salmonids to construction-related increases on turbidity and suspended sediment, any disruptions of the normal behavior are expected to be brief and unlikely to cause adverse effects. With the implementation of the proposed AMMs, potential effects on listed salmonids are expected to be negligible.

5.2.5.2.3.2 Green Sturgeon

Based on their large size, mobility, and benthic feeding adaptations, green sturgeon are unlikely to be affected by increases in turbidity and suspended sediment during in-water construction activities at CCF.

5.2.5.2.4 Assess Effects on Designated Critical Habitat

5.2.5.2.4.1 Salmonids

Increases in turbidity and suspended sediment levels during construction of the new SCCF intake structure and NCCF emergency spillway will affect the PBFs of the designated critical habitat of CCV steelhead. Elevated turbidity and suspended sediment generated by in-water construction activities would primarily affect the PBFs of freshwater rearing habitat and migration corridors through temporary degradation of water quality and potential sedimentation of potential food-producing areas. These effects will be localized and temporary and therefore unlikely to significantly affect the conservation value of rearing and migration habitat in the action area.

5.2.5.2.4.2 Green Sturgeon

Increases in turbidity and suspended sediment levels during construction of the new SCCF intake structure and NCCF emergency spillway will affect the PBFs of the designated critical habitat for southern DPS green sturgeon. These effects would be limited to localized, temporary degradation of the PBFs of water quality and potential sedimentation of food-producing areas. No long-term or permanent effects on critical habitat are expected.

5.2.5.3 Contaminants

Dredging, excavation, and expansion of the CCF and construction of new water conveyance facilities presents an exposure risk to salmonids and green sturgeon from potential spills of hazardous materials from construction equipment and from potential exposure and re-suspension of contaminated sediment. The risk of accidental spills of contaminants and other potentially hazardous materials would be similar to that described for the north Delta intakes (section 5.2.2.3) due to the proximity of construction activities to the waters of CCF and adjacent waterways. Implementation of AMM 5, *Spill Prevention, Containment, and Countermeasure Plan*, and AMM14 *Hazardous Materials Management* (see Appendix 3.F *General Avoidance and Minimization Measures*) is expected to minimize the potential for introduction of contaminants into surface waters and guide rapid and effective response in the case of inadvertent spills of hazardous materials. With implementation of these and other required construction BMPs (e.g., AMM 3, *Stormwater Pollution Prevention Plan*), the risk of contaminant spills or discharges to Delta waters from in-water or upland sources would be effectively minimized.

As described in Section 5.2.2.3 *Contaminants*, contaminated sediments can adversely affect fish through direct exposure from mobilized sediment or indirect exposure through accumulation of contaminants in the food web. Consequently, dredging, excavation, and expansion of CCF poses a substantial short-term and long-term risk of exposure of fish and other aquatic organisms to elevated concentrations of contaminants. Current estimates indicate the dredging will affect up to 1,932 acres of CCF while expansion of the SCCF will create an additional 590 acres of newly exposed sediment. The proximity of the south Delta to agricultural, industrial, and municipal sources indicates that a broad range of contaminants that are toxic to fish and other aquatic biota, including metals (e.g., copper, mercury), hydrocarbons, pesticides, and ammonia, could be present. Mud and silt in south Delta waterways have been shown to contain elevated concentrations of contaminants, including mercury, pesticides (chlorpyrifos, diazinon, DDT), and other toxic substances (California State Water Resources Control Board 2010). Impairments in Delta waterways also include heavy metals such as selenium, cadmium, and nickel (G. Fred Lee & Associates 2004). Thus, exposure and resuspension of sediments during in-water construction could lead to degradation of water quality and adverse effects on fish or their food resources in the action area.

The potential for introduction of contaminants from disturbed sediments will be addressed through the implementation of specific measures addressing containment, handling, storage, and disposal of contaminated sediments, as described under AMM6 *Disposal of Spoils, Reusable Tunnel Material, and Dredged Material* in Appendix 3.F *General Avoidance and Minimization Measures*. These measures include the preparation and implementation of a pre-construction sampling and analysis plan (SAP) to characterize contaminants and determine appropriate BMPs to minimize or avoid mobilization of contaminated sediments during in-water construction activities. Because potential mobilization of contaminants is closely linked to sediment disturbance and associated increases in turbidity and suspended sediment, turbidity monitoring and control measures (e.g., silt curtains) to achieve compliance with existing Basin Plan objectives will be important measures for limiting dispersal of contaminated sediments during dredging and other in-water construction activities.

5.2.5.3.1 Assess Species Exposure

5.2.5.3.1.1 Salmonids

The potential for contaminant spills would exist throughout the construction period with the highest risk occurring during in-water construction activities. Based on the general timing of migration of listed salmonids in the action area, the potential for direct exposure to contaminants would exist for steelhead adults in August-November, and juvenile steelhead (yearling and older smolts), juvenile spring-run Chinook salmon (yearling smolts), and juvenile winter-run Chinook salmon (young-of-the year) in November. SJR-basin spring-run Chinook salmon juveniles may also be present in November, assuming juveniles exhibit similar emigration patterns to Sacramento River spring-run populations. However, exposure to contaminants may occur throughout the year and persist after construction due to the exposure of newly exposed sediment, and repeated resuspension or exposure of sediments by wind, currents, and subsequent maintenance dredging.

5.2.5.3.1.2 Green Sturgeon

The risk of exposure of adult green sturgeon to potential contaminant spills at CCF may be lower than other regions of the Delta because of the location and timing of construction activities relative to the primary migration route (Sacramento River) and timing of upstream migration (late February to early May). Juvenile green sturgeon may be present year-round and therefore could be exposed to potential contaminant spills as well as potential contaminants in newly exposed sediment throughout the year. In comparison to salmonids, green sturgeon are more likely to be exposed to contaminated sediments and food sources because of their relatively long residence time (3-4 years for rearing juveniles) and prolonged contact with sediment both externally (e.g., resting and foraging on the bottom) and through ingestion of benthic food organisms.

5.2.5.3.2 Assess Species Response

5.2.5.3.2.1 Salmonids

As described in section 5.2.2.3, the discharge of contaminants into the aquatic environment can cause direct or indirect effects on fish depending on the type, concentrations, and fate of contaminants. In addition to direct exposure from spills or re-suspension of contaminated sediments, contaminants can enter the aquatic food web and accumulate in fish through their diet, leading to lethal and sublethal effects, including effects on behavior, tissues and organs, reproduction, growth, and immune system (Connon et al. 2009).

5.2.5.3.2.2 Green Sturgeon

The potential effects of contaminants and general exposure mechanisms described above are also applicable to green sturgeon.

5.2.5.3.3 Assess Risk to Individuals

5.2.5.3.3.1 Salmonids

Implementation of the proposed *Spill Prevention, Containment, and Countermeasure Plan* (AMM 5), *Hazardous Materials Management* (AMM6), and *Stormwater Pollution Prevention Plan* (AMM3) is expected to minimize the potential for spills or discharges of contaminants into Old River. Adherence to all preventative, response, and disposal measures in the approved plans are expected to reduce the potential effects to listed fish species to discountable levels. No information is available on potential contaminant risks associated with disturbance and exposure of sediments in CCF. However, this risk is expected to be minimized by developing and implementing a SAP to characterize contaminants and determine appropriate BMPs to minimize or avoid mobilization of contaminated sediments during in-water construction activities. Some exposure of listed salmonids to sediment-borne contaminants or elevated contaminants in food organisms may be unavoidable because of the potential dispersal of contaminants during construction and continued disturbance and exposure of sediments during maintenance dredging and natural sediment transport processes.

5.2.5.3.3.2 Green Sturgeon

The proposed AMMs to minimize the potential for spills or discharges of contaminants during proposed construction activities at CCF also expected to protect green sturgeon. Compared to salmonids, however, green sturgeon are considered to be at higher risk of exposure to contaminated sediments because of their benthic orientation, diet, and relatively long residence of juveniles in the Delta (3-4 years), which increases the duration of exposure at CCF as well as the probability of encountering elevated contaminants at other construction sites (north Delta intakes, barge landings, and HOR gate).

5.2.5.3.4 Assess Effects on Designated Critical Habitat

5.2.5.3.4.1 Salmonids

The potential release of contaminants through spills or sediment disturbance could affect the PBFs of the designated critical habitat of CCV steelhead through adverse effects on water quality and food resources (reduced abundance of benthic invertebrates and consumption of contaminated benthic invertebrates). With implementation of the proposed AMMs, the risk of adverse effects of contaminants on critical habitat would be negligible.

5.2.5.3.4.2 Green Sturgeon

The potential release of contaminants through spills or sediment disturbance could affect the PBFs of the designated critical habitat of southern DPS green sturgeon through adverse effects on water quality and food resources (reduced abundance of benthic invertebrates and consumption of contaminated benthic invertebrates). With implementation of the proposed AMMs, the risk of adverse effects of contaminants on critical habitat would be negligible.

5.2.5.4 Underwater Noise

During construction of the CCF water conveyance facilities, activities that are likely to generate underwater noise include in-water pile driving, riprap placement, dredging, and barge operations. Pile driving conducted in or near open water poses the greatest risk to fish because the levels of underwater noise produced by impulsive types of sounds often reach levels of sufficient intensity to injure or kill fish within a certain radius of the source piles (Popper and Hastings 2009). Other activities such as riprap placement, dredging, and barge operations generally produce more continuous, lower energy sounds below the thresholds associated with direct injury but may cause avoidance behavior or temporary hearing loss or physiological stress if avoidance is not possible or exposure is prolonged (Popper and Hastings 2009).

Pile driving conducted in or near open water can produce underwater noise of sufficient intensity to injure or kill fish within a certain radius of the source piles. Pile driving information for CCF is available for the embankments, divider wall, siphon at NCCF outlet, and siphon at Byron Highway (Appendix 3.E *Pile Driving Assumptions for the Proposed Action*). Pile driving operations include the installation of an estimated 10,294 temporary sheet piles to construct the cofferdams for the embankments and divider wall, and 2,160 14-inch diameter concrete or steel pipe piles to construct the siphon at the NCCF outlet. Pile driving for the siphon under Byron Highway is not addressed in the following analysis because all pile driving would be conducted on land and more than 200 feet from water potentially containing listed fish species. A total of 4 construction seasons will likely be required to complete pile driving operations based on the estimated duration of pile installation (Appendix 3.D *Construction Schedule for the Proposed Action*).

DWR proposes to minimize the potential exposure of listed fish species to pile driving noise by conducting all in-water construction activities between July 1 and November 30. In addition, DWR 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 fish species (Appendix 3.F *General Avoidance and Minimization Measures*, AMM9 *Underwater Sound Control and Abatement Plan*). These measures include the use of vibratory and other non-impact driving methods as well as other physical and operational measures to limit the intensity and duration of underwater noise levels when listed fish species may be present. Where impact pile driving is required, hydroacoustic monitoring will be performed to determine compliance with established objectives (e.g., distances to cumulative noise thresholds) and identify corrective actions to be taken should the thresholds be exceeded.

5.2.5.4.1 Assess Species Exposure

5.2.5.4.1.1 Salmonids

Based on continued operation of CCF and potential entrainment of listed fish species into CCF during in-water construction activities (July 1-November 30), potential exposure of listed salmonids to pile driving noise would exist for adult steelhead in August-November, and juvenile steelhead (yearling and older smolts), spring-run Chinook salmon (yearling smolts), and winter-run Chinook salmon (young-of-the year) in November. SJR-basin spring-run Chinook salmon juveniles may also be present in November, assuming juveniles exhibit similar emigration patterns to Sacramento River spring-run populations.

5.2.5.4.1.2 Green Sturgeon

Both adult and juvenile green sturgeon are known to occur in CCF and the adjacent south Delta channels. The in-water construction period (July 1–November 30) will avoid the peak upstream migration period of green sturgeon (late February to early May) although adults (post-spawning adults) and juveniles may be present in the Delta year-round and therefore potentially exposed to pile driving noise during the in-water construction period.

5.2.5.4.2 Assess Species Response

5.2.5.4.2.1 Salmonids

As described for the north Delta intakes, the potential responses of fish to pile driving noise can range from behavioral effects to direct injury or mortality, depending on a number of biological, physical, and exposure variables. Sound exposure criteria currently in use by state and federal resource and transportation agencies in California, Oregon, and Washington to evaluate the potential for injury to pile driving activities are presented in Table 5.2-5. The peak SPL is considered the maximum sound pressure level a fish can receive from a single strike without injury. The cumulative SEL is considered the total amount of acoustic energy that a fish can receive from a single or multiple strikes without injury. Pile driving and other sources of construction noise may also cause behavioral responses that could disrupt or delay normal activities, potentially leading to adverse effects on survival, growth, and reproductive success. Insufficient data are currently available to support the establishment of a noise threshold for behavioral effects (Popper et al. 2006); however, it is generally assumed that 150 dB RMS is an appropriate threshold for behavioral effects.

5.2.5.4.2.2 Green Sturgeon

The interim criteria in Table 5.2-1 are assumed to be applicable to green sturgeon based on general similarities in anatomy and physiology (e.g., presence of a swim bladder) to other fishes for which data are available.

5.2.5.4.3 Assess Risk to Individuals

Table 5.2-5 presents the extent, timing, and duration of pile driving noise levels predicted to exceed the interim injury and behavioral thresholds during installation of cofferdam sheet piles for the embankments and divider wall, and the structural piles for the NCCF siphon based on application of the NMFS spreadsheet model and the assumptions presented in Appendix 3.E *Pile Driving Assumptions for the Proposed Action*. For cofferdam sheet piles, it is assumed that approximately 70% of the length of each pile can be driven using vibratory pile driving, with impact driving used to finalize pile placement. For the NFFC siphon piles, the current design assumes the use of impact pile driving only. However, some degree of attenuation is expected assuming that the cofferdams can be fully dewatered. Therefore, predictions are shown for two scenarios, one in which dewatering results in a 5 dB reduction in reference noise levels, and one in which no attenuation is possible.

Table 5.2-5. Extent, Timing, and Duration of Pile Driving Noise Levels Predicted to Exceed the Interim Injury and Behavioral Thresholds at CCF.

Facility	Distance to 206 dB SPL Injury Threshold (feet)	Distance to Cumulative 187 dB SEL Injury Threshold[1, 2] (feet)	Distance to 150 dB RMS Behavioral Threshold[2] (feet)	Number and Timing of Construction Seasons	Timing of Pile Driving	Duration of Pile Driving (days)
Clifton Court Forebay						
Embankment Cofferdams	30	2,814	13,058	1 (Year 5)	Jul–Nov	85
Divider Wall	30	2,814	13,058	1 (Year 4)	Jul–Nov	86
NCCF Siphon (no attenuation)	46	1,774	9,607	2 (Years 2-3)	Jul–Nov	72
NCCF Siphon (with attenuation)	20	823	4,458	2 (Years 2-3)	Jul–Nov	72

[1] Computed distances to injury thresholds are governed by the distance to "effective quiet" (150 dB SEL). Calculation assumes that single strike SELs <150 dB do not accumulate to cause injury. Accordingly, once the distance to the cumulative injury threshold exceeds the distance to effective quiet, increasing the number of strikes does not increase the presumed injury distance.

[2] Distance to injury and behavioral thresholds assume an attenuation rate of 4.5 dB per doubling of distance and an unimpeded propagation path; on-land pile driving, vibratory driving or other non-impact driving methods, dewatering of cofferdams, and the presence of major river bends or other channel features can impede sound propagation and limit the extent of underwater sounds exceeding the injury and behavioral thresholds.

Sound monitoring data collected during similar types of pile driving operations indicate that single-strike peak SPLs exceeding the interim injury thresholds are expected to be limited to areas within 30 feet of the cofferdam sheet piles and 20-46 feet of the NCCF siphon piles (Table 5.2-5). Based on a cumulative (daily) threshold of 187 dB, the risk of injury is calculated to extend 2,814 feet away from the source piles during installation of cofferdam sheet piles and 1,774 feet during installation of the NCCF siphon piles (823 feet if the cofferdams can be dewatered).[8] Based on a threshold of 150 dB RMS, the potential for behavioral effects is calculated to extend 13,058 and 9,607 feet (4,458 if the cofferdams can be dewatered), respectively. Such exposures would occur over a period of up to 72 days (36 days per season) during installation of the NCCF siphon piles (second and third years of construction activities at CCF), 86 days during cofferdam construction for the divider wall (year 4), and 85 days during cofferdam construction for the embankments (year 5).

5.2.5.4.3.1 Salmonids

Based on the general migration timing of listed salmonids in the Delta, pile driving activities at CCF could overlap with the presence of adult steelhead in August-November, and juvenile steelhead (yearling and older smolts), spring-run Chinook salmon (yearling smolts), and winter-run Chinook salmon (young-of-the year) in November.

Peak SPLs exceeding the injury criteria would be limited to a distance of 30 feet from the cofferdam sheet piles, affecting a very small fraction of CCF during sheet pile installation. During installation of the NCCF siphon piles, peak SPLs exceeding the injury criteria would

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[8] In this case, the distance to the injury thresholds are governed by the distance to "effective quiet" (150 cB SEL).

extend 20-46 feet from the source piles, affecting approximately 7-15% of the width (300 feet) of the channel entrance available for fish to pass from CCF to the SFPF (assuming half-width construction of the NCCF siphon). Thus, adults and juvenile salmonids would continue to have access to large areas of CCF and sufficient area to pass the construction sites and avoid exposure to potentially harmful noise levels. However, areas subject to cumulative levels of pile driving noise exceeding the 187 dB cumulative SEL threshold are predicted to extend up to 2,814 feet away from the source piles during installation of the cofferdam sheet piles, affecting from 25-50% of CCF, and up to 1,774 feet away from the source piles during installation of the siphon piles, affecting 15-20% of CCF and the entire width of the channel entrance leading to the SFPF. Assuming a 5 dB reduction in noise levels can be achieved through dewatering of the cofferdams at the NCCF siphon, the distances to the 187 dB threshold can be approximately halved but noise levels would remain above the cumulative injury thresholds in all waters at the SFPF entrance channel and surrounding waters up to 823 feet away. Pile driving noise exceeding the 150 dB RMS would encompass much or all of CCF during installation of the cofferdam sheet piles and siphon piles (up to 9,607-13,058 feet), and thus could affect the behavior of all fish that are present or entrained into CCF during pile driving operations.

Thus, the potential exists for noise-related injury and mortality of listed salmonids that become entrained into CCF during active pile driving operations. This risk would exist for up to 36 days per year during construction of the NCCF siphon, and 86 days per year during installation of the embankment and divider wall cofferdams. This risk is particularly high in CCF because of limited opportunities to avoid pile driving noise and the presence of other stressors that may compound or contribute to poor survival in CCF, especially for juvenile salmonids that are subject to high pre-screen mortality rates in CCF (Gingras 1997, Clark et al. 2009). To minimize this risk, DWR 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 fish species (Appendix 3.F *General Avoidance and Minimization Measures*, AMM9 *Underwater Sound Control and Abatement Plan*). These measures include the use of vibratory and other non-impact driving methods as well as other physical and operational measures to limit the intensity and duration of underwater noise levels when listed fish species may be present. Where impact pile driving is required, hydroacoustic monitoring will be performed to determine compliance with established objectives (e.g., distances to cumulative noise thresholds) and identify corrective actions to be taken should the thresholds be exceeded.

5.2.5.4.3.2 Green Sturgeon

The assessment above is assumed to be generally applicable to green sturgeon. Although capable of avoiding pile driving noise and other construction-related disturbances, juvenile and adult sturgeon have a relatively high risk of injury or behavioral effects from pile driving noise because of their year-round residence in the Delta. Similar to juvenile salmonids, this risk is particularly high in CCF where green sturgeon would have limited opportunities to avoid pile driving and other construction-generated noise that will likely affect much of the forebay during the four years of pile driving operations.

5.2.5.4.4 Assess Effects on Designated Critical Habitat

5.2.5.4.4.1 Salmonids

CCF is not part of the designated critical habitat for CCV steelhead and thus actions taken within the forebay itself do not affect the PBFs for migration and rearing. However, pile driving noise would occur in Old River and other adjacent channels during construction of the new SSCF intake structure and NCCF emergency spillway. This represents a temporary impact on the designated critical habitat of CCV steelhead. Elevated underwater noise levels would occur only during active pile driving operations and would return to baseline levels whenever pile driving operations cease each day. No long-term or permanent effects on critical habitat would occur.

5.2.5.4.4.2 Green Sturgeon

The designated critical habitat of DPS green sturgeon also does not include CCF but does include other waters in the Delta. Thus, pile driving noise in Old River during construction of the new SSCF intake structure and NCCF emergency spillway would result in a temporary impact on the designated critical habitat of southern DPS greens sturgeon. Elevated underwater noise levels would occur only during active pile driving operations and would return to baseline levels whenever pile driving operations cease each day. No long-term or permanent effects on critical habitat would occur.

5.2.5.5 Fish Stranding

Installation of cofferdams or silt curtains to isolate construction and dredging areas in CCF and the adjacent Old River channel has the potential to strand and subject fish to direct exposure to construction activities within the enclosed structures. Installation of cofferdams and silt curtains will be limited to the proposed in-water construction period (July 1-November 30) to avoid the peak abundance of listed fish species in the action area. When listed fish species may be present, DWR proposes to minimize potential stranding losses by implementing a fish rescue and salvage plan (Appendix 3.F *General Avoidance and Minimization Measures*, AMM8 *Fish Rescue and Salvage Plan*). This plan will be submitted to the fish and wildlife agencies (NMFS, USFWS, CDFW) for review and approval prior to implementation. The plan will include detailed procedures for fish rescue and salvage, including collection, holding, handling, and release, that would apply to all in-water activities with the potential to entrap fish. All fish rescue and salvage operations will be conducted under the guidance of a qualified fish biologist. The biologist, in consultation with a designated agency biologist, will determine the appropriate fish collection and relocation methods based on site-specific conditions and construction methods. Collection methods may include seines, dip nets, and electrofishing if permitted.

5.2.5.5.1 Assess Species Exposure

5.2.5.5.1.1 Salmonids

Based on continued operation of CCF and potential entrainment of listed fish species into CCF during in-water construction activities (July 1-November 30), the potential for stranding of listed salmonids exists for adult steelhead in August-November, and juvenile steelhead (yearling and older smolts), spring-run Chinook salmon (yearling smolts), and winter-run Chinook salmon (young-of-the year) in November. SJR-basin spring-run Chinook salmon juveniles may also be present in November, assuming juveniles exhibit similar emigration patterns to Sacramento River spring-run populations.

5.2.5.5.1.2 Green sturgeon

Both adult and juvenile green sturgeon are known to occur in CCF and the adjacent south Delta channels. The in-water construction period (July 1–November 30) will avoid the peak upstream migration period of green sturgeon (late February to early May) although adults (post-spawning adults) and juveniles may be present in the Delta year-round and therefore potentially subject to stranding during the in-water construction period.

5.2.5.5.2 Assess Species Response

5.2.5.5.2.1 Salmonids

Although capable of avoiding active construction areas, juvenile and adult steelhead are at some risk of being stranded within the cofferdams or silt curtains. Any stranded fish within the cofferdams would likely be killed by subsequent dewatering and construction within the enclosed structures. The fate of steelhead that may become stranded within the 200-acre cells surrounded by silt curtains in CCF is less certain. Although CCF is not considered suitable rearing and migration habitat for salmonids, confinement and prolonged exposure (months) to elevated turbidity, suspended sediment, and noise inside the silt curtains would result in further degradation of habitat conditions and increased exposure to predation.

5.2.5.5.2.2 Green Sturgeon

The potential for stranding of green sturgeon within the cofferdams or silt curtains is assumed to be similar to that of salmonids.

5.2.5.5.3 Assess Risk to Individuals

5.2.5.5.3.1 Salmonids

The risk of stranding of steelhead and subsequent injury or mortality is low based on the minimal overlap in timing of cofferdam closure and silt curtain deployment with the migration timing of adult and juvenile steelhead in the action area. Where practical, this risk will be reduced further by conducting fish rescue and salvage activities. However, it may be impractical or infeasible to rescue fish from the large areas surrounded by cofferdams and silt curtains in CCF. Regardless, such measures may not significantly reduce the overall risk of mortality because of the low survival of steelhead and other listed fish species in CCF under baseline conditions.

5.2.5.5.3.2 Green Sturgeon

The potential for stranding and associated risks of injury or mortality of green sturgeon are assumed to be similar to that of steelhead.

5.2.5.5.4 Assess Effects on Designated Critical Habitat

5.2.5.5.4.1 Salmonids

The potential for stranding would have a temporary adverse effect on the PBFs of designated critical habitat of CCV steelhead (safe and unobstructed migratory corridors) in Old River within the aquatic footprints of the SSCF intake structure and NCCF emergency spillway. Most of the waters affected by cofferdams and silt curtains would be confined to CCF which is not part of the designated critical habitat of steelhead or other listed salmonids.

5.2.5.5.4.2 Green Sturgeon

The potential for stranding would have a similar effect on the designated critical habitat of southern DPS green sturgeon

5.2.5.6 Direct Physical Injury

Fish could be injured or killed by direct contact with equipment or materials during in-water construction activities in CCF and the adjacent Old River channel. Potential mechanisms include fish being crushed by rock (riprap), impinged by sheetpiles, entrained by dredges, or struck by propellers. In addition to the proposed in-water work period, DWR proposes to implement a number of AMMs to minimize the potential for impacts on listed fish species, including *Worker Awareness Training; Erosion and Sediment Control Plan; Disposal of Spoils, Reusable Tunnel Material, and Dredged Material; Barge Operations Plan; Underwater Sound Control and Abatement Plan, and Fish Rescue and Salvage Plan* (Appendix 3.F *General Avoidance and Minimization Measures*).

5.2.5.6.1 Assess Species Exposure

5.2.5.6.1.1 Salmonids

Based on continued operation of CCF and potential entrainment of listed fish species into CCF during in-water construction activities (July 1-November 30), the potential for direct injury of listed salmonids would exist for adult steelhead in August-November, and juvenile steelhead (yearling and older smolts), spring-run Chinook salmon (yearling smolts), and winter-run Chinook salmon (young-of-the year) in November. SJR-basin spring-run Chinook salmon juveniles may also be present in November, assuming juveniles exhibit similar emigration patterns to Sacramento River spring-run populations.

5.2.5.6.1.2 Green Sturgeon

Both adult and juvenile green sturgeon are known to occur in CCF and the adjacent south Delta channels. The in-water construction period (July 1–November 30) will avoid the peak upstream migration period of green sturgeon (late February to early May) although adults (post-spawning adults) and juveniles may be present in the Delta year-round and therefore subject to direct injury during the in-water construction period.

5.2.5.6.2 Assess Species Response

5.2.5.6.2.1 Salmonids

Most salmonids that are likely to be present in the action area at the time in-water construction activities are likely to be large, migrating adults and juveniles that would be expected to avoid or move away from active construction areas.

5.2.5.6.2.2 Green Sturgeon

Similarly, most green sturgeon that are likely to occur in the action area are likely to be large, actively swimming adults and juveniles that are capable of avoiding active construction areas.

5.2.5.6.3 Assess Risk to Individuals

5.2.5.6.3.1 Salmonids

There is a low risk of injury of salmonids based on their likely response to active construction activities.

5.2.5.6.3.2 Green Sturgeon

There is a low risk of injury of green sturgeon based on the likely response to active construction activities.

5.2.5.6.4 Assess Effects on Designated Critical Habitat

5.2.5.6.4.1 Salmonids

The potential for injury during in-water construction activities would have a temporary adverse effect on the PBFs of the designated critical habitat of CCV steelhead (safe and unobstructed migratory corridors) in Old River within the aquatic footprints of the SSCF intake structure and NCCF emergency spillway. Most of the waters where injury could occur would be confined to CCF which is not part of the designated critical habitat of steelhead or other listed salmonids.

5.2.5.6.4.2 Green Sturgeon

The potential for injury would have a similar effect on the designated critical habitat of southern DPS green sturgeon.

5.2.5.7 Loss/Alteration of Habitat

Construction of the new water conveyance facilities at CCF would result in temporary to permanent losses or alteration of aquatic habitat in CCF and, near the new SCCF intake and the NCCF emergency spillway, in the Old River. Temporary effects of construction activities on water quality, including turbidity and suspended sediment, underwater noise, and contaminants, were previously discussed. The following analysis focuses on permanent impacts on physical habitat associated with construction activities. Cofferdam installation, dredging, embankment construction, and construction of CCPP, NCCF emergency spillway, and SCCF intake, and NCCF canal and siphons would affect an estimated 1,932 acres of tidal perennial habitat (Mapbook M3.A) through changes in water depths, vegetation, and substrate. Permanent impacts on aquatic habitat encompass an estimated 30,750 linear feet of shoreline and 258 acres of tidal perennial habitat in CCF that would be replaced by cofferdams, permanent fill, and in-water structures associated with the new CCPP, embankments, canals and siphons, and intake structure and spillway. This is considered a permanent alteration of habitat that would exist throughout the construction period (4 years).

During construction activities, DWR will implement AMM2, *Construction Best Management Practices and Monitoring*, to protect listed fish, wildlife, and plant species, their designated critical habitat, and other sensitive natural communities (Appendix 3.F *General Avoidance and Minimization Measures*). These BMPs include a number of measures to limit the extent of disturbance of aquatic and riparian habitat during construction, and, following construction, to restore temporarily disturbed areas to pre-construction conditions. All construction and site restoration BMPs will be subject to an approved construction and post-construction monitoring plan to ensure their effectiveness. Compensation for unavoidable impacts on aquatic habitat in CCF is not proposed because CCF is not considered suitable habitat for listed salmonids or green sturgeon, and is not part of their designated critical habitat.

5.2.5.7.1 Assess Species Exposure

5.2.5.7.1.1 Salmonids

All migrating or rearing salmonids that occur in the action area during construction activities would be potentially exposed to physical losses and alteration of aquatic and channel margin habitat in CCF and the adjacent Old River channel.

5.2.5.7.1.2 Green Sturgeon

All migrating or rearing green sturgeon that occur in the action area during construction activities would be potentially exposed to physical losses and alteration of aquatic habitat in CCF and the adjacent Old River channel.

5.2.5.7.2 Assess Species Response

5.2.5.7.2.1 Salmonids

As described in Section 5.2.4, *HOR Gate*, the PBFs of critical habitat supporting migration and rearing of steelhead in the south Delta have been degraded from historical conditions. CCF and the adjacent south Delta channels have been highly altered for the purpose of water conveyance and lack many of the PBFs of critical habitat of listed salmonids due to alteration of natural flow patterns, high predator densities, levee clearing and armoring, channel dredging, entrainment, and lost connectivity of migration corridors. Because salmonids that are entrained into CCF generally suffer high mortality rates (pre-screening losses) (Gingras 1997, Clark et al. 2009), CCF is not considered suitable habitat for listed salmonids, and has been excluded from the designated critical habitat of listed salmonids. Some reductions are expected in the quality of passage and rearing conditions for juvenile salmonids due to habitat loss and increases in predator habitat associated with alteration of hydraulic conditions and losses of shallow water habitat, instream cover, and benthic food resources within the dredged areas and permanent footprints of the water conveyance facilities. Overall, however, these changes are not expected to significantly affect migration and rearing success of adult and juvenile steelhead in the action area because of the low quality of existing habitat conditions.

5.2.5.7.2.2 Green Sturgeon

Based on the degraded status of aquatic habitat in the south Delta and the lack of suitable passage conditions for anadromous fish in CCF, the anticipated effects of construction activities on aquatic habitat are not expected to significantly affect overall migration and rearing success of adult and juvenile green sturgeon in the action area. Dredging in CCF is expected to temporarily degrade potential foraging habitat for green sturgeon by disrupting benthic invertebrates. This would incrementally affect portions of CCF as dredging proceeds but is not expected to adversely affect feeding and growth of green sturgeon because of the availability of undisturbed habitat in adjacent waters.

5.2.5.7.3 Assess Risk to Individuals

5.2.5.7.3.1 Salmonids

Because of the degraded status of aquatic habitat in CCF and Old River, projected changes in physical habitat associated dredging and expansion of CCF and construction of the new water conveyance facilities is not expected to significantly affect the survival, growth, or reproduction of individual salmonids.

5.2.5.7.3.2 Green Sturgeon

Because of the degraded status of aquatic habitat in CCF and Old River, projected changes in physical habitat associated dredging and expansion of CCF and construction of the new water conveyance facilities is not expected significantly affect the survival, growth, or reproduction of individual green sturgeon.

5.2.5.7.4 Assess Effects on Designated Critical Habitat

5.2.5.7.4.1 Salmonids

Impacts to the designated critical habitat of CCV steelhead would be limited to temporary and permanent impacts on migration and juvenile rearing habitat in Old River due to construction of the new SSCF intake structure and North CCF (NCCF) emergency spillway. DWR proposes to offset impacts to the designated critical habitat of CCV steelhead through restoration of tidal marsh or channel margin (SRA cover) habitat at an approved restoration site or purchase of conservation credits at an approved conservation bank. Compensation for impacts on aquatic habitat in CCF is not proposed because CCF is not considered suitable habitat for listed salmonids, and is not part of their designated critical habitat. Consequently, no long-term effects on the conservation value of designated critical habitat are expected.

5.2.5.7.4.2 Green Sturgeon

Impacts to the designated critical habitat of southern DPS green sturgeon would be limited to temporary and permanent impacts on migration and juvenile rearing habitat in Old River due to construction of the new SSCF intake structure and North CCF (NCCF) emergency spillway. DWR proposes to offset impacts to the designated critical habitat of green sturgeon through restoration of tidal marsh or channel margin (SRA cover) habitat at an approved restoration site or purchase of conservation credits at an approved conservation bank. Compensation for impacts on aquatic habitat in CCF is not proposed because CCF is not considered suitable habitat for green sturgeon and is not part of their designated critical habitat. Consequently, no long-term effects on the conservation value of designated critical habitat are expected.

5.3 Effects of Water Facility Maintenance on Fish

5.3.1 North Delta Intakes

Maintenance of the proposed intake facilities (including intakes, pumping plants, sedimentation basins, and solids lagoons) includes regular visual inspections and adjustments of the facilities to maintain compliance with engineering and performance standards, routine maintenance, and periodic repairs of mechanical, structural, and electrical components. Emergency maintenance is also anticipated. It is anticipated that major equipment repairs and overhauls would be conducted at a centralized maintenance shop at one of the intake facilities or at the intermediate pumping plant site.

Maintenance activities that could affect listed fish species and aquatic habitat include hydraulic dredging or mechanical excavation of accumulated sediment around the intake structures; periodic removal of debris and biofouling organisms (e.g., algae, clams, mussels) from the log boom, fish screen panels, cleaning system, and other structural and mechanical elements exposed to the river; and levee maintenance activities, including repairs (e.g., RSP replacement) and vegetation control on the waterside levee slope. It is anticipated that in-river dredging will be required every 2-3 years on average. A formal dredging plan describing specific maintenance dredging activities will be developed prior to dredging activities. Guidelines related to dredging activities and disposal and reuse of spoils, including compliance with in-water work windows and turbidity standards, are described in AMM6, *Disposal and Reuse of Spoils, Reusable Tunnel Material, and Dredged Material* (Appendix 3.F *General Avoidance and Minimization*

Measures). The replacement of RSP may necessitate access and work either from the levee crest (e.g., using an excavator) or from the water (e.g., using a barge and crane).

During maintenance activities, in-water dredging and riprap replacement pose the highest risk to listed fish species because of the potential for direct injury or harassment of fish. As described in Section 5.2.1, *Preconstruction Studies (Geotechnical Exploration)*, restriction of dredging, riprap replacement, and other in-water activities to the proposed in-water work window (June 1-October 31) will minimize the exposure of listed fish species to turbidity and suspended sediment, noise, and other construction-related hazards (e.g., direct physical injury). It is assumed that in-river maintenance dredging and riprap replacement will also be restricted to this period. Restriction of in-river activities to these months would avoid the peak winter and spring migration and rearing seasons of listed salmonids with the exception of adult steelhead, which may peak in abundance in the action area during the late summer and fall months (September–October). This period also avoids the peak upstream migration period of adult green sturgeon in the Sacramento River (late February to early May); however, adults (including post-spawning adults) and rearing juveniles may be present in the Delta year-round and therefore subject to dredging activities throughout the proposed in-water work window.

As described in Section 5.2.1, *Preconstruction Studies (Geotechnical Exploration)*, dredging and riprap replacement could result in harassment of fish from increases in turbidity, suspended sediment, and noise; injury or mortality from entrainment or direct contact with active dredges, vessels (e.g., propeller strikes), or materials (e.g., riprap); and adverse effects on rearing habitat from loss or degradation of benthic habitat and associated food resources. The likelihood of exposure of listed fish species and critical habitat is expected to be low based on the location and timing of maintenance activities relative to the distribution, abundance, and timing of sensitive life stages; the low quality of rearing habitat at the proposed intake locations; and the localized, temporary nature of maintenance activities. Potential adverse effects on listed species and designated critical habitat will be further minimized by implementing a number of construction and maintenance AMMs to limit the extent and duration of potential impacts on aquatic habitat: *Worker Awareness Training; Construction Best Management Practices and Monitoring; Stormwater Pollution Prevention Plan (SWPPP); Erosion and Sediment Control Plan; Spill Prevention, Containment, and Countermeasure Plan (SPCCP); Hazardous Material Management Plan;* and *Disposal and Reuse of Spoils, Reusable Tunnel Material, and Dredged Material; and Barge Operations Plan* (Appendix 3.F *General Avoidance and Minimization Measures*).

5.3.2 Barge Landings

Maintenance activities at the barge landings would likely include regular or periodic visual inspections, routine maintenance, and periodic repairs of the docking, loading, and unloading facilities. Maintenance activities also include the replacement of riprap to repair eroded or damaged portions of the waterside levee slope and crown. Vegetation control measures would be performed as part of levee maintenance. Where in-water work is required, maintenance activities will be restricted to the proposed in-water work window (August 1–October 31) to minimize exposure of juvenile salmonids. However, this window overlaps with the upstream migration of adult steelhead in later summer and fall. In addition, juvenile and adult green sturgeon may be present in the Delta year-round and therefore potentially present during the in-water work window. Potential adverse effects on listed species and designated critical habitat will be minimized by implementing a number of construction and maintenance AMMs to limit the extent and duration of potential impacts on aquatic habitat: *Worker Awareness Training; Construction Best Management Practices and Monitoring; Stormwater Pollution Prevention Plan (SWPPP); Erosion and Sediment Control Plan; Spill Prevention, Containment, and Countermeasure Plan (SPCCP); Hazardous Material Management Plan;* and *Disposal and Reuse of Spoils, Reusable Tunnel Material, and Dredged Material; and Barge Operations Plan* (Appendix 3.F *General Avoidance and Minimization Measures*).

5.3.3 Head of Old River Gate

Maintenance of the Head of Old River (HOR) gate, including fishway, boat lock, and navigation structures, includes require regular visual inspections and adjustments of the facilities to maintain compliance with engineering and performance standards, and periodic repairs to prevent mechanical, structural, and electrical failures. Emergency maintenance is also anticipated. Routine maintenance includes regular servicing and repair of motors, compressors, and control systems, and periodic repairs to the mechanical and structural elements of the gate, fishway, and boat lock. Maintenance activities include periodic dredging to remove accumulated sediment from around the gate structure, dewatering of the gate facilities for inspection and maintenance, and replacement of riprap to repair eroded or damaged portions of the waterside levee slope. Vegetation control measures would be performed as part of levee maintenance.

Maintenance dredging may be required every 3 to 5 years to remove sediment that may potentially interfere with navigation, fish passage, and gate operations. Dredging would be conducted with a hydraulic or sealed clamshell dredge operated from a barge or from the top of the levee. A floating turbidity control curtain will be used to limit the dispersion of suspended sediment during dredging operations. A formal dredging plan describing specific maintenance dredging activities will be developed prior to dredging activities. Guidelines related to dredging activities and disposal and reuse of spoils, including compliance with in-water work windows and turbidity standards, are described in Appendix 3.F *General Avoidance and Minimization Measures*, AMM6 *Disposal and Reuse of Spoils, Reusable Tunnel Material, and Dredged Material*.

Each gate bay would be inspected annually at the end of the wet season for sediment accumulation. Each miter or radial gate bay would include stop log guides and pockets for stop log posts to facilitate the dewatering of individual bays for inspection and maintenance. Major maintenance could require a temporary cofferdam upstream and downstream for dewatering. When listed fish species may be present during dewatering operations, DWR proposes to minimize potential stranding losses by implementing a fish rescue and salvage plan (Appendix 3.F *General Avoidance and Minimization Measures, AMM8 Fish Rescue and Salvage Plan*).

Maintenance activities that have the greatest potential to affect listed species and critical habitat are dredging and cofferdam installation and dewatering. As described in Section 5.2.3 *Barge Landings*, restriction of dredging, cofferdam installation, and other in-water activities to the proposed in-water work window (August 1–November 30) will avoid the primary winter and spring migration period of juvenile steelhead. Adult steelhead may be present in the late summer and fall and therefore may be exposed to maintenance activities during the proposed in-water work window. There is a low risk of exposure of adult green sturgeon based on the location and timing of in-water maintenance activities. However, juvenile green sturgeon may be present in the Delta year-round and therefore potentially present in the action area during in-water maintenance activities.

As described in Section 5.2.4, *Head of Old River*, dredging, cofferdam installation, and riprap placement could result in harassment of listed fish species from increases in turbidity, suspended sediment, and noise; direct injury or mortality from stranding, entrainment, or direct contact with equipment or materials during cofferdam installation, dredging, barge operations, and riprap placement; and adverse effects on rearing and migration habitat from loss or degradation of benthic habitat and potential increases in predator habitat. However, the likelihood of exposure of listed fish species from these sources is considered low based on the location and timing of these activities relative to the distribution, abundance, and timing of sensitive life stages; the low quality of rearing habitat in Old River; and the localized, temporary nature of maintenance activities. DWR proposes to minimize potential effects on listed fish species and aquatic habitat by preparing and implementing a formal dredging plan describing specific maintenance dredging activities, including compliance with in-water work windows and turbidity standards, as described in AMM6, *Disposal and Reuse of Spoils, Reusable Tunnel Material, and Dredged Material* (Appendix 3.F *General Avoidance and Minimization Measures*). If cofferdam installation is required, DWR proposes to minimize potential stranding losses by implementing a fish rescue and salvage plan (Appendix 3.F *General Avoidance and Minimization Measures, AMM8 Fish Rescue and Salvage Plan*). Potential adverse effects on listed species and designated critical habitat will be further minimized by implementing a number of construction and maintenance AMMs to limit the extent and duration of potential impacts on aquatic habitat: *Worker Awareness Training; Construction Best Management Practices and Monitoring; Stormwater Pollution Prevention Plan (SWPPP); Erosion and Sediment Control Plan; Spill Prevention, Containment, and Countermeasure Plan (SPCCP); Hazardous Material Management Plan;* and *Disposal and Reuse of Spoils, Reusable Tunnel Material, and Dredged Material; and Barge Operations Plan* (Appendix 3.F *General Avoidance and Minimization Measures*).

5.3.4 Clifton Court Forebay

Maintenance of the water conveyance facilities and other infrastructure at CCF (including Clifton Court Pumping Plant [CCPP], divider and perimeter embankments, outlet canals and siphons, South CCF [SCCF] intake structure, and North CCF [NCCF] emergency spillway) will include regular visual inspections and adjustments of the facilities to maintain compliance with engineering and performance standards, and periodic repairs to prevent mechanical, structural, and electrical failures. Emergency maintenance is also anticipated. Maintenance requirements potentially affecting listed fish species and aquatic habitat in CCF and Old River include dredging or mechanical excavation of accumulated sediment around the pumping, intake, and outlet facilities, and embankment maintenance activities, including repairs (e.g., RSP replacement) and vegetation control on the divider and perimeter embankments. With upstream sediment removal at the north Delta sedimentation facilities and expansion of storage capacity at CCF, the need for additional dredging of NCCF and SCCF over the first 50 years following construction is expected to be minimal. (The aquatic weed control program is analyzed in Section 5.4.1 *Proposed Delta Exports and Related Hydrodynamics*).

As described in Section 5.2.5, *Clifton Court Forebay*, restriction of maintenance dredging, embankment repairs, and other in-water activities to the proposed in-water work window (July 1–November 30) will avoid the periods when juvenile winter-run Chinook salmon, spring-run Chinook salmon, and steelhead are most likely to occur in the south Delta. The risk of exposure of adult winter-run and spring-run Chinook salmon is considered negligible based on the location and timing of maintenance activities. Small numbers of juvenile steelhead and spring-run Chinook salmon may be exposed to maintenance activities in November while adult steelhead may be present from August through November. Juvenile and adult green sturgeon may be present in the Delta year-round and therefore potentially present in the action area during in-water maintenance activities.

As described in Section 5.2. 5, *Clifton Court Forebay*, dredging, levee repairs, and other in-water activities could result in harassment of listed fish species from increases in turbidity, suspended sediment, and noise; direct injury or mortality from stranding, entrainment, or direct contact with equipment or materials during cofferdam installation, dredging, barge operations, and riprap placement; and adverse effects on rearing and migration habitat from loss or degradation of benthic habitat and potential increases in predator habitat. However, the likelihood of exposure of listed fish species from these sources is considered low based on the location and timing of these activities relative to the distribution, abundance, and timing of sensitive life stages; the low quality of rearing and migration habitat in CCF and Old River; and the localized, temporary nature of maintenance activities. Potential adverse effects on listed species and designated critical habitat[9] will be further minimized by implementing a number of construction and maintenance AMMs to limit the extent and duration of potential impacts on aquatic habitat: *Worker Awareness Training; Construction Best Management Practices and Monitoring; Stormwater Pollution Prevention Plan (SWPPP); Erosion and Sediment Control Plan; Spill Prevention, Containment, and Countermeasure Plan (SPCCP); Hazardous Material Management Plan;* and *Disposal and Reuse of Spoils, Reusable Tunnel Material, and Dredged Material; and Barge Operations Plan* (Appendix 3.F *General Avoidance and Minimization Measures*).

5.4 Effects of Water Facility Operations on Fish

5.4.1 Proposed Delta Exports and Related Hydrodynamics

The assessment of the effects of Delta water facility operations on winter-run Chinook salmon, spring-run Chinook salmon, steelhead, and green sturgeon is divided into five main sections. Section 5.4.1.1 *Deconstruct the Action* cross-references the appropriate sections of Chapter 3 and the appendices of Chapter 5. Section 5.4.1.2, *Assess Species Exposure*, examines the general temporal and spatial occurrence of the species in the Delta, before specifically examining the potential for exposure to the different elements of the PA. Section 5.4.1.3, *Assess Species Response to the Proposed Action*, examines how the different elements of the PA could affect fish, e.g., through entrainment or changes in river flow. Section 5.4.1.4, *Assess Risk to Individuals*, considers the potential for risk to individuals given the exposure and species

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[9] Old River only; CCF is not part of the designated critical habitat of CCV steelhead and southern DPS green sturgeon.

response described in Sections 5.4.1.2 and 5.4.1.3. Section 5.4.1.5, *Effects of the Action on Designated Critical Habitat*, assesses the potential effects of the PA on critical habitat for the fish; for all four species, critical habitat has been designated and is present in the action area. The analysis of critical habitat focuses on potential effects to the following relevant PBFs for each species in the Delta and adjacent areas:

- Winter-run Chinook salmon: access from the Pacific Ocean to spawning areas in the upper Sacramento River; habitat areas and prey that are not contaminated; riparian habitat that provides for successful juvenile development and survival; access downstream so that juveniles can migrate from spawning grounds to San Francisco Bay and the Pacific Ocean

- Spring-run Chinook salmon and Central Valley steelhead: freshwater migration corridors; estuarine areas

- Green sturgeon (for estuarine habitats): food resources; water flow; water quality; migratory corridor; water depth; and sediment quality.

5.4.1.1 Deconstruct the Action

Water facility operations are described in Section 3.3 *Operations and Maintenance of New and Existing Facilities* of Chapter 3, *Description of the Proposed Action*. Important modeling methods and results simulating operations of the PA and NAA are provided in Appendix 5.A *CalSim II Modeling and Results* and Appendix 5.B *DSM2 Modeling and Results*. These results are used to provide the assessment of proposed Delta exports and related hydrodynamics.

5.4.1.2 Assess Species Exposure

The following account of species exposure to the effects of proposed Delta exports and related hydrodynamics is adapted from the account by NMFS (2009) in the OCAP BiOp, with updated information as pertinent.

5.4.1.2.1 Salmonids

5.4.1.2.1.1 Winter-Run Chinook Salmon

5.4.1.2.1.1.1 Temporal Occurrence

Adult winter-run Chinook salmon first enter the San Francisco Bay Estuary from the Pacific Ocean starting in November (Table 5.4-1). Adults continue to enter the bay throughout the winter months and into late spring (May/June), passing through the Delta region as they migrate upriver towards their spawning grounds below Keswick Dam (CVP/SWP operations BA; U.S. Fish and Wildlife Service 2001, 2003a). This broad period of juvenile outmigration helps the species adapt to variable conditions in the ocean that can differentially affect individuals depending on when they enter the ocean (Johnson 2015). Therefore, the tail ends of the migratory periods of each species are important to species viability even though the abundance of the juveniles at the extreme ends of the migration periods is small. As a result, this effects analysis evaluates effects of the PA during the entire period of winter-run Chinook salmon occurrence in the Delta, including evaluating each month of the period of presence distinctly where possible and appropriate (e.g., Table 5.4-8).

The main pulse of emigrating juvenile winter-run Chinook salmon from the upper Sacramento River enter the Delta in December and January and can extend through April, depending on the water year type[10]. Beach seines and mid-water trawls on the mainstem Sacramento River near the City of Sacramento indicate that some fish enter the Delta as early as mid-November and early December (U.S. Fish and Wildlife Service 2001, 2003a). Monitoring by the USFWS at Chipps Island in the western Delta indicates that winter-run are detected leaving the Delta from September through June, with a peak in emigration occurring in March and April. This peak in emigration timing is supported by the pattern of recoveries of winter-run sized Chinook salmon at the SWP's Skinner Fish Protection Facility and the CVP's Tracy Fish Collection Facility (TFCF) in the South Delta. A pattern of greatest temporal occurrence in the west Delta during late February/March/early April, indicating emigration, is indicated by genetic identification of winter-run Chinook juveniles caught at Chipps Island (Pyper et al. 2013), with this pattern also generally seen in salvage of genetically identified winter-run Chinook juveniles at the south Delta export facilities (Harvey et al. 2014).

In addition to the seasonal component of juvenile emigration, distinct increases in recovered fish appear to be correlated with high precipitation events and increases in-river flow and turbidity following rain events (U.S. Fish and Wildlife Service 2001, 2003a). Based on analysis of scales, winter-run smolts enter the ocean environment at an average fork length of 118 mm, indicating a freshwater residence time of approximately 5 to 9 months, most of which is presumed to occur upstream between RBDD and the Delta. Otolith microchemistry studies indicate that around 47-65% of adult winter-run that returned to spawn in 2007 – 2009 reared as juveniles in non-natal habitats (i.e., outside the Sacramento River upstream of Knights Landing), of which around 11-36% were within the Delta. The time period spent within the Delta by these fish ranged from approximately 2 to 8 weeks (~14-56 days; Phillis, pers. comm.). This contrasts with estimates of residence time of ~40-120 days from winter-run-sized juveniles captured in monitoring at Knights Landing and Chipps Island (del Rosario et al. 2013).

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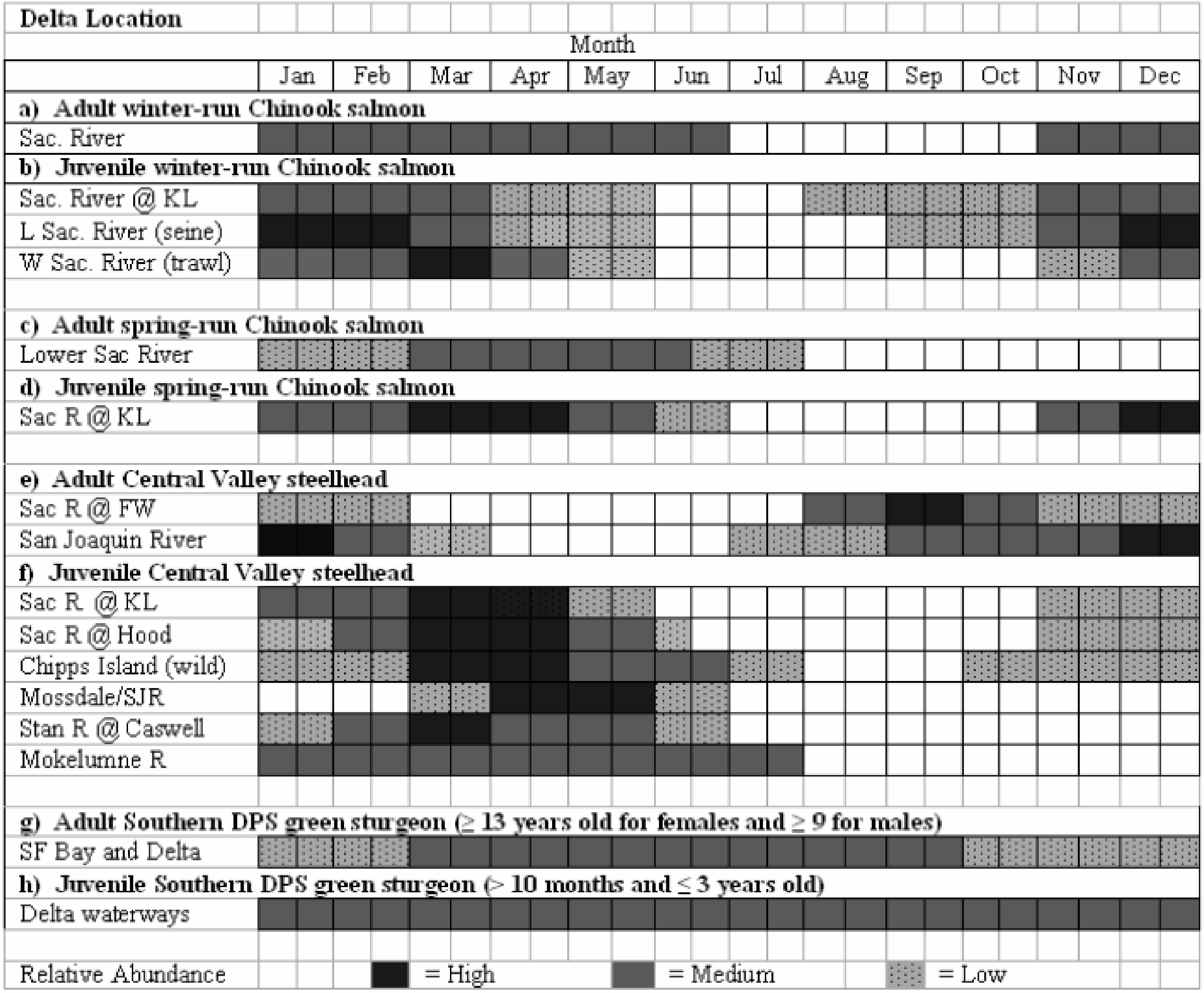
[10] Note that timings discussed in this section are largely based on length-at-date assignments of Chinook salmon race, which have some uncertainty (Harvey et al. 2014).

Table 5.4-1. Temporal Distribution of Winter-Run Chinook Salmon, Spring-Run Chinook Salmon, Central Valley Steelhead, and Green Sturgeon within the Delta.



Delta Location																								
	Month																							
	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
a) Adult winter-run Chinook salmon																								
Sac. River	▓	▓	▓	▓	▓	▓	▓	▓	▓	▓	▓	▓									▓	▓	▓	▓
b) Juvenile winter-run Chinook salmon																								
Sac. River @ KL	▓	▓	▓	▓	▓	▓	░	░	░	░					░	░	░	░	░	░	▓	▓	▓	▓
L Sac. River (seine)	█	█	█	█	▓	▓	░	░	░	░							░	░	░	░	▓	▓	█	█
W Sac. River (trawl)	▓	▓	▓	▓	█	█	▓	▓	░	░											░	░	▓	▓
c) Adult spring-run Chinook salmon																								
Lower Sac River	░	░	░	░	▓	▓	▓	▓	▓	▓	▓	░	░	░										
d) Juvenile spring-run Chinook salmon																								
Sac R @ KL	▓	▓	▓	▓	█	█	█	█	▓	▓	░	░									▓	▓	█	█
e) Adult Central Valley steelhead																								
Sac R @ FW	░	░	░	░											▓	▓	█	█	▓	▓	░	░	░	░
San Joaquin River	█	█	▓	▓	░	░							░	░	░	░	▓	▓	▓	▓	▓	▓	█	█
f) Juvenile Central Valley steelhead																								
Sac R. @ KL	▓	▓	▓	▓	█	█	█	█	░	░											░	░	░	░
Sac R @ Hood	░	░	▓	▓	█	█	█	█	▓	▓	░										░	░	░	░
Chipps Island (wild)	░	░	░	░	█	█	█	█	▓	▓	▓	▓	░	░					░	░	░	░	░	░
Mossdale/SJR					░	░	█	█	█	█	░	░												
Stan R @ Caswell	░	░	▓	▓	█	█	▓	▓	▓	▓	░	░												
Mokelumne R	▓	▓	▓	▓	▓	▓	▓	▓	▓	▓	▓	▓	▓	▓										
g) Adult Southern DPS green sturgeon (≥ 13 years old for females and ≥ 9 for males)																								
SF Bay and Delta	░	░	░	░	▓	▓	▓	▓	▓	▓	▓	▓	▓	▓	▓	▓	▓	▓	░	░	░	░	░	░
h) Juvenile Southern DPS green sturgeon (> 10 months and ≤ 3 years old)																								
Delta waterways	▓	▓	▓	▓	▓	▓	▓	▓	▓	▓	▓	▓	▓	▓	▓	▓	▓	▓	▓	▓	▓	▓	▓	▓
Relative Abundance				█	= High					▓	= Medium						░	= Low						

Source: NMFS (2009: 335).

Note: KL = Knights Landing. FW = Fremont Weir.

5.4.1.2.1.1.2 Spatial Occurrence

The main adult winter-run migration route through the Delta region is believed to be the mainstem of the Sacramento River. However, there is the potential for adults to "stray" into the San Joaquin River side of the Delta while on their upstream migration, particularly early in the migratory season (November and December). Significant amounts of Sacramento River water flow into the San Joaquin River side of the Delta through the DCC (when open), Georgiana Slough, and Three Mile Slough. These sources of Sacramento River water can create false attraction into the lower San Joaquin River. Adult winter-run that choose this path would be delayed in their upstream migration while they mill in the lower San Joaquin River, searching for the distinctive olfactory cues of the Sacramento River. Adults could re-enter the Sacramento River through Georgiana Slough or the Delta reaches of the Mokelumne River system when the DCC is open. The extent of this delay and the proportion of adults moving into the lower San Joaquin River are unknown. Adult winter-run do not typically inhabit the San Joaquin River mainstem upstream of Middle River or within the waterways of the South Delta in any appreciable numbers (Yoshiyama *et al*. 1996, 1998, 2001).

Juvenile winter-run are present in the waterways of the North Delta (*i.e.*, Sacramento River, Steamboat Slough, Sutter Slough, Miner Slough, and Cache Slough complex), Central Delta (Georgiana Slough, DCC, Snodgrass Slough, and Mokelumne River complex below Dead Horse Island), South Delta leading to the CVP and SWP pumping facilities including Old and Middle Rivers, and the interconnecting waterways between these main channels such as Victoria Canal, Woodward Canal, and Connection Slough, and the western Delta including the main channels of the San Joaquin and Sacramento rivers and Three Mile Slough. NMFS (2009: 336) did not anticipate seeing adult winter-run upstream of Middle River on the San Joaquin River mainstem or within the waterways of the South Delta in any appreciable numbers. NMFS (2009: 336) also did not anticipate seeing any significant numbers of juvenile winter-run in the Eastern Delta near Stockton (*i.e.*, White Slough, Disappointment Slough, Fourteenmile Slough), or the mainstem of the San Joaquin River upstream of Columbia and Turner Cuts. Presence of winter-run adults and juveniles may occur in other parts of the Delta not described above.

5.4.1.2.1.2 Spring-Run Chinook Salmon

5.4.1.2.1.2.1 Temporal Occurrence

Adult spring-run enter the San Francisco Bay Estuary from the ocean in January to late February (Table 5.4-1). They move through the Delta prior to entering the Sacramento River system. Based on the available information for fish from the Sacramento River basin, spring-run show two distinct juvenile emigration patterns in the Central Valley. Fish may either emigrate to the Delta and ocean during their first year of life as YOY, typically in the following spring after hatching, or hold over in their natal streams and emigrate the following fall as yearlings. Typically, yearlings enter the Delta as early as November and December and continue to enter the Delta through at least March. They are larger and less numerous than the YOY smolts that enter the Delta from January through June. The peak of YOY spring-run presence in the Delta is during the month of April, as indicated by the recoveries of spring-run size fish in the CVP and SWP salvage operations and the Chipps Island trawls. Frequently, it is difficult to distinguish the YOY spring-run outmigration from that of the fall-run due to the similarity in their spawning and emergence times. The overlap of these two runs makes for an extended pulse of Chinook salmon smolts through the Delta each spring, frequently lasting into June. This broad period of juvenile outmigration helps the species adapt to variable conditions in the ocean that can differentially affect individuals depending on when they enter the ocean (Johnson 2015). Therefore, the tail ends of the migratory periods of each species are important to species viability even though the abundance of the juveniles at the extreme ends of the migration periods is small. As a result, this effects analysis evaluates effects of the PA during the entire period of spring-run Chinook salmon occurrence in the Delta, including evaluating each month of the period of presence distinctly where possible and appropriate (e.g., Table 5.4-8).

The temporal occurrence of SJR-basin spring-run Chinook salmon may ultimately be similar to the populations from the Sacramento River basin, although this will not be known until monitoring data are examined in the future. For the purposes of this effects analysis, the timing for the SJR-basin spring-run Chinook salmon (including the springtime running Chinook salmon from the tributaries, discussed below) is assumed to be similar to that of the Sacramento River basin populations.

5.4.1.2.1.2.2 Spatial Occurrence

Currently, the only recognized populations of spring-run occur in the Sacramento River basin. Historical populations that occurred in the river basins to the south (*i.e.*, southern Sierra watersheds) have been extirpated, although reintroduction of spring-run to the San Joaquin River has begun (NMFS 2016b). As previously described in Section 4.5.2 *Chinook Salmon, Central Valley Spring-Run ESU* in Chapter 4, *Action Area and Environmental Baseline*, although there have been observations of springtime running Chinook salmon returning to the San Joaquin tributaries in recent years, there is insufficient information to determine the specific origin of these fish, and whether or not they are straying into the basin or returning to natal streams (NMFS 2016: 8).

The main migration route for adult spring-run from the Sacramento River basin is the Sacramento River channel through the Delta. Similar to winter-run, Sacramento River basin adults may stray into the San Joaquin River side of the Delta due to the inflow of Sacramento River basin water through one of the interconnecting waterways branching off of the mainstem Sacramento River towards the San Joaquin River. Starting in February, the closure of the DCC radial gates minimizes the influence of this pathway, but flows in the channels of Georgiana and Three Mile Slough provide sufficient flows of water to the San Joaquin River to induce straying from “spurious” olfactory cues present in these waterways. SJR-basin spring-run Chinook salmon presumably use the San Joaquin River as their main migration pathway through the Delta, both as juveniles and adults.

Juvenile Sacramento River basin spring-run are present in the same waterways as winter-run in the North Delta, Central Delta, South Delta, and the interconnecting waterways, including the main channels of the San Joaquin and Sacramento rivers and Three Mile Slough. NMFS (2009: 337) did not anticipate seeing any significant numbers of juvenile spring-run in the Eastern Delta or the mainstem of the San Joaquin River upstream of Columbia and Turner Cuts; this situation has presumably changed with the reintroduction of spring-run to the San Joaquin River, and the SJR-basin spring-run Chinook salmon presumably occur in these areas.

5.4.1.2.1.3 Central Valley Steelhead

5.4.1.2.1.3.1 Temporal Occurrence

Adult steelhead have the potential to be found within the Delta during much of the year, although the primary period of occurrence is late summer/fall/winter (Table 5.4-1). Unlike Chinook salmon, steelhead can spawn more than once, so post-spawn adults (typically females) have the potential to move back downstream through the Delta after completing their spawning in their natal streams. These fish are termed runbacks or kelts. Typically, adult steelhead moving into the Sacramento River basin begin to enter the Delta during mid to late summer, with fish entering the Sacramento River system from July to early September. Kelts are typically seen later in the spring following spawning. Steelhead entering the San Joaquin River basin are believed to have a later spawning run. Adults enter the system starting in late October through December, indicating presence in the Delta a few weeks earlier. Typically water quality in the lower San Joaquin River is marginal during this time, with elevated water temperatures and low DO levels presenting barriers to upstream migration. Early winter rains help to break up these barriers and provide the stimulus to adult steelhead holding in the Delta to move up river towards their spawning reaches in the San Joaquin River tributaries. Fish may continue entering the system through the winter months. Juvenile steelhead are recovered in the USFWS Chipps Island trawls from October through July. There appears to be a difference in the emigration timing between wild and hatchery-reared steelhead smolts. Adipose fin-clipped hatchery fish are typically recovered at Chipps Island from January through March, with the peak in recoveries occurring in February and March. This time period corresponds to the schedule of hatchery releases of steelhead smolts from the different Central Valley hatcheries (Nobriga and Cadrett 2003, CVP/SWP operations BA). The timing of wild steelhead (unclipped) emigration is more spread out. Emigration occurs over approximately 6 months, with peaks in February and March, based on salvage records at the CVP and SWP fish collection facilities. Individual unclipped fish first begin to be collected in fall and early winter, and may extend through early summer (June and July). Wild fish that are collected at the CVP and SWP facilities late in the season may be from the San Joaquin River system, based on the proximity of the basin to the pumps and the timing of the spring pulse flows in the tributaries (April-May). The size of emigrating steelhead smolts typically ranges from 200 to 250 mm in length, with wild fish tending to be at the upper end of this range (Nobriga and Cadrett 2003, CVP/SWP operations BA). The broad period of juvenile outmigration helps the species adapt to variable conditions in the ocean that can differentially affect individuals depending on when they enter the ocean (Johnson 2015). Therefore, the tail ends of the migratory periods of each species are important to species viability even though the abundance of the juveniles at the extreme ends of the migration periods is small. As a result, this effects analysis evaluates effects of the PA during the entire period of steelhead occurrence in the Delta, including evaluating each month of the period of presence distinctly where possible and appropriate (e.g., Table 5.4-8).

5.4.1.2.1.3.2 Spatial Occurrence

Populations of CV steelhead occur throughout the watersheds of the Central Valley; however, the primary population source occurs within the watersheds of the Sacramento River basin. Small, apparently self-sustaining populations of steelhead exist in the Mokelumne River system (although influenced by the Mokelumne River Hatchery steelhead program), the Calaveras River (natural) and the Stanislaus River (natural). Furthermore, otolith microchemistry analysis has shown that juvenile *O. mykiss* collected from the Tuolumne and Merced rivers had maternal steelhead origins (Zimmerman *et al*. 2008). Upstream migrating adult steelhead enter both the

Sacramento River basin and the San Joaquin River basin through their respective mainstem river channels. Adult steelhead entering the Mokelumne River system (including Dry Creek and the Cosumnes River) and the Calaveras River system are likely to move up the mainstem San Joaquin River channel before branching off into the channels of their natal rivers. It is also likely that some adult steelhead bound for the San Joaquin River system may detour through the South Delta waterways and enter the San Joaquin River through Old River near Mossdale. However, due to the number of potential routes, the early entrance of adults into the Delta, and the potential for the DCC to remain open for a substantial portion of the upstream spawning migration, the "actual" route that an adult steelhead follows before committing to its natal watershed could be quite complex. Therefore, adult steelhead could be in any of the larger channels in the Delta region during their spawning migrations. Likewise, steelhead kelts could also be found in any of the channels of the Delta during their return to the ocean. Data for this particular life stage is lacking.

Outmigrating steelhead smolts enter the Delta primarily from the Sacramento River (North Delta region) and from the San Joaquin River (South Delta region). Steelhead smolts from the Mokelumne River system and the Calaveras River system enter the Eastern Delta. The Mokelumne River fish can either follow the north or south forks of the Mokelumne River through the Central Delta before entering the San Joaquin River at RM 22. Some fish may enter the San Joaquin River farther upstream if they diverge from the South Fork of the Mokelumne River into Little Potato Slough. Fish from the Calaveras River enter the San Joaquin River downstream of the Port of Stockton near RM 38. Steelhead smolts from the San Joaquin River basin enter the Delta at Mossdale. Prior to the installation of the temporary rock Head of Old River Barrier (HORB) on approximately April 15, steelhead smolts exiting the San Joaquin River basin can follow either of two routes to the ocean. Fish may either stay in the mainstem of the San Joaquin River and move northwards towards the Port of Stockton and the Central Delta, or they may enter the South Delta through the Head of Old River and move northwards towards the lower San Joaquin River through Old and Middle rivers and their associated network of channels and waterways. When the rock HORB is not installed, approximately 50 percent of the San Joaquin River flow is directed into Old River. This percentage increases if the CVP and SWP are pumping at elevated levels. In fact, in low flow conditions with high pumping rates, the net flow in the mainstem of the San Joaquin between the Port of Stockton and Old River may reverse direction and flow upstream into the Head of Old River. When the HORB is installed, flow in the San Joaquin River is retained in the mainstem and fish are directed northwards towards the Port of Stockton and eventually through the Central Delta. Given the multiple points of entry into the Delta system, CV steelhead are likely to be found in any of the waterways of the Delta, but particularly in the main channels leading to their natal river systems.

5.4.1.2.1.4 Exposure to North Delta Exports

The potential for exposure of listed salmonids to the NDD would be very similar in terms of timing to that described for the Delta Cross Channel by NMFS (2009: 402-403), as discussed in Section 5.4.1.2.1.7, *Exposure to Delta Cross Channel*. However, a greater proportion of Sacramento River basin fish would pass the NDD than the DCC because a portion of fish (~20-40%, based on Perry et al. [2010, 2012]) would be expected to enter Sutter/Steamboat Sloughs prior to reaching the DCC. Some fish would enter the Delta from the Yolo Bypass because of passage through the notch of the modified Fremont Weir[11]; Roberts et al. (2013) estimated this would range from a mean of ~8% in drier years to ~16% in wetter years for winter-run and spring-run Chinook salmon (Table 5.4-2 and Table 5.4-3). However, winter-run Chinook emigrate from the upper Sacramento River basin and so a greater proportion may be exposed to Fremont Weir compared to spring-run Chinook salmon, for which many individuals leave Butte Creek via the lower Sutter Bypass and therefore may not encounter the Fremont Weir notch. Any fish entering the Delta from the Yolo Bypass would avoid exposure to the NDD. No spring-run Chinook salmon from the San Joaquin River basin would be expected to be exposed to the NDD, other than occasional straying adults for which the effects would be insignificant because of their large size and swimming ability.

Table 5.4-2. Annual Percentage of Winter-Run Chinook Salmon Juveniles Approaching Fremont Weir That Would Be Entrained Onto the Yolo Bypass Under Existing Conditions and with Notching of Fremont Weir

Water Year	Water-Year Type	Existing Conditions	With Notch
1997	W	15.9	22.5
1998	W	4.9	11.1
1999	W	2.0	14.3
2000	AN	16.3	25.2
2001	D	0.0	7.5
2002	D	0.1	6.3
2003	AN	1.7	15.9
2004	BN	0.7	9.2
2005	AN	0.0	9.9
2006	W	6.2	13.9
2007	D	0.0	6.0
2008	C	0.0	11.6
2009	D	0.0	10.2
2010	BN	0.4	11.2
2011	W	2.5	13.2
Average (1997–2011)		3.4	12.5
Wet and Above Normal Water Year Average		6.2	15.7
Dry and Critical Water Year Average		0.0	8.3

Source: Roberts et al. 2013.

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[11] The notch modification would occur under the NAA and the PA.

Table 5.4-3. Annual Percentage of Spring-Run Chinook Salmon Juveniles Approaching Fremont Weir That Would Be Entrained Onto the Yolo Bypass Under Existing Conditions and with Notching of Fremont Weir

Water Year	Water-Year Type	Existing Conditions	With Notch
1997	W	13.2	21.1
1998	W	6.1	11.2
1999	W	1.1	13.7
2000	AN	8.0	18.4
2001	D	0.0	4.1
2002	D	0.1	7.6
2003	AN	0.7	14.0
2004	BN	0.5	10.6
2005	AN	0.0	11.5
2006	W	7.2	16.2
2007	D	0.0	8.7
2008	C	0.0	11.3
2009	D	0.0	6.5
2010	BN	0.5	12.3
2011	W	13.0	22.7
Average (1997–2011)		3.4	12.7
Wet and Above Normal Water Year Average		6.2	16.1
Dry and Critical Water Year Average		0.0	7.7

Source: Roberts et al. 2013.

5.4.1.2.1.5 Exposure to South Delta Exports

The potential for exposure to the effects of south Delta exports would follow the basic timing outlined in the earlier species-specific discussions and additional information presented for the Delta Cross Channel in Section 5.4.1.2.1.7, *Exposure to Delta Cross Channel*. Hydrodynamic effects of the south Delta export facilities could occur for juveniles emigrating from the Sacramento River basin and entering the interior Delta, principally at Georgiana Slough (the DCC generally would be closed during this period); the percentage of juveniles migrating down the main stem Sacramento River that use the Georgiana Slough migration pathway generally is around 10-30%[12] (Perry et al. 2010, 2012). Steelhead and spring-run Chinook salmon from the San Joaquin River basin would be expected to be exposed to the south Delta export facilities in greater frequency than salmonids from the Sacramento River basin because their migration pathways include the south Delta.

5.4.1.2.1.6 Exposure to Head of Old River Gate Operations

Of the listed salmonids occurring in the Delta, only steelhead and spring-run Chinook salmon from the San Joaquin River basin would be expected to be exposed to near-field effects of the HOR gate based on its geographic location. Operations of the gate would coincide with the

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[12] As previously described, a portion of fish would enter the Yolo Bypass, thereby making exposure to south Delta export effects unlikely. The 10-30% estimate applies to fish entering the Delta on the main stem Sacramento River.

migratory period of both juvenile (spring) and adult (fall/winter) steelhead, whereas the main coincidence with spring-run Chinook would be for juveniles and adults in spring (with a lesser overlap possibly in fall for any emigrating yearlings). Far-field effects of the HOR gate in terms of flow routing down the San Joaquin River would also affect steelhead and spring-run Chinook salmon from the San Joaquin basin, and could also affect winter-run and spring-run Chinook salmon and green sturgeon from the Sacramento River basin if occurring in the interior Delta.

5.4.1.2.1.7 Exposure to Delta Cross Channel

The proportion of juvenile Chinook salmon that enter the Delta from the Sacramento River is given in Table 6-34 of NMFS (2009: 402). Salvage and loss across months (http://www.usbr.gov/mp/cvo/fishrpt.html) represents fish presence in the South Delta (Table 5.4-1). The closure of the DCC gates under the NMFS (2009) BiOp's Action 4.1 is described in Section 3.3.2.4, *Operational Criteria for the Delta Cross Channel Gates*, and would be expected to result in nearly all juvenile salmonids from the Sacramento River basin encountering the DCC when the gates are closed. The majority of adult winter-run would migrate during the main period of DCC closure, whereas spring-run Chinook salmon and steelhead could encounter a mixture of open and closed gate configurations, depending on migration timing and gate operations.

5.4.1.2.1.8 Exposure to Suisun Marsh Facilities

5.4.1.2.1.8.1 Suisun Marsh Salinity Control Gates

Operation of the SMSCG from October through May coincides with the upstream migration of adult Central Valley anadromous salmonids. The late winter and spring downstream migration of Central Valley salmonids also overlaps with the operational period of the SMSCG. As adult Central Valley anadromous salmonids travel between the ocean and their natal Central Valley streams, Montezuma Slough provides an alternative route to their primary migration corridor through Suisun Bay. Fisheries sampling conducted by CDFW indicates many adult Central Valley salmon migrate upstream through Montezuma Slough (Edwards *et al*. 1996, Tillman *et al*. 1996), but the proportion of the total run utilizing this route is unknown.

5.4.1.2.1.8.2 Roaring River Distribution System

As described previously for the SMSCG, some anadromous salmonids (juveniles and adults) would occur in Montezuma Slough and therefore could be exposed to the RRDS, although the intake is screened.

5.4.1.2.1.8.3 Morrow Island Distribution System

NMFS (2009: 438) noted that Goodyear Slough is not a migratory corridor for listed salmonids, which would be likely to limit the potential for exposure to the MIDS.

5.4.1.2.1.8.4 Goodyear Slough Outfall

NMFS (2009: 438) suggested that listed salmonids are not likely to encounter the Goodyear Slough structure because of its location.

5.4.1.2.1.9 Exposure to North Bay Aqueduct

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. No steelhead have been captured in the monitoring surveys between 1996 to 2004, the dates available on the DFG website. Based on the geographic location of the Barker Slough Pumping Plant in the north Delta, it is unlikely that any listed salmonids from the San Joaquin River basin would be exposed to the facility.

5.4.1.2.1.10 Exposure to Other Facilities

5.4.1.2.1.10.1 Contra Costa Canal Rock Slough Intake

As described by NMFS (2009: 411), winter-run Chinook salmon are present from approximately December through June based on salvage records from the CVP/SWP fish collection facilities. The peak occurrence of winter-run in the south Delta is from January through March. Juvenile spring-run are present in the South Delta in the vicinity of the CCWD diversions from January through June with peak occurrence from March through May. Central Valley steelhead may be present in the waters of the South Delta from October through July, but have peak occurrence from January through March (National Marine Fisheries Service 2009: 411).

5.4.1.2.1.10.2 Clifton Court Forebay Aquatic Weed Control Program

The application of aquatic herbicide to the waters of Clifton Court Forebay will occur during the summer months of July and August. The probability of exposing salmonids to the herbicide is very low due to the life history of Chinook salmon and steelhead in the Central Valley's Delta region. Migrations of juvenile winter-run and spring-run fish primarily occur outside of the summer period in the Delta. Historical salvage data indicates that in wet years, a few steelhead may be salvaged as late as early July, but this is uncommon and the numbers are based on a few individuals in the salvage collections. 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.

5.4.1.2.2 Green Sturgeon

5.4.1.2.2.1 Temporal Occurrence

NMFS (2009: 338) noted that adult green sturgeon enter the San Francisco Bay estuary in early winter (January/February) before initiating their upstream spawning migration into the Delta. Adults move through the Delta from February through April[13], arriving in the upper Sacramento River between April and June (Heublein 2006, Kelly *et al.* 2007). Following their initial spawning run upriver, adults may hold for a few weeks to months in the upper river (*i.e.*, GCID aggregation site; see Vogel 2005, 2008a) or immediately migrate back down river to the Delta. Those fish that hold upriver move back downstream later in the fall, during the first rains per the review by Klimley et al. (2015). Radio-tagged adult green sturgeon have been tracked moving downstream from the GCID aggregation site past Knights Landing during the summer and fall into November and December, following their upstream migrations the previous spring. It

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[13] This is consistent with the life history presented in a recent review by Klimley et al. (2015), whose Figure 1 showed upstream migration in March and April.

appears that pulses of flow in the river "trigger" downstream migration in the late fall, similar to behavior exhibited by adult green sturgeon on the Rogue and Klamath River systems (Erickson *et al.* 2002, Benson *et al.* 2007). Klimley et al. (2015: 1-2) noted "The southern DPS green sturgeon migrates in the spring to spawn in the Sacramento River and returns to the estuary in the fall, winter, and spring", suggesting that adults can be found in the Delta and estuary for much of the year.

Per NMFS (2009: 338), adults and sub-adults may also reside for extended periods in the western Delta as well as in Suisun and San Pablo bays. Like other estuaries along the west coast of North America, adult and sub-adult green sturgeon (from both Northern and Southern DPSs) frequently congregate in the tidal portions of the San Francisco Bay estuary during the summer and fall, with the recent review by Klimley et al. (2015) also suggesting that these fish may be present at this location in spring. It is not known exactly why these congregations occur, but they do not appear to be related to spawning activities, as most fish do not move upriver out of tidewater. Based on radio and acoustic tag data gathered to date from adult green sturgeon, fish that spawn in one river system do not spawn in other river systems.

Juveniles are believed to use the Delta for rearing for the first 1 to 3 years of their life before moving out to the ocean. 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. Juveniles are recovered at the SWP and CVP fish collection facilities year round and range in size from 136 mm to 774 mm, with an average size of 330 mm (National Marine Fisheries Service 2009: 338).

5.4.1.2.2.2 Spatial Occurrence

As described by NMFS (2009: 340-341), adult green sturgeon are presumed to primarily use the mainstem of the Sacramento River through the Delta when making their upstream spawning migrations. During high water conditions that result in the flooding of the Yolo bypass, adult green sturgeon may also utilize the floodplain of the Yolo bypass to move northwards from Cache Slough to the Sacramento River at Fremont Weir. This has resulted in stranding during some years, as exemplified in April 2011 (Thomas et al. 2013). During other times of the year, green sturgeon may be present in any of the waterways of the Delta, based on sturgeon tag returns. Sturgeon report card data for 2007-2015 show that reported green sturgeon captures by anglers in or near the Delta were consistently high in Suisun Bay and the Sacramento River between Knights Landing and Chipps Island, with other high-ranking areas including San Pablo Bay and Carquinez Strait (Table 5.4-5), Green sturgeon captured in these locations have ranged from 12 inches to 86 inches. Other areas within the Delta reaching relatively high ranks of total reported captures included the Sacramento Deepwater Ship Channel (4th in 2015) and Montezuma Slough (5th in 2015). The report card data confirm that green sturgeon occur quite broadly within the Delta, with individuals also having been caught in Old River (8 fish from 2007-2015) and in the San Joaquin River between Stockton and the Highway 140 bridge upstream of the Delta (40 fish from 2007 to 2015). These fish ranged from 47 to 66 inches (Table 5.4-4).

The pattern of occurrence throughout the Delta from sturgeon report card data is consistent with the observations of NMFS (2009: 341), who noted that juvenile and sub-adult green sturgeon are found throughout the waters of the Delta, having been recovered at the CVP and SWP fish collection facilities and from areas on the San Joaquin River near San Andreas Shoals.

Table 5.4-4. Catch of Green Sturgeon from Sturgeon Report Cards, 2007-2015.

Location Name	Rank of Catch	Number of Anglers	Winter Catch	Spring Catch	Summer Catch	Fall Catch	Unknown Catch	Total	Number Measured	Minimum Length (inches)	Maximum Length (inches)	Average Length (inches)
Sacramento River: Red Bluff to Hwy 32 bridge												
2010												
2011												
2012												
2013												
2014												
2015												
Sacramento River: Hwy 32 bridge to Colusa												
2010		18		7	15			22	22	47	65	57.6
2011												
2012		4			4			4	1	90	90	90
2013		3	0	0	4	0	0	4	0			
2014		4		1	3			4	2	70	84	77
2015		1		1				1				
Sacramento River: Red Bluff to Colusa												
2007	1	11	17	2	10	38		67	1	65		
2008		44	3	50	2	0		55	55	46.5	66	57.2
2009		49	3	51	1			53	53	46	84	56.9
Sacramento River: Colusa to Knights Landing												
2007		5	4	3		1	1	9				
2008	4	97	37	84	0	5		126	126	46	66	58.9
2009		61	24	45		1		70	70	46	66	56.7
2010		41		11	35			46	46	48	66	60
2011		4			4			4				
2012		2			2			2	1	72	72	72

Location Name	Rank of Catch	Number of Anglers	Winter Catch	Spring Catch	Summer Catch	Fall Catch	Unknown Catch	Total	Number Measured	Minimum Length (inches)	Maximum Length (inches)	Average Length (inches)
2013		3	0	1	2	0	0	3	0			
2014		1			1			1	1	72	72	72
2015		3		2	1			3	1	64	64	64
Sacramento River: Knights Landing to Rio Vista												
2007		12	2	6	1	7		16	1	36		
2008	1	201	93	144	3	32		272	271	46	66	56.4
2009	2	174	67	139		11		217	217	46	66	55.7
2010	3	115		57	72		15	144	144	46	66	56.1
2011	4	6		4	1		1	7	3	14	71	34.3
2012	4	17		5	8		4	17	5	18	56	38.2
2013	3	12	0	7	5	0	7	19	12	14	74	32.7
2014	4	11		8	2		1	11	6	12	64	35.5
2015		6		4			2	6	4	25	54	42.5
Sacramento River: Rio Vista to Chipps Island												
2007	2	42	17	10	4	28	3	62	7	19	86	42
2008	1	212	100	84	14	74		272	271	46	71	54.7
2009	3	162	80	53	9	58		200	197	46	67	54.7
2010	2	176		75	55	6	90	226	226	46	66	54.2
2011	5	6		2	1	2	1	6	2	28	29	28.5
2012	2	28		10	4	1	17	32	8	18	72	39.5
2013	1	28	0	10	4	5	25	44	18	12	57	31.2
2014	1	29		17	24		3	44	10	12	40	28.4
2015	1	41	1	23	27		8	59	16	18	44	26.6
Feather River												
2007		1			2			2				
2008		2	1	1	0	0		2	2	51	60	55.5
2009		4	1	3				4	4	59	66	61.3

Location Name	Rank of Catch	Number of Anglers	Winter Catch	Spring Catch	Summer Catch	Fall Catch	Unknown Catch	Total	Number Measured	Minimum Length (inches)	Maximum Length (inches)	Average Length (inches)
2010												
2011		1			1			1				
2012												
2013												
2014												
2015												
American River												
2007												
2008		1	1	0	0	0		1	1	57	57	57
2009								0				
2010												
2011												
2012												
2013		1	0	0	0	0	1	1	0			
2014												
2015												
Sacramento Deepwater Ship Channel												
2007		3		1		2		3	1	24		
2008		49	28	19	1	14		62	62	46	65	54.6
2009		38	27	9	2	16		54	54	46	66	54.6
2010		39		16	6	1	23	46	46	46	65	53.5
2011		1					1	1	1	21	21	21
2012		2			1		1	2				
2013		8	0	1	2	1	4	8	1	46	46	46
2014		5		4		1	1	6	1	30	30	30
2015	4	7		6	2		3	11	7	20	72	35.1
Yolo Bypass												

Location Name	Rank of Catch	Number of Anglers	Winter Catch	Spring Catch	Summer Catch	Fall Catch	Unknown Catch	Total	Number Measured	Minimum Length (inches)	Maximum Length (inches)	Average Length (inches)
2007												
2008		15	5	12	0	1		18	18	48	66	58.1
2009		14	9	7		2		18	18	48	65	54.2
2010		22		14	11	1	3	29	29	46	66	58.6
2011												
2012												
2013												
2014												
2015												
Montezuma Slough												
2007		13	5	4	1	4		14	1	27		
2008		72	35	35	2	14		86	86	46	75	56.1
2009		84	39	44	9	16		108	107	46	65	54.2
2010		51		21	20	9	9	59	59	46	66	55.1
2011		2		2				2	2	22	24	23
2012		4		1	4	1		6	3	12	60	28
2013		6	0	1	4	0	2	7	3	24	28	25.3
2014		6		2	4	1		7	2	10	14	12
2015	5	9		2	6	1	2	11	5	20	39	30.6
Napa River												
2007		6	1	4	1	1		7	1	28		
2008		61	24	31	7	4		66	66	46	65.7	52.2
2009		80	34	42	11	2		89	83	46	66	53.5
2010		83		36	47	10	4	97	97	46	72	54.6
2011		3			4			4				
2012	5	8			8	2		10	3	28	36	31.7
2013		1	0	0	3	0	0	3	0			

Location Name	Rank of Catch	Number of Anglers	Winter Catch	Spring Catch	Summer Catch	Fall Catch	Unknown Catch	Total	Number Measured	Minimum Length (inches)	Maximum Length (inches)	Average Length (inches)
2014		3		1	1		1	3	2	25	32	28.5
2015		9		3	5		1	9				
Petaluma River												
2007		1				1		1				
2008		3	3	1	0	0		4	4	48	57	52
2009		6	1	5				6	5	49	65	58
2010		20		6	14			20	18	46	65	53.9
2011												
2012		1			2			2	2	40	42	41
2013		1	0	1	0	0	0	1	1	60	60	60
2014												
2015												
San Joaquin River: Upstream of HWY 140 bridge												
2007												
2008		6	4	0	0	2		6	6	47	62	53
2009		1		1				1	1	64	64	64
2010		2		1			2	3	3	50	66	60.3
2011												
2012												
2013		1	0	0	0	0	1	1	0			
2014												
2015												
San Joaquin River: HWY 140 bridge to Stockton												
2007												
2008		8	1	7	0	1		9	9	49	66	58.1
2009		13	4	10		2		16	16	47	62	54.3
2010												

Location Name	Rank of Catch	Number of Anglers	Winter Catch	Spring Catch	Summer Catch	Fall Catch	Unknown Catch	Total	Number Measured	Minimum Length (inches)	Maximum Length (inches)	Average Length (inches)
2011												
2012												
2013												
2014		2		1			1	2				
2015												
San Joaquin River: Stockton to Sherman Lake												
2008		36	20	8	2	17		47	47	46	65	53.3
2009		51	25	19	2	18		64	64	46	66	52.8
2010		37		19	13	6	10	48	48	46	65	53.5
2011		4			1	1	2	4				
2012												
2013		3	0	0	1	1	1	3	2	22	50	36
2014		7		6	2		1	9	2	27	74	50.5
2015		3		3	3		1	7	4	24	45	34.5
Old River												
2007												
2008		2	0	1	0	1		2	2	46.5	62	54.3
2009		2	1		1			2	2	46	47	46.5
2010		2		2				2	2	54	60	57
2011												
2012												
2013												
2014		1		1				1				
2015		1					1	1	1	27	27	27
San Pablo Bay												
2007	5	15	5	12	2	1		20	1	38		
2008	5	101	52	54	2	7		115	114	46	69	54.6

Location Name	Rank of Catch	Number of Anglers	Winter Catch	Spring Catch	Summer Catch	Fall Catch	Unknown Catch	Total	Number Measured	Minimum Length (inches)	Maximum Length (inches)	Average Length (inches)
2009	5	95	32	66	7	7		112	109	46	65	53
2010	5	85	1	61	34	4	3	103	102	46	66	54
2011	1	19		6	9	11	2	28	11	21	59	37.5
2012		6		4	2			6				
2013	4	10	0	11	2	0	2	15	5	19	36	28.6
2014	3	15		15	3			18	6	17	40	29
2015	3	18		14	6	1	1	22	8	22	37	28.9
Carquinez Strait												
2008		60	22	25	9	8		64	64	46	66	54.4
2009		45	13	17	16	9		55	54	46	66	54.4
2010		44	2	16	27	6	5	56	56	46	66	54.9
2011	3	6		1	3	2	2	8	1	30	30	30
2012	3	9		8	3	3	6	20				
2013	5	9	0	9	1	2	1	13	1	30	30	30
2014	5	7		4	5		2	11	7	18	32	25.4
2015		10	1	3	3		4	10	5	14	35	27.6
Suisun Bay												
2007	4	23	4	9	3	14		30	5	22	40	30
2008	2	210	83	97	32	50		262	259	46	75	54.3
2009	1	266	101	110	35	79		325	324	46	66	53.7
2010	1	198		85	78	19	65	247	247	28	66	53.9
2011	2	15		2	8	4	6	20	4	13	27	21.8
2012	1	46		19	10	9	24	62	19	13	39	25.5
2013	2	31	0	8	17	2	11	38	11	8	48	29.5
2014	2	28		13	8	6	6	33	11	18	44	29.1
2015	2	40		18	14	6	9	47	20	19	45	27.7
Grizzly Bay												

Location Name	Rank of Catch	Number of Anglers	Winter Catch	Spring Catch	Summer Catch	Fall Catch	Unknown Catch	Total	Number Measured	Minimum Length (inches)	Maximum Length (inches)	Average Length (inches)
2007		11	2	3	1	8		14				
2008		41	22	11	3	14		50	50	46	66	54.3
2009		47	26	14	6	13		59	59	46	65	52.8
2010		20		7	8		7	22	22	46	65	54.5
2011		2		1			2	3	2	33	36	34.5
2012		8		2	1		5	8				
2013		6	0	1	3	1	1	6	0			
2014		2		2				2				
2015		3		1		1	1	3	2		42	
San Francisco Bay: North of HWY 80												
2007		1	1			1		2				
2008		15	12	6	0	2		20	20	47	65	56.3
2009		11	7	3	1	3		14	14	49	65	57.2
2010		11		14	3	1		18	18	47	62	53.9
2011												
2012												
2013												
2014												
2015												
San Francisco Bay: South of HWY 80												
2007		1		1				1				
2008	3	124	121	19	4	22		166	163	46	66	55.9
2009	4	107	108	6	2	11		127	127	5	65	55.1
2010	4	83		90	3		11	104	104	46	65	54.9
2011												
2012		1			2		2	2	2	52	86	69
2013												

Location Name	Rank of Catch	Number of Anglers	Winter Catch	Spring Catch	Summer Catch	Fall Catch	Unknown Catch	Total	Number Measured	Minimum Length (inches)	Maximum Length (inches)	Average Length (inches)
2014												
2015		1			1			1	1	52	52	52
Source: Gleason et al. (2008), DuBois et al. (2009, 2010, 2011, 2012, 2014), DuBois (2013), DuBois and Harris (2015, 2016).												

5.4.1.2.2.3 Exposure to North Delta Exports

The temporal and spatial patterns of occurrence discussed in the previous two sections would influence the potential for exposure of green sturgeon to the NDD. Data specific to potential near-field exposure of green sturgeon to the NDD are not available, but as previously noted, juveniles can be present in the Delta year-round. See also the discussion from NMFS (2009: 403) related to the DCC (Section 5.4.1.2.2.6, *Exposure to Delta Cross Channel*).

5.4.1.2.2.4 Exposure to South Delta Exports

The temporal and spatial patterns of occurrence discussed in Sections 5.4.1.2.2.1, *Temporal Occurrence,* and 5.4.1.2.2.2, *Spatial Occurrence,* would influence the potential for exposure of green sturgeon to the effects of the south Delta export facilities; those sections were adapted from NMFS's (2009: 338, 340-341) assessment of the potential for exposure of green sturgeon to Delta exports and related hydrodynamics.

5.4.1.2.2.5 Exposure to Head of Old River Gate Operations

Green sturgeon juveniles (present year-round) and upstream-migrating adults (spring) could be exposed to the winter/spring and fall operations of the HOR gate. However, given that green sturgeon may be extirpated from the San Joaquin River (Israel and Klimley 2008), adults exposed to the HOR gate may be a small subset of individuals ultimately returning to the Sacramento River. Nevertheless, the occurrence of green sturgeon in reported catch in the San Joaquin River in and upstream of the HOR gate location (Table 5.4-5) indicates that some individuals could be exposed to HOR gate operations.

5.4.1.2.2.6 Exposure to Delta Cross Channel

NMFS (2009: 403) noted that little is known about the migratory behavior of juvenile green sturgeon in the Sacramento River basin. NMFS (2009: 403) also considered that 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. NMFS (2009: 403) noted that more information is required to accurately assess the migratory movements of juvenile sturgeon in the river system, as well as their movements within the Delta during their rearing phase in estuarine/Delta waters. Although newer information on juvenile movements is available—i.e., the summary by Klimley et al. (2015) of juvenile movements; see Section 5.4.1.3.2.2.*1 Indirect Mortality Within the Delta*—this information does not inform the exposure assessment for DCC given that it focused on green sturgeon juveniles released in the lower San Joaquin River. Adult green sturgeon are likely to encounter closed DCC gates during their upstream spawning migration in winter and early spring, but encounter open gates during their downstream migration in summer and fall following spawning (National Marine Fisheries Service 2009: 403).

5.4.1.2.2.7 Exposure to Suisun Marsh Facilities

5.4.1.2.2.7.1 Suisun Marsh Salinity Control Gates

Operation of the SMSCG from October through May coincides with the upstream migration of adult green sturgeon, which could be exposed to the gates during the up to 20 days of annual operation. Sub-adult green sturgeon can be found in Suisun Marsh year-round (Matern *et al*. 2002), and adult green sturgeon may also use Montezuma Slough as a migration route between the ocean and their natal spawning areas in the upper Sacramento River. Montezuma Slough is part of designated critical habitat for green sturgeon (74 FR 52300).

5.4.1.2.2.7.2 Roaring River Distribution System

The RRDS is located in Montezuma Slough which, as noted previously for the SMSCG, is designated critical habitat for green sturgeon.

5.4.1.2.2.7.3 Morrow Island Distribution System

NMFS (2009: 438) noted that Goodyear Slough, where MIDS is located, is not a migratory corridor for green sturgeon. However, Goodyear Slough is part of designated critical habitat for the species (74 FR 52300).

5.4.1.2.2.7.4 Goodyear Slough Outfall

As previously noted for MIDS, Goodyear Slough is not a migratory corridor for green sturgeon and NMFS (2009: 438) considered it unlikely that green sturgeon would encounter the Goodyear Slough outfall because of its location.

5.4.1.2.2.8 Exposure to North Bay Aqueduct

Green sturgeon are assumed to occur in the waters of Cache Slough and the Sacramento ship channel as green sturgeon have been caught in these waters by sport fisherman (National Marine Fisheries Service 2009: 416).

5.4.1.2.2.9 Exposure to Other Facilities

5.4.1.2.2.9.1 Contra Costa Canal Rock Slough Intake

Both juvenile and sub-adult green sturgeon are expected to be present year round in the South Delta as indicated by the salvage record (NMFS 2009: 411). Adult green sturgeon have been caught by sport fisherman in the mainstem of the San Joaquin River from Sherman Island to the Port of Stockton in most months of the year based on the draft 2007 sturgeon report card (California Department of Fish and Game 2008). Presence in the South Delta is assumed for the same period. During the 75 day pumping reduction from March 15 to May 31 and the 30 day no pumping period (April 1 to April 30), the effects of the CCWD action is significantly reduced or eliminated. In addition, Rock Slough is not part of designated critical habitat for green sturgeon (74 FR 52300).

5.4.1.2.2.9.2 Clifton Court Forebay Aquatic Weed Control Program

As described by NMFS (2009: 387-388), juvenile and sub-adult green sturgeon are recovered year-round at the CVP/SWP facilities, albeit in low numbers, and have higher levels of salvage during the months of July and August compared to the other months of the year. The reason for this distribution is unknown at present. Therefore, juvenile and sub-adult green sturgeons are likely to be present during the application of the herbicides as part of the aquatic weed control program, and could be exposed to mechanical removal efforts occurring on an as-needed basis.

5.4.1.3 Assess Species Response to the Proposed Action

The response of listed salmonids and green sturgeon to the proposed action is discussed in this section, with the potential effects divided into near-field and far-field effects. Near-field effects are those occurring close to an operations facility, e.g., predation at the NDD screens or the HOR gate. Far-field effects are those occurring over a broader area, e.g., lower through-Delta survival caused by less river flow downstream of the NDD.

5.4.1.3.1 Salmonids

5.4.1.3.1.1 Near-Field Effects

5.4.1.3.1.1.1 North Delta Exports

As described in Section 3.2.2.2, *Fish Screen Design*, the NDD will be provided with fish screens designed to minimize the risk that fish will be entrained into the intakes, or injured by impingement on the fish screens, during operations[14]. The process of the fish screen design has been and will continue to be subject to extensive collaborative discussions with the fish agencies affecting both final design and initial operations of the screens, during which their operations will be "tuned" to minimize risks to fish. As also described in Section 3.4.8 *Monitoring and Research Program*, a number of studies will be conducted to monitor NDD fish screen performance and allow refinement to meet design criteria.

5.4.1.3.1.1.1.1 Entrainment

Juvenile Chinook salmon at sizes of 30 mm or greater may occur near the north Delta intake structures (National Marine Fisheries Service 1997). Juvenile steelhead migrating downstream in the Sacramento River that will be exposed to the north Delta intakes typically range in length from approximately 150 to 250 mm. Based on a conservative body fineness ratio of 10 (from Delta Smelt estimates by Young et al. 1997) and applying the equations of Young et al. (1997), the NDD's fish screens with a 1.75-mm opening would be estimated to be effective at excluding juvenile Chinook salmon of 22-mm standard length and greater, as well as juvenile steelhead, which generally are larger than Chinook salmon during their Delta residence (McEwan 2001). Therefore, little to no entrainment of salmonids is expected at the proposed north Delta diversions. Note, however, that one juvenile Chinook salmon of 32-mm fork length—standard length would be slightly shorter—was collected during entrainment monitoring at the Freeport Regional Water Project intake in January 2012 (Kozlowski pers comm.), a facility with the same screen opening size as proposed for the NDD. This suggests occasional entrainment of very small Chinook salmon could occur at the north Delta intakes, although most would be expected to be excluded.

5.4.1.3.1.1.1.2 Impingement, Screen Contact, and Screen Passage Time

Juvenile salmonids would have the potential to contact and be impinged on the screens of the NDD. Experimental studies at the UC Davis Fish Treadmill facility found that Chinook salmon experienced frequent contact with the simulated fish screen but were rarely impinged (defined as prolonged screen contacts >2.5 minutes) and impingement was not related to any of the experimental variables examined (Swanson et al. 2004a). The extent to which the relatively benign experimental environment is representative of Sacramento River conditions is uncertain, but the proposed NDD intake screens would have a smooth screen surface and the potential for frequent screen cleaning (cycle time no more than 5 minutes), which would provide additional

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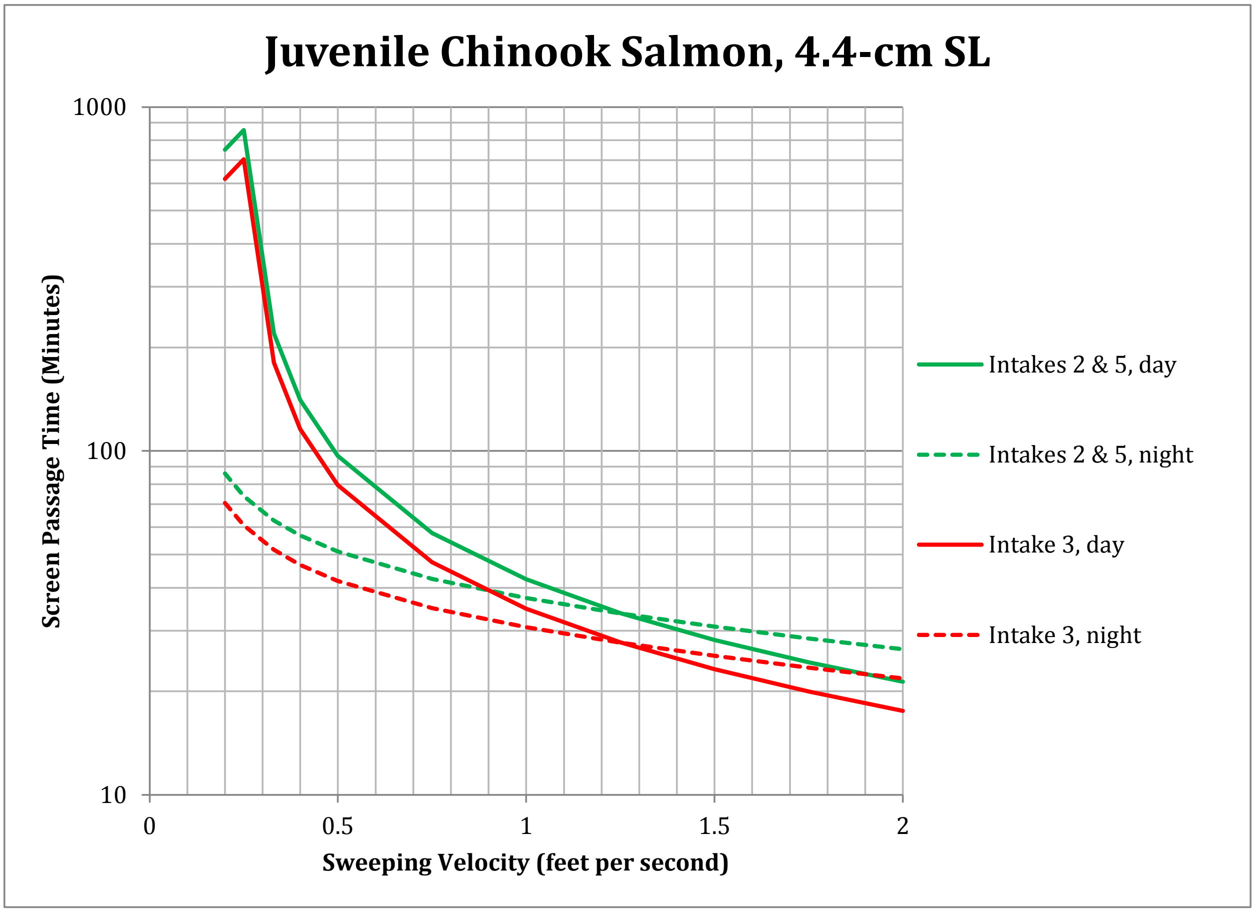
[14] Fish screens would be removed as necessary during maintenance, which could be accompanied by dewatering, for example (see Section 3.3.6.1.1, *Intake Dewatering*, of Chapter 3, *Description of the Proposed Action*). Pumping would not occur in bays with fish screens removed, and therefore there would be no risk of entrainment during these times.

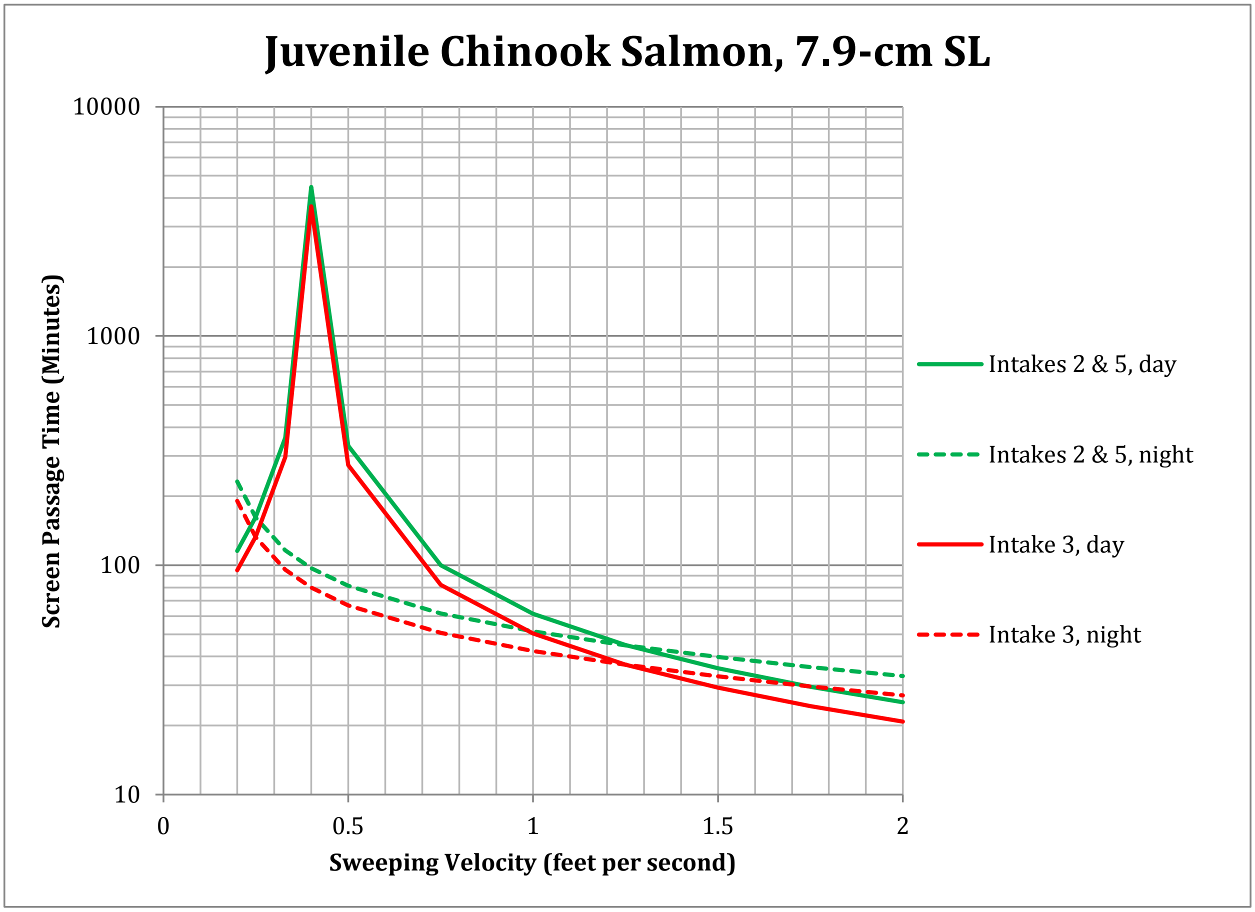
protection to minimize screen surface impingement of juvenile Chinook salmon and steelhead. The smooth surface also would serve to reduce the risk of abrasion and scale loss for any fish that does come into contact with the screens (Swanson et al. 2004a).

Although Swanson et al. (2004a) provide equations to estimate screen contact rate for juvenile Chinook salmon, preliminary calculations for this effects analysis suggested that these equations did not perform well for the lengths of screen proposed for the NDD. Additionally, the equations derived from this study, conducted in a two-foot wide channel, may not be wholly applicable to the effects of NDD, where fish will be in a much wider channel and may be able to move away from the screens or may not be in an area of the channel exposed to their effects. Screen passage time is another useful measure of potential effects on Chinook salmon, with shorter passage times being more desirable to limit the potential for adverse effects (e.g., predation or screen contact). Application of the relationships from Swanson et al. (2004a) for a representative winter water temperature of 12°C illustrated how screen passage time may differ in relation to sweeping velocity at an approach velocity of 0.2 ft/s (see methods description in Appendix 5.D, *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale*, Section 5.D.1.1.1.1, *Screen Passage Time*) (Figure 5.4-1 and Figure 5.4-2). It should be noted that the equations of Swanson et al. (2004a) give very long screen passage times at certain sweeping velocity and approach velocity combinations, e.g., over 4,600 minutes for 7.9-cm fish along intakes 2 and 5 at sweeping velocity of 0.4 ft/s (Figure 5.4-2). Such estimates are far in excess of the duration of the experimental trials (120 minutes) used to derive the swimming data and therefore should be treated with caution. The peaks in the estimated screen passage times shown in Figure 5.4-1 and Figure 5.4-2 reflect the swimming response of the tested juvenile Chinook salmon and their general negative rheotaxis (swimming against the prevailing current). To the left of the peaks, swimming velocity was sufficient to give net upstream progress, so that in theory the fish would pass the screen in an upstream direction. To the right of the peaks, swimming velocity increases but does not keep up with the increase in sweeping velocity, resulting in fish passing the screen in a downstream direction. Very high estimated screen passage time at the peaks reflects fish that would be maintaining station in front of a screen for a long time. Larger fish have greater swimming ability, so their peak screen passage time is somewhat greater (Figure 5.4-2) than that of smaller fish (Figure 5.4-1). Swimming velocity is lower at night than during the day for a given set of flow conditions; this generally results in screen passage time decreasing as sweeping velocity increases over the full range of sweeping flows examined here, because screen passage velocity becomes more negative (i.e., fish move downstream more quickly). Longer screens increase screen passage time: for example, at a sweeping velocity of 0.4 ft/s during the night, a 7.9-cm juvenile would pass the screens of intakes 2 and 5 (each ~1,350 feet long) in ~97 minutes, compared to ~80 minutes for intake 3 (1,100 feet long) (Figure 5.4-1 and Figure 5.4-2). Juvenile salmonids migrating downstream close to shore may encounter several of the proposed intakes within a few hours, depending on travel time. Because of the lack of an established relationship between passage time, screen contact rate and injury or mortality, it is not possible to conclude with high certainty what the effects of the NDD may be on juvenile Chinook salmon or indeed on juvenile steelhead, which Swanson et al. (2004a) noted behaved similarly in the Fish Treadmill tests. This uncertainty would be addressed with monitoring and targeted studies examining impingement and passage time along the intakes. Swanson et al. (2004a) also found that at warmer temperatures (19°C), the larger fish had a greater tendency to move downstream with the current (negative rheotaxis), consistent with a behavioral shift to outmigration; this would result in considerably lower screen passage times.



Note: The total screen length for intakes 2 and 5 would be 1,350 feet each; intake 3's screen length would be 1,110 feet. Plot only includes mean responses and does not consider model uncertainty.

Figure 5.4-1. Estimated Screen Passage Time for Juvenile Chinook Salmon (4.4-cm Standard Length) Encountering Proposed NDD Fish Screens at Approach Velocity of 0.2 Feet per Second during the Day and Night.



Note: The total screen length for intakes 2 and 5 would be 1,350 feet each; intake 3's screen length would be 1,110 feet. Plot only includes mean responses and does not consider model uncertainty.

Figure 5.4-2. Estimated Screen Passage Time for Juvenile Chinook Salmon (7.9-cm Standard Length) Encountering Proposed NDD Fish Screens at Approach Velocity of 0.2 Feet per Second during the Day and Night.

5.4.1.3.1.1.1.3 Predation

Predation of juvenile salmonids at the NDD could occur if predatory fish aggregated along the screens, as has been observed at other long screens in the Central Valley (Vogel 2008b). The only study of predation along a long fish screen occurred at the Glenn Colusa Irrigation District's (GCID) Sacramento River pump station (Vogel 2008b). In that study, mean survival of tagged juvenile Chinook salmon along the fish screens (total length just under 1,300 feet) in 2007—this being the only year of the study in which flow-control blocks at the weir at the downstream end of the fish screen were removed, to reduce predatory fish concentration—was ~95%. However, the percentage of tagged juvenile Chinook salmon released at the upstream end of the fish screen that were recaptured at a downstream sampling location was similar or slightly greater than for fish released at the downstream end of the fish screen, when standardized for the distance that the fish had to travel to the recapture site. These data suggest that survival along the screen was at least similar to survival in the portion of the channel without the screen (i.e., screen survival was similar to baseline survival, if the latter is assumed to be represented by the channel downstream of the screen). However, test fish providing the estimate of survival in the channel downstream of the screen were released prior to the fish that were released at the upstream end of the fish screen, which could have confounded comparisons of relative survival between these groups if predatory fishes became partly satiated prior to the arrival of the fish released at the upstream end of the screen (thus making their survival relatively higher than otherwise would have occurred) (Vogel 2008b).

Although the GCID facility is closest in size to the proposed NDD and has received considerable study in terms of fish survival, the GCID facility and the proposed NDD screens are substantially different. The GCID facility is located along a relatively narrow oxbow channel (about 10 to 50 meters wide) in the middle Sacramento River near Hamilton City, while the north Delta intakes would be located on the much wider channel of the mainstem lower Sacramento River (about 150 to 180 meters wide). In addition, the fish tested at GCID were relatively small (mean length generally less than 70 mm; Vogel 2008b) in comparison to the sizes of salmonid that would occur near the NDD (e.g., winter-run Chinook salmon mean length generally would be greater than 70 mm; del Rosario et al. 2013), which could give different susceptibility to predation. Under the PA, there would be three intakes constituting the NDD, compared to only one for the GCID facility, so that the cumulative length of screen would be considerably greater for the PA. Therefore, there is uncertainty to what extent the results from the GCID studies may represent the situation at the NDD.

Analysis of potential predation of juvenile Chinook salmon using a bioenergetics approach (see the public draft BDCP's Appendix 5.F, *Biological Stressors on Covered Fish,* Section 5.F.3.2.1 [California Department of Water Resources 2013]) suggested that loss along the NDD[15] would be an order of magnitude lower than estimated at the GCID facility (e.g., for winter-run Chinook salmon the bioenergetics estimates were considerably less than 0.3%). These estimates are uncertain because of the various assumptions in the modeling and do not provide context for how such losses would compare to baseline losses without the NDD. Overall, there is potential for predation of juvenile salmonids along the NDD, which would constitute an adverse effect. Implementation of the localized reduction of predatory fishes at the NDD, if implemented, could reduce the potential for predation, although this measure is uncertain in its effectiveness and will be subject to adaptive management (see Appendix 3.H). Further discussion is provided in Section 5.5.2, *Localized Reduction of Predatory Fishes to Minimize Predator Density at North and South Delta Export Facilities*. Studies in tidal channels in or near the Delta indicate that predator reduction can be effective, given sufficient effort. Sabal et al. (2016) found that survival of outmigrating juvenile Chinook salmon below Woodbridge Irrigation District Dam (in the tidal Mokelumne River upstream of the Delta) increased by 25-29% following striped bass removal, with the percentage change in survival being positively related to the number of striped bass removed. Cavallo et al. (2013) found that survival of juvenile Chinook salmon in the North Fork Mokelumne River within the Delta increased from < 80% to >99% following a first predator removal event, but decreased to pre-removal density following a second removal event, suggesting that a more sustained removal effort was necessary. Overall, this illustrates the potential benefits (though uncertain) to juvenile salmonid survival as a result of predator removal

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[15] Although the screen lengths analyzed were different to those proposed under the PA, the order of magnitude of the results would remain the same if modeling specific to the PA was undertaken.

efforts; however, uncertainty in the efficacy of localized reduction of predatory fishes at the NDD remains. Therefore, it is not clear that this measure will be effective in mitigating the potential adverse effect to juvenile salmonids from the NDD. Although it is uncertain that the measure would be effective, for purposes of this analysis, it is assumed that it would not be.

5.4.1.3.1.1.2 South Delta Exports

As described by NMFS (2009: 341-374), direct entrainment of juvenile winter-run Chinook salmon, spring-run Chinook salmon, and Central Valley steelhead includes a number of components contributing to loss. These include the following.

- SWP
    - Prescreen loss (from Clifton Court Forebay radial gates to primary louvers at the Skinner Fish Protection Facility): 75% loss
    - Louver efficiency: 25% loss
    - Collection, handling, trucking, and release: 2% loss
    - Post release: 10% loss
    - Total loss (combination of the above): 83.5%
- CVP
    - Prescreen loss (in front of trash racks and primary louvers): 15% loss
    - Louver efficiency: 53.2% loss
    - Collection, handling, trucking, and release: 2% loss
    - Post release: 10% loss
    - Total loss (combination of the above): 35.1%

The present analysis provides quantitative analyses of entrainment differences between NAA and PA, and a qualitative discussion of potential predation differences between NAA and PA. The above loss percentages are assumed not to differ between NAA and PA, so the differences are attributable to differences in export pumping. Clifton Court Forebay's configuration will change under the PA with the division into north and south cells (Section 3.2.5.1.2, *Clifton Court Forebay*), so that the potential active storage (12,050 acre feet; see page 14-8 in Appendix 3.B, *Conceptual Engineering Report, Volume 1*) for the proposed South Clifton Court Forebay would be somewhat less than the active storage under existing conditions (~14,700 acre feet, based on the difference in storage between maximum and minimum normal water surface elevations; see page 4-2 in Appendix 3.B, *Conceptual Engineering Report, Volume 1*). This could result in lower residence times for a given level of Banks pumping under the PA compared to NAA, which may result in less prescreen loss under the PA for a given level of Banks pumping. Gingras (1997: 16-17) found a significant negative relationship between export rate and prescreen loss for marked juvenile Chinook salmon in Clifton Court Forebay and reasoned that this presumably reflected the inverse relationship between export rate and residence time in the Forebay. Recent hydrodynamic studies have confirmed the inverse relationship between export pumping and transit time for passive particles across the Forebay (MacWilliams and Gross 2013), although specific relationships for juvenile salmonids are lacking. Given the lack of specific relationships between residence time and prescreen loss for juvenile salmonids, for this effects analysis it is assumed that there is no difference in prescreen loss between NAA and PA across Clifton Court Forebay attributable to Banks pumping and the reconfiguration of the Forebay under the PA.

Outside of Clifton Court Forebay, the other major difference in configuration of the SWP south Delta export facility under the PA will be the inclusion of a control structure in the Banks approach channel leading to the Skinner Fish Protective Facility. This control structure will consist of three channels, each with a radial gate[16]; all gates will either be fully closed (when export is occurring only from the NDD) or fully open (when export is occurring from only the south Delta export facilities or from both the NDD and south Delta). The change in configuration from a 250-foot-wide channel to a control structure with total width of around 170 feet consisting of three channels and dividing walls could alter the suitability of the approach channel habitat for predatory fishes. For example, if predatory fishes are able to exploit the hydrodynamics created by the concrete divisions between the channels, predation risk could increase under the PA. This risk cannot be quantified based on available information.

Following completion of PA construction and commencement of PA operations, studies will be undertaken as part of the Clifton Court Forebay Technical Team described in Section 3.2.5.1.3, Clifton Court Forebay Technical Team, to estimate the extent to which the reconfigured Clifton Court Forebay and associated changes to the south Delta export facilities change the prescreen loss of juvenile salmonids (i.e., from the Clifton Court Forebay radial gates to the primary louvers at the Skinner Fish Protective Facility) relative to the assumptions currently made for estimating loss and take per the NMFS (2009) BiOp (or the prevailing assumptions at the commencement of PA operations). These studies will consist of releases of tagged (acoustic or PIT) or otherwise marked juvenile salmonids, followed by recapture or detection in order to estimate survival in different parts of the salvage process, as has been done in previous studies (Gingras 1997; Clark et al. 2009). The results of these experiments will inform the need to change the loss multipliers used to estimate loss and take as a function of expanded salvage. Should the experiments indicate statistically significant differences between the PA loss multipliers and the prevailing multipliers used prior to the commencement of PA operations, and following regulatory agency approval, the new PA multipliers will from then on be applied to subsequent loss estimates that are used to estimate the level of incidental take in relation to the level of incidental take that has been authorized by NMFS/DFW for the PA in each water year. South Delta export pumping will be managed in real time, as currently occurs, in order to ensure

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[16] The drawings presented in the CER Volume 2 (dated April 1, 2015) that were included as Appendix 3.C of the working draft BA were incorrect in indicating a weir would be included in the control structure in the Banks approach channel. Such weirs would only be included in the water control structures in other parts of the new conveyance system, which would be in areas to which fish would not have access (other than the fish not successfully salvaged at the Skinner/Tracy facilities or screened by the NDD) and therefore would not affect losses as part of the salvage process.

that losses of listed juvenile salmonids remain below the authorized incidental take, which will have been set to a level that limits the potential for jeopardy for the species.

Construction activities in Clifton Court Forebay could interact with operations to affect the survival of juvenile salmonids, for example, by increasing the potential for prescreen loss, given that there is some evidence that anthropogenic noise can affect predation rates of fishes (Simpson et al. 2016). However, as noted in Section 5.2.5.2.1, *Salmonids*, the timing of in-water construction activities (June 1–November 30) would avoid the periods when juvenile winter-run Chinook salmon, spring-run Chinook salmon, and steelhead are most likely to be present in the south Delta. Thus, the interaction of operations with construction would be expected to affect only a limited portion of the juvenile salmonid populations, and any effect cannot be quantified because of the lack of specific information for how prescreen loss would differ as a result of construction noise, for example. It is also not possible to quantify the extent to which any equipment or structures left in the Forebay between in-water work periods (e.g., in winter/spring) would affect the prescreen loss of juvenile salmonids. It is possible that such equipment or structures could provide predator habitat and therefore increase predation risk.

5.4.1.3.1.1.2.1 Entrainment

5.4.1.3.1.1.2.1.1 Salvage-Density Method: Winter-Run Chinook Salmon, Spring-Run Chinook Salmon, and Steelhead

The salvage-density method was used to assess differences in south Delta exports and resulting entrainment[17] during the periods of occurrence of juvenile salmonids in the Delta, based on historical salvage data. Details of the method, together with results by month and water year, are presented in Appendix 5.D, *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale*, Section 5D.1.1.2, *South Delta Exports*. Note that although this method provides an index of entrainment loss, it is most appropriately viewed comparatively, and functions primarily to illustrate south Delta export differences between scenarios. The method does not account for differences in salvage and entrainment loss that could occur because of other operational effects, e.g., changes in juvenile salmonid routing because of the NDD or the HOR gate.

The results of the salvage-density method showed that, based on modeled south Delta exports, mean entrainment loss at the south Delta export facilities would be lower under PA than NAA in all water year types for winter-run Chinook salmon, spring-run Chinook salmon, and steelhead (Table 5.4-5, Table 5.4-6, and Table 5.4-7). The differences between PA and NAA were greater in wetter water years, as a result of less south Delta export pumping facilitated by operation of the NDD. For winter-run Chinook salmon, the differences ranged from 16% less under PA at the SWP in critical years to 82% less under PA at the CVP in wet years (Table 5.4-5). For spring-run Chinook salmon, the differences ranged from 11% less under PA at the CVP in critical years to 92% less under PA at the CVP in wet years (Table 5.4-5). For steelhead, the differences ranged

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[17] As noted in Appendix 5.D, *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale*, Section 5D.1.1.2, *South Delta Exports*, there is uncertainty regarding the population-level significance of south Delta entrainment losses for salmonids (and green sturgeon). Regardless of the significance of this loss, this effects analysis provides relative differences between the NAA and PA.

from 1% less under PA at the SWP in critical years to 80% less under PA at the CVP in wet years (Table 5.4-5).

Table 5.4-5. Estimated Mean Entrainment Index (Number of Fish Lost, Based on Normalized Salvage Data) of Juvenile Winter-Run Chinook Salmon for NAA and PA Scenarios at the CVP/SWP Salvage Facilities, By Water Year Type

Water Year Type	State Water Project				Central Valley Project		
	NAA	PA	PA vs. NAA[1]		NAA	PA	PA vs. NAA[1]
Wet	10,629	3,531	-7,097 (-67%)		1,404	248	-1,156 (-82%)
Above Normal	5,995	3,073	-2,922 (-49%)		613	134	-479 (-78%)
Below Normal	5,655	3,434	-2,221 (-39%)		790	529	-261 (-33%)
Dry	3,327	2,775	-552 (-17%)		731	481	-250 (-34%)
Critical	917	772	-145 (-16%)		305	244	-62 (-20%)

Notes: [1]Negative values indicate lower entrainment loss under the proposed action (PA) than under the no action alternative (NAA).

Table 5.4-6. Estimated Mean Entrainment Index (Number of Fish Lost, Based on Nonnormalized Salvage Data) of Juvenile Spring-Run Chinook Salmon for NAA and PA Scenarios at the CVP/SWP Salvage Facilities, By Water Year Type

Water Year Type	State Water Project				Central Valley Project		
	NAA	PA	PA vs. NAA[1]		NAA	PA	PA vs. NAA[1]
Wet	27,193	5,743	-21,449 (-79%)		13,600	1,125	-12,474 (-92%)
Above Normal	16,923	2,873	-14,049 (-83%)		5,176	1,035	-4,140 (-80%)
Below Normal	4,892	3,061	-1,831 (-37%)		853	642	-211 (-25%)
Dry	10,936	7,378	-3,557 (-33%)		2,271	1,655	-616 (-27%)
Critical	5,859	4,804	-1,055 (-18%)		1,991	1,777	-214 (-11%)

Notes: [1]Negative values indicate lower entrainment loss under the proposed action (PA) than under the no action alternative (NAA).

Table 5.4-7. Estimated Mean Entrainment Index (Number of Fish Lost, Based on Nonnormalized Salvage Data) of Juvenile Steelhead for NAA and PA Scenarios at the CVP/SWP Salvage Facilities, By Water Year Type

Water Year Type	State Water Project				Central Valley Project		
	NAA	PA	PA vs. NAA[1]		NAA	PA	PA vs. NAA[1]
Wet	5,464	1,671	-3,792 (-69%)		1,045	212	-833 (-80%)
Above Normal	11,221	6,493	-4,729 (-42%)		1,834	585	-1,249 (-68%)
Below Normal	8,413	5,409	-3,004 (-36%)		2,337	1,595	-742 (-32%)
Dry	8,147	6,633	-1,513 (-19%)		1,625	1,057	-568 (-35%)
Critical	4,819	4,771	-48 (-1%)		838	597	-242 (-29%)

Notes: [1]Negative values indicate lower entrainment loss under the proposed action (PA) than under the no action alternative (NAA).

The salvage-density method analysis was applied to steelhead and spring-run Chinook salmon without regard to the region of origin (i.e., Sacramento River vs. San Joaquin River basins) because this information is not known. It is not clear from these data to what extent the entrainment results could represent San Joaquin River basin steelhead and spring-run Chinook salmon. San Joaquin River basin steelhead and spring-run Chinook salmon may be more likely to enter the CVP export facility via the Delta Mendota Canal than enter Clifton Court Forebay because the CVP entrance is located on Old River upstream of the SWP intake at Clifton Court Forebay and therefore would be the first source of entrainment these fish would encounter, if migrating down Old River. Evidence for this hypothesis is provided by salvage data of coded-wire-tagged juvenile San Joaquin River spring-run Chinook salmon that were released in spring 2016 (Marcinkevage pers. comm.). A total of 165,000 spring-run juveniles were released on March 18 at Hills Ferry, with a total of 129 of these fish recorded in SWP and CVP salvage sampling between March 20 and April 6. Adjusting for the losses before salvage sampling (i.e., prescreen loss and louver efficiency; see 5.4.1.3.1.1.2 *South Delta Exports*) gives adjusted totals of 43 spring-run juveniles that otherwise would have been sampled at SWP and 304 spring-run juveniles that otherwise would have been sampled at CVP. During the period from March 20 to April 6, the total water exported was 56,341 acre feet by the SWP and 73,935 acre-feet by the CVP[18]. Thus, the salvage density of the released spring-run juveniles that were sampled, adjusted for losses, would be around 5.4 times greater for the CVP (0.00411 fish per acre-foot) compared to the SWP (0.00076 fish per acre-foot). Overall, this provides evidence that consideration of CVP exports is an appropriate indicator of the potential for entrainment differences between PA and NAA, as the density of San Joaquin River fish entrained at CVP is likely to be considerably greater than at SWP.

Results of differences in entrainment between the PA and NAA from the salvage density method are presented in Table 5.4-7 for each facility separately. The results indicate there is generally a greater difference between NAA and PA for the CVP than for the SWP. This suggests that entrainment of San Joaquin River basin steelhead could be proportionally less than for Sacramento River basin steelhead; this is particularly true when considering that these results do not account for the presence of the HOR gate, which would route many juvenile steelhead away from the south Delta export facilities. In contrast to steelhead, entrainment results for juvenile spring-run Chinook salmon based on the salvage-density method suggest that there would be less of a difference between PA and NAA at the CVP compared to the SWP in drier years (Table 5.4-6; although the differences were still appreciable), which may be somewhat indicative of results for spring-run Chinook salmon from the San Joaquin River basin; however, as with steelhead, these results do not account for the presence of the HOR gate, which would route away from the south Delta export facilities many juvenile spring-run Chinook salmon entering the Delta down the San Joaquin River.

5.4.1.3.1.1.2.1.2 Salvage Based on Zeug and Cavallo (2014): Winter-Run Chinook Salmon

As described previously, the salvage-density method is essentially a means of examining changes in south Delta exports weighted by historic salvage density to account for species timing between months; the method does not account for potential non-linear relationships between salvage (entrainment) and south Delta exports, nor does it account for other factors that may influence salvage, such as Delta channel flows that could influence the survival or migration routes that juvenile salmonids may take. Zeug and Cavallo (2014) recently demonstrated that

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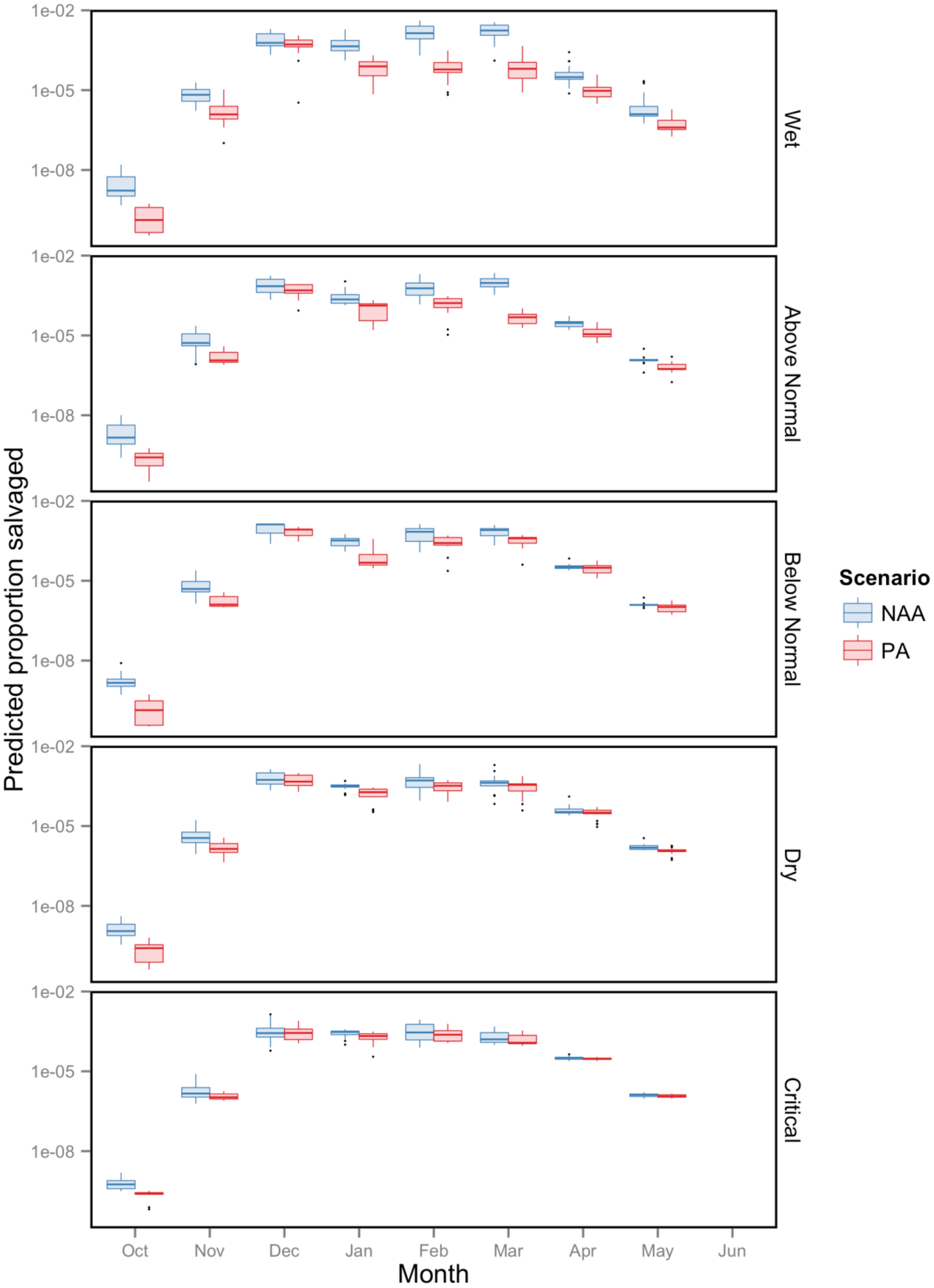
[18] http://www.dfg.ca.gov/delta/apps/salvage/, accessed July 3, 2016.

these other factors could be linked statistically to salvage of marked hatchery-reared juvenile Chinook salmon. The methods employed by Zeug and Cavallo (2014) were used to compare salvage between the NAA and PA scenarios (see methods description in Appendix 5.D, *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale,* Section 5.D.1.1.2.2, *Salvage Based on Zeug and Cavallo (2014)*). Two operational factors influencing survival were included in the analysis. From the modeling, south Delta exports have a positive relationship with the probability of salvage and a positive relationship with count of fish salvaged, i.e., greater south Delta exports give a greater probability of salvage occurring, and more fish are salvaged when salvage occurs. Sacramento River flow downstream of the NDD has a positive relationship with the probability of zero salvage (possibly reflecting hydrodynamic influences in terms of lower probability of entering the interior Delta and therefore being salvaged) and a weak positive relationship with the count of fish that are salvaged (possibly reflecting the hydrodynamic influence of more flow giving better survival of the fish that do enter the interior Delta and are entrained by the export facilities, or more fish being cued to emigrate from the Delta). The analysis was conducted for winter-run Chinook salmon alone because marked spring-run Chinook salmon have only been salvaged in very low numbers and no studies of steelhead with marks specific to given release locations were available.

The analysis showed that in wet years salvage of juvenile winter-run Chinook salmon was predicted to be substantially higher under NAA relative to PA (Figure 5.4-3). These differences were particularly apparent in October and November (medians were 82-92% less under PA; although the proportion was very small in October, reflecting very low occurrence in this month; see Figure 5.D.42 in Appendix 5.D, *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale*) and again from January through March (medians were 81–95% less under PA). In wet years, median salvage under PA ranged from 15% less than NAA in December to 92% less in October. In wetter years, more water is diverted from the NDD rather than the south Delta export facilities, reducing the chance that fish will be salvaged. A similar pattern of salvage was observed in above normal years, with median salvage under PA ranging from 31% less than NAA in December to 95% less than NAA in March. In below normal and dry years, considerably lower salvage under the PA was also evident in October, November, and January (80–94% lower median salvage under PA), but the differences were less in February–April (4–50% lower median salvage under PA) relative to wetter years (60–96% lower median salvage under PA). This may occur as exports shift from the north to the south delta and less water is exported. In critical years, differences in median salvage ranged from 1% higher under PA in December to 63% lower under PA in October.

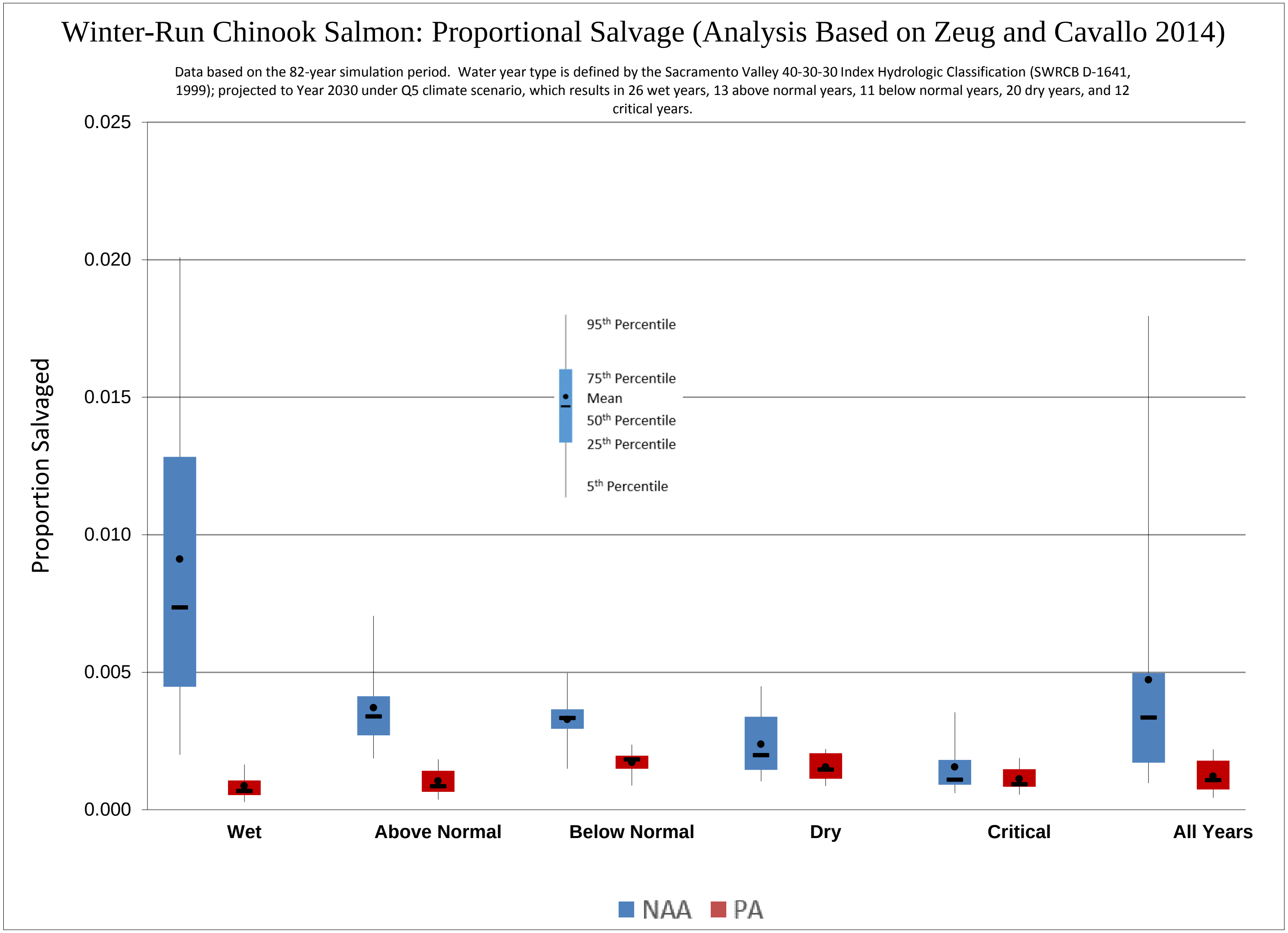
Annual estimates of proportional salvage for all 82 water years reflected the differences previously discussed for the monthly patterns: salvage was less under PA and the magnitude of the difference varied considerably between years (Figure 5.4-4 and Figure 5.4-5, Table 5.4-8), which again is related to the proportion of water diverted from the north delta. In wetter years when south Delta exports were low, less fish were estimated to be salvaged and the divergence in estimates between scenarios was greater.

There is considerable annual variability in the estimates of salvage. Non-parametric bootstrapping (i.e., generation of 500 annual salvage estimates for each scenario by randomly sampling from the original data, with replacement, and refitting the statistical model) revealed that the 95% confidence intervals for the NAA and PA scenarios overlapped in all years (Figure 5.4-6), partly as a result of extrapolation beyond the range of the data from which the model was developed. This illustrates that there is uncertainty in the magnitude of difference in salvage that may occur between NAA and PA, although the mean predictions were within the range of those observed in the data used to develop the relationships.



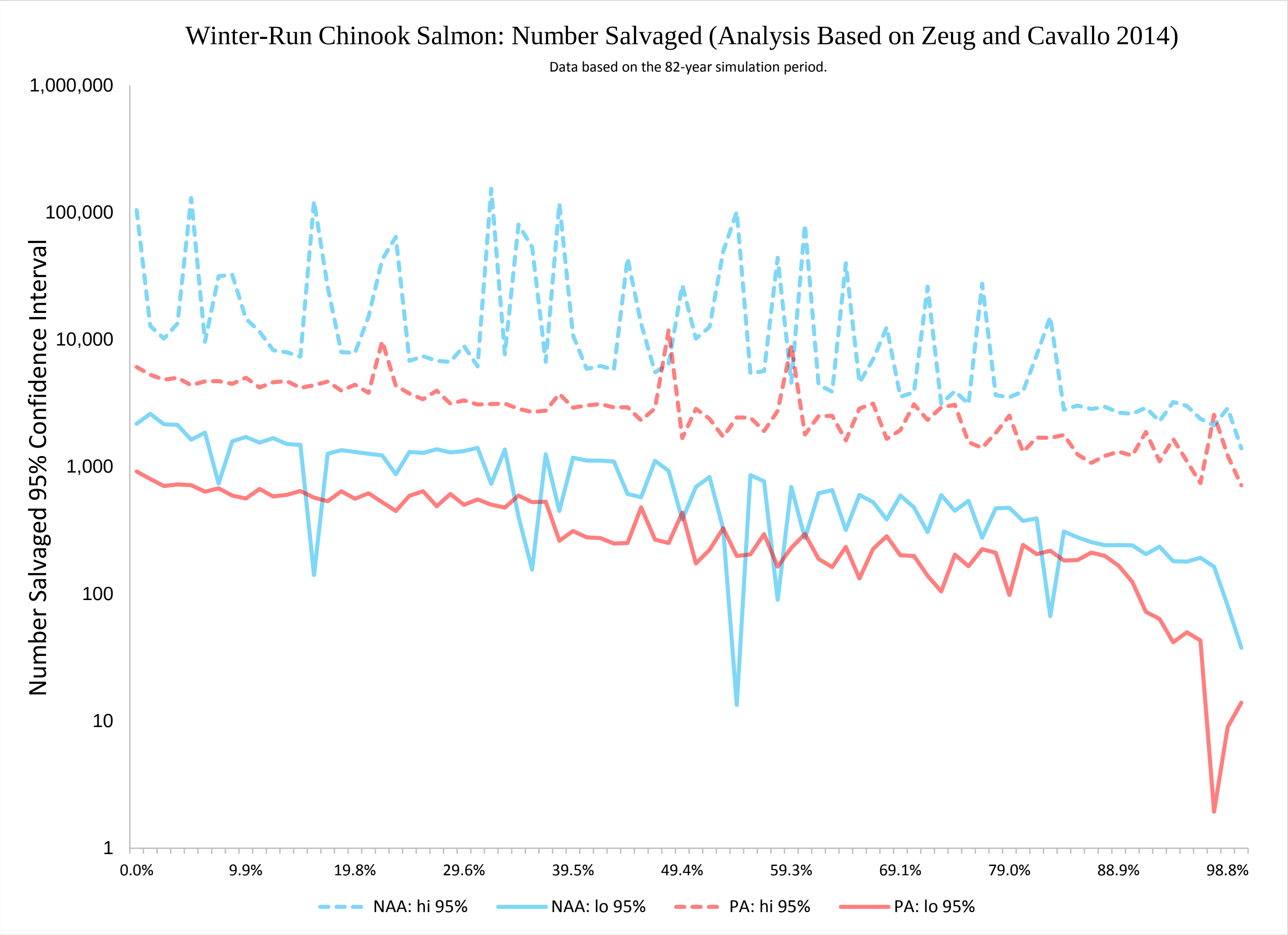
Note: Plot only includes annual mean responses and does not consider model uncertainty.

Figure 5.4-3. Predicted Proportion of Annual Salvage of Juvenile Winter-Run Chinook Salmon in October-June, from the Analysis Based on Zeug and Cavallo (2014).



Note: Plot only includes annual mean responses and does not consider model uncertainty.

Figure 5.4-4. Box Plots of Annual Proportion of Juvenile Winter-Run Chinook Salmon Salvaged, Grouped by Water-Year Type, from the Analysis Based on Zeug and Cavallo (2014).

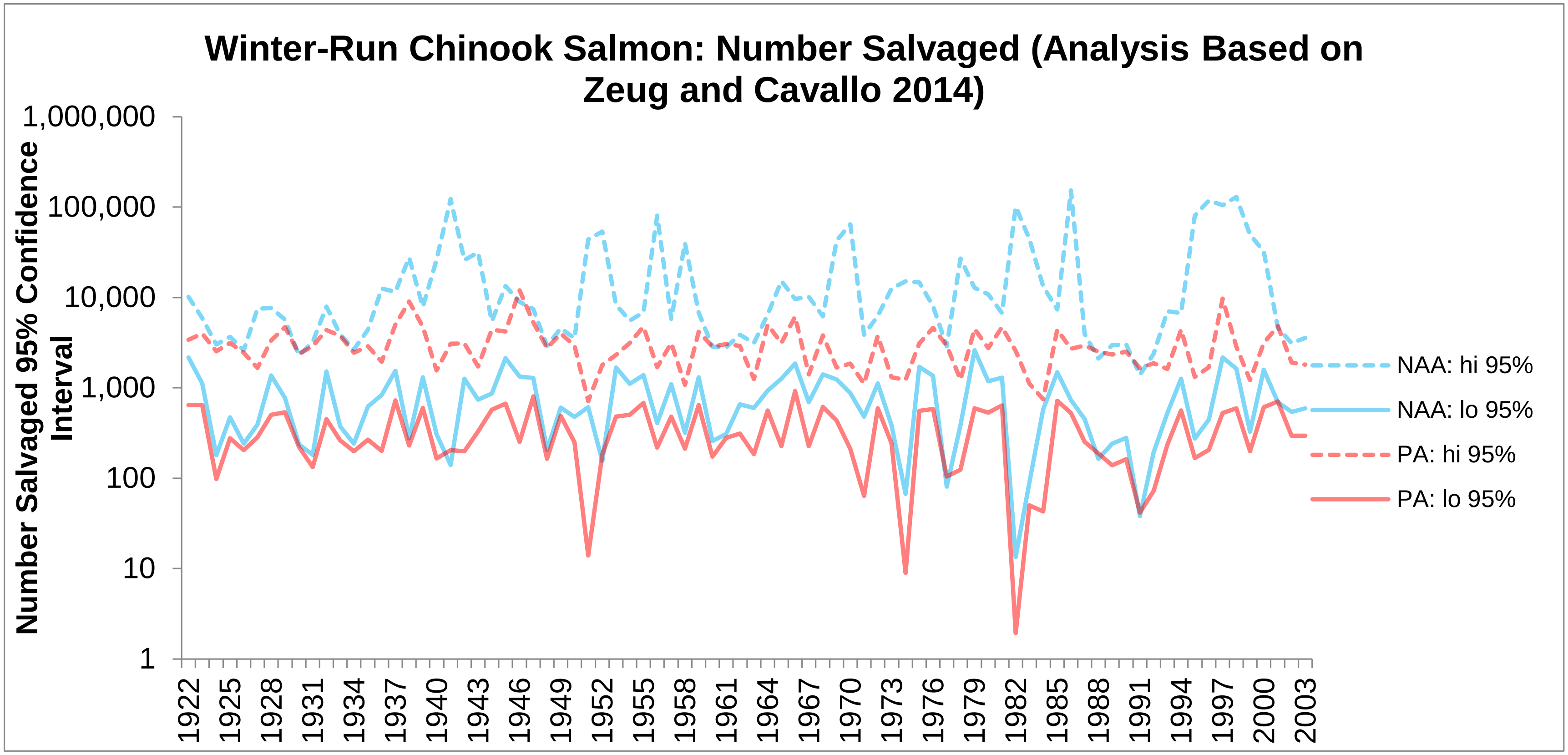


Note: Data are sorted by mean estimate, with only 95% confidence intervals shown. The plot is based on numbers of fish as opposed to proportions in order to avoid a negative logarithmic scale. All years assumed 1,000,000 fish were released.

Figure 5.4-5. Exceedance Plot of Annual Number of Juvenile Winter-Run Chinook Salmon Salvaged, from the Analysis Based on Zeug and Cavallo (2014).

Table 5.4-8. Mean Annual Proportion of Winter-Run Chinook Salmon Salvaged, By Water Year-Type, from the Analysis Based on Zeug and Cavallo (2014).

WY	Pulse protection flows		
	NAA	PA	PA vs. NAA
W	0.0091	0.0009	-0.0082 (-91%)
AN	0.0037	0.0010	-0.0027 (-72%)
BN	0.0033	0.0017	-0.0016 (-48%)
D	0.0024	0.0016	-0.0008 (-35%)
C	0.0016	0.0011	-0.0004 (-28%)



Note: The plot is based on numbers of fish as opposed to proportions in order to avoid a negative logarithmic scale. All years assumed 1,000,000 fish were released.

Figure 5.4-6. 95% Confidence Interval of Annual Number of Winter-Run Chinook Salmon Salvaged (From 1,000,000 Released), from the Analysis Based on Zeug and Cavallo (2014).

5.4.1.3.1.1.2.2 Predation

Appreciable losses of juvenile salmonids occurs because of predation in association with the south Delta export facilities (Gingras 1997; Clark et al. 2009). Less entrainment of juvenile salmonids, as estimated in the preceding sections with the salvage-density method and salvage estimates based on Zeug and Cavallo (2014), would be expected to result in less entrainment-related predation loss. To the extent that the localized reduction of predatory fishes, discussed further in Section 5.5.2, *Localized Reduction of Predatory Fishes to Minimize Predator Density at North and South Delta Export Facilities*, reduces predator abundance in Clifton Court Forebay, predation risk to juvenile salmonids could be further reduced under the PA relative to the NAA. However, there is uncertainty in the efficacy of predatory fish reduction, given that previous efforts did not yield measurable changes in predator population size within the Forebay (Brown et al. 1996); for the purposes of this effects analysis it is not assumed to be effective.

5.4.1.3.1.1.3 Head of Old River Gate

The proposed HOR gate would have the potential to considerably increase the proportion of San Joaquin River basin-origin juvenile steelhead and spring-run Chinook salmon that remain in the main-stem San Joaquin River rather than entering Old River, as well as increasing their migration speed; these far-field effects of the HOR gate are discussed further in the analyses of channel velocity in Section 5.4.1.3.1.2.1.1, *Channel Velocity (DSM2-HYDRO),* and flow routing into channel junctions in Section 5.4.1.3.1.2.1.2.1, *Flow Routing into Channel Junctions*. This section focuses on potential near-field operational effects of the HOR gate, namely predation and blockage of upstream passage.

5.4.1.3.1.1.3.1 Predation

Studies of the rock barrier installed at the HOR in 2012 suggested the structure created eddies that could have resulted in enhanced predatory fish habitat and increased predation on juvenile salmonids (California Department of Water Resources 2015a); such adverse effects could also occur to juvenile steelhead and spring-run Chinook salmon from the San Joaquin River as a result of HOR gate operations when the gate is closed. Such effects arose because the barrier was not located immediately adjacent to the San Joaquin River, but slightly downstream in Old River. Given that the HOR gate could be operated in intermediate positions between fully closed and fully open (lying flat on the channel bed), there would be potential for the creation of hydrodynamic conditions providing opportunities for predators to ambush passing (possibly disoriented) juvenile steelhead and spring-run Chinook salmon. The extent to which any near-field predation at the HOR gate would offset the anticipated beneficial effects of a greater proportion of fish and flow remaining in the San Joaquin River is unclear, although the available data for fall-run juvenile Chinook salmon suggest that in general the presence of a barrier improves through-Delta survival (see review by Hankin et al. 2010 and comparison of 2012 [rock barrier] versus 2013 [no barrier] by Brandes and Buchanan 2016; however, see also comments by Anderson et al. [2012] with specific reference to the uncertainty in the effectiveness of the 2012 HOR rock barrier implementation in protecting out-migrating salmonid smolts).

5.4.1.3.1.1.3.2 Upstream Passage

Adult steelhead and spring-run Chinook salmon returning to natal tributaries in the San Joaquin River basin via Old River could experience migration delay when encountering the HOR gate during its October- June operational period since steelhead adults are present between December and February. The HOR gate would include a fish passage structure meeting NMFS and USFWS guidelines in order to allow passage of upstream migrating salmonids, including steelhead and Chinook salmon. The existing fall rock barrier includes a 30-foot-wide notch at elevation 2.3 feet NAVD, which is intended to allow passage of upstream-migrating salmonids. NMFS (2013a: 89) considered that this notch would result in minimal delay to upstream migrating steelhead, and presumably the same conclusion is reasonable for spring-run Chinook salmon. The fish passage structure for the PA's proposed gate also would be intended to minimize delay to upstream migrants, therefore minimizing the potential for adverse effects.

5.4.1.3.1.1.4 Delta Cross Channel

The principal effect of the DCC would be to influence the proportion of juvenile winter-run Chinook salmon, spring-run Chinook salmon, and steelhead entering the interior Delta, where survival is lower, during downstream migration from the Sacramento River basin. These effects are discussed further in Section 5.4.1.3.1.2.1.2, *Entry into Interior Delta*, in relation to far-field effects.

An additional potential effect of DCC operations is delayed migration of adult salmonids migrating upstream to the Sacramento River basin. NMFS (2009: 406) noted that adults destined for the Sacramento River basin may be blocked or delayed by the DCC gates if they have entered the Mokelumne River system and are downstream of the DCC gates. During the main period of winter-run and spring-run Chinook salmon upstream migration (winter/spring), there would be little to no difference in the number of days the gates would be open between NAA and PA (see Table 5.A.6-31 in Appendix 5.A, *CalSim II Modeling and Results*). The overlap of steelhead migration with the fall months means that they could encounter a greater frequency of the DCC gates being open under the PA because of several operational criteria[19] described in Section 5.A.5.1.5.2 of Appendix 5.A. The CalSim modeling showed that in September of ~20% of years, sufficient water was exported by the NDD that the 25,000-cfs threshold for closure of the DCC is not exceeded, whereas it is exceeded under the NAA in the same years and results in closure of the DCC more than under PA (see Table 5.A.6-31 in Appendix 5.A). Additionally, in October-November, reservoir releases later in the year under the NAA triggered the 7,500-cfs Sacramento River at Wilkins Slough threshold assumed to coincide with juvenile salmon migration into the Delta, which resulted in a greater number of days with DCC closed under NAA. Last, the DCC may also have been open more under the PA to maintain water quality conditions per D-1641 (Rock Slough salinity standard). These factors could result in a greater proportion of steelhead that are destined for the Sacramento River basin entering the central Delta and moving up the Mokelumne River system, therefore delaying migration somewhat, particularly if the DCC gates are subsequently closed.

The potential for delay of adult salmonids entering the central Delta and moving up the Mokelumne River system may be dependent on the duration of DCC openings. Assessing the

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[19] The same operational criteria are assumed for the NAA and PA.

duration of DCC openings in each month for the NAA and PA and the potential effects on upstream-migrating adult salmonids is complicated by overlaps of closure periods across months (e.g., DCC opening in one month, followed by closure in the subsequent month). The month of November perhaps illustrates best how the duration of DCC opening could differ between NAA and PA. Openings commencing in November occurred at a similar frequency under NAA (n = 25 openings over the 82-year CalSim period) and PA (n = 22 openings). Openings tended to be longer under the PA (mean = 14.0 days, median = 8 days, mode = 20 days) than the NAA (mean = 8.6 days, median = 6 days, mode = 3 days) (Figure 5.4-7). NMFS (2009: 406) suggested that adult salmonids that are migrating to the Sacramento River basin have the ability to drop back and swim around the DCC gates during intermittent openings to meet water quality standards or tidal operations. The lower frequency of intermittent openings under the PA for the example month of November suggests that there could be greater potential for delay to upstream-migrating adult steelhead returning to the Sacramento River basin than there would be under the NAA. A greater frequency of multi-day openings therefore could have some adverse effects on adult steelhead attempting to reach the Sacramento River through the DCC, by decreasing the attraction flows from the Sacramento River and delaying migration if the DCC gates were subsequently closed. The proportion of steelhead that could be affected by this mechanism is unknown, with the only data from which to make inferences regarding the proportion of upstream-migrating adult salmonids that could take the DCC pathway via the central Delta/Mokelumne River being for fall-run Chinook salmon. Stein and Cuetara (2004) found that of 66 adult fall-run Chinook salmon acoustically tagged and released in Suisun Marsh, 47 of these fish left the Delta in the Sacramento River at Hood. Of these 47 fish, 10 (21%) traveled via the interior Delta, including the DCC, and movement out of the DCC was always when a strong positive flow into the DCC was occurring. During Stein and Cuetara's (2004) study (October-November 2003), the DCC was open 100% of the time. This indicates that some portion of upstream-migrating adult salmonids, including steelhead, could be delayed by a greater frequency of multi-day opening and subsequent closure under the PA in some years. Further study would be required to ascertain the extent to which adult steelhead could find an alternative pathway through the Delta, or how long they may hold below the gates until they are reopened.

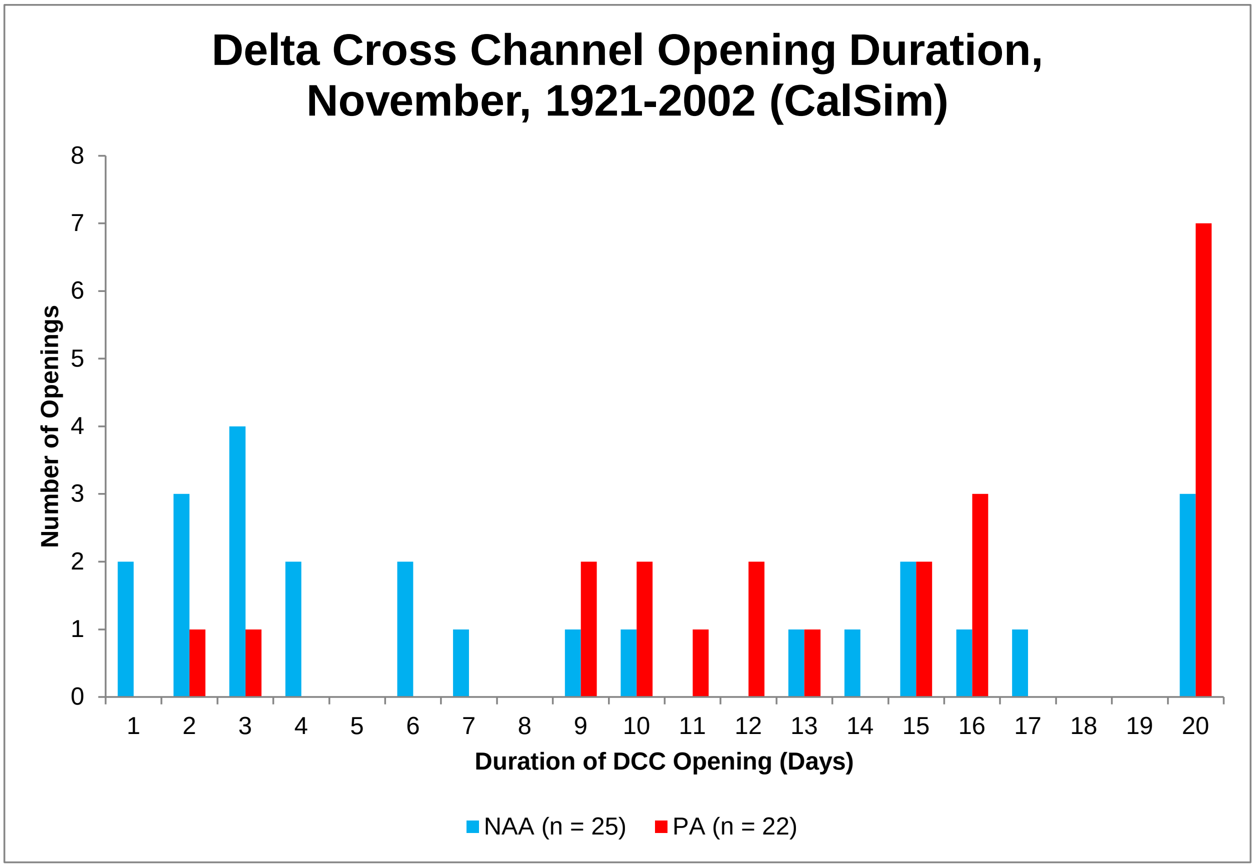

Figure 5.4-7. Duration of Delta Cross Channel Openings that Began in November, from CalSim Modeling of 1921-2002.

5.4.1.3.1.1.5 Suisun Marsh Facilities

5.4.1.3.1.1.5.1 Suisun Marsh Salinity Control Gates

The principal potential effect of the Suisun Marsh Salinity Control Gates (SMSCG) being closed up to 20 days per year from October through May is delay of upstream-migrating adult winter-run Chinook salmon, spring-run Chinook salmon, and steelhead that have entered Montezuma Slough from its westward end and are seeking to exit the slough at its eastward end. Vincik (2013) found some evidence that opening of the boat lock improved passage rates of acoustically tagged adult Chinook salmon, and that even with the gates up, ~30-40% of fish returned downstream. Adult salmonids that do not continue upstream past the SMSCG are expected to return downstream by backtracking through Montezuma Slough to Suisun Bay, and they likely find the alternative upstream route to their natal Central Valley streams through Suisun and Honker Bays (National Marine Fisheries Service 2009: 435). NMFS (2009: 436) noted that the effect of the SMSCG when closed are uncertain on adult salmonids, but suggested that if the ultimate destination of adult spring-run Chinook salmon and steelhead in natal tributaries is reliant on access provided by short-duration, high-streamflow events, delay in the Delta could affect reproductive viability. This would be less of an issue for winter-run Chinook salmon, which when in the Delta are typically several weeks or months away from spawning and use the mainstem Sacramento River, to which access would not be dependent on short-duration streamflow events. Results of the DSM2 modeling indicate that the flow through the SMSCG would be very similar under NAA and PA (see Table 5.B.5-29 in Appendix 5.B, *DSM2 Methods and Results*), indicating that operation of the gates would be similar under NAA and PA.

As described by NMFS (2009: 436), downstream migrating juvenile salmonids may also be affected by the operation of the SMSCG, given the overlap of operations with the occurrence of these species. NMFS (2009: 436; citations omitted) noted:

> As juvenile salmon and steelhead emigrate downstream, some fish will pass through Montezuma Slough as they travel towards the ocean. If the SMSCG are in operation, the gates will open and close twice each day with the tides. On the ebb tide, the gates are open and fish will pass downstream into Montezuma Slough without restriction. On the flood tide, the gates are closed and freshwater flow and the passage of juvenile fish will be restricted. Most juvenile listed salmonids in the western Delta entering San Francisco Bay are expected to be actively emigrating smolts. Smolts are likely taking advantage of the ebb tide to pass downstream, and, thus, the operation of the SMSCG is not expected to significantly impede their downstream movement in the estuary.

In addition to the lack of impediments to passage, NMFS (2009: 437; citations omitted) noted the following with respect to near-field predation effects:

> Salmonid smolt predation by striped bass and pikeminnow could be exacerbated by operation of the SMSCG. These predatory fish are known to congregate in areas where prey species can be easily ambushed. Pikeminnow are not typically major predators of juvenile salmonids, but both pikeminnow and striped bass are opportunistic predators that will take advantage of localized, unnatural circumstances. The SMSCG provides an enhanced opportunity for predation because fish passage is blocked or restricted when the structure is operating. However, DWR proposes to limit the operation of the SMSCG to only periods required for compliance with salinity control standards, and this operational frequency is expected to be 10-20 days per year. Therefore, the SMSCG will not provide the stable environment which favors the establishment of a local predatory fish population and the facility is not expected to support conditions for an unusually large population of striped bass and pikeminnow.

Operational criteria for the SMSCG would not change under the PA relative to NAA, and, as previously shown, operations modeling suggested that there would be little difference between NAA and PA in terms of SMSCG opening. Therefore, the potential for adverse near-field effects on downstream-migrating juvenile salmonids would be limited.

5.4.1.3.1.1.5.2 Roaring River Distribution System

As described by NMFS (2009: 437-438), the Roaring River Distribution System (RRDS)'s water intake (eight 60-inch-diameter culverts) is equipped with fish screens (3/32-inch opening, or 2.4 mm) operated to maintain screen approach velocity of 0.2 ft/s (for Delta Smelt protection), so that juvenile winter-run Chinook salmon, spring-run Chinook salmon, and steelhead would be excluded from entrainment. Therefore effects from the RRDS would be discountable.

5.4.1.3.1.1.5.3 Morrow Island Distribution System

NMFS (2009: 438) considered it unlikely that juvenile winter-run Chinook salmon, spring-run Chinook salmon, and steelhead would be entrained by the three unscreened 48-inch culverts that form the Morrow Island Distribution System (MIDS) water intake, as a result of their larger size and better swimming ability relative to the size of fall-run Chinook salmon observed to have been entrained (<45 mm), and also because the location of the MIDS intake on Goodyear Slough is not on a migratory corridor for listed juvenile salmonids. Therefore effects from the MIDS would be discountable.

5.4.1.3.1.1.5.4 Goodyear Slough Outfall

NMFS (2009: 438) concluded that it would be unlikely that winter-run Chinook salmon, spring-run Chinook salmon, and steelhead 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.

5.4.1.3.1.1.6 North Bay Aqueduct

Pumping rates at the North Bay Aqueduct Barker Slough Intake generally would be similar under the NAA and PA (see Table 5.B.5-35 in Appendix 5.B, *DSM2 Methods and Results*). Regardless of differences in the rate of pumping and any resulting differences in exposure to the intake under NAA and PA, the basic conclusions from NMFS (2009: 417) apply:

> [The] screens, which were designed to protect juvenile salmonids per NMFS criteria, should prevent entrainment and greatly minimize any impingement of fish against the screen itself. Furthermore, the location of the pumping plant on Barker Slough is substantially removed from the expected migrational corridors utilized by emigrating Chinook salmon and steelhead smolts in the North Delta system.

Therefore, there would be expected to be a minimal adverse effect from the North Bay Aqueduct intake on juvenile winter-run Chinook salmon, spring-run Chinook salmon, and steelhead from the Sacramento River basin.

5.4.1.3.1.1.7 Other Facilities

5.4.1.3.1.1.7.1 Contra Costa Canal Rock Slough Intake

The 1.75-mm-opening, 0.2 ft/s-approach-velocity fish screen installed at the Rock Slough intake is intended to prevent entrainment of listed fish, including juvenile winter-run Chinook salmon, spring-run Chinook salmon, and steelhead, into the Contra Costa Canal. However, the 4 mechanical rakes making up the screen cleaning system are unable to handle the large amount of aquatic vegetation that ends up on the fish screen (National Marine Fisheries Service 2015a: 2). This has resulted in a number of operational issues that have resulted in problems such as capture of adult salmon by rake heads (Seedall 2015) and operation of the fish screen only on ebb tides (National Marine Fisheries Service 2015b).This has led Reclamation to test alternative technology (a prototype rake) to improve vegetation removal, an action that NMFS (2015a: 4) concluded would improve fish protection (i.e., screen efficiency) by minimizing the chance a listed fish would be entrained or impinged on the fish screen. In addition, mechanical removal of aquatic weeds within Rock Slough in 2015 to facilitate testing of the new rake design was expected by NMFS (2015b: 4) to improve screen efficiency, reduce predation of juvenile salmonids by vegetation-associated predatory fishes, and reduce adult salmonid mortality during screen maintenance. As noted by NMFS (2015a: 4), Rock Slough is off the main migratory routes through the Delta for listed fish species, however, due to tidal action, salmon and steelhead occasionally stray into Rock Slough. Modeled pumping suggested that diversions under the PA generally would be similar to NAA, with the exception of April and May, when diversions were modeled to be greater under the PA (see Table 5.B.5-36 in Appendix 5.B, *DSM2 Methods and Results*). The overall diversions for the Rock Slough intake and the other CCWD intakes on Old River and Middle River do not differ greatly between NAA and PA, suggesting that Rock Slough may have been favored in the modeling of PA for operational reasons, e.g., Old and Middle River flow criteria, for example. Greater use of the Rock Slough intake would be likely to increase take of juvenile salmonids under the PA compared to NAA. However, resolution of the aforementioned issues regarding screen effectiveness would be expected to minimize the potential for any adverse effects.

5.4.1.3.1.1.7.2 Clifton Court Forebay Aquatic Weed Control Program

The application of copper-based herbicides in Clifton Court Forebay is intended to reduce the standing crop of invasive aquatic weeds, among which the dominant species is *Egeria densa*. As reviewed by NMFS (2009: 388-390), aquatic weed control with copper-based herbicides to treat *Egeria* and other aquatic weeds in Clifton Court Forebay has the potential to result in a variety of negative physiological effects on juvenile salmonids, ranging from sublethal effects such as diminished olfactory sensitivity (e.g., reduced ability to imprint on natal streams or to avoid chemical contaminants) to lethal effects. Winter-run Chinook salmon, spring-run Chinook salmon, and steelhead would be expected to be minimally exposed to such effects because their period of occurrence within Clifton Court Forebay is entirely or nearly entirely before the July/August timeframe for herbicide treatment. Entrainment of juvenile winter-run Chinook salmon, spring-run Chinook salmon, and steelhead into Clifton Court Forebay would be expected to be less under the PA than NAA in July-August (see Tables 5.D-21, 5.D-22, 5.D-23, 5.D.24, and 5.D-25 in Appendix 5.D, *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale*, for juvenile steelhead, for example), which would reduce the exposure of these species to any adverse effects of herbicide treatment compared to the situation under the NAA (although exposure would be expected to be minimal under both the NAA and PA scenarios).

Mechanical removal of aquatic weeds in Clifton Court Forebay would occur on an as needed basis and therefore could coincide with occurrence of juvenile winter-run Chinook salmon, spring-run Chinook salmon, and steelhead. In assessing the potential for adverse effects of the 2013-2017 Water Hyacinth Control Program in the Delta, NMFS (2013b: 11) concluded that mechanical removal could have negative effects to listed species but that these would be discountable because of several factors, including that mechanical removal would be limited to dense water hyacinth mats where listed salmonids are not likely to be present. Presumably within Clifton Court Forebay there would be greater potential for juvenile salmonids to encounter mechanical removal of water hyacinth, given that hyacinth and fish may follow similar pathways across the Forebay toward the intake channel and the trash racks. However, any potential adverse effects from mechanical removal of water hyacinth or other aquatic weeds (e.g., injury from contact with cutting blades) would potentially be offset by the reduced probability of predation by weed-associated predatory fishes and increases in salvage efficiency at the Skinner Fish Delta Fish Protective Facility because of reduced smothering by weeds.

5.4.1.3.1.2 Far-Field Effects

5.4.1.3.1.2.1 Indirect Mortality Within the Delta

5.4.1.3.1.2.1.1 Channel Velocity (DSM2-HYDRO)

Delta channel flows have considerable importance for downstream migrating juvenile salmonids, as shown by studies in which through-Delta survival of Chinook salmon smolts positively correlated with flow (Newman 2003; Perry 2010) although one recent study by Zeug and Cavallo (2013) did not find evidence for effects of inflow on the probability of recovery of coded-wire-tagged Chinook salmon in ocean fisheries. Flow-related survival, in terms of the influence of downstream river (net) flow, may be more important in areas with largely unidirectional downstream flow and lesser tidal influence, as opposed to strong tidal influence, because tidal influence progressively becomes much greater with movement downstream. The Delta Passage Model, for example, does not include a net flow-survival relationship in the Sacramento River below Rio Vista, because such a relationship is not supported by existing data (Appendix 5.D, *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale,* Section 5.D.1.2.2, *Delta Passage Model*). Further evidence of possible greater importance of flow in riverine reaches (as opposed to tidal reaches) comes from the recent study of Michel et al. (2015), who found that survival of acoustically tagged juvenile late fall-run Chinook salmon from the upper Sacramento River to the Golden Gate Bridge was greatest in 2011, the highest flow year, and that survival in the other years (2007-2010) was lower and did not differ greatly; the overall pattern was driven by in-river (upstream of Delta) survival being considerably greater in 2011 than the other years, whereas through-Delta survival was similar in all five years.

The PA has the potential to both adversely and beneficially change channel flows in the Delta, through changes in north and south Delta export patterns in relation to the NAA. Although north Delta exports would reduce Sacramento River flows downstream of the NDD, this would allow greater south and central Delta channel flows because of less south Delta exports.

As described in Appendix 5.D, *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale*, Section 5.D.1.2.1.1.1, *Velocity,* velocity generally is a superior variable than flow for examining potential effects on fish because its effects do not vary with channel size and velocity has a direct relationship with bioenergetics. However, for the present analysis, the summary is based only on velocity, without linkage to biological outcomes such as sustained fish swimming speed, and represents a somewhat new methodology in terms of assessing potential differences, having only recently been applied in Reclamation/DWR's Biological Review for Endangered Species Act Compliance with the WY 2015 Drought Contingency Plan April through September Project

Description[20]. In addition, the behavior of juvenile salmonids, particularly with respect to selective tidal-stream transport (Delaney et al. 2014) means that simple differences in velocity may not translate into biological outcomes between scenarios and therefore indicates that there is uncertainty as to the significance of the velocity-based results to listed salmonids beyond general trends in differences. A comparison of hydrodynamic conditions in important Delta channels for the NAA and PA scenarios was undertaken based on 15-minute DSM2-HYDRO velocity outputs. Three velocity metrics were assessed: magnitude of channel velocity; magnitude of negative velocity; and proportion of time in each day that velocity was negative. Lower overall velocity, greater negative velocity, and a greater proportion of negative velocity are all indicators of potential adverse effects to juvenile salmonids, e.g., by delaying migration or causing advection into migration pathways with lower survival. As previously noted, the lack of an explicit biological outcome in the modeling means that there is some uncertainty in the biological significance of the results; other analyses used herein to assess effects, such as the Delta Passage Model and the analysis based on Perry (2010), provide more explicit context as to biological significance because differences in flow are converted to potential differences in survival. Note that the summary of velocity differences between NAA and PA does not account for real-time operations that would be done in order to limit potential operational effects by assessing flow conditions in the context of fish presence, e.g., by using monitoring data from at or upstream of the Delta periphery (e.g., Knights Landing on the Sacramento River or Mossdale on the San Joaquin River).

A comprehensive description of the results is presented in Appendix 5.D, *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale,* Section 5.D.1.2.1.2, *Results*. In this section, the detailed information presented with text and graphs in Appendix 5.D is summarized in color-coded tables, which highlight differences in medians of 5% or greater between PA and NAA. These differences are plotted and described across the full range of variability of the data in Appendix 5.D.

With respect to overall velocity, operational differences between NAA and PA led to differences in channel velocity. Within the south Delta and San Joaquin River, the changes would be positive for migrating juvenile salmonids because channel velocity was generally greater under the PA (Table 5.4-9). In the San Joaquin River, this was caused by the closure of the HOR gate (assumed in the modeling to be open during days in October prior to the D-1641 San Joaquin River pulse, 100% closed during the pulse, 50% closed from January–June 15, and 100% open during the remaining months), and median channel 21 velocity downstream of the HOR was around 10–50% greater (0.02–0.08 ft/s greater). In Old River downstream of the south Delta export facilities, the differences were related to less south Delta exports; however, in April and May it was also apparent that in drier years median velocity was less positive under PA than NAA. Although the PA criteria are consistent with the OMR flows and San Joaquin I/E ratio requirements in the current BiOps, and south Delta export pumping is almost always lower (Appendix 5.A, *CALSIM Methods and Results,* Figures 5.A.6-27-1 to 5.A.6-27-19 and Table 5.A.6-27), in April and May the assumption of the HOR gate being 50% closed, combined with

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[20] Available at http://www.waterboards.ca.gov/waterrights/water_issues/programs/drought/docs/tucp/2015/biorev2_aprsep.pdf

differing modeling assumptions for south Delta exports[21], results in Old River channel velocity that was slightly lower under PA than NAA (although both had positive median velocity). Channel velocity in Old River upstream of the south Delta export facilities was less positive under the PA than NAA, reflecting less south Delta exports under the PA (i.e., the export facilities exert some hydrodynamic influence by increasing velocity toward them) and the HOR gate, which blocks flow from entering 50% of the time during January–June 15.

In the north Delta, less flow in the Sacramento River downstream of the NDD (channel 418) under the PA led to lower median channel velocity under the PA relative to NAA (Table 5.4-9). Reflecting the fact that greater diversion would occur in wetter years, the difference in median velocity for channel 418 ranged from 10–24% less under PA in wet years to 4–11% less in critical years, which equated to absolute differences of 0.23–0.57 ft/s in wet years to 0.04–0.15 ft/s in critical years. Sacramento River channels farther downstream (421 and 423, upstream and downstream of Georgiana Slough) had similar patterns of difference, but with lower magnitude of change, reflecting greater tidal influence; this was also evident in Sutter Slough (channel 379) and Steamboat Slough (channel 383) (Table 5.4-9), with the latter being farther downstream than the former.

Considering only negative velocity estimates, under the PA the median negative velocity in the San Joaquin River downstream of Old River was greater (closer to zero) than under NAA, with the relative difference decreasing as water years became drier (Table 5.4-10); there was little difference farther downstream near the confluence with the Mokelumne River, reflecting greater tidal influence. Negative velocity estimates in Old River downstream of the south Delta export facilities under the PA were either less than or similar to (defined as <5% difference in the medians) those under NAA, whereas in Old River upstream of the facilities, the negative velocities were greater (again reflecting less south Delta exports and the influence of the HOR gate, both of which would increase the influence of flood tides in this channel). In the north Delta, the estimates of negative velocity must be interpreted with caution because in many cases negative velocity occurred for only a very small proportion of time (particularly in the more upstream channels such as Sutter Slough and the Sacramento River downstream of the NDD and upstream of Georgiana Slough; see Table 5.4-11). For the situations where an appreciable proportion of velocity estimates were negative under both scenarios, (e.g., Steamboat Slough and the Sacramento River downstream of Georgiana Slough), median negative velocity under PA was similar to or more negative than median negative velocity under NAA. This is consistent with less Sacramento River flow because of the NDD, increasing the flood tide influence on velocity. The absolute differences in median negative velocity were not large, however; for example, in the Sacramento River downstream of Georgiana Slough, differences in the periods during which there was a greater proportion of negative velocity (typically drier years) generally were much less than 0.1 ft/s (Table 5.4-10).

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[21] To some extent the results reflect the fact that there were differences in the CalSim modeling between the San Luis rule curves assumed for the NAA and PA: the NAA was more conservative in terms of being well below criteria for April-May San Luis reservoir filling, whereas the PA assumed a different curve and was much closer to criteria in some instances. Additional discussion of the rule curve differences is provided in Appendix 5.A, *CALSIM Methods and Results*, Section 5.A.4.4.

The median daily proportion of negative velocity again illustrated the effect of the HOR gate in the San Joaquin River downstream of HOR, where the proportion under the PA generally was less than under NAA, although farther downstream near the confluence with the Mokelumne River the tidal influence resulted in little to no difference between PA and NAA (Table 5.4-11). The daily proportion of negative velocity in Old River downstream of the south Delta export facilities under PA was similar to or less than NAA, whereas upstream of the facilities, the greater tidal influence caused by the HOR gate and less south Delta exports led to an greater proportion of time with negative velocity. In the north Delta, as previously noted in the analysis of negative velocity, the farther upstream channels had little to no negative velocity much of the time (e.g., Sutter Slough and the Sacramento River downstream of the NDD) (Table 5.4-11). Of concern from the perspective of salmonids migrating down the Sacramento River was greater frequency of negative velocity in the Sacramento River downstream of Georgiana Slough under the PA relative to the NAA, with differences between medians ranging from little difference (<5%) in a number of water-year types/months to >110% more (0.09 in absolute difference) in March of below normal years.

Overall, the results of the analysis of channel velocity suggest the potential for adverse effects to migrating juvenile winter-run and spring-run Chinook salmon and juvenile steelhead migrating downstream through the north Delta from the Sacramento River basin caused by lower overall velocity, greater negative velocity, and a greater proportion of time with negative velocity, which may delay migration and result in greater repeated exposure to entry into migration routes with lower survival, particularly because of entry into Georgiana Slough (see also discussion of flow routing into channel junctions). Juvenile steelhead and spring-run Chinook salmon emigrating from the San Joaquin River basin would potentially benefit from the HOR gate, which would increase overall velocity and reduce negative velocity in the San Joaquin River, as well as reducing the daily proportion of negative velocity; these effects would be greatest farther upstream. Salmonids from both the Sacramento and San Joaquin River basins generally would potentially benefit from interior Delta channel velocity (e.g., Old River downstream of the south Delta export facilities) that would be somewhat more positive and less frequently negative. As previously noted, the summary of Delta hydrodynamic conditions based on DSM2 does not account for the results of coordinated monitoring and research that will be done under the Adaptive Management Program and real-time operations that would be done in order to limit potential operational effects to avoid jeopardy while maximizing water supplies, by assessing flow conditions in the context of fish presence, e.g., by using monitoring data from at or upstream of the Delta periphery (e.g., Knights Landing on the Sacramento River or Mossdale on the San Joaquin River).

Table 5.4-9. Median 15-minute Velocity in Important Delta Channels, from DSM2-HYDRO Modeling, with Green Shading Indicating PA is ≥5% More than NAA and Red Shading Indicating PA is ≥5% Less than NAA.

DSM2 Channel	Location	Water Year Type	December			January			February			March			April			May			June		
			NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
21	San Joaquin River downstream of HOR	W	0.263	0.264	0.001 (0%)	0.378	0.433	0.054 (14%)	0.473	0.533	0.060 (13%)	0.482	0.548	0.066 (14%)	0.428	0.493	0.065 (15%)	0.407	0.462	0.055 (13%)	0.330	0.355	0.025 (8%)
		AN	0.182	0.185	0.003 (2%)	0.239	0.295	0.056 (23%)	0.308	0.371	0.064 (21%)	0.295	0.368	0.073 (25%)	0.271	0.351	0.081 (30%)	0.254	0.331	0.078 (31%)	0.152	0.196	0.045 (30%)
		BN	0.115	0.119	0.004 (4%)	0.131	0.202	0.071 (54%)	0.265	0.318	0.053 (20%)	0.169	0.251	0.082 (49%)	0.199	0.286	0.087 (44%)	0.166	0.245	0.079 (47%)	0.097	0.118	0.022 (22%)
		D	0.087	0.089	0.002 (3%)	0.112	0.171	0.059 (52%)	0.167	0.223	0.057 (34%)	0.172	0.228	0.056 (32%)	0.167	0.234	0.067 (40%)	0.155	0.217	0.061 (39%)	0.090	0.110	0.020 (22%)
		C	0.085	0.086	0.001 (1%)	0.087	0.128	0.041 (47%)	0.120	0.167	0.048 (40%)	0.104	0.142	0.038 (37%)	0.099	0.134	0.035 (35%)	0.092	0.128	0.035 (38%)	0.076	0.083	0.008 (11%)
45	San Joaquin River near the confluence with the Mokelumne River	W	0.240	0.251	0.011 (4%)	0.432	0.488	0.056 (13%)	0.471	0.554	0.083 (18%)	0.452	0.550	0.098 (22%)	0.439	0.474	0.034 (8%)	0.394	0.430	0.036 (9%)	0.232	0.293	0.061 (27%)
		AN	0.140	0.155	0.015 (11%)	0.269	0.300	0.031 (11%)	0.334	0.368	0.034 (10%)	0.293	0.385	0.092 (31%)	0.298	0.324	0.026 (9%)	0.247	0.270	0.022 (9%)	0.142	0.171	0.030 (21%)
		BN	0.061	0.081	0.020 (34%)	0.131	0.191	0.060 (45%)	0.237	0.260	0.023 (10%)	0.168	0.197	0.029 (17%)	0.213	0.222	0.009 (4%)	0.172	0.186	0.014 (8%)	0.130	0.139	0.008 (6%)
		D	0.068	0.076	0.008 (11%)	0.118	0.149	0.031 (27%)	0.184	0.198	0.013 (7%)	0.192	0.203	0.011 (6%)	0.195	0.208	0.014 (7%)	0.158	0.172	0.014 (9%)	0.134	0.143	0.010 (7%)
		C	0.085	0.087	0.002 (2%)	0.092	0.111	0.020 (21%)	0.148	0.150	0.002 (1%)	0.152	0.161	0.010 (6%)	0.144	0.148	0.004 (3%)	0.122	0.126	0.004 (3%)	0.124	0.124	0.000 (0%)
94	Old River downstream of the south Delta export facilities	W	-0.250	-0.175	0.075 (30%)	0.004	0.227	0.224 (5831%)	0.036	0.448	0.412 (1138%)	0.052	0.505	0.454 (877%)	0.350	0.486	0.136 (39%)	0.296	0.453	0.157 (53%)	-0.110	0.170	0.279 (255%)
		AN	-0.358	-0.272	0.087 (24%)	-0.121	0.008	0.129 (107%)	-0.062	0.087	0.149 (240%)	-0.146	0.265	0.411 (282%)	0.189	0.230	0.041 (22%)	0.164	0.197	0.032 (20%)	-0.181	-0.061	0.120 (66%)
		BN	-0.446	-0.363	0.083 (19%)	-0.200	0.003	0.203 (101%)	-0.108	-0.051	0.057 (53%)	-0.171	-0.100	0.071 (42%)	0.109	0.061	-0.048 (-44%)	0.088	0.061	-0.027 (-30%)	-0.131	-0.077	0.054 (41%)
		D	-0.368	-0.321	0.046 (13%)	-0.213	-0.134	0.079 (37%)	-0.133	-0.086	0.047 (35%)	-0.097	-0.074	0.024 (24%)	0.067	0.047	-0.020 (-30%)	0.039	0.043	0.004 (11%)	-0.112	-0.043	0.069 (61%)
		C	-0.266	-0.222	0.044 (16%)	-0.214	-0.190	0.023 (11%)	-0.107	-0.108	0.000 (0%)	-0.019	-0.016	0.003 (16%)	0.056	0.034	-0.022 (-39%)	0.045	0.029	-0.015 (-35%)	0.035	0.052	0.017 (48%)
212	Old River upstream of the south Delta export facilities	W	0.682	0.701	0.018 (3%)	0.946	0.867	-0.079 (-8%)	1.120	1.036	-0.084 (-8%)	1.199	1.075	-0.124 (-10%)	1.171	1.074	-0.097 (-8%)	1.161	1.069	-0.093 (-8%)	0.666	0.621	-0.045 (-7%)
		AN	0.574	0.558	-0.016 (-3%)	0.705	0.578	-0.127 (-18%)	0.794	0.689	-0.105 (-13%)	0.818	0.754	-0.064 (-8%)	0.814	0.640	-0.174 (-21%)	0.805	0.612	-0.193 (-24%)	0.301	0.159	-0.142 (-47%)
		BN	0.493	0.465	-0.028 (-6%)	0.503	0.362	-0.141 (-28%)	0.713	0.555	-0.158 (-22%)	0.583	0.350	-0.234 (-40%)	0.657	0.387	-0.269 (-41%)	0.589	0.327	-0.262 (-44%)	0.132	0.047	-0.085 (-64%)
		D	0.445	0.428	-0.017 (-4%)	0.452	0.287	-0.165 (-36%)	0.541	0.378	-0.162 (-30%)	0.575	0.387	-0.188 (-33%)	0.584	0.363	-0.221 (-38%)	0.546	0.346	-0.200 (-37%)	0.113	0.037	-0.076 (-67%)
		C	0.418	0.394	-0.024 (-6%)	0.393	0.248	-0.145 (-37%)	0.467	0.300	-0.167 (-36%)	0.410	0.251	-0.159 (-39%)	0.378	0.235	-0.143 (-38%)	0.359	0.200	-0.160 (-44%)	0.009	-0.011	-0.020 (-229%)
365	Delta Cross Channel	W	0.016	0.016	0.000 (0%)	0.013	0.013	0.000 (1%)	0.014	0.014	0.000 (0%)	0.015	0.015	0.000 (1%)	0.016	0.016	0.000 (2%)	0.016	0.016	0.000 (2%)	0.422	0.471	0.049 (12%)
		AN	0.025	0.027	0.001 (6%)	0.014	0.014	0.000 (1%)	0.015	0.015	0.000 (1%)	0.015	0.015	0.000 (2%)	0.014	0.014	0.000 (2%)	0.013	0.013	0.000 (2%)	0.662	0.576	-0.087 (-13%)
		BN	0.036	0.037	0.001 (3%)	0.011	0.012	0.001 (5%)	0.013	0.013	0.000 (1%)	0.012	0.012	0.000 (1%)	0.012	0.013	0.000 (1%)	0.011	0.011	0.000 (2%)	0.667	0.613	-0.053 (-8%)
		D	0.043	0.043	0.000 (-1%)	0.011	0.011	0.000 (2%)	0.012	0.012	0.000 (0%)	0.013	0.013	0.000 (0%)	0.012	0.012	0.000 (0%)	0.010	0.011	0.000 (2%)	0.675	0.609	-0.065 (-10%)
		C	0.040	0.039	-0.001	0.010	0.010	0.000	0.011	0.011	0.000	0.010	0.011	0.000	0.010	0.010	0.000	0.008	0.009	0.000	0.535	0.518	-0.017

DSM2 Channel	Location	Water Year Type	December			January			February			March			April			May			June		
			NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
					(-1%)			(1%)			(0%)			(2%)			(0%)			(2%)			(-3%)
379	Sutter Slough	W	1.691	1.478	-0.214 (-13%)	2.573	2.270	-0.304 (-12%)	3.045	2.765	-0.280 (-9%)	2.536	2.208	-0.327 (-13%)	1.763	1.648	-0.116 (-7%)	1.687	1.543	-0.143 (-8%)	1.036	0.807	-0.229 (-22%)
		AN	1.101	1.012	-0.089 (-8%)	1.866	1.578	-0.288 (-15%)	2.564	2.305	-0.259 (-10%)	2.052	1.769	-0.283 (-14%)	1.345	1.270	-0.075 (-6%)	1.022	0.958	-0.065 (-6%)	0.799	0.656	-0.143 (-18%)
		BN	0.996	0.902	-0.094 (-9%)	1.079	1.015	-0.064 (-6%)	1.327	1.192	-0.134 (-10%)	1.146	0.992	-0.154 (-13%)	0.937	0.922	-0.015 (-2%)	0.856	0.832	-0.023 (-3%)	0.763	0.681	-0.082 (-11%)
		D	0.875	0.823	-0.052 (-6%)	1.008	0.939	-0.069 (-7%)	1.202	1.090	-0.112 (-9%)	1.236	1.052	-0.185 (-15%)	0.956	0.946	-0.010 (-1%)	0.821	0.799	-0.022 (-3%)	0.758	0.659	-0.099 (-13%)
		C	0.766	0.721	-0.046 (-6%)	0.932	0.892	-0.040 (-4%)	1.006	0.909	-0.097 (-10%)	0.846	0.805	-0.041 (-5%)	0.751	0.734	-0.017 (-2%)	0.649	0.607	-0.042 (-6%)	0.610	0.562	-0.048 (-8%)
383	Steamboat Slough	W	1.972	1.789	-0.183 (-9%)	2.932	2.617	-0.315 (-11%)	3.448	3.120	-0.328 (-10%)	2.868	2.495	-0.373 (-13%)	2.021	1.903	-0.118 (-6%)	1.888	1.742	-0.146 (-8%)	1.346	1.140	-0.206 (-15%)
		AN	1.394	1.313	-0.081 (-6%)	2.161	1.916	-0.245 (-11%)	2.937	2.632	-0.305 (-10%)	2.346	2.042	-0.304 (-13%)	1.581	1.538	-0.044 (-3%)	1.275	1.206	-0.070 (-5%)	1.026	0.930	-0.095 (-9%)
		BN	1.235	1.156	-0.079 (-6%)	1.362	1.276	-0.086 (-6%)	1.631	1.518	-0.113 (-7%)	1.397	1.239	-0.158 (-11%)	1.169	1.140	-0.030 (-3%)	1.089	1.062	-0.027 (-2%)	0.972	0.941	-0.031 (-3%)
		D	1.115	1.066	-0.049 (-4%)	1.272	1.196	-0.076 (-6%)	1.493	1.384	-0.109 (-7%)	1.483	1.307	-0.177 (-12%)	1.204	1.177	-0.027 (-2%)	1.032	1.012	-0.020 (-2%)	0.964	0.918	-0.046 (-5%)
		C	0.987	0.936	-0.051 (-5%)	1.175	1.121	-0.054 (-5%)	1.249	1.143	-0.106 (-8%)	1.083	1.019	-0.064 (-6%)	0.960	0.942	-0.018 (-2%)	0.816	0.808	-0.008 (-1%)	0.779	0.776	-0.003 (0%)
418	Sacramento River downstream of proposed NDD	W	2.224	1.901	-0.323 (-15%)	3.416	2.884	-0.532 (-16%)	4.052	3.484	-0.568 (-14%)	3.347	2.775	-0.571 (-17%)	2.305	2.070	-0.235 (-10%)	2.191	1.939	-0.252 (-12%)	1.524	1.162	-0.362 (-24%)
		AN	1.494	1.351	-0.143 (-10%)	2.473	2.019	-0.453 (-18%)	3.409	2.918	-0.491 (-14%)	2.700	2.240	-0.460 (-17%)	1.752	1.615	-0.137 (-8%)	1.343	1.225	-0.119 (-9%)	1.206	0.982	-0.224 (-19%)
		BN	1.365	1.219	-0.145 (-11%)	1.432	1.312	-0.120 (-8%)	1.744	1.538	-0.206 (-12%)	1.508	1.279	-0.229 (-15%)	1.240	1.186	-0.054 (-4%)	1.140	1.081	-0.060 (-5%)	1.157	1.017	-0.140 (-12%)
		D	1.222	1.131	-0.091 (-7%)	1.349	1.227	-0.122 (-9%)	1.594	1.411	-0.183 (-11%)	1.623	1.353	-0.269 (-17%)	1.265	1.218	-0.047 (-4%)	1.096	1.041	-0.055 (-5%)	1.149	0.992	-0.157 (-14%)
		C	1.081	0.993	-0.088 (-8%)	1.245	1.163	-0.082 (-7%)	1.333	1.182	-0.151 (-11%)	1.134	1.059	-0.075 (-7%)	1.019	0.977	-0.042 (-4%)	0.885	0.814	-0.071 (-8%)	0.928	0.826	-0.102 (-11%)
421	Sacramento River upstream of Georgiana Slough	W	1.858	1.672	-0.186 (-10%)	2.737	2.445	-0.292 (-11%)	3.191	2.903	-0.288 (-9%)	2.679	2.337	-0.342 (-13%)	1.897	1.773	-0.124 (-7%)	1.786	1.637	-0.149 (-8%)	1.407	1.115	-0.292 (-21%)
		AN	1.322	1.241	-0.081 (-6%)	2.031	1.773	-0.258 (-13%)	2.736	2.467	-0.269 (-10%)	2.210	1.921	-0.288 (-13%)	1.472	1.418	-0.055 (-4%)	1.154	1.074	-0.080 (-7%)	1.114	0.955	-0.159 (-14%)
		BN	1.194	1.113	-0.082 (-7%)	1.251	1.167	-0.084 (-7%)	1.501	1.374	-0.127 (-8%)	1.295	1.139	-0.156 (-12%)	1.076	1.053	-0.023 (-2%)	0.986	0.954	-0.032 (-3%)	1.067	0.980	-0.087 (-8%)
		D	1.087	1.040	-0.047 (-4%)	1.173	1.099	-0.073 (-6%)	1.372	1.263	-0.109 (-8%)	1.381	1.198	-0.183 (-13%)	1.103	1.084	-0.020 (-2%)	0.944	0.914	-0.030 (-3%)	1.058	0.955	-0.103 (-10%)
		C	0.956	0.902	-0.054 (-6%)	1.080	1.039	-0.041 (-4%)	1.147	1.053	-0.094 (-8%)	0.989	0.945	-0.045 (-5%)	0.885	0.867	-0.018 (-2%)	0.756	0.733	-0.024 (-3%)	0.852	0.814	-0.039 (-5%)
423	Sacramento River downstream of Georgiana Slough	W	1.713	1.578	-0.134 (-8%)	2.467	2.211	-0.256 (-10%)	2.857	2.593	-0.265 (-9%)	2.429	2.129	-0.300 (-12%)	1.755	1.670	-0.085 (-5%)	1.623	1.522	-0.102 (-6%)	1.147	0.975	-0.171 (-15%)
		AN	1.229	1.161	-0.067 (-5%)	1.857	1.680	-0.177 (-10%)	2.463	2.205	-0.259 (-11%)	2.015	1.764	-0.251 (-12%)	1.402	1.368	-0.034 (-2%)	1.127	1.072	-0.055 (-5%)	0.824	0.739	-0.086 (-10%)
		BN	1.063	0.993	-0.070 (-7%)	1.199	1.121	-0.077 (-6%)	1.458	1.359	-0.100 (-7%)	1.235	1.091	-0.144 (-12%)	1.020	0.998	-0.022 (-2%)	0.947	0.927	-0.020 (-2%)	0.767	0.743	-0.024 (-3%)
		D	0.949	0.903	-0.046 (-5%)	1.120	1.055	-0.065 (-6%)	1.328	1.228	-0.100 (-8%)	1.313	1.150	-0.162 (-12%)	1.058	1.032	-0.025 (-2%)	0.890	0.877	-0.013 (-2%)	0.759	0.723	-0.037 (-5%)
		C	0.829	0.784	-0.046 (-6%)	1.023	0.973	-0.050 (-5%)	1.095	0.999	-0.096 (-9%)	0.945	0.883	-0.062 (-7%)	0.824	0.810	-0.014 (-2%)	0.674	0.669	-0.005 (-1%)	0.596	0.594	-0.001 (0%)

Table 5.4-10. Median 15-minute Negative Velocity in Important Delta Channels, from DSM2-HYDRO Modeling, with Green Shading Indicating PA is ≥5% More than NAA and Red Shading Indicating PA is ≥5% Less than NAA.

DSM2 Channel	Location	Water Year Type	December			January			February			March			April			May			June		
			NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
21	San Joaquin River downstream of HOR	W	-0.298	-0.295	0.003 (1%)	-0.246	-0.194	0.052 (21%)	-0.182	-0.133	0.049 (27%)	-0.166	-0.121	0.045 (27%)	-0.154	-0.104	0.051 (33%)	-0.187	-0.124	0.063 (34%)	-0.222	-0.205	0.017 (7%)
		AN	-0.334	-0.332	0.002 (1%)	-0.284	-0.233	0.051 (18%)	-0.246	-0.187	0.059 (24%)	-0.225	-0.170	0.055 (25%)	-0.194	-0.132	0.062 (32%)	-0.215	-0.149	0.066 (31%)	-0.267	-0.249	0.017 (7%)
		BN	-0.321	-0.317	0.004 (1%)	-0.309	-0.251	0.058 (19%)	-0.281	-0.220	0.061 (22%)	-0.258	-0.198	0.060 (23%)	-0.229	-0.167	0.061 (27%)	-0.249	-0.190	0.059 (24%)	-0.299	-0.287	0.012 (4%)
		D	-0.333	-0.330	0.002 (1%)	-0.318	-0.259	0.059 (19%)	-0.306	-0.250	0.057 (18%)	-0.309	-0.254	0.054 (18%)	-0.277	-0.226	0.051 (18%)	-0.291	-0.239	0.052 (18%)	-0.312	-0.301	0.011 (4%)
		C	-0.338	-0.337	0.001 (0%)	-0.341	-0.294	0.047 (14%)	-0.317	-0.266	0.051 (16%)	-0.324	-0.282	0.042 (13%)	-0.327	-0.288	0.039 (12%)	-0.325	-0.284	0.041 (13%)	-0.322	-0.319	0.003 (1%)
45	San Joaquin River near the confluence with the Mokelumne River	W	-1.314	-1.307	0.008 (1%)	-1.223	-1.199	0.023 (2%)	-1.161	-1.118	0.043 (4%)	-1.196	-1.146	0.049 (4%)	-1.206	-1.188	0.018 (1%)	-1.231	-1.212	0.018 (1%)	-1.296	-1.264	0.032 (2%)
		AN	-1.343	-1.332	0.010 (1%)	-1.284	-1.268	0.016 (1%)	-1.255	-1.236	0.018 (1%)	-1.265	-1.219	0.045 (4%)	-1.285	-1.272	0.013 (1%)	-1.306	-1.297	0.010 (1%)	-1.340	-1.331	0.009 (1%)
		BN	-1.376	-1.364	0.012 (1%)	-1.341	-1.316	0.025 (2%)	-1.295	-1.283	0.012 (1%)	-1.321	-1.304	0.016 (1%)	-1.303	-1.297	0.005 (0%)	-1.316	-1.310	0.006 (0%)	-1.333	-1.330	0.003 (0%)
		D	-1.370	-1.365	0.005 (0%)	-1.348	-1.334	0.014 (1%)	-1.331	-1.321	0.010 (1%)	-1.323	-1.315	0.008 (1%)	-1.314	-1.310	0.004 (0%)	-1.328	-1.323	0.005 (0%)	-1.339	-1.336	0.003 (0%)
		C	-1.358	-1.355	0.002 (0%)	-1.351	-1.345	0.005 (0%)	-1.333	-1.329	0.004 (0%)	-1.337	-1.334	0.003 (0%)	-1.341	-1.339	0.002 (0%)	-1.336	-1.335	0.001 (0%)	-1.333	-1.334	0.000 (0%)
94	Old River downstream of the south Delta export facilities	W	-0.962	-0.953	0.009 (1%)	-0.895	-0.849	0.045 (5%)	-0.859	-0.775	0.084 (10%)	-0.873	-0.724	0.149 (17%)	-0.715	-0.706	0.009 (1%)	-0.733	-0.711	0.022 (3%)	-0.917	-0.815	0.102 (11%)
		AN	-0.977	-0.968	0.008 (1%)	-0.922	-0.884	0.038 (4%)	-0.910	-0.870	0.040 (4%)	-0.927	-0.812	0.115 (12%)	-0.821	-0.838	-0.017 (-2%)	-0.818	-0.834	-0.016 (-2%)	-0.963	-0.929	0.034 (4%)
		BN	-1.002	-0.996	0.006 (1%)	-0.956	-0.888	0.068 (7%)	-0.921	-0.889	0.031 (3%)	-0.940	-0.915	0.025 (3%)	-0.844	-0.877	-0.033 (-4%)	-0.843	-0.867	-0.024 (-3%)	-0.932	-0.923	0.009 (1%)
		D	-0.992	-0.987	0.006 (1%)	-0.965	-0.931	0.034 (4%)	-0.936	-0.919	0.017 (2%)	-0.929	-0.912	0.016 (2%)	-0.865	-0.882	-0.017 (-2%)	-0.851	-0.866	-0.014 (-2%)	-0.929	-0.917	0.012 (1%)
		C	-0.950	-0.952	-0.002 (0%)	-0.955	-0.943	0.012 (1%)	-0.916	-0.915	0.001 (0%)	-0.896	-0.905	-0.008 (-1%)	-0.888	-0.897	-0.009 (-1%)	-0.866	-0.878	-0.012 (-1%)	-0.898	-0.898	0.001 (0%)
212	Old River upstream of the south Delta export facilities	W	-0.451	-0.461	-0.010 (-2%)	-0.461	-0.698	-0.237 (-51%)	-0.377	-0.691	-0.314 (-83%)	-0.342	-0.661	-0.319 (-93%)	-0.418	-0.705	-0.288 (-69%)	-0.504	-0.766	-0.262 (-52%)	-0.261	-0.319	-0.058 (-22%)
		AN	-0.481	-0.465	0.016 (3%)	-0.531	-0.718	-0.187 (-35%)	-0.490	-0.678	-0.188 (-38%)	-0.431	-0.773	-0.342 (-79%)	-0.506	-0.767	-0.261 (-52%)	-0.550	-0.807	-0.257 (-47%)	-0.306	-0.348	-0.043 (-14%)
		BN	-0.433	-0.445	-0.012 (-3%)	-0.526	-0.761	-0.236 (-45%)	-0.501	-0.678	-0.177 (-35%)	-0.465	-0.675	-0.210 (-45%)	-0.548	-0.750	-0.202 (-37%)	-0.604	-0.798	-0.194 (-32%)	-0.369	-0.396	-0.027 (-7%)
		D	-0.472	-0.479	-0.008 (-2%)	-0.500	-0.699	-0.199 (-40%)	-0.544	-0.707	-0.163 (-30%)	-0.578	-0.723	-0.145 (-25%)	-0.620	-0.767	-0.147 (-24%)	-0.642	-0.793	-0.151 (-24%)	-0.400	-0.430	-0.030 (-8%)
		C	-0.591	-0.573	0.018 (3%)	-0.554	-0.700	-0.146 (-26%)	-0.596	-0.716	-0.121 (-20%)	-0.691	-0.797	-0.106 (-15%)	-0.735	-0.829	-0.094 (-13%)	-0.731	-0.830	-0.099 (-14%)	-0.473	-0.489	-0.016 (-3%)
365	Delta Cross Channel	W	-0.052	-0.052	0.000 (0%)	-0.050	-0.050	0.000 (0%)	-0.050	-0.049	0.000 (1%)	-0.051	-0.051	0.000 (1%)	-0.052	-0.052	0.000 (0%)	-0.052	-0.052	0.000 (0%)	-0.056	-0.060	-0.004 (-7%)
		AN	-0.052	-0.052	0.000 (0%)	-0.052	-0.052	0.000 (0%)	-0.052	-0.052	0.000 (0%)	-0.052	-0.052	0.000 (1%)	-0.052	-0.052	0.000 (0%)	-0.053	-0.053	0.000 (0%)	-0.059	-0.061	-0.002 (-3%)
		BN	-0.053	-0.053	0.000 (0%)	-0.052	-0.052	0.000 (0%)	-0.051	-0.051	0.000 (0%)	-0.052	-0.052	0.000 (0%)	-0.052	-0.052	0.000 (0%)	-0.052	-0.052	0.000 (0%)	-0.057	-0.059	-0.002 (-3%)
		D	-0.054	-0.054	0.000 (0%)	-0.052	-0.052	0.000 (0%)	-0.052	-0.052	0.000 (0%)	-0.052	-0.052	0.000 (0%)	-0.051	-0.052	0.000 (0%)	-0.052	-0.052	0.000 (0%)	-0.058	-0.060	-0.002 (-3%)

DSM2 Channel	Location	Water Year Type	December			January			February			March			April			May			June		
			NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
		C	-0.055	-0.055	0.000 (-1%)	-0.052	-0.052	0.000 (0%)	-0.051	-0.051	0.000 (0%)	-0.051	-0.051	0.000 (0%)	-0.051	-0.051	0.000 (0%)	-0.051	-0.051	0.000 (0%)	-0.099	-0.095	0.004 (4%)
379	Sutter Slough	W	-0.120	-0.127	-0.007 (-6%)	-0.077	-0.073	0.003 (5%)	-0.025	-0.022	0.003 (12%)	NA*	NA	NA	-0.111	-0.119	-0.008 (-7%)	-0.124	-0.122	0.002 (2%)	-0.147	-0.135	0.011 (8%)
		AN	-0.224	-0.209	0.015 (7%)	-0.099	-0.062	0.037 (37%)	-0.206	-0.177	0.029 (14%)	NA	-0.027	NA	-0.154	-0.150	0.003 (2%)	-0.140	-0.123	0.017 (12%)	-0.135	-0.104	0.032 (24%)
		BN	-0.218	-0.199	0.019 (9%)	-0.173	-0.162	0.010 (6%)	-0.295	-0.271	0.025 (8%)	-0.096	-0.094	0.002 (2%)	-0.154	-0.142	0.012 (8%)	-0.132	-0.136	-0.005 (-3%)	-0.139	-0.145	-0.005 (-4%)
		D	-0.194	-0.180	0.014 (7%)	-0.136	-0.128	0.008 (6%)	-0.153	-0.143	0.010 (7%)	-0.127	-0.115	0.013 (10%)	-0.172	-0.163	0.009 (5%)	-0.149	-0.136	0.013 (9%)	-0.143	-0.156	-0.013 (-9%)
		C	-0.231	-0.240	-0.010 (-4%)	-0.192	-0.121	0.071 (37%)	-0.149	-0.173	-0.024 (-16%)	-0.166	-0.145	0.021 (12%)	-0.146	-0.144	0.002 (2%)	-0.249	-0.248	0.001 (1%)	-0.222	-0.230	-0.008 (-3%)
383	Steamboat Slough	W	-0.404	-0.399	0.005 (1%)	-0.362	-0.364	-0.002 (-1%)	-0.185	-0.250	-0.065 (-35%)	-0.160	-0.347	-0.187 (-117%)	-0.372	-0.397	-0.025 (-7%)	-0.410	-0.438	-0.028 (-7%)	-0.550	-0.579	-0.029 (-5%)
		AN	-0.492	-0.516	-0.025 (-5%)	-0.345	-0.340	0.005 (2%)	-0.525	-0.461	0.064 (12%)	-0.246	-0.324	-0.078 (-32%)	-0.367	-0.393	-0.027 (-7%)	-0.431	-0.456	-0.025 (-6%)	-0.567	-0.594	-0.026 (-5%)
		BN	-0.484	-0.512	-0.028 (-6%)	-0.457	-0.470	-0.014 (-3%)	-0.419	-0.435	-0.015 (-4%)	-0.392	-0.419	-0.027 (-7%)	-0.434	-0.463	-0.029 (-7%)	-0.480	-0.490	-0.010 (-2%)	-0.578	-0.547	0.030 (5%)
		D	-0.541	-0.559	-0.018 (-3%)	-0.439	-0.474	-0.035 (-8%)	-0.376	-0.421	-0.045 (-12%)	-0.384	-0.409	-0.025 (-7%)	-0.471	-0.474	-0.003 (-1%)	-0.472	-0.476	-0.004 (-1%)	-0.582	-0.578	0.003 (1%)
		C	-0.625	-0.648	-0.023 (-4%)	-0.499	-0.494	0.005 (1%)	-0.419	-0.485	-0.066 (-16%)	-0.487	-0.516	-0.029 (-6%)	-0.503	-0.516	-0.014 (-3%)	-0.613	-0.621	-0.007 (-1%)	-0.691	-0.696	-0.005 (-1%)
418	Sacramento River downstream of proposed NDD	W	-0.120	-0.136	-0.017 (-14%)	-0.091	-0.092	-0.002 (-2%)	NA	-0.073	NA	NA	0.000	NA	-0.168	-0.160	0.008 (5%)	-0.145	-0.154	-0.008 (-6%)	-0.156	-0.175	-0.019 (-12%)
		AN	-0.250	-0.242	0.008 (3%)	-0.065	-0.064	0.001 (2%)	-0.265	-0.220	0.046 (17%)	NA	-0.036	NA	-0.200	-0.183	0.017 (8%)	-0.150	-0.140	0.010 (7%)	-0.202	-0.156	0.046 (23%)
		BN	-0.254	-0.231	0.023 (9%)	-0.187	-0.180	0.007 (4%)	-0.374	-0.359	0.015 (4%)	-0.126	-0.114	0.012 (9%)	-0.175	-0.178	-0.002 (-1%)	-0.150	-0.160	-0.010 (-7%)	-0.135	-0.135	0.000 (0%)
		D	-0.233	-0.200	0.032 (14%)	-0.141	-0.139	0.002 (1%)	-0.154	-0.149	0.005 (3%)	-0.115	-0.119	-0.004 (-3%)	-0.194	-0.182	0.012 (6%)	-0.168	-0.158	0.010 (6%)	-0.157	-0.152	0.005 (3%)
		C	-0.272	-0.266	0.006 (2%)	-0.224	-0.146	0.078 (35%)	-0.155	-0.188	-0.033 (-21%)	-0.183	-0.169	0.014 (8%)	-0.166	-0.162	0.004 (3%)	-0.285	-0.281	0.005 (2%)	-0.271	-0.263	0.009 (3%)
421	Sacramento River upstream of Georgiana Slough	W	-0.074	-0.080	-0.006 (-8%)	-0.061	-0.052	0.008 (14%)	NA	-0.104	NA	NA	-0.033	NA	-0.123	-0.123	0.001 (0%)	-0.111	-0.147	-0.036 (-33%)	-0.152	-0.158	-0.006 (-4%)
		AN	-0.190	-0.187	0.003 (2%)	-0.047	-0.084	-0.037 (-78%)	-0.179	-0.139	0.040 (22%)	NA	-0.058	NA	-0.156	-0.137	0.019 (12%)	-0.110	-0.142	-0.032 (-29%)	-0.186	-0.147	0.038 (21%)
		BN	-0.218	-0.179	0.038 (18%)	-0.141	-0.141	0.000 (0%)	-0.304	-0.278	0.025 (8%)	-0.088	-0.096	-0.008 (-9%)	-0.133	-0.161	-0.028 (-21%)	-0.115	-0.146	-0.031 (-27%)	-0.113	-0.133	-0.020 (-18%)
		D	-0.178	-0.161	0.017 (10%)	-0.103	-0.105	-0.002 (-2%)	-0.106	-0.118	-0.012 (-11%)	-0.077	-0.092	-0.014 (-18%)	-0.149	-0.157	-0.008 (-5%)	-0.125	-0.145	-0.020 (-16%)	-0.162	-0.142	0.020 (12%)
		C	-0.223	-0.223	0.000 (0%)	-0.163	-0.108	0.054 (33%)	-0.113	-0.152	-0.039 (-35%)	-0.134	-0.139	-0.004 (-3%)	-0.122	-0.139	-0.018 (-15%)	-0.219	-0.234	-0.015 (-7%)	-0.247	-0.256	-0.009 (-4%)
423	Sacramento River downstream of Georgiana Slough	W	-0.347	-0.343	0.005 (1%)	-0.310	-0.297	0.013 (4%)	-0.225	-0.217	0.008 (4%)	-0.144	-0.286	-0.142 (-98%)	-0.317	-0.338	-0.021 (-7%)	-0.356	-0.384	-0.028 (-8%)	-0.545	-0.580	-0.035 (-6%)
		AN	-0.448	-0.468	-0.020 (-4%)	-0.297	-0.285	0.012 (4%)	-0.467	-0.402	0.065 (14%)	-0.213	-0.268	-0.054 (-25%)	-0.312	-0.333	-0.021 (-7%)	-0.377	-0.403	-0.026 (-7%)	-0.576	-0.610	-0.034 (-6%)
		BN	-0.449	-0.479	-0.030 (-7%)	-0.396	-0.414	-0.017 (-4%)	-0.354	-0.372	-0.018 (-5%)	-0.329	-0.363	-0.034 (-10%)	-0.385	-0.412	-0.026 (-7%)	-0.434	-0.443	-0.008 (-2%)	-0.582	-0.585	-0.002 (0%)
		D	-0.505	-0.520	-0.015 (-3%)	-0.389	-0.426	-0.037 (-9%)	-0.329	-0.369	-0.039 (-12%)	-0.334	-0.348	-0.014 (-4%)	-0.417	-0.419	-0.002 (0%)	-0.430	-0.435	-0.005 (-1%)	-0.589	-0.600	-0.011 (-2%)
		C	-0.587	-0.608	-0.021	-0.438	-0.444	-0.006	-0.373	-0.432	-0.059	-0.435	-0.463	-0.028	-0.460	-0.472	-0.012	-0.566	-0.576	-0.010	-0.678	-0.682	-0.004

DSM2 Channel	Location	Water Year Type	December			January			February			March			April			May			June		
			NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
					(-4%)			(-1%)			(-16%)			(-6%)			(-3%)			(-2%)			(-1%)

Note: *NA denotes that there were no negative velocity estimates.

Table 5.4-11. Median Daily Proportion of Negative Velocity in Important Delta Channels, from DSM2-HYDRO Modeling, with Green Shading Indicating PA is ≥5% Less than NAA and Red Shading Indicating PA is ≥5% More than NAA.

DSM2 Channel	Location	Water Year Type	December			January			February			March			April			May			June		
			NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
21	San Joaquin River downstream of HOR	W	0.438	0.438	0.000 (0%)	0.365	0.250	-0.115 (-31%)	0.219	0.083	-0.135 (-62%)	0.167	0.063	-0.104 (-63%)	0.234	0.094	-0.141 (-60%)	0.292	0.135	-0.156 (-54%)	0.385	0.323	-0.063 (-16%)
		AN	0.469	0.458	-0.010 (-2%)	0.438	0.406	-0.031 (-7%)	0.406	0.333	-0.073 (-18%)	0.396	0.260	-0.135 (-34%)	0.396	0.292	-0.104 (-26%)	0.406	0.323	-0.083 (-21%)	0.448	0.438	-0.010 (-2%)
		BN	0.469	0.469	0.000 (0%)	0.458	0.427	-0.031 (-7%)	0.438	0.396	-0.042 (-10%)	0.438	0.396	-0.042 (-10%)	0.427	0.385	-0.042 (-10%)	0.438	0.396	-0.042 (-10%)	0.458	0.458	0.000 (0%)
		D	0.469	0.469	0.000 (0%)	0.458	0.438	-0.021 (-5%)	0.458	0.427	-0.031 (-7%)	0.458	0.438	-0.021 (-5%)	0.448	0.417	-0.031 (-7%)	0.448	0.427	-0.021 (-5%)	0.469	0.458	-0.010 (-2%)
		C	0.469	0.469	0.000 (0%)	0.469	0.448	-0.021 (-4%)	0.458	0.438	-0.021 (-5%)	0.458	0.448	-0.010 (-2%)	0.458	0.448	-0.010 (-2%)	0.458	0.448	-0.010 (-2%)	0.469	0.469	0.000 (0%)
45	San Joaquin River near the confluence with the Mokelumne River	W	0.479	0.479	0.000 (0%)	0.458	0.448	-0.010 (-2%)	0.448	0.438	-0.010 (-2%)	0.448	0.438	-0.010 (-2%)	0.448	0.438	-0.010 (-2%)	0.448	0.448	0.000 (0%)	0.469	0.469	0.000 (0%)
		AN	0.490	0.490	0.000 (0%)	0.469	0.469	0.000 (0%)	0.458	0.458	0.000 (0%)	0.458	0.448	-0.010 (-2%)	0.458	0.458	0.000 (0%)	0.469	0.469	0.000 (0%)	0.479	0.479	0.000 (0%)
		BN	0.500	0.490	-0.010 (-2%)	0.490	0.479	-0.010 (-2%)	0.479	0.479	0.000 (0%)	0.479	0.479	0.000 (0%)	0.469	0.469	0.000 (0%)	0.479	0.469	-0.010 (-2%)	0.479	0.479	0.000 (0%)
		D	0.500	0.490	-0.010 (-2%)	0.490	0.479	-0.010 (-2%)	0.479	0.479	0.000 (0%)	0.479	0.479	0.000 (0%)	0.469	0.469	0.000 (0%)	0.479	0.479	0.000 (0%)	0.479	0.479	0.000 (0%)
		C	0.490	0.490	0.000 (0%)	0.490	0.490	0.000 (0%)	0.479	0.479	0.000 (0%)	0.479	0.479	0.000 (0%)	0.479	0.479	0.000 (0%)	0.479	0.479	0.000 (0%)	0.479	0.479	0.000 (0%)
94	Old River downstream of the south Delta export facilities	W	0.583	0.573	-0.010 (-2%)	0.531	0.490	-0.042 (-8%)	0.531	0.448	-0.083 (-16%)	0.531	0.438	-0.094 (-18%)	0.448	0.438	-0.010 (-2%)	0.458	0.448	-0.010 (-2%)	0.531	0.479	-0.052 (-10%)
		AN	0.583	0.583	0.000 (0%)	0.531	0.510	-0.021 (-4%)	0.531	0.500	-0.031 (-6%)	0.542	0.469	-0.073 (-13%)	0.469	0.469	0.000 (0%)	0.469	0.469	0.000 (0%)	0.542	0.521	-0.021 (-4%)
		BN	0.667	0.604	-0.063 (-9%)	0.552	0.490	-0.063 (-11%)	0.521	0.521	0.000 (0%)	0.542	0.531	-0.010 (-2%)	0.479	0.490	0.010 (2%)	0.479	0.490	0.010 (2%)	0.531	0.521	-0.010 (-2%)
		D	0.594	0.583	-0.010 (-2%)	0.552	0.531	-0.021 (-4%)	0.531	0.531	0.000 (0%)	0.521	0.521	0.000 (0%)	0.490	0.500	0.010 (2%)	0.490	0.490	0.000 (0%)	0.521	0.510	-0.010 (-2%)
		C	0.542	0.542	0.000 (0%)	0.552	0.552	0.000 (0%)	0.521	0.521	0.000 (0%)	0.500	0.500	0.000 (0%)	0.490	0.490	0.000 (0%)	0.490	0.490	0.000 (0%)	0.490	0.490	0.000 (0%)
212	Old River upstream of the south Delta export facilities	W	0.344	0.354	0.010 (3%)	0.292	0.396	0.104 (36%)	0.125	0.354	0.229 (183%)	0.094	0.297	0.203 (217%)	0.177	0.365	0.188 (106%)	0.229	0.396	0.167 (73%)	0.188	0.385	0.198 (106%)
		AN	0.344	0.365	0.021 (6%)	0.365	0.427	0.063 (17%)	0.313	0.406	0.094 (30%)	0.271	0.417	0.146 (54%)	0.344	0.427	0.083 (24%)	0.365	0.438	0.073 (20%)	0.438	0.464	0.026 (6%)
		BN	0.333	0.365	0.031 (9%)	0.385	0.448	0.063 (16%)	0.365	0.427	0.063 (17%)	0.354	0.438	0.083 (24%)	0.375	0.438	0.063 (17%)	0.396	0.448	0.052 (13%)	0.469	0.490	0.021 (4%)
		D	0.375	0.375	0.000 (0%)	0.385	0.448	0.063 (16%)	0.385	0.448	0.063 (16%)	0.396	0.448	0.052 (13%)	0.406	0.448	0.042 (10%)	0.417	0.458	0.042 (10%)	0.479	0.500	0.021 (4%)
		C	0.396	0.406	0.010 (3%)	0.406	0.458	0.052 (13%)	0.396	0.448	0.052 (13%)	0.438	0.469	0.031 (7%)	0.438	0.469	0.031 (7%)	0.438	0.469	0.031 (7%)	0.500	0.500	0.000 (0%)
365	Delta Cross Channel	W	0.448	0.448	0.000 (0%)	0.427	0.427	0.000 (0%)	0.427	0.417	-0.010 (-2%)	0.427	0.427	0.000 (0%)	0.438	0.427	-0.010 (-2%)	0.427	0.427	0.000 (0%)	0.073	0.083	0.010 (14%)
		AN	0.458	0.458	0.000	0.448	0.448	0.000	0.438	0.438	0.000	0.438	0.438	0.000	0.448	0.448	0.000	0.458	0.458	0.000	0.031	0.063	0.031

DSM2 Channel	Location	Water Year Type	December			January			February			March			April			May			June		
			NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
					(0%)			(0%)			(0%)			(0%)			(0%)			(0%)			(100%)
		BN	0.458	0.448	-0.010 (-2%)	0.469	0.458	-0.010 (-2%)	0.458	0.458	0.000 (0%)	0.458	0.458	0.000 (0%)	0.458	0.458	0.000 (0%)	0.469	0.458	-0.010 (-2%)	0.042	0.063	0.021 (50%)
		D	0.458	0.458	0.000 (0%)	0.469	0.469	0.000 (0%)	0.458	0.458	0.000 (0%)	0.458	0.458	0.000 (0%)	0.458	0.458	0.000 (0%)	0.469	0.469	0.000 (0%)	0.042	0.073	0.031 (75%)
		C	0.458	0.458	0.000 (0%)	0.469	0.469	0.000 (0%)	0.469	0.469	0.000 (0%)	0.469	0.469	0.000 (0%)	0.469	0.469	0.000 (0%)	0.469	0.469	0.000 (0%)	0.146	0.156	0.010 (7%)
379	Sutter Slough	W	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)
		AN	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.083	0.063	-0.021 (-25%)
		BN	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.052	0.063	0.010 (20%)	0.104	0.083	-0.021 (-20%)
		D	0.000	0.063	0.063 (Inf.)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.052	0.052	0.000 (0%)	0.104	0.104	0.000 (0%)
		C	0.167	0.203	0.036 (22%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.021	0.021 (Inf.)	0.083	0.094	0.010 (13%)	0.167	0.188	0.021 (12%)	0.240	0.250	0.010 (4%)
383	Steamboat Slough	W	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.198	0.302	0.104 (53%)
		AN	0.125	0.167	0.042 (33%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.031	0.031 (Inf.)	0.188	0.229	0.042 (22%)	0.302	0.333	0.031 (10%)
		BN	0.167	0.229	0.063 (37%)	0.115	0.146	0.031 (27%)	0.000	0.094	0.094 (Inf.)	0.042	0.146	0.104 (250%)	0.219	0.250	0.031 (14%)	0.281	0.281	0.000 (0%)	0.313	0.313	0.000 (0%)
		D	0.260	0.281	0.021 (8%)	0.182	0.224	0.042 (23%)	0.021	0.125	0.104 (500%)	0.000	0.125	0.125 (Inf.)	0.224	0.229	0.005 (2%)	0.271	0.271	0.000 (0%)	0.313	0.323	0.010 (3%)
		C	0.333	0.344	0.010 (3%)	0.219	0.250	0.031 (14%)	0.146	0.214	0.068 (46%)	0.281	0.292	0.010 (4%)	0.302	0.302	0.000 (0%)	0.344	0.354	0.010 (3%)	0.375	0.375	0.000 (0%)
418	Sacramento River downstream of proposed NDD	W	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)
		AN	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)
		BN	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.031	0.052	0.021 (67%)	0.000	0.000	0.000 (0%)
		D	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.021	0.042	0.021 (100%)	0.000	0.000	0.000 (0%)
		C	0.141	0.156	0.016 (11%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.005	0.005 (Inf.)	0.073	0.083	0.010 (14%)	0.156	0.167	0.010 (7%)	0.130	0.135	0.005 (4%)
421	Sacramento River upstream of Georgiana Slough	W	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)
		AN	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.031	0.031 (Inf.)	0.000	0.000	0.000 (0%)
		BN	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.042	0.073	0.031 (75%)	0.000	0.000	0.000 (0%)
		D	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.021	0.073	0.052 (250%)	0.000	0.000	0.000 (0%)
		C	0.135	0.156	0.021 (15%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.052	0.052 (Inf.)	0.083	0.104	0.021 (25%)	0.167	0.167	0.000 (0%)	0.125	0.135	0.010 (8%)
423	Sacramento River downstream of Georgiana	W	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.281	0.333	0.052 (19%)
		AN	0.146	0.188	0.042 (29%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.063	0.063 (Inf.)	0.208	0.250	0.042 (20%)	0.344	0.365	0.021 (6%)

DSM2 Channel	Location	Water Year Type	December			January			February			March			April			May			June		
			NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
	Slough	BN	0.188	0.250	0.063 (33%)	0.135	0.167	0.031 (23%)	0.000	0.115	0.115 (Inf.)	0.083	0.177	0.094 (113%)	0.240	0.250	0.010 (4%)	0.292	0.292	0.000 (0%)	0.354	0.354	0.000 (0%)
		D	0.281	0.302	0.021 (7%)	0.198	0.240	0.042 (21%)	0.083	0.146	0.063 (75%)	0.000	0.146	0.146 (Inf.)	0.229	0.240	0.010 (5%)	0.281	0.281	0.000 (0%)	0.354	0.365	0.010 (3%)
		C	0.344	0.354	0.010 (3%)	0.240	0.260	0.021 (9%)	0.177	0.229	0.052 (29%)	0.292	0.292	0.000 (0%)	0.302	0.313	0.010 (3%)	0.354	0.354	0.000 (0%)	0.396	0.396	0.000 (0%)

5.4.1.3.1.2.1.2 Entry into Interior Delta

Juvenile salmonids may enter the interior Delta from the mainstem Sacramento and San Joaquin Rivers through junctions such as Georgiana Slough/Delta Cross Channel and the HOR. Survival through the interior Delta from the Sacramento River has been shown to be consistently appreciably lower than in the river mainstem (Perry et al. 2010, 2013; Brandes and McLain 2001; Singer et al. 2013), whereas some evidence supports higher main stem survival for the San Joaquin River (reviewed by Hankin et al. 2010) and other evidence does not (Buchanan et al. 2013, 2015[22]). Perry et al. (2013) found that, based on observed patterns for hatchery-origin late fall–run Chinook salmon, eliminating entry into the interior Delta through Georgiana Slough and the Delta Cross Channel would increase overall through-Delta survival by up to approximately one-third (10-35%); this represents an absolute increase in survival of 2-7%. The need to reduce entry into the interior Delta by juvenile salmonids was recognized in the NMFS (2009) BiOp, which requires that engineering solutions be investigated to lessen the issue; such solutions may include physical or nonphysical barriers.

The PA has the potential to result in changes in interior Delta entry on the Sacramento River and the San Joaquin River. Less flow in the Sacramento River (as would occur because of exports by the NDD) leads to a greater tidal influence at the Georgiana Slough/DCC junction (Perry et al. 2015) and a greater proportion of flow entering the junction (Cavallo et al. 2015); installation of a nonphysical barrier at the Georgiana Slough junction would aim to minimize the biological consequences of these changes in hydrodynamics by allowing flow to enter Georgiana Slough but preventing fish from entering the distributary 23. Installation of the HOR gate under the PA would greatly reduce entry into Old River from the San Joaquin River. These factors are discussed in this section.

5.4.1.3.1.2.1.2.1 Flow Routing Into Channel Junctions

Perspective on potential differences in juvenile salmonid entry into the interior Delta between modeled operations of the NAA and PA was provided by assessing differences in the proportion of flow entering important channel junctions from the Sacramento River and the San Joaquin River based on DSM2-HYDRO modeling (Appendix 5.D, *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale,* Section 5.D.1.2.1.1.2, *Flow Routing at Junctions*, for methods, with results in Section 5.D.1.2.1.2.2, *Flow Routing at Junctions*, of the same appendix). Assessment of the proportion of flow entering a junction generally is a reasonable proxy for the proportion of fish entering the junction (Cavallo et al. 2015). As noted previously in the analysis of velocity, the summary provided herein does not account for the results of the coordinated monitoring and research under the Adaptive Management Program and real-time operations that would be done

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[22] The study of Buchanan et al. (2015) occurred in 2012, when a rock barrier was in place at HOR, resulting in very few fish entering Old River (presumably through the barrier culverts), giving high uncertainty in the estimates of survival via the Old River route (which was not significantly different from survival in the San Joaquin River mainstem route). See also discussion by Anderson et al. (2012) for the Report of the 2012 Delta Science Program Independent Review Panel (IRP) on the Long-term Operations Opinions (LOO) Annual Review.

[23] Note that there is essentially no effect of south Delta exports on the proportion of flow (and fish) entering Georgiana Slough (Cavallo et al. 2015).

in order to limit potential operational effects to avoid jeopardy while maximizing water supplies, by assessing flow conditions in the context of fish presence, e.g., by using monitoring data from at or upstream of the Delta periphery (e.g., Knights Landing on the Sacramento River or Mossdale on the San Joaquin River).

For the Sacramento River, the junctions analyzed included Sutter and Steamboat Sloughs, for which less entry from the mainstem Sacramento River is actually a negative effect, as these are relatively high survival migration pathways that allow fish to avoid entry into the interior Delta (Perry et al. 2010; 2012), Georgiana Slough, and the DCC. The junctions off the mainstem San Joaquin River that were analyzed included the HOR, Turner Cut, Columbia Cut, Middle River, and mouth of Old River.

For the Sacramento River, the analysis of flow routing into channel junctions showed that at Sutter Slough, the most upstream junction, there generally would be little difference in proportion of flow entering the junction between NAA and PA, although in one case (December of critical years) the difference in median proportion was 5% less under PA (0.01 absolute difference) (Table 5.4-12). Slightly farther downstream at Steamboat Slough, there were more incidences of median proportion being >5% less under PA (0.01-0.02 less absolute difference in February and March of below normal and dry years). Differences in flow routing into the Delta Cross Channel in December to May are discountable because the gates are usually closed in these months[24], whereas there were negligible differences in June, when the gates are opened again (see summary of gate openings in Table 5.B.5-24 in Appendix 5.B, *DSM2 Methods and Results*). The proportion of flow entering Georgiana Slough under the PA was generally similar to (<5% difference) or somewhat greater than the proportion entering under NAA, with the largest difference between medians in March of dry years (11% more under the PA, or 0.04 in absolute terms).

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[24] However, in drought years temporary changes to DCC criteria could be made, as has occurred in recent years. See Section 3.7.1.2, *Recent Drought Management Actions*, in Chapter 3, *Description of the Proposed Action*, for further discussion.

Table 5.4-12. Median Daily Proportion of Flow Entering Important Delta Channels, from DSM2-HYDRO Modeling, with Green Shading Indicating PA is ≥5% Less than NAA and Red Shading Indicating PA is ≥5% More than NAA(Except for Sutter/Steamboat Sloughs, where Entry is Considered Beneficial and the Color Scheme is Reversed).

Junction	Water Year Type	December			January			February			March			April			May			June		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Sutter Slough (Entry is beneficial)	W	0.262	0.262	0.000 (0%)	0.264	0.263	-0.001 (0%)	0.267	0.265	-0.002 (-1%)	0.265	0.265	0.000 (0%)	0.263	0.263	0.000 (0%)	0.263	0.263	0.000 (0%)	0.219	0.193	-0.026 (-12%)
	AN	0.259	0.257	-0.002 (-1%)	0.261	0.261	0.000 (0%)	0.263	0.263	0.000 (0%)	0.262	0.263	0.001 (0%)	0.262	0.261	-0.001 (0%)	0.262	0.258	-0.004 (-2%)	0.181	0.174	-0.007 (-4%)
	BN	0.257	0.252	-0.005 (-2%)	0.259	0.258	-0.001 (0%)	0.261	0.261	0.000 (0%)	0.260	0.259	-0.001 (0%)	0.261	0.259	-0.002 (-1%)	0.240	0.238	-0.002 (-1%)	0.175	0.181	0.006 (3%)
	D	0.227	0.219	-0.008 (-4%)	0.256	0.254	-0.002 (-1%)	0.260	0.259	-0.001 (0%)	0.260	0.259	-0.001 (0%)	0.259	0.259	0.000 (0%)	0.242	0.239	-0.003 (-1%)	0.173	0.174	0.001 (1%)
	C	0.195	0.185	-0.010 (-5%)	0.254	0.247	-0.007 (-3%)	0.259	0.256	-0.003 (-1%)	0.249	0.239	-0.010 (-4%)	0.230	0.225	-0.005 (-2%)	0.199	0.195	-0.004 (-2%)	0.151	0.152	0.001 (1%)
Steamboat Slough (Entry is beneficial)	W	0.254	0.242	-0.012 (-5%)	0.278	0.272	-0.006 (-2%)	0.291	0.284	-0.007 (-2%)	0.277	0.270	-0.007 (-3%)	0.257	0.253	-0.004 (-2%)	0.252	0.249	-0.003 (-1%)	0.182	0.180	-0.002 (-1%)
	AN	0.207	0.203	-0.004 (-2%)	0.259	0.248	-0.011 (-4%)	0.279	0.272	-0.007 (-3%)	0.263	0.257	-0.006 (-2%)	0.238	0.229	-0.009 (-4%)	0.202	0.203	0.001 (0%)	0.164	0.169	0.005 (3%)
	BN	0.200	0.193	-0.007 (-4%)	0.213	0.209	-0.004 (-2%)	0.238	0.220	-0.018 (-8%)	0.218	0.205	-0.013 (-6%)	0.196	0.196	0.000 (0%)	0.192	0.194	0.002 (1%)	0.164	0.168	0.004 (2%)
	D	0.192	0.190	-0.002 (-1%)	0.199	0.197	-0.002 (-1%)	0.222	0.210	-0.012 (-5%)	0.232	0.212	-0.020 (-9%)	0.197	0.198	0.001 (1%)	0.192	0.194	0.002 (1%)	0.163	0.169	0.006 (4%)
	C	0.192	0.193	0.001 (1%)	0.198	0.196	-0.002 (-1%)	0.203	0.199	-0.004 (-2%)	0.193	0.194	0.001 (1%)	0.190	0.191	0.001 (1%)	0.191	0.193	0.002 (1%)	0.180	0.183	0.003 (2%)
Delta Cross Channel (Entry is adverse)	W	0.006	0.007	0.001 (17%)	0.004	0.004	0.000 (0%)	0.003	0.003	0.000 (0%)	0.004	0.004	0.000 (0%)	0.005	0.006	0.001 (20%)	0.006	0.006	0.000 (0%)	0.386	0.379	-0.007 (-2%)
	AN	0.009	0.010	0.001 (11%)	0.005	0.006	0.001 (20%)	0.004	0.004	0.000 (0%)	0.005	0.006	0.001 (20%)	0.007	0.008	0.001 (14%)	0.010	0.011	0.001 (10%)	0.432	0.426	-0.006 (-1%)
	BN	0.009	0.010	0.001 (11%)	0.009	0.009	0.000 (0%)	0.007	0.008	0.001 (14%)	0.008	0.009	0.001 (13%)	0.010	0.010	0.000 (0%)	0.011	0.011	0.000 (0%)	0.437	0.430	-0.007 (-2%)
	D	0.011	0.011	0.000 (0%)	0.010	0.010	0.000 (0%)	0.008	0.009	0.001 (13%)	0.008	0.009	0.001 (13%)	0.010	0.010	0.000 (0%)	0.011	0.011	0.000 (0%)	0.442	0.429	-0.013 (-3%)
	C	0.013	0.013	0.000 (0%)	0.010	0.010	0.000 (0%)	0.009	0.010	0.001 (11%)	0.011	0.011	0.000 (0%)	0.011	0.011	0.000 (0%)	0.012	0.013	0.001 (8%)	0.389	0.379	-0.010 (-3%)
Georgiana Slough (Entry is adverse)	W	0.314	0.342	0.028 (9%)	0.293	0.295	0.002 (1%)	0.291	0.292	0.001 (0%)	0.292	0.293	0.001 (0%)	0.302	0.304	0.002 (1%)	0.307	0.311	0.004 (1%)	0.396	0.393	-0.003 (-1%)
	AN	0.395	0.401	0.006 (2%)	0.304	0.327	0.023 (8%)	0.292	0.293	0.001 (0%)	0.299	0.302	0.003 (1%)	0.336	0.360	0.024 (7%)	0.417	0.405	-0.012 (-3%)	0.420	0.402	-0.018 (-4%)
	BN	0.411	0.418	0.007 (2%)	0.396	0.400	0.004 (1%)	0.339	0.379	0.040 (12%)	0.391	0.417	0.026 (7%)	0.424	0.416	-0.008 (-2%)	0.433	0.422	-0.011 (-3%)	0.414	0.412	-0.002 (0%)
	D	0.415	0.419	0.004 (1%)	0.421	0.423	0.002 (0%)	0.382	0.400	0.018 (5%)	0.366	0.406	0.040 (11%)	0.416	0.411	-0.005 (-1%)	0.432	0.423	-0.009 (-2%)	0.415	0.403	-0.012 (-3%)
	C	0.387	0.384	-0.003 (-1%)	0.412	0.428	0.016 (4%)	0.418	0.416	-0.002 (0%)	0.431	0.429	-0.002 (0%)	0.440	0.434	-0.006 (-1%)	0.404	0.397	-0.007 (-2%)	0.363	0.347	-0.016 (-4%)
Head of Old River (Entry is adverse)	W	0.649	0.642	-0.007 (-1%)	0.580	0.322	-0.258 (-44%)	0.537	0.282	-0.255 (-47%)	0.534	0.323	-0.211 (-40%)	0.525	0.259	-0.266 (-51%)	0.527	0.259	-0.268 (-51%)	0.515	0.497	-0.018 (-3%)
	AN	0.663	0.661	-0.002 (0%)	0.616	0.349	-0.267 (-43%)	0.577	0.280	-0.297 (-51%)	0.560	0.264	-0.296 (-53%)	0.529	0.253	-0.276 (-52%)	0.537	0.252	-0.285 (-53%)	0.530	0.474	-0.056 (-11%)
	BN	0.679	0.667	-0.012 (-2%)	0.635	0.342	-0.293 (-46%)	0.602	0.353	-0.249 (-41%)	0.611	0.289	-0.322 (-53%)	0.559	0.264	-0.295 (-53%)	0.581	0.279	-0.302 (-52%)	0.504	0.412	-0.092 (-18%)
	D	0.667	0.662	-0.005 (-1%)	0.647	0.362	-0.285 (-44%)	0.634	0.371	-0.263 (-41%)	0.629	0.385	-0.244 (-39%)	0.597	0.322	-0.275 (-46%)	0.602	0.335	-0.267 (-44%)	0.467	0.377	-0.090 (-19%)

Junction	Water Year Type	December			January			February			March			April			May			June		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
	C	0.642	0.639	-0.003 (0%)	0.638	0.405	-0.233 (-37%)	0.622	0.383	-0.239 (-38%)	0.594	0.398	-0.196 (-33%)	0.567	0.393	-0.174 (-31%)	0.580	0.383	-0.197 (-34%)	0.367	0.307	-0.060 (-16%)
Turner Cut (Entry is adverse)	W	0.176	0.173	-0.003 (-2%)	0.176	0.181	0.005 (3%)	0.191	0.187	-0.004 (-2%)	0.197	0.190	-0.007 (-4%)	0.180	0.189	0.009 (5%)	0.177	0.187	0.010 (6%)	0.190	0.183	-0.007 (-4%)
	AN	0.171	0.169	-0.002 (-1%)	0.167	0.174	0.007 (4%)	0.175	0.185	0.010 (6%)	0.182	0.185	0.003 (2%)	0.170	0.188	0.018 (11%)	0.167	0.186	0.019 (11%)	0.173	0.173	0.000 (0%)
	BN	0.177	0.172	-0.005 (-3%)	0.165	0.168	0.003 (2%)	0.169	0.181	0.012 (7%)	0.169	0.181	0.012 (7%)	0.164	0.182	0.018 (11%)	0.161	0.176	0.015 (9%)	0.163	0.164	0.001 (1%)
	D	0.168	0.167	-0.001 (-1%)	0.164	0.170	0.006 (4%)	0.161	0.170	0.009 (6%)	0.159	0.168	0.009 (6%)	0.157	0.170	0.013 (8%)	0.157	0.168	0.011 (7%)	0.160	0.160	0.000 (0%)
	C	0.161	0.161	0.000 (0%)	0.161	0.167	0.006 (4%)	0.158	0.166	0.008 (5%)	0.152	0.159	0.007 (5%)	0.150	0.157	0.007 (5%)	0.151	0.158	0.007 (5%)	0.153	0.153	0.000 (0%)
Columbia Cut (Entry is adverse)	W	0.169	0.166	-0.003 (-2%)	0.166	0.163	-0.003 (-2%)	0.171	0.161	-0.010 (-6%)	0.173	0.157	-0.016 (-9%)	0.155	0.157	0.002 (1%)	0.155	0.157	0.002 (1%)	0.169	0.161	-0.008 (-5%)
	AN	0.166	0.164	-0.002 (-1%)	0.161	0.162	0.001 (1%)	0.165	0.165	0.000 (0%)	0.166	0.158	-0.008 (-5%)	0.153	0.160	0.007 (5%)	0.151	0.159	0.008 (5%)	0.164	0.161	-0.003 (-2%)
	BN	0.171	0.167	-0.004 (-2%)	0.160	0.158	-0.002 (-1%)	0.162	0.165	0.003 (2%)	0.161	0.164	0.003 (2%)	0.151	0.160	0.009 (6%)	0.149	0.158	0.009 (6%)	0.157	0.156	-0.001 (-1%)
	D	0.164	0.163	-0.001 (-1%)	0.159	0.161	0.002 (1%)	0.156	0.160	0.004 (3%)	0.153	0.158	0.005 (3%)	0.149	0.156	0.007 (5%)	0.148	0.154	0.006 (4%)	0.154	0.152	-0.002 (-1%)
	C	0.158	0.157	-0.001 (-1%)	0.157	0.160	0.003 (2%)	0.152	0.158	0.006 (4%)	0.147	0.151	0.004 (3%)	0.144	0.148	0.004 (3%)	0.144	0.149	0.005 (3%)	0.147	0.147	0.000 (0%)
Middle River (Entry is adverse)	W	0.189	0.186	-0.003 (-2%)	0.183	0.178	-0.005 (-3%)	0.185	0.174	-0.011 (-6%)	0.184	0.168	-0.016 (-9%)	0.167	0.168	0.001 (1%)	0.169	0.169	0.000 (0%)	0.186	0.176	-0.010 (-5%)
	AN	0.190	0.187	-0.003 (-2%)	0.180	0.178	-0.002 (-1%)	0.182	0.180	-0.002 (-1%)	0.183	0.173	-0.010 (-5%)	0.170	0.175	0.005 (3%)	0.170	0.174	0.004 (2%)	0.183	0.180	-0.003 (-2%)
	BN	0.194	0.189	-0.005 (-3%)	0.182	0.175	-0.007 (-4%)	0.180	0.180	0.000 (0%)	0.181	0.179	-0.002 (-1%)	0.171	0.176	0.005 (3%)	0.170	0.175	0.005 (3%)	0.178	0.177	-0.001 (-1%)
	D	0.188	0.186	-0.002 (-1%)	0.181	0.180	-0.001 (-1%)	0.179	0.178	-0.001 (-1%)	0.177	0.178	0.001 (1%)	0.171	0.175	0.004 (2%)	0.170	0.174	0.004 (2%)	0.176	0.175	-0.001 (-1%)
	C	0.180	0.180	0.000 (0%)	0.179	0.179	0.000 (0%)	0.175	0.176	0.001 (1%)	0.171	0.172	0.001 (1%)	0.169	0.172	0.003 (2%)	0.169	0.172	0.003 (2%)	0.170	0.170	0.000 (0%)
Mouth of Old River (Entry is adverse)	W	0.178	0.174	-0.004 (-2%)	0.177	0.172	-0.005 (-3%)	0.181	0.170	-0.011 (-6%)	0.177	0.164	-0.013 (-7%)	0.162	0.161	-0.001 (-1%)	0.163	0.161	-0.002 (-1%)	0.174	0.167	-0.007 (-4%)
	AN	0.174	0.172	-0.002 (-1%)	0.173	0.171	-0.002 (-1%)	0.175	0.172	-0.003 (-2%)	0.173	0.164	-0.009 (-5%)	0.159	0.162	0.003 (2%)	0.159	0.161	0.002 (1%)	0.171	0.169	-0.002 (-1%)
	BN	0.177	0.173	-0.004 (-2%)	0.168	0.164	-0.004 (-2%)	0.169	0.169	0.000 (0%)	0.165	0.164	-0.001 (-1%)	0.158	0.162	0.004 (3%)	0.158	0.161	0.003 (2%)	0.167	0.167	0.000 (0%)
	D	0.171	0.170	-0.001 (-1%)	0.167	0.166	-0.001 (-1%)	0.165	0.165	0.000 (0%)	0.162	0.163	0.001 (1%)	0.158	0.161	0.003 (2%)	0.158	0.160	0.002 (1%)	0.166	0.164	-0.002 (-1%)
	C	0.166	0.165	-0.001 (-1%)	0.166	0.166	0.000 (0%)	0.163	0.163	0.000 (0%)	0.157	0.159	0.002 (1%)	0.155	0.156	0.001 (1%)	0.156	0.158	0.002 (1%)	0.161	0.161	0.000 (0%)

For the San Joaquin River, the assumption of 50% closure of the PA's HOR gate from January to June 15, subject to RTO adjustments, led to appreciably less flow (~30-50%) entering Old River under the PA compared to NAA (Table 5.4-12). For Turner Cut, the next downstream junction, the proportion of flow entering the junction generally was greater under PA than NAA (median by water year type up to 11% greater, or 0.02 in absolute value), reflecting more flow remaining in the river main stem because of the HOR gate; this is consistent with the observations of Cavallo et al. (2015), who estimated (based on DSM2-HYDRO modeling) that more fish would enter the HOR with higher flow—for the PA, the flow that otherwise would have gone into Old River progresses to Turner Cut, thus producing a similar effect at that location. With movement downstream to other junctions, differences in flow routing into the junctions between NAA and PA were less which, as noted by Cavallo et al. (2015) reflects greater tidal influence; where lower proportions of flow entered the junctions under PA, this probably reflected less south Delta export pumping than NAA.

Overall, the analysis suggested that juvenile salmonids migrating down the Sacramento River would have somewhat greater potential to enter the interior Delta through Georgiana Slough, potentially resulting in adverse effects from the relatively low survival probability in that migration route. Minimization of this adverse effect would be undertaken with the installation of a nonphysical barrier at the Georgiana Slough junction (discussed in the next section). As previously noted, the summary of Delta hydrodynamic conditions based on DSM2 does not account for real-time operations that would be done in order to limit potential operational effects, by assessing flow conditions in the context of fish presence. Juvenile salmonids migrating down the San Joaquin River would, based on flow routing, potentially benefit from a HOR gate, which would considerably reduce entry into Old River and therefore reduce entrainment at the south Delta export facilities. Effects of the HOR gate in terms of near-field effects were discussed in Section 5.4.1.3.1.1.3, *Head of Old River Gate*.

5.4.1.3.1.2.1.2.2 Nonphysical Fish Barrier at Georgiana Slough

Installation of a nonphysical fish barrier at the Georgiana Slough junction would aim to minimize the potential for increased entry of fish into the junction caused by hydrodynamic changes because of the NDD, as described above. The probability of entry into Georgiana Slough is positively related to the location of the critical streakline, which is the streamwise division of flow vectors between the Sacramento River and Georgiana Slough (Perry et al. 2014). Occurrence of juvenile salmonids on the Sacramento River side of the critical streakline reduces the probability of entry into Georgiana Slough, so nonphysical barriers are installed such that their position increases the probability of juvenile salmonids remaining on the Sacramento River side of the critical streakline. The two types of nonphysical barrier with greatest potential for use at this junction are the Bioacoustic Fish Fence (BAFF) and Floating Fish Guidance Structure (FFGS); both have been tested at this location. A BAFF consists of acoustic deterrence stimuli broadcast from loudspeakers and contained within a bubble curtain that is illuminated with strobe lights (to allow the fish to orient away from the sound stimulus better). A BAFF was tested at Georgiana Slough in 2011 and 2012, using acoustically tagged juvenile salmonids. It was found that BAFF operations in 2011 reduced entry of late fall-run Chinook salmon into Georgiana Slough from 22.1% (0.221) to 7.4% (0.074), a reduction of around two thirds, and that operations in 2012 reduced entry of late fall-run Chinook salmon from 24.2% (0.242) to 11.8% (0.118), or a reduction of approximately half, with a similar reduction for steelhead (26.4% to 11.6%) (see summary by California Department of Water Resources 2015b: 3-11 to 3-

14). There is therefore potential to minimize adverse effects of hydrodynamic effects of the PA, given that the analysis of flow routing into Georgiana Slough based on DSM2-HYDRO data suggested potential increases in median proportional flow entry of up to 11-12% (see Table 5.4-12 in Section 5.4.1.3.1.2.1.2.1, *Flow Routing into Channel Junctions)* and some of the results of the through-Delta survival analyses show lower potential survival under the PA because of flow-survival relationships (see Section 5.4.1.3.1.2.1.3, *Through-Delta Survival*). Perry et al. (2013) illustrated that through-Delta survival of acoustically tagged juvenile late fall-run Chinook salmon could proportionally increase by 10-35% if interior Delta entry was eliminated, based on data for five of six releases they examined. This suggests that if an NPB reduced the probability of juvenile Chinook salmon taking the interior Delta pathway through Georgiana Slough by 50% (the lower of the two overall BAFF effectiveness estimates from 2011 and 2012), this could result in ~5-17% greater through-Delta survival.

However, it is important to consider several important limitations of the BAFF testing. First, the tested Chinook salmon were larger individuals (e.g., 110-140-mm fork length in 2011), which may result in better swimming ability and effectiveness of the BAFF relative to the smaller sizes of winter-run and spring-run Chinook salmon that would encounter the BAFF. Second, all fish were hatchery-raised, and therefore may have behaved differently than wild fish would in relation to a BAFF. Last, river flow in 2011 was very high, resulting in largely unidirectional, downstream flow, which could have improved BAFF effectiveness; however, the more variable flow conditions in 2012, including periods of reverse flow, illustrated that the BAFF has potential to be effective across a variety of environmental conditions if an engineering solution is desired.

In contrast to the BAFF, the FFGS tested at Georgiana Slough in 2014 showed limited effectiveness. At intermediate discharge (200-400 m^3/s; ~7,000-14,000 cfs), juvenile Chinook salmon entry into Georgiana Slough was five percentage points lower when the FFGS was turned on[25] (19.1% on; 23.9% off) (Romine et al. 2016). At higher discharge (>400 m^3/s), entry into Georgiana Slough was higher when the FFGS was turned on (19.3% on; 9.7% off), and at lower discharge (0-200 m^3/s) entry into Georgiana Slough was lower when the FFGS was turned on (43.7% on; 47.3% off). Overall entry into Georgiana Slough was 22% with the FFGS turned on, and 23% with the FFGS turned off. The results of the FFGS effectiveness study, coupled with the complex hydrodynamics of the Sacramento River-Georgiana Slough junction, suggest that dynamic deployment of an FFGS should be considered (Romine et al. 2016). For example, the greater entry into Georgiana Slough at higher flows could have been caused by turbulence around the structure, which could be decreased by angling the FFGS more toward shore at higher flows. Intermediate orientations, angles, lengths, and depths of FFGS could have resulted in different results. Overall, the results of the 2014 FFGS study suggest that this technology was less effective than the BAFF.

Effects of nonphysical barrier construction and near-field predation are discussed in Section 5.5.3, *Georgiana Slough Nonphysical Fish Barrier*.

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[25] In this study, “on” = FFGS angled towards the river channel to guide downstream-migrating juvenile Chinook salmon to the Sacramento River side of the critical streakline, “off” = FFGS angled parallel to the river bank in order to minimize any potential guiding effects (i.e., to provide a contrast to the “turned on” position).

5.4.1.3.1.2.1.3 Through-Delta Survival

Various analytical tools were used to provide greater biological context for the previously described operations-related differences in Delta hydrodynamics between the NAA and PA. These included the Delta Passage Model; analyses based on Newman (2003) and Perry (2010); the winter-run Chinook salmon life cycle models, IOS and OBAN; and the SalSim Through-Delta Survival Function. This section describes the principal results of these analyses. The tools were all focused on Chinook salmon, but the inferences from the results may be applicable to juvenile steelhead, given that there are similarities between Chinook salmon and steelhead with respect to at least some features of their Delta ecology (e.g., losses in Clifton Court Forebay [Gingras 1997; Clark et al. 2009] and relative loss by migration pathways through the Delta [Singer et al. 2013]) and their migration timing overlaps that of the listed juvenile Chinook salmon.

5.4.1.3.1.2.1.3.1 Delta Passage Model: Winter-Run and Sacramento River Basin Spring-Run Chinook Salmon

The Delta Passage Model (DPM) integrates operational effects of the NAA and PA that could influence survival of migrating juvenile winter-run and Sacramento River basin spring-run Chinook salmon through the Delta: differences in channel flows (flow-survival relationships), differences in routing based on flow proportions (e.g., entry into the interior Delta, where survival is lower), and differences in south Delta exports (export-survival relationships). Details of the DPM analysis are provided in Appendix 5.D, *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale*, Section 5.D.1.2.2, *Delta Passage Model*. As with all such modeling tools, the DPM does not account for the results of the coordinated monitoring and research under the Adaptive Management Program and real-time operational adjustments that would occur in relation to fish presence, for example. The analysis was not applied to San Joaquin River basin spring-run Chinook salmon because the results for San Joaquin River fall-run Chinook salmon illustrate that the DPM results are influenced by proposed PA operations that are very different than those that have been observed in reality and upon which the modeled relationships are based (see Appendix 5.E., *Essential Fish Habitat*, Section 5.E.5.3.1.2.1.2.1, *Indirect Mortality within the Delta*). Instead, the SalSim through-Delta survival function was applied for estimating potential San Joaquin River basin spring-run Chinook salmon through-Delta survival (see Section 5.4.1.3.1.2.1.3.5, *SalSim Through-Delta Survival Function: San Joaquin River Basin Spring-Run Chinook Salmon*).

For winter-run Chinook salmon, the DPM results suggested that total through-Delta survival would be similar or lower under the PA than the NAA (Figure 5.4-8 and Figure 5.4-9). Mean total through-Delta survival under the PA ranged from 0.24 in critical years to 0.43 in wet years, with a range of 2% less than NAA in wet and above normal years to 7% less in dry years (Table 5.4-13). Mean survival down the mainstem Sacramento River route under the PA ranged from 0.26 in critical years to 0.46 in wet years, and the difference from NAA ranged from 4% less in critical years to 8% less in below normal and dry years, reflecting the influence of less river flow downstream of the NDD under the PA. As would be expected given that both scenarios assumed a notched Fremont Weir, Yolo Bypass entry was very similar between NAA and PA scenarios, and survival was identical (because the random draws from the route-specific survival distribution [Appendix 5.D, *Quantitative Methods and Detailed Results for Effects Analysis of*

Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale, Section 5.D.1.2.2.2.5.4, *Route-Specific Survival*] were the same for NAA and PA). A slightly lower (1-2%) proportion of fish entered Sutter and Steamboat Sloughs under the PA compared to NAA (reflecting the flow routing into junctions; see Table 5.4-12 in Section 5.4.1.3.1.2.1.2.1, *Flow Routing into Channel Junctions*), and the difference in mean survival for this route between PA and NAA was similar to that of the mainstem Sacramento River, reflecting the similar flow-survival relationships in the relevant reaches (see Appendix 5.D, *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale,* Section 5.D.1.2.2.2.5.5, *Flow-Dependent Survival*). A slightly greater (1-2%[26]) proportion of fish used the interior Delta migration route under the PA compared to NAA (again reflecting the flow routing into junctions; see Table 5.4-12- in Section 5.4.1.3.1.2.1.2.1, *Flow Routing into Channel Junctions*), and mean survival in this route was appreciably greater (19-28%) in wet and above normal years, which reflected appreciably less south Delta exports under the PA[27].

Seventy-five randomized iterations of the DPM allowed 95% confidence intervals to be calculated for the annual estimates of through-Delta survival (Appendix 5.D, *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale,* Section 5.D.1.2.2.4, *Randomization to Illustrate Uncertainty*); of the 81 years in the simulation, the PA and NAA had non-overlapping confidence intervals in 10 years and all were lower under the PA (Figure 5.4-10). Of the 10 years, 3 were wet years (12% of all wet years), 1 was an above normal year (8% of all above normal years), 2 were below normal years (18% of all below normal years), 4 were dry years (20% of all dry years), and none were critical years. This suggests that the magnitudes of difference observed from the DPM would be most likely to be statistically detectable in below normal or dry years, although it is acknowledged that the DPM incorporates flow-survival and other relationships from a variety of studies and its measures of uncertainty are drawn from these relationships[28]; an integrated field study of through-Delta survival during PA implementation

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[26] To provide perspective on the actual number of fish that the 1-2% entering the interior Delta would represent, estimates of the number of juveniles entering the Delta are necessary. Such numbers are calculated on an annual basis by NMFS for the purposes of calculating allowable incidental take of winter-run Chinook salmon. NMFS estimated that between c. 124,500 and 3,739,000 juvenile winter-run Chinook salmon entered the Delta annually over the past decade (data from the NMFS [2014] Floating Fish Guidance Structure BiOp, plus updates for 2015 based on the 2016 NMFS letter to Reclamation estimating the JPE [Available: http://www.westcoast.fisheries.noaa.gov/publications/Central_Valley/Water%20Operations/winter-run_juvenile_production_estimate__jpe__-_january_28__2016.pdf, accessed March 11, 2016]).

[27] In addition, the DPM's export-survival relationship does not calculate absolute survival, but a ratio of survival in the interior Delta to survival in reach Sac3 (Appendix 5.D, *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale*, Section 5.D.1.2.2.2.5.6, *Export-Dependent Survival*), and in wetter years the difference in survival in reach Sac3 between NAA and PA begins to level off as the flow-survival relationship begins to asymptote (Figure 5.D-45 in Appendix 5.D), so that less south Delta exports have a greater effect on survival at greater Sacramento River flows.

[28] As noted in the independent review panel report for the working draft BA, it is possible that the true annual values could lie near the bottom boundary of the confidence interval for PA and near the top boundary of the confidence interval for NAA (Simenstad et al. 2016). This would result in greater differences than suggested by the comparison of annual mean values. By the same rationale, it is also possible that the true annual values could lie near the top boundary of the confidence intervals for both PA and NAA, in which case the differences would be more similar to the differences between means.

would not necessarily have similar uncertainty in survival estimates. In addition, the operations modeling included a wider range of conditions than occurred during the field studies upon which the DPM model relationships were based, which contributes to the uncertainty. To provide insight into the conditions leading to years with non-overlapping confidence intervals, mean flow into reach Sac 3 (Sacramento River downstream of Georgiana Slough)[29] and south Delta exports, both weighted by proportion of the population entering the Delta, were plotted in relation to years with overlapping confidence intervals. This illustrated that years with non-overlapping confidence intervals were found in the range of weighted mean Sacramento River flow into reach Sac3 of ~7,000-12,500 cfs for NAA and ~5,500-10,000 cfs for PA (Figure 5.4-11). This corresponds closely with weighted mean flows in below normal years (NAA: 7,826 cfs; PA: 6,687 cfs) and dry years (NAA: 7,116 cfs; PA: 6,048 cfs), which is logical given that these had the greatest differences in survival (Table 5.4-13). In years with less flow, there are greater constraints on north Delta exports, whereas in wetter years, the rate of change in survival per unit of river flow decreases (Figure 5.D-45 in Appendix 5.D, *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale*). Therefore, there would be the greatest potential for adverse effects in below normal and dry years. As previously stated this analysis does not account for the results of the coordinated monitoring and research under the Adaptive Management Program and real-time operational adjustments that would be made in response to fish presence, which would seek to maximize water supplies while limiting potential adverse effects as appropriate to avoid jeopardy.

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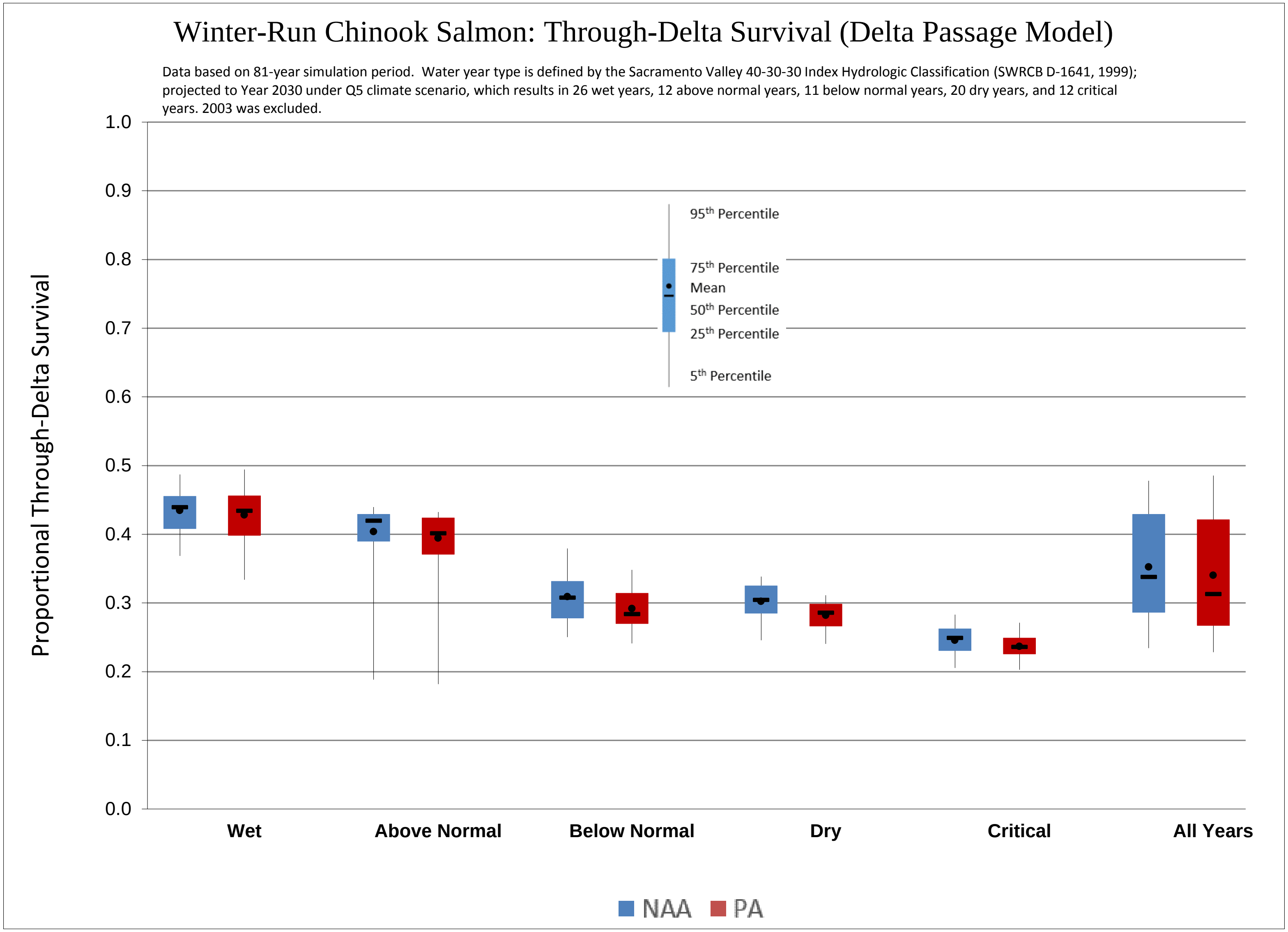
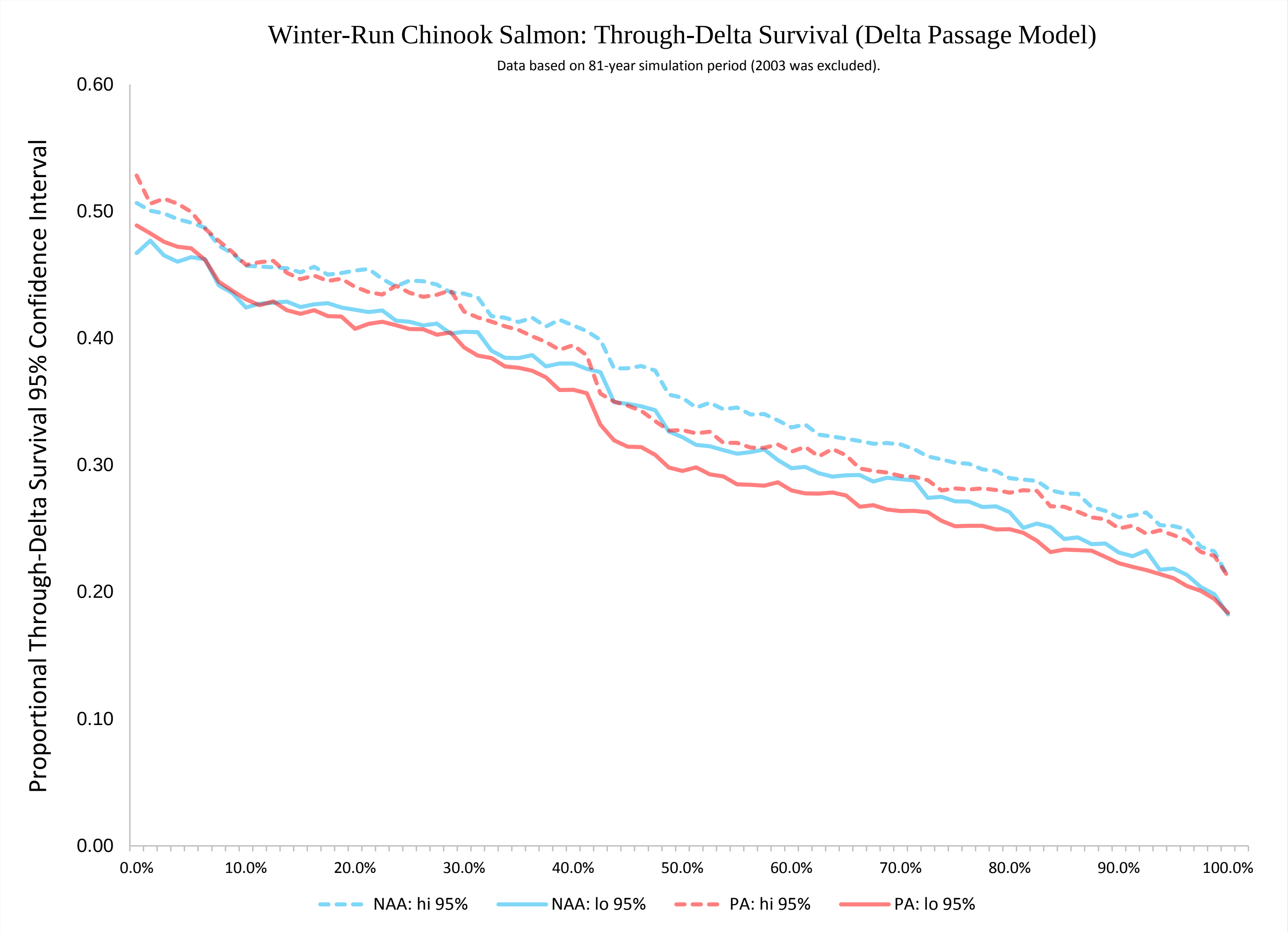
[29] This reach was chosen because it is the basis for the Sacramento River flow-survival relationships in the DPM, from Perry (2010).



Note: Plot only includes annual mean responses and does not consider model uncertainty.

Figure 5.4-8. Box Plots of Winter-Run Chinook Salmon Annual Through-Delta Survival Estimated from the Delta Passage Model, Grouped by Water Year Type.



Note: Data are sorted by mean estimate, with only 95% confidence intervals shown.

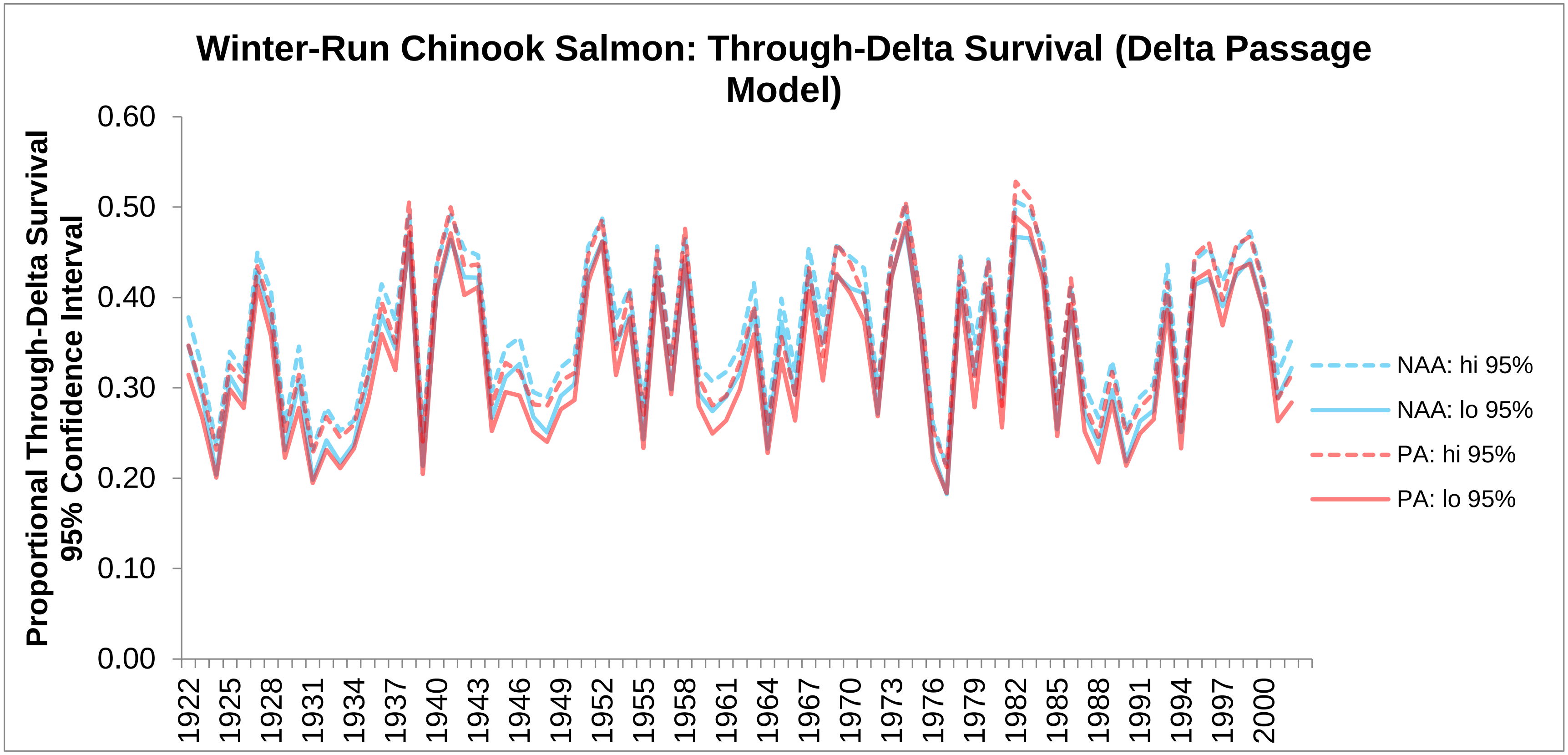
Figure 5.4-9. Exceedance Plot of Winter-Run Chinook Salmon Annual Through-Delta Survival Estimated from the Delta Passage Model.

Table 5.4-13. Delta Passage Model: Winter-Run Chinook Salmon Mean Through-Delta (Total) Survival, Mainstem Sacramento River survival, and Proportion Using and Surviving Other Migration Routes.

WY	Total Survival			Mainstem Sacramento River Survival			Yolo Bypass					
							Proportion Using Route			Survival		
	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
W	0.43	0.43	-0.01 (-2%)	0.48	0.46	-0.02 (-5%)	0.22	0.22	0.00 (1%)	0.47	0.47	0.00 (0%)
AN	0.40	0.39	-0.01 (-2%)	0.44	0.42	-0.02 (-6%)	0.16	0.17	0.00 (1%)	0.47	0.47	0.00 (0%)
BN	0.31	0.29	-0.02 (-6%)	0.34	0.31	-0.03 (-8%)	0.06	0.06	0.00 (2%)	0.47	0.47	0.00 (0%)
D	0.30	0.28	-0.02 (-7%)	0.33	0.30	-0.03 (-8%)	0.06	0.06	0.00 (2%)	0.47	0.47	0.00 (0%)
C	0.25	0.24	-0.01 (-4%)	0.27	0.26	-0.01 (-4%)	0.03	0.03	0.00 (0%)	0.47	0.47	0.00 (0%)

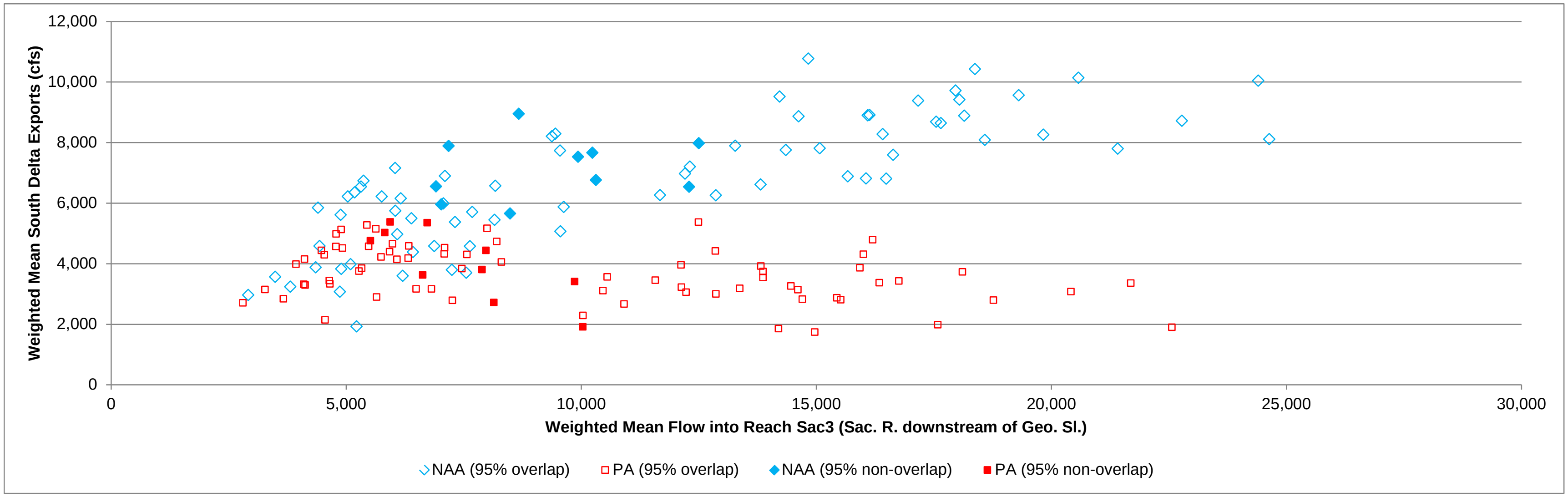
WY	Sutter/Steamboat Sloughs						Interior Delta (Via Georgiana Slough/DCC)					
	Proportion Using Route			Survival			Proportion Using Route			Survival		
	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
W	0.29	0.28	-0.01 (-2%)	0.52	0.50	-0.02 (-4%)	0.26	0.26	0.00 (2%)	0.18	0.23	0.05 (28%)
AN	0.30	0.29	-0.01 (-2%)	0.49	0.46	-0.02 (-5%)	0.26	0.27	0.01 (2%)	0.17	0.20	0.03 (19%)
BN	0.31	0.30	-0.01 (-2%)	0.38	0.35	-0.03 (-7%)	0.27	0.28	0.01 (2%)	0.14	0.15	0.01 (5%)
D	0.30	0.30	-0.01 (-2%)	0.37	0.34	-0.03 (-8%)	0.27	0.28	0.01 (2%)	0.14	0.14	0.00 (0%)
C	0.29	0.29	0.00 (-1%)	0.31	0.30	-0.01 (-4%)	0.29	0.29	0.00 (1%)	0.13	0.12	0.00 (-1%)

Note: Survival in Sutter/Steamboat Sloughs and Interior Delta routes includes survival in the Sacramento River prior to entering the channel junctions.



Note: Lines indicate 95% confidence intervals from the 75 iterations of the DPM.

Figure 5.4-10. Time Series of 95% Confidence Interval Annual Juvenile Winter-Run Chinook Salmon Through-Delta Survival Estimated from the Delta Passage Model.



Note: 95% overlap and non-overlap refers to years with overlapping and non-overlapping confidence intervals from DPM.

Figure 5.4-11. Delta Passage Model: Annual mean Sacramento River Flow into Reach Sac3 (Downstream of Georgiana Slough) and South Delta Exports, Weighted by Proportional Entry into the Delta of Winter-Run Chinook Salmon, Classified into Years of Overlapping and Non-overlapping Through-Delta Survival 95% Confidence Intervals.

For spring-run Chinook salmon, the DPM results suggested that through-Delta survival under the PA would be similar to or lower than the NAA (Figure 5.4-12 and Figure 5.4-13), with the differences being less than those for winter-run Chinook salmon. Mean total through-Delta survival under the PA ranged from 0.22 in critical years to 0.42 in wet years, with a range of 1% less than NAA in wet and critical years to 4% less in dry years (Table 5.4-14). Mean survival down the mainstem Sacramento River route under the PA ranged from 0.23 in critical years to 0.44 in wet years, and the difference from NAA ranged from 1% less in critical years to 5% less in above normal and dry years, reflecting the influence of less river flow downstream of the NDD under the PA. Yolo Bypass entry was similar between NAA and PA scenarios (both assumed a notched weir), and survival was identical (because the random draws from the route-specific survival distribution [Appendix 5.D, *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale,* Section 5.D.1.2.2.2.5.4, *Route-Specific Survival*] were the same for NAA and PA). A slightly lower (0-2%) proportion of fish entered Sutter and Steamboat Sloughs under the PA compared to NAA (reflecting the flow routing into junctions; see Table 5.4-12 in Section 5.4.1.3.1.2.1.2.1, *Flow Routing into Channel Junctions*), and the difference in mean survival for this route between PA and NAA was similar to that of the mainstem Sacramento River, reflecting the similar flow-survival relationships in the relevant reaches (Appendix 5.D, *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale,* Section 5.D.1.2.2.2.5, *Flow-Dependent Survival*). A similar or slightly greater (1-2%) proportion of fish used the interior Delta migration route under the PA compared to NAA (again reflecting the flow routing into junctions; see Table 5.4-12 in Section 5.4.1.3.1.2.1.2.1, *Flow Routing into Channel Junctions*), and mean survival in this route was greater (11–19%) in wet and above normal years, which reflected appreciably less south Delta exports under the PA.

As noted for winter-run Chinook salmon, seventy-five randomized iterations of the DPM allowed 95% confidence intervals to be calculated for the annual estimates of through-Delta survival (Appendix 5.D, *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale,* Section 5.D.1.2.2.4, *Randomization to Illustrate Uncertainty*). The 95% confidence intervals for NAA and PA overlapped in all years (Figure 5.4-14), illustrating that the magnitude of differences may be difficult to detect statistically if field studies were undertaken during PA implementation to assess effects[30]. The spring-run Chinook salmon DPM results suggested small differences in survival under the PA compared to NAA, whereas the analysis based on Newman (2003) (discussed in the next section) suggested that differences in survival would be largely undetectable (despite the Delta same entry timing being used for both). This reflects model differences (with further discussion being provided for the analysis based on Newman [2003] in the next section): in the DPM, the benefits of less south Delta exports under the PA are only experienced by the proportion of the population entering the interior Delta (0.25-0.30 take this route), whereas for the analysis based on Newman (2003), the effect of exports is applied to the

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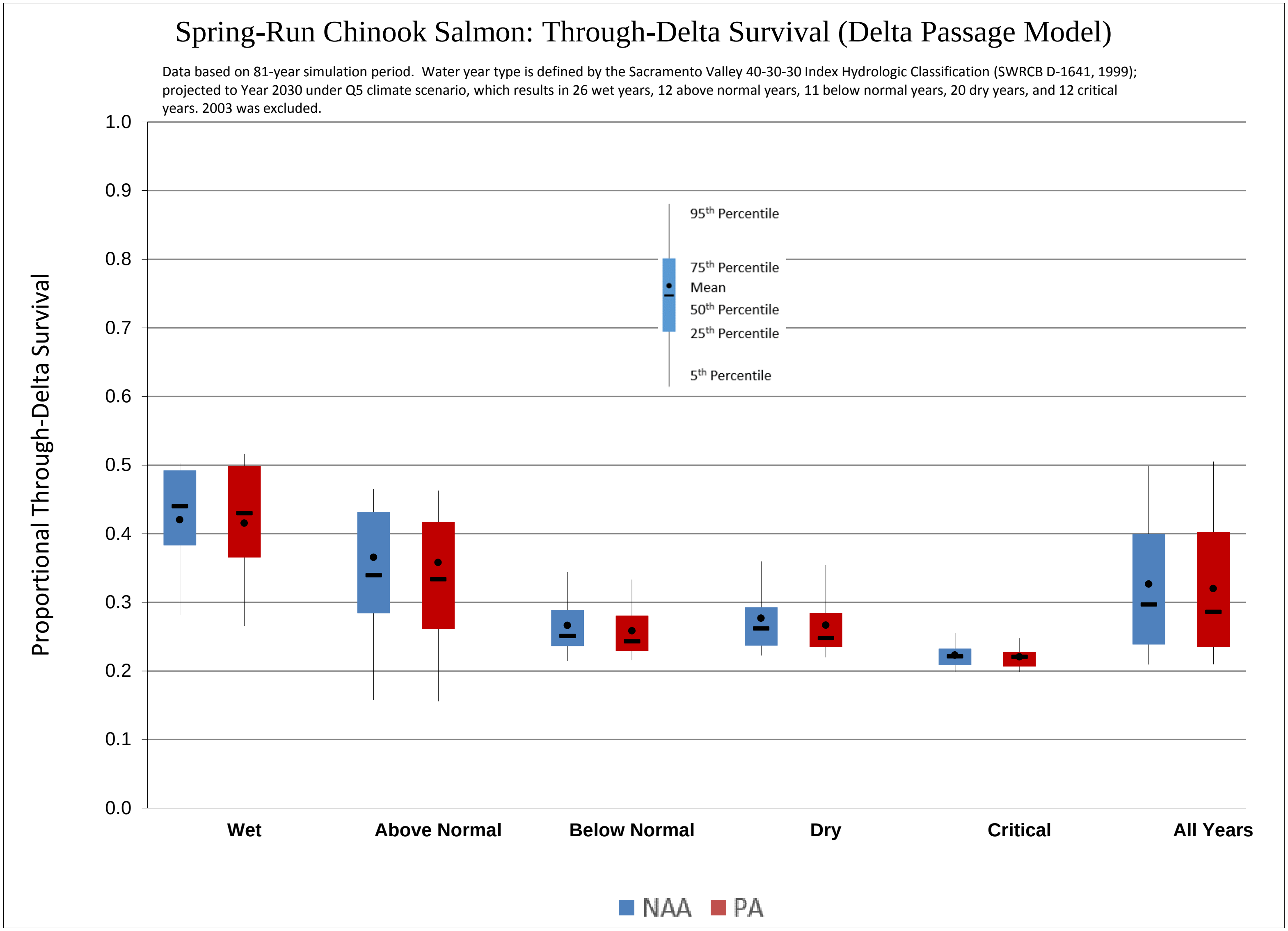
[30] As noted for winter-run Chinook salmon, it is acknowledged that the DPM incorporates flow-survival and other relationships from a variety of studies and its measures of uncertainty are drawn from these relationships; an integrated field study of through-Delta survival during PA implementation would not necessarily have similar uncertainty in survival estimates.

entire population; and in the DPM, the export-survival effect is weaker than the flow-survival effect (Model Demonstration results in Appendix 5.D, *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale*, Section 5.D.1.2.2.5.2.3, *Model Demonstration*) and is calculated as a ratio of survival in reach Sac3 (which is lower because of the NDD), whereas as discussed in the following section, in the analysis based on Newman (2003) the export-survival effect is similar in magnitude to the flow-survival effect—the “offsetting” of south and north Delta exports results in similar survival under PA and NAA for the analysis based on Newman (2003). Further discussion of these issues and the Sacramento River flow and south Delta exports during the spring-run Chinook salmon migration period used for the DPM are provided in the analysis based on Newman (2003), which is found in the next section. Overall, the DPM results suggested the potential for a small negative effect on spring-run Chinook salmon juveniles from the PA but, as previously stated for winter-run Chinook salmon, this analysis does not account for the results of the coordinated monitoring and research under the Adaptive Management Program and real-time operational adjustments that would be made in response to fish presence, which would seek to maximize water supplies while limiting potential adverse effects as appropriate to avoid jeopardy.

Table 5.4-14. Delta Passage Model: Spring-Run Chinook Salmon Mean Through-Delta (Total) Survival, Mainstem Sacramento River survival, and Proportion Using and Surviving Other Migration Routes.

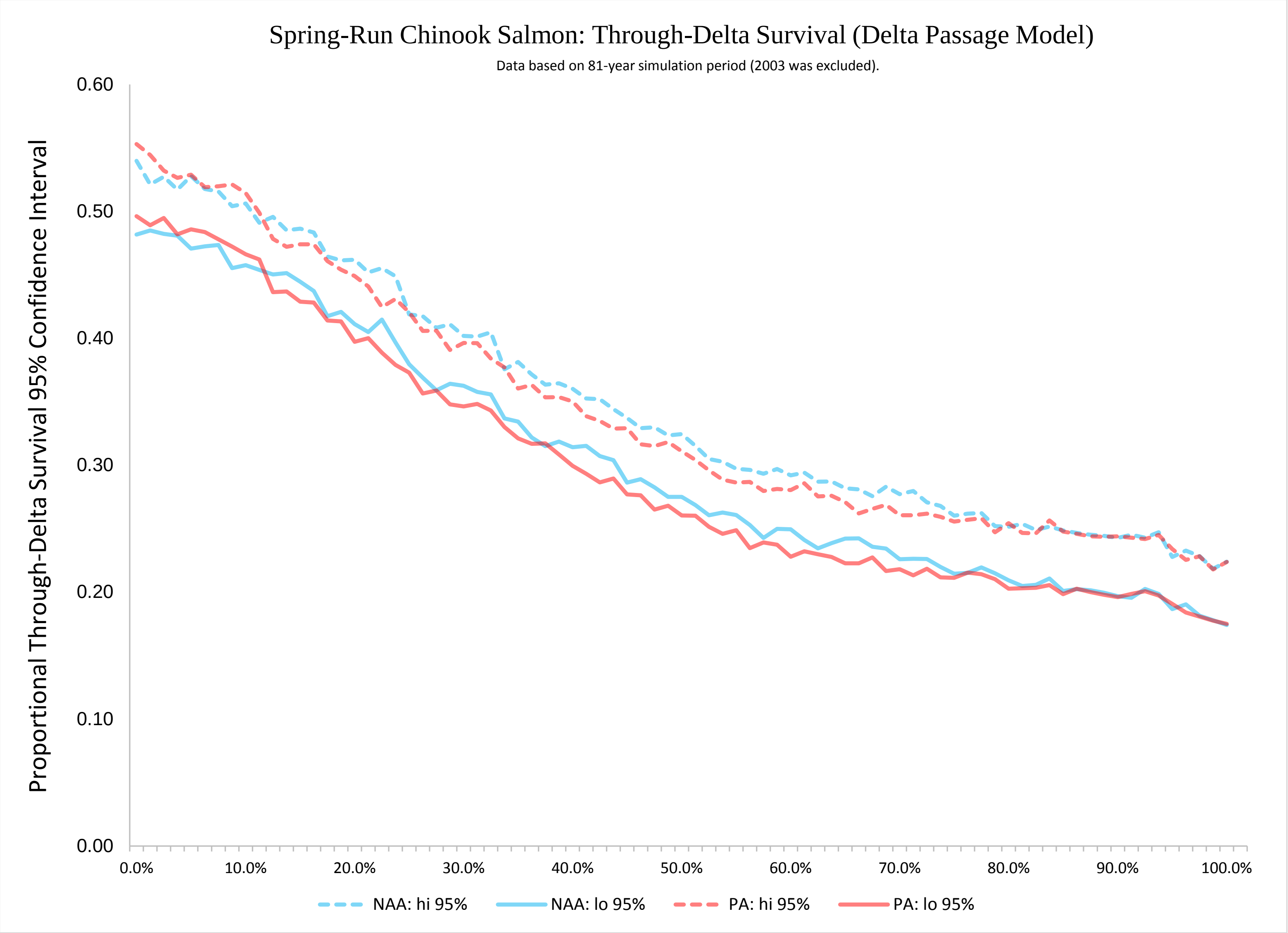
WY	Total Survival			Mainstem Sacramento River Survival			Yolo Bypass					
							Proportion Using Route			Survival		
	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
W	0.42	0.42	0.00 (-1%)	0.46	0.44	-0.02 (-4%)	0.19	0.19	0.00 (1%)	0.47	0.47	0.00 (0%)
AN	0.37	0.36	-0.01 (-2%)	0.39	0.37	-0.02 (-5%)	0.13	0.14	0.01 (5%)	0.47	0.47	0.00 (0%)
BN	0.27	0.26	-0.01 (-3%)	0.29	0.28	-0.01 (-4%)	0.04	0.04	0.00 (-2%)	0.47	0.47	0.00 (0%)
D	0.28	0.27	-0.01 (-4%)	0.30	0.28	-0.01 (-5%)	0.05	0.05	0.00 (-1%)	0.47	0.47	0.00 (0%)
C	0.22	0.22	0.00 (-1%)	0.24	0.23	0.00 (-1%)	0.03	0.03	0.00 (-2%)	0.47	0.47	0.00 (0%)
WY	Sutter/Steamboat Sloughs						Interior Delta (Via Georgiana Slough/DCC)					
	Proportion Using Route			Survival			Proportion Using Route			Survival		
	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
W	0.29	0.28	0.00 (-1%)	0.50	0.48	-0.02 (-4%)	0.26	0.26	0.00 (1%)	0.21	0.25	0.04 (19%)
AN	0.29	0.29	-0.01 (-2%)	0.43	0.41	-0.02 (-4%)	0.27	0.27	0.00 (1%)	0.19	0.21	0.02 (11%)
BN	0.30	0.30	0.00 (-1%)	0.32	0.31	-0.01 (-4%)	0.28	0.28	0.00 (1%)	0.15	0.15	0.00 (2%)
D	0.30	0.29	0.00 (-1%)	0.34	0.32	-0.01 (-4%)	0.28	0.28	0.00 (1%)	0.15	0.15	0.00 (1%)
C	0.28	0.28	0.00 (0%)	0.28	0.27	0.00 (-1%)	0.30	0.30	0.00 (0%)	0.13	0.13	0.00 (1%)

Note: Survival in Sutter/Steamboat Sloughs and Interior Delta routes includes survival in the Sacramento River prior to entering the channel junctions.



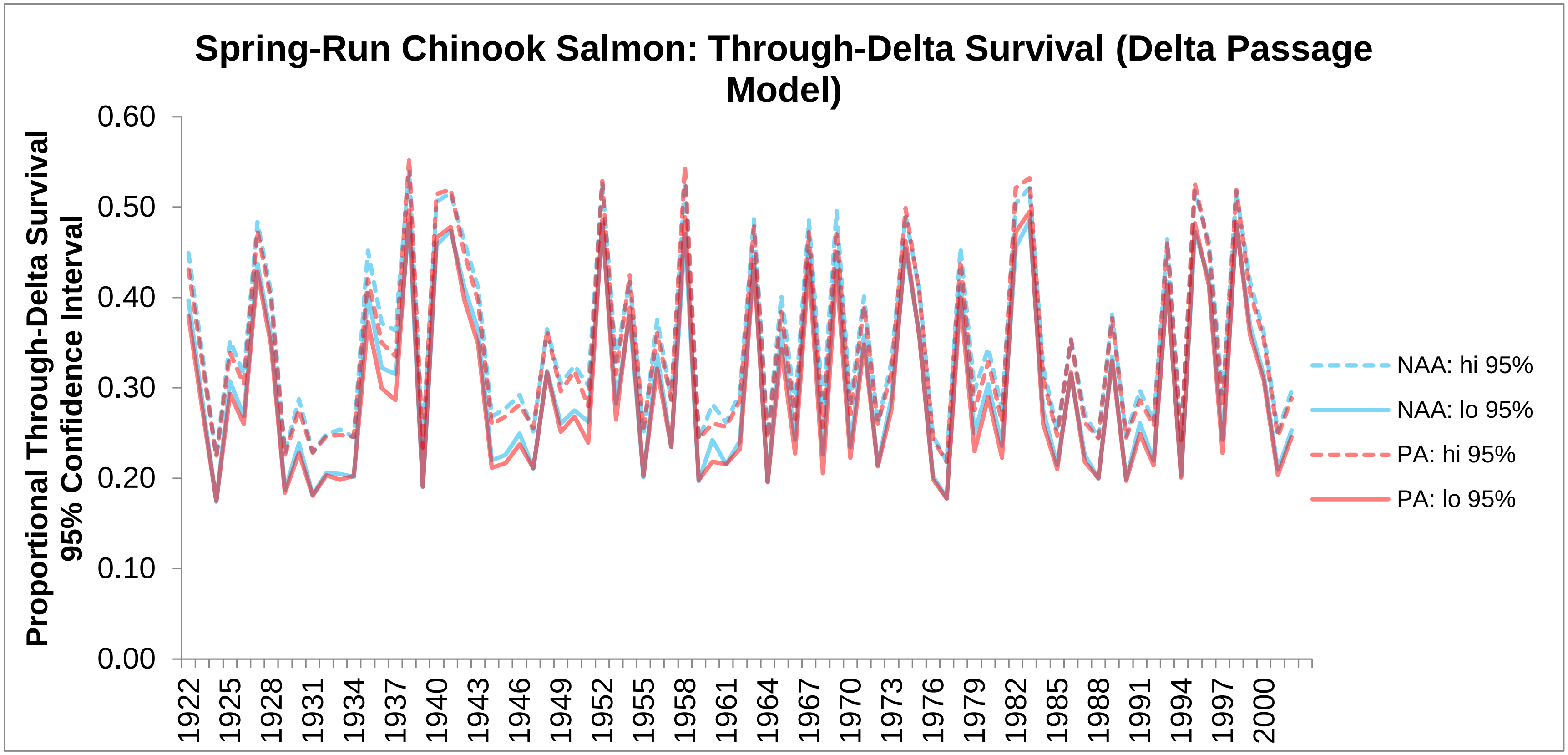
Note: Plot only includes annual mean responses and does not consider model uncertainty.

Figure 5.4-12. Box Plots of Spring-Run Chinook Salmon Annual Through-Delta Survival Estimated from the Delta Passage Model, Grouped by Water Year Type.



Note: Data are sorted by mean estimate, with only 95% confidence intervals shown.

Figure 5.4-13. Exceedance Plot of Spring-Run Chinook Salmon Annual Through-Delta Survival Estimated from the Delta Passage Model.



Note: Lines indicate 95% confidence intervals from the 75 iterations of the DPM.

Figure 5.4-14. Time Series of 95% Confidence Interval Annual Juvenile Spring-Run Chinook Salmon Through-Delta Estimated from the Delta Passage Model.

5.4.1.3.1.2.1.3.2 Analysis Based on Newman (2003): Sacramento River Spring-Run Chinook Salmon

In addition to the DPM, an analysis based on Newman (2003) was undertaken to assess the potential effects of the PA on juvenile spring-run Chinook salmon migrating through the Delta from the Sacramento River basin. The method is described further in Appendix 5.D, *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale,* Section 5.D.1.2.3, *Analysis Based on Newman (2003)*, but essentially allows estimation of through-Delta survival as a function of river flow (Sacramento River below the NDD, to capture flow-survival effects), south Delta exports, and other covariates, including salinity, turbidity, DCC position, and water temperature. As noted in Appendix 5.D, the analysis does not include winter-run Chinook salmon because the data used by Newman (2003) were derived from studies of smolts released during the main fall-run/spring-run Chinook salmon migration period, which is after the main winter-run migration period, and the method requires water temperature data. Note that the analysis based on Newman (2003) does not include representation of near-field mortality effects from the NDD (e.g., predation or impingement at the NDD), but instead focuses on far-field effects.

The results of the analysis based on Newman (2003) suggested that difference in overall mean survival between the NAA and PA for spring-run Chinook salmon would be very small across all water year types (Figure 5.4-15, Figure 5.4-16, Figure 5.4-17). When examined by NDD bypass flow level, the minor differences between NAA and PA were also apparent (Table 5.4-15)[31].

The results are driven by several factors. The timing of spring-run Chinook salmon entry into the Delta was assumed to be the same as that used for the DPM, for which entry occurs during spring (March–May), with a pronounced unimodal peak in April (Figure 5.D-42 in Appendix 5.D, *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale*). During April under the PA, south Delta exports and Sacramento River flow downstream of the NDD are similar in their absolute differences from the NAA (Table 5.4-16; for additional south Delta exports information, see also Figures 5.A.6-27-1 to 5.A.6-27-6, Figures 5.A.6-27-7 to 5.A.6-27-19, and Table 5.A.6-27 in Appendix 5.A, *CalSim II Modeling and Results*). In other words, less Sacramento River flow downstream of the NDD is offset by less south Delta exports. The analysis based on Newman (2003) includes a rate of change in juvenile Chinook salmon survival per unit of flow that is similar for the Sacramento River and south Delta exports (see Figure 5.D-61 in Appendix 5.D), so that a similar change in Sacramento River flows (less) and exports (less) results in similar survival, as the analysis showed.[32] As noted in the previous section describing the DPM results, this results in differences in the results compared to DPM results, for which survival under PA was slightly lower than under NAA.

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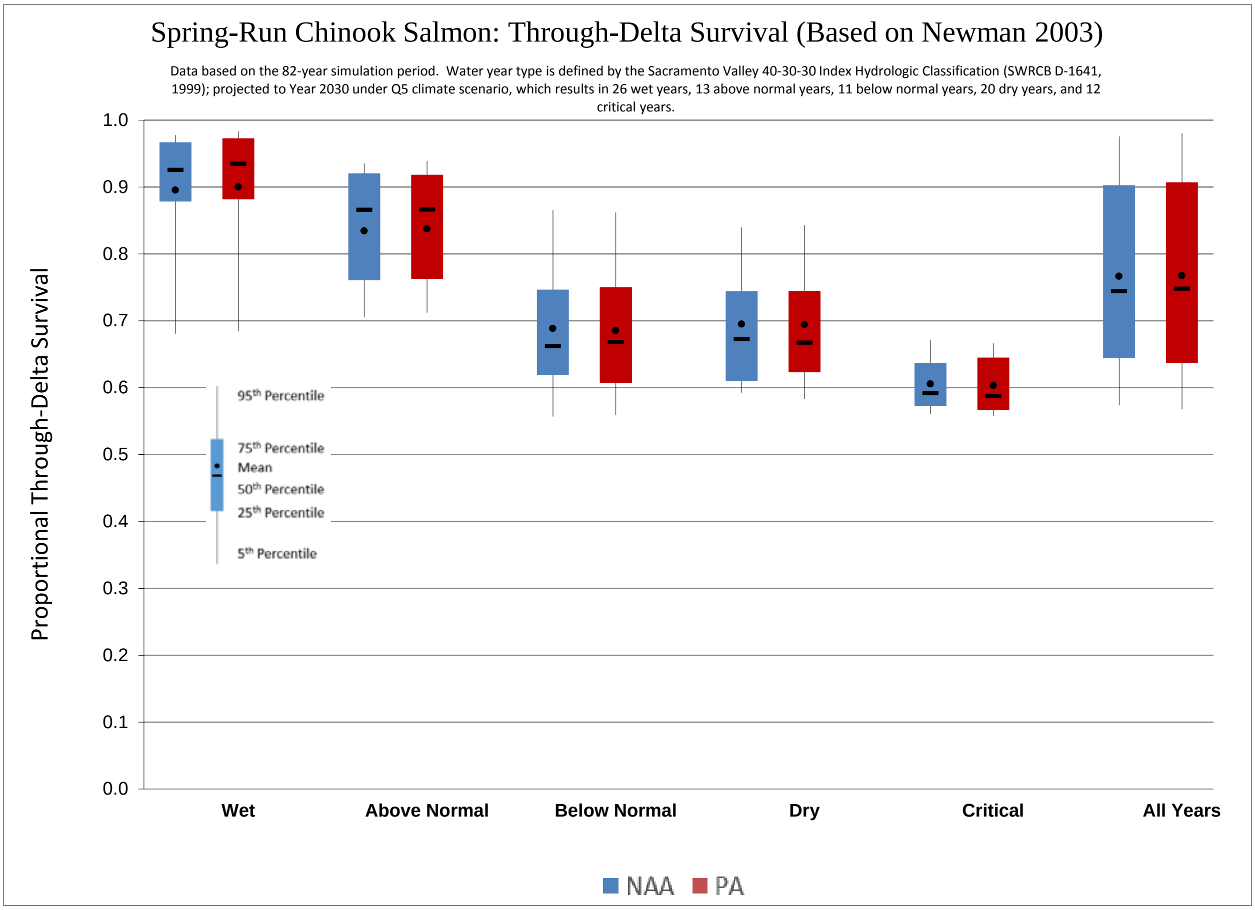
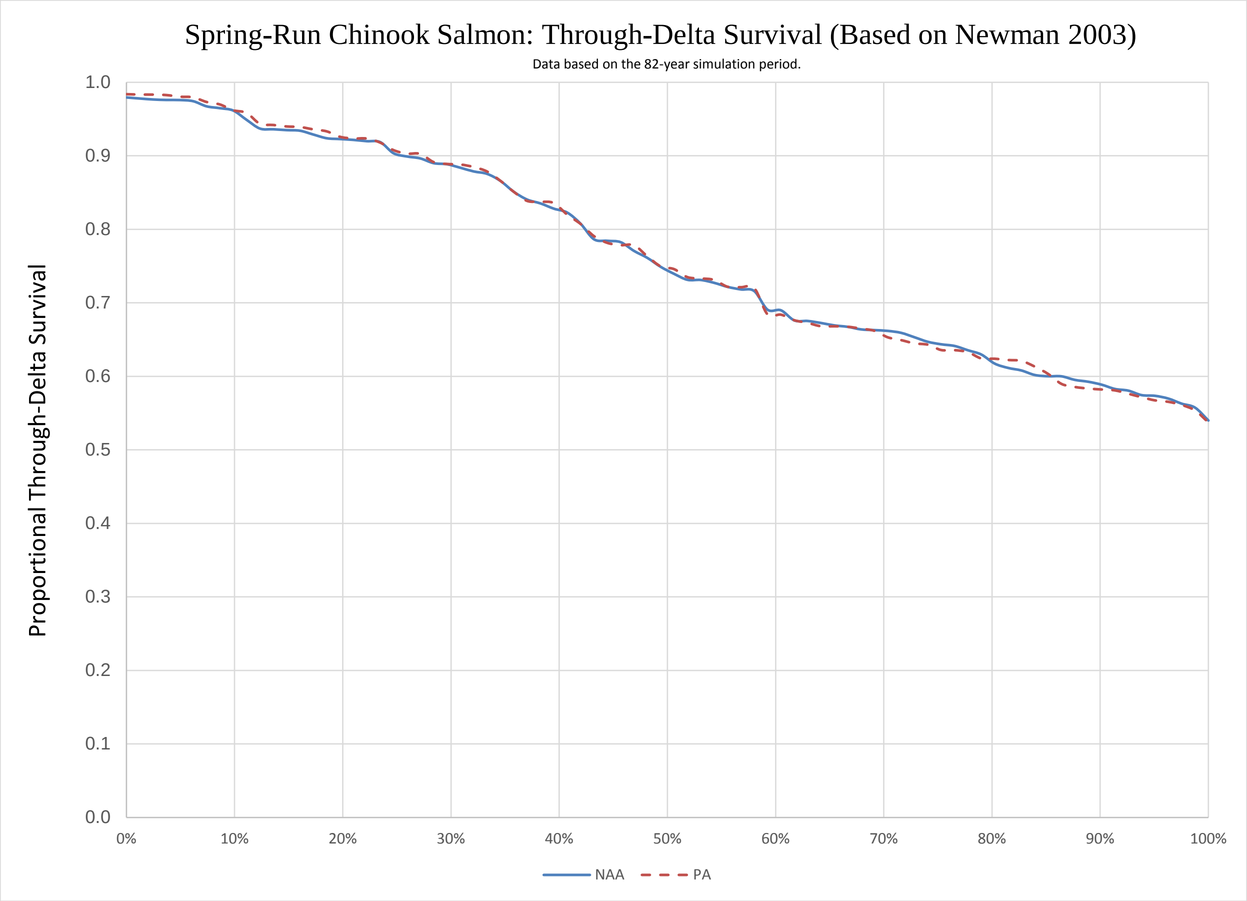
[31] Based on agency request, an unweighted version of these data is presented in Appendix 5.D, *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale*, Section 5.D.1.2.3.3, *Results* (Table 5.D-46), which again shows the similarity between NAA and PA.

[32] The relative effect of south Delta exports and Sacramento River flow downstream of the NDD are illustrated in Figure 5.D-64 in Appendix 5.D, Section 5.D.1.2.3, *Analysis Based on Newman (2003).*



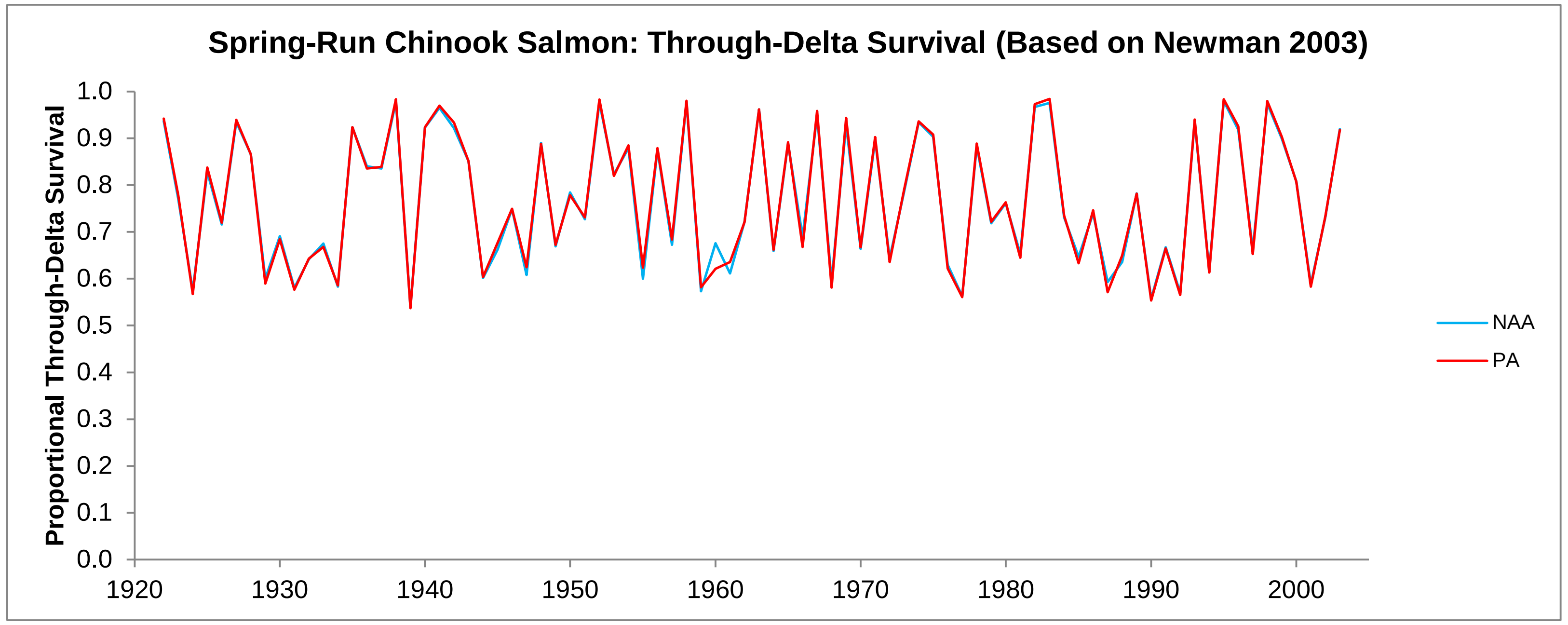
Note: Plot only includes annual mean responses and does not consider model uncertainty.

Figure 5.4-15. Box Plots of Spring-Run Chinook Salmon Annual Through-Delta Survival Estimated from the Analysis Based on Newman (2003), Grouped by Water Year Type.



Note: Plot only includes annual mean responses and does not consider model uncertainty.

Figure 5.4-16. Exceedance Plot of Spring-Run Chinook Salmon Annual Through-Delta Survival Estimated from the Analysis Based on Newman (2003).



Note: Plot only includes annual mean responses and does not consider model uncertainty.

Figure 5.4-17. Time Series of Spring-Run Chinook Salmon Annual Through-Delta Survival Estimated from the Analysis Based on Newman (2003).

Table 5.4-15. Mean Annual Spring-Run Chinook Salmon Weighted Annual Through-Delta Survival Estimated from the Analysis Based on Newman (2003), Divided into Each NDD Bypass Flow Level.

WY	Pulse protection flows			Level 1 bypass flows			Level 2 bypass flows			Level 3 bypass flows			Total		
	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
W	0.00	0.00	0.00 (0%)	0.00	0.00	0.00 (2%)	0.04	0.04	0.00 (1%)	0.85	0.85	0.00 (0%)	0.90	0.90	0.00 (0%)
AN	0.00	0.00	0.00 (1%)	0.01	0.01	0.00 (0%)	0.06	0.06	0.00 (2%)	0.77	0.77	0.00 (0%)	0.83	0.84	0.00 (0%)
BN	0.00	0.00	0.00 (0%)	0.25	0.24	0.00 (-1%)	0.31	0.31	0.00 (0%)	0.13	0.13	0.00 (-1%)	0.69	0.69	0.00 (0%)
D	0.00	0.00	0.00 (-1%)	0.21	0.21	0.00 (0%)	0.39	0.39	0.00 (0%)	0.09	0.09	0.00 (0%)	0.69	0.69	0.00 (0%)
C	0.01	0.01	0.00 (-1%)	0.51	0.50	0.00 (-1%)	0.09	0.09	0.00 (1%)	0.00	0.00	0.00 (0%)	0.61	0.60	0.00 (0%)

Table 5.4-16. Mean South Delta Exports and Sacramento River Flow Downstream of the NDD in March-May, by Water-Year Type.

WY	South Delta Exports									Sacramento River Flow Downstream of the NDD (Bypass Flows)								
	March			April			May			March			April			May		
	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
W	9,461	1,706	-7,755 (-82%)	2,977	395	-2,582 (-87%)	3,378	570	-2,808 (-83%)	47,988	40,145	-7,844 (-16%)	34,998	32,406	-2,592 (-7%)	29,839	26,747	-3,092 (-10%)
AN	7,826	902	-6,924 (-88%)	1,801	369	-1,432 (-80%)	1,720	411	-1,309 (-76%)	40,801	34,100	-6,700 (-16%)	24,080	22,944	-1,136 (-5%)	16,711	15,444	-1,266 (-8%)
BN	6,089	3,825	-2,264 (-37%)	1,774	1,340	-435 (-24%)	1,624	1,034	-590 (-36%)	18,542	15,051	-3,492 (-19%)	14,076	13,607	-469 (-3%)	12,460	12,027	-433 (-3%_
D	4,868	3,619	-1,249 (-26%)	2,052	1,493	-559 (-27%)	2,054	1,337	-717 (-35%)	21,284	17,259	-4,025 (-19%)	14,895	14,348	-547 (-4%)	11,633	11,382	-251 (-2%_
C	2,701	2,139	-561 (-21%)	1,430	1,267	-163 (-11%)	1,415	1,207	-208 (-15%)	12,529	11,683	-846 (-7%)	10,290	10,144	-147 (-1%)	8,214	8,031	-184 (-2%)

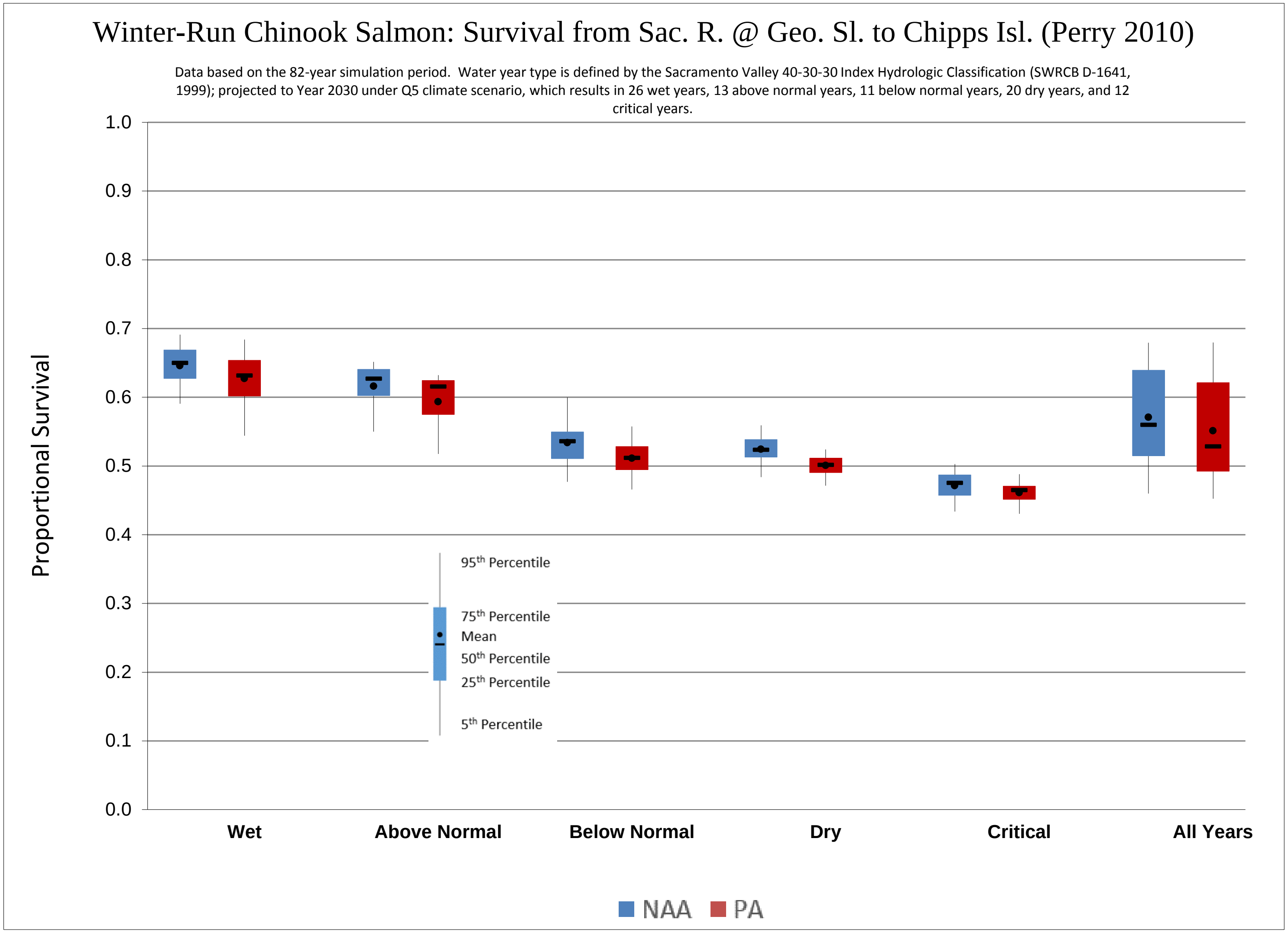
5.4.1.3.1.2.1.3.3 Analysis Based on Perry (2010): Winter-Run and Sacramento River Basin Spring-Run Chinook Salmon

In addition to the DPM and the analysis based on Newman (2003), which both allow consideration of the through-Delta juvenile Chinook salmon survival changes in relation to the far-field effects of both north and south Delta exports simultaneously, a focused analysis based on Perry (2010) was undertaken to focus solely on the potential flow-survival effects of the PA's proposed NDD on juvenile winter-run and spring-run Chinook salmon survival, particularly with respect to Sacramento River flows bypassing the NDD (i.e., pulse protection flows and level 1-3 bypass flows). The method is described further in Appendix 5.D, *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale*, Section 5.D.1.2.4, and allows estimation of through-Delta survival from the Sacramento River at Georgiana Slough to Chipps Island, based on the implementation of the Perry (2010) flow-survival relationship from the DPM. The analysis based on Perry (2010) does not include representation of near-field mortality effects from the NDD (e.g., predation or impingement at the NDD), but instead focuses on far-field effects.

The results of the analysis based on Perry (2010) suggested that annual through-Delta survival in the Sacramento River from Georgiana Slough to Chipps Island would be similar or slightly lower, depending on water year type and pulse protection flow, under the PA relative to the NAA for both juvenile winter-run Chinook salmon (Figure 5.4-18 and Figure 5.4-19; Table 5.4-17; see also Figure 5.D-71 in Appendix 5.D, *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale*) and juvenile spring-run Chinook salmon (Figure 5.4-20 and Figure 5.4-21; Table 5.4-18; see also Figure 5.D-77 in Appendix 5.D, *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale*). As would be expected, for winter-run Chinook salmon the relative difference between NAA and PA scenarios in weighted survival generally was greater with the progression from pulse protection flows (0–2% relative difference), to level 1 bypass flows (2–5% relative difference), to level 2 bypass flows (3-7% relative difference), to level 3 bypass flows (2–12%) (Table 5.4-17). For winter-run Chinook salmon, the greatest differences in overall survival (4–5% less under PA) were in above normal, below normal, and dry years, a pattern that generally was also true for spring-run Chinook salmon (Table 5.4-18). However, the relative differences between NAA and PA for through-Delta survival of spring-run Chinook salmon (1–3% less under the PA, depending on water year type) were less than for winter-run (2–5% less under the PA).

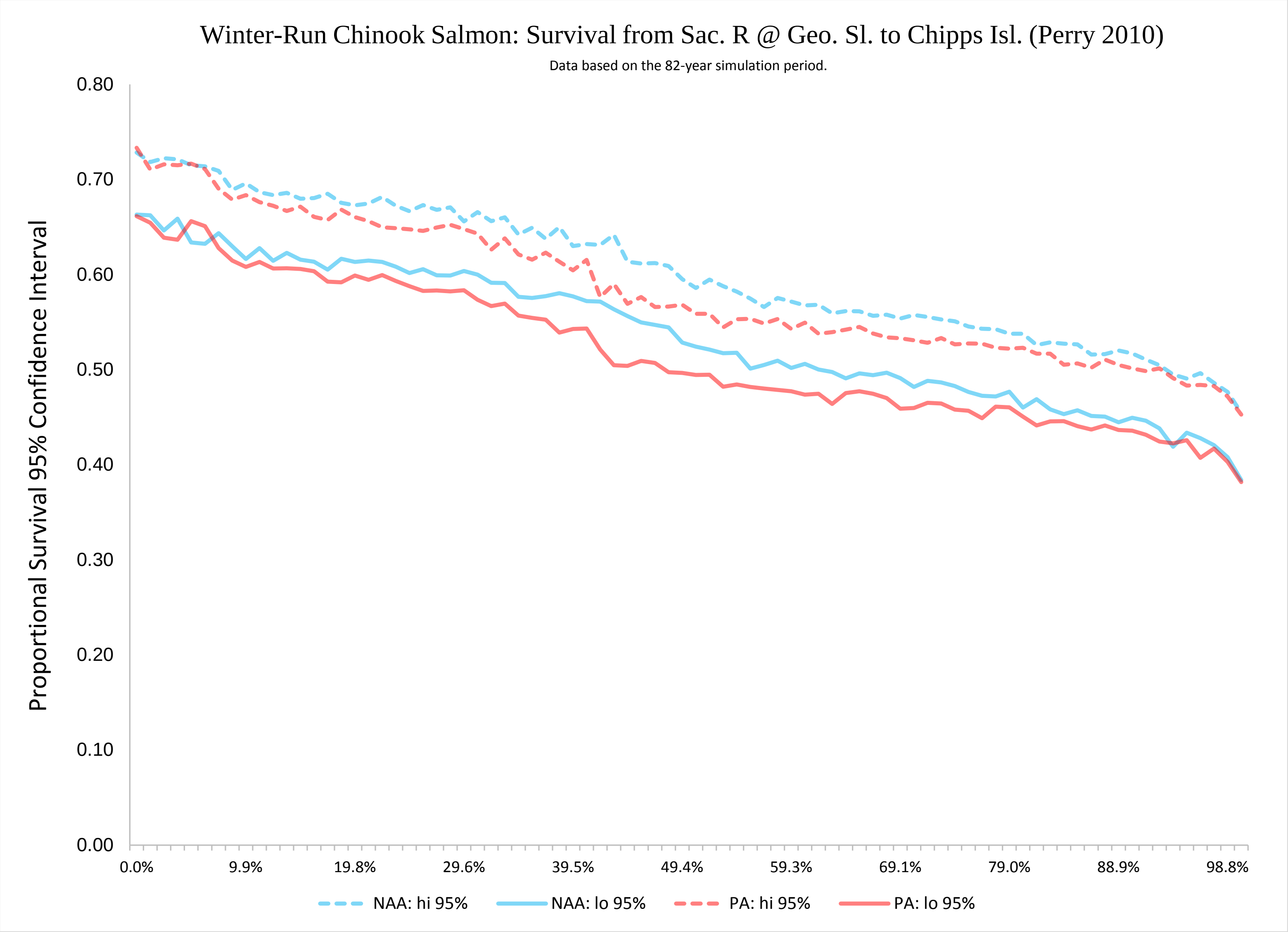
Note that there is appreciable variability in the underlying relationship between Sacramento River flow and survival, as represented in the analysis based on Perry (2010) (Figure 5.D-65 in Appendix 5.D, *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale*). Plots of annual estimated weighted survival and 95% confidence intervals presented in Appendix 5.D show considerable overlap in the estimate for the NAA and PA scenarios: for both winter-run and spring-run Chinook salmon, the estimates of weighted survival for pulse-protection flows, level 1-3 bypass flows, and overall survival overlap in all pairs of NAA and PA scenarios across the 82 years that were included in the analysis (see Figures 5.D-66 to 5.D-70 and Figures 5.D-72 to 5.D-76 in Appendix 5.D). This suggests that although the results discussed above show potentially less survival under the PA relative to the NAA, it might be challenging to statistically detect this small magnitude of difference during PA monitoring, for example.

Given that the analyses described above were for fixed winter-run and spring-run Chinook salmon entry distributions, it also was of interest to examine the differences in juvenile Chinook salmon survival based on Perry (2010) when assuming an equal daily weighting for entry distribution during December-June, the main juvenile Chinook salmon Delta entry period (Table 5.4-19). Although the entry distribution to the Delta was assumed to be the same on each day (i.e., equal daily weighting), the patterns from this analysis were similar to those observed for winter-run and spring-run Chinook salmon: lower survival under the PA relative to NAA (Figure 5.4-22 and Figure 5.4-23), with the relative differences between PA and NAA increasing with the movement from pulse protection flows (0–2%), to level 1 bypass flows (1–4%), to level 2 bypass flows (2–4%), to level 3 bypass flows (3–6%). In addition, the 95% confidence intervals for through-Delta survival estimates under all flow levels overlapped in every year between the NAA and PA scenarios (see Figures 5.D-78 to 5.D-82 in Appendix 5.D, *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale,* Section 5.D.1.2.4.3, *Results*), again suggesting that it might be challenging to statistically detect the small magnitude of the PA effect during monitoring of implementation.



Note: Plot only includes annual mean responses and does not consider model uncertainty.

Figure 5.4-18. Box Plots of Juvenile Winter-Run Chinook Salmon Annual Total Survival from the Sacramento River at Georgiana Slough to Chipps Island, Estimated from the Analysis Based on Perry (2010), Grouped by Water Year Type.



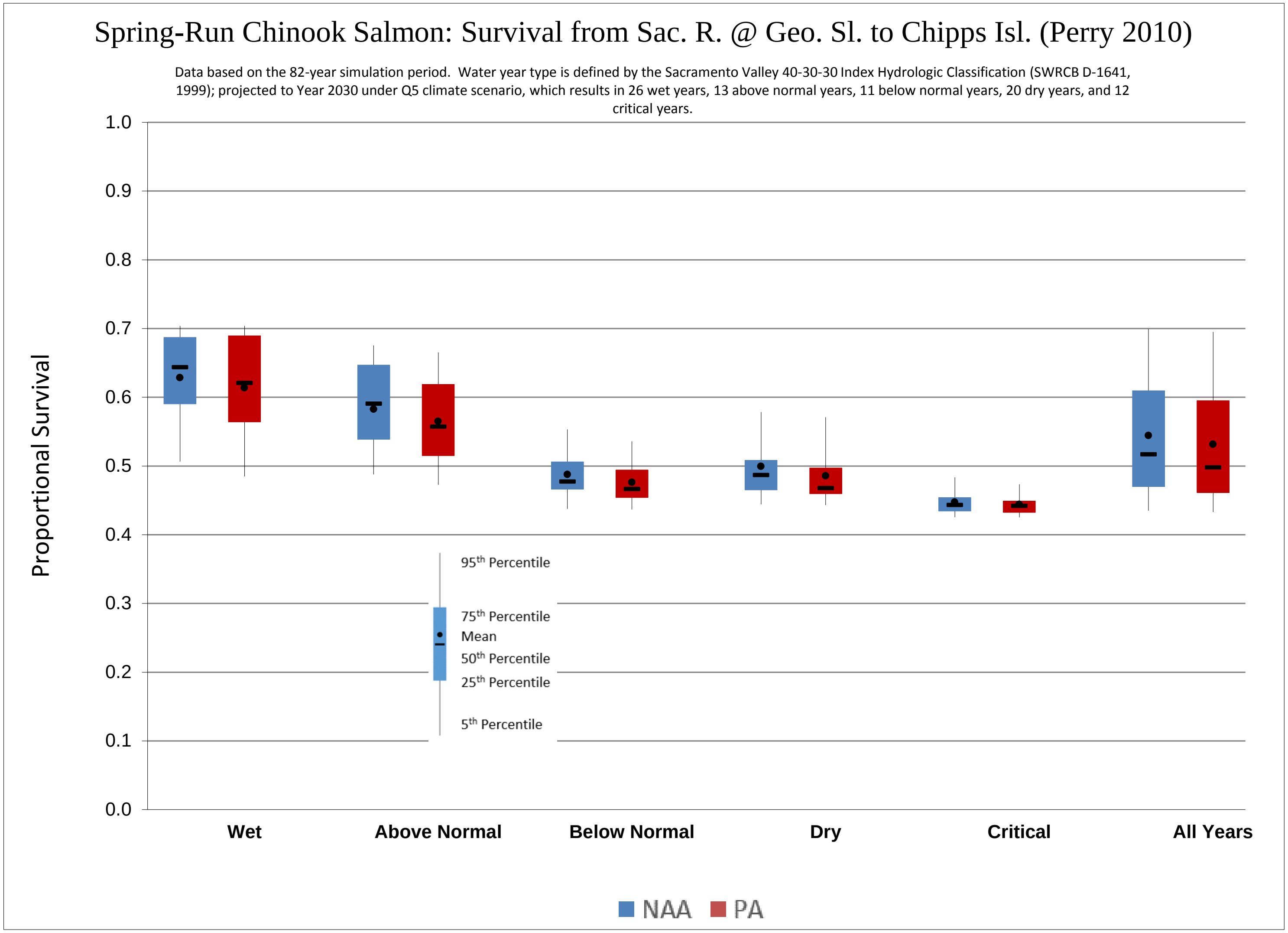
Note: Data are sorted by mean estimate, with only 95% confidence intervals shown.

Figure 5.4-19. Exceedance Plot of Juvenile Winter-Run Chinook Salmon Annual Total Survival from the Sacramento River at Georgiana Slough to Chipps Island, Estimated from the Analysis Based on Perry (2010).

Table 5.4-17. Mean Annual Juvenile Winter-Run Chinook Salmon Weighted Survival from the Sacramento River at Georgiana Slough to Chipps Island By Water Year Type, Estimated from the Analysis Based on Perry (2010), Divided into Each NDD Bypass Flow Level.

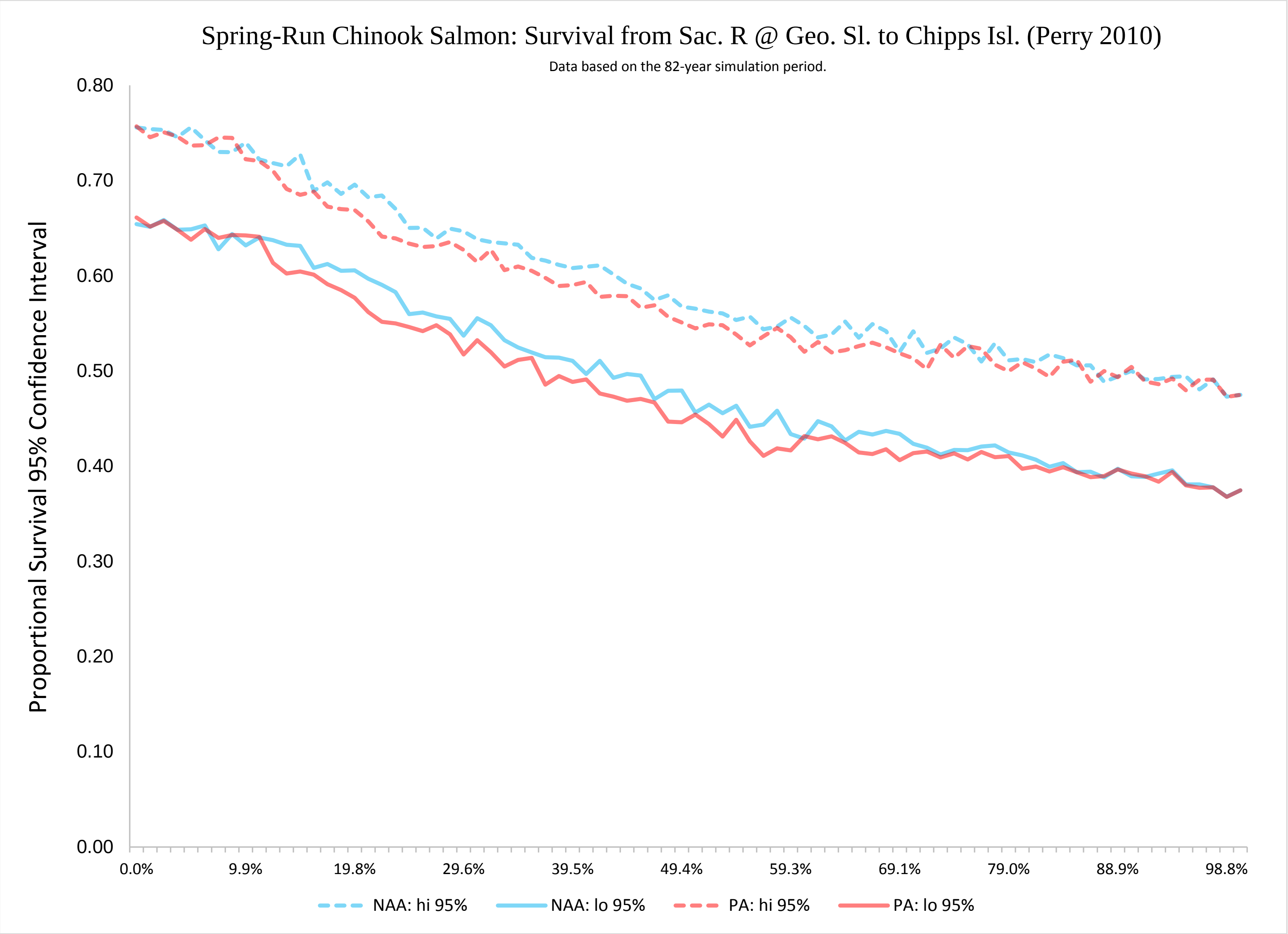
WY	Pulse protection flows			Level 1 bypass flows			Level 2 bypass flows			Level 3 bypass flows			Total		
	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
W	0.05	0.05	0.00 (0%)	0.16	0.15	-0.01 (-5%)	0.08	0.08	0.00 (-5%)	0.35	0.34	-0.01 (-2%)	0.65	0.63	-0.02 (-3%)
AN	0.04	0.04	0.00 (-1%)	0.20	0.19	-0.01 (-3%)	0.09	0.09	0.00 (-3%)	0.29	0.27	-0.01 (-5%)	0.62	0.59	-0.02 (-4%)
BN	0.04	0.04	0.00 (-1%)	0.29	0.28	-0.01 (-3%)	0.15	0.14	-0.01 (-6%)	0.05	0.05	0.00 (-10%)	0.53	0.51	-0.02 (-4%)
D	0.03	0.03	0.00 (-2%)	0.35	0.34	-0.01 (-4%)	0.12	0.11	-0.01 (-7%)	0.03	0.02	0.00 (-12%)	0.52	0.50	-0.02 (-5%)
C	0.03	0.03	0.00 (-1%)	0.41	0.40	-0.01 (-2%)	0.03	0.03	0.00 (-4%)	NA	NA	NA	0.47	0.46	-0.01 (-2%)

Note: Survival for a given flow level is weighted by the proportion of the juvenile population occurring during that flow level. NA indicates there were no level 3 bypass flows in critical years.



Note: Plot only includes annual mean responses and does not consider model uncertainty.

Figure 5.4-20. Box Plots of Juvenile Spring-Run Chinook Salmon Annual Total Survival from the Sacramento River at Georgiana Slough to Chipps Island, Estimated from the Analysis Based on Perry (2010), Grouped by Water Year Type.



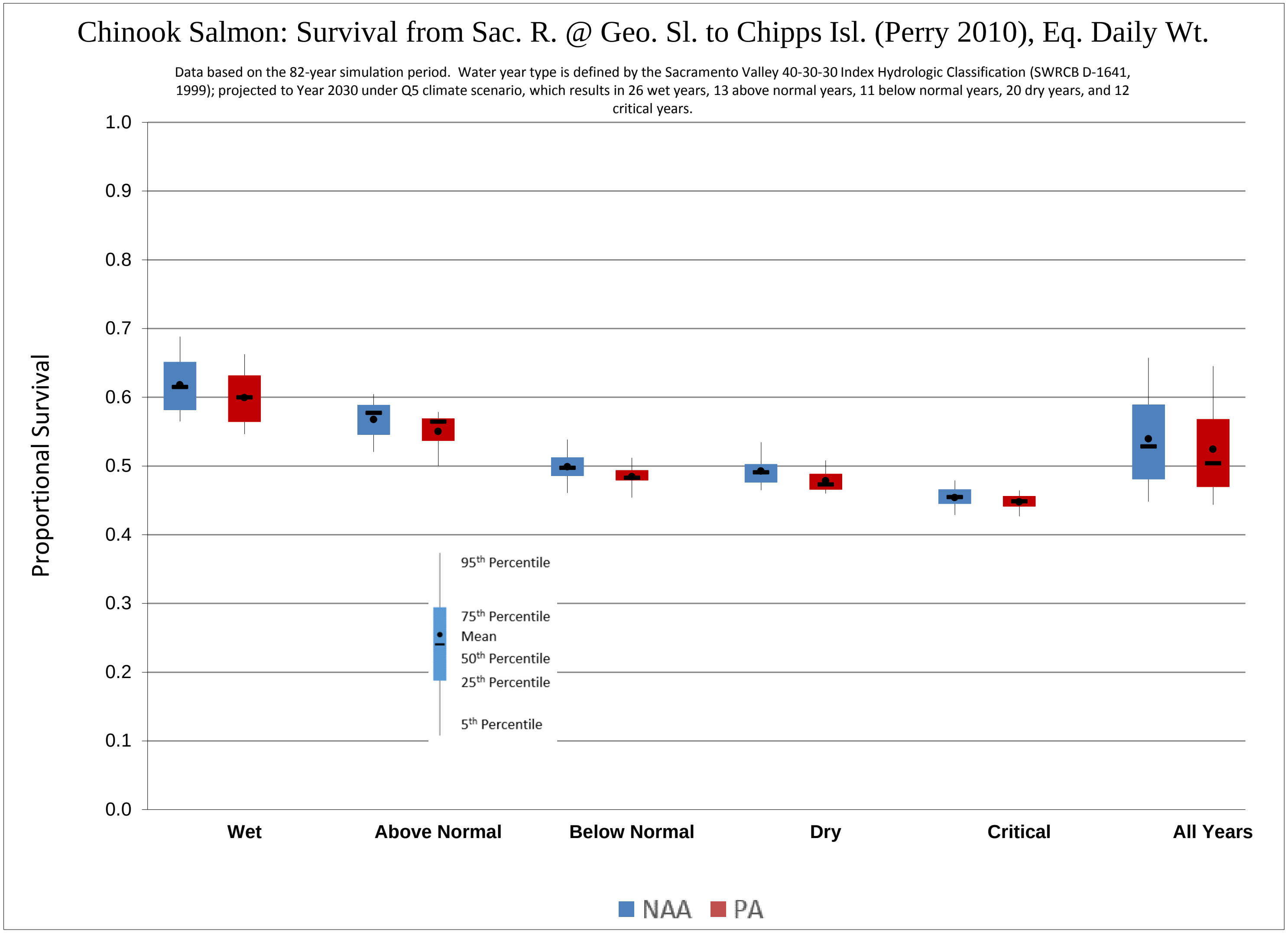
Note: Data are sorted by mean estimate, with only 95% confidence intervals shown.

Figure 5.4-21. Exceedance Plot of Juvenile Spring-Run Chinook Salmon Annual Total Survival from the Sacramento River at Georgiana Slough to Chipps Island, Estimated from the Analysis Based on Perry (2010).

Table 5.4-18. Mean Annual Juvenile Spring-Run Chinook Salmon Weighted Survival from the Sacramento River at Georgiana Slough to Chipps Island By Water Year Type, Estimated from the Analysis Based on Perry (2010), Divided into Each NDD Bypass Flow Level.

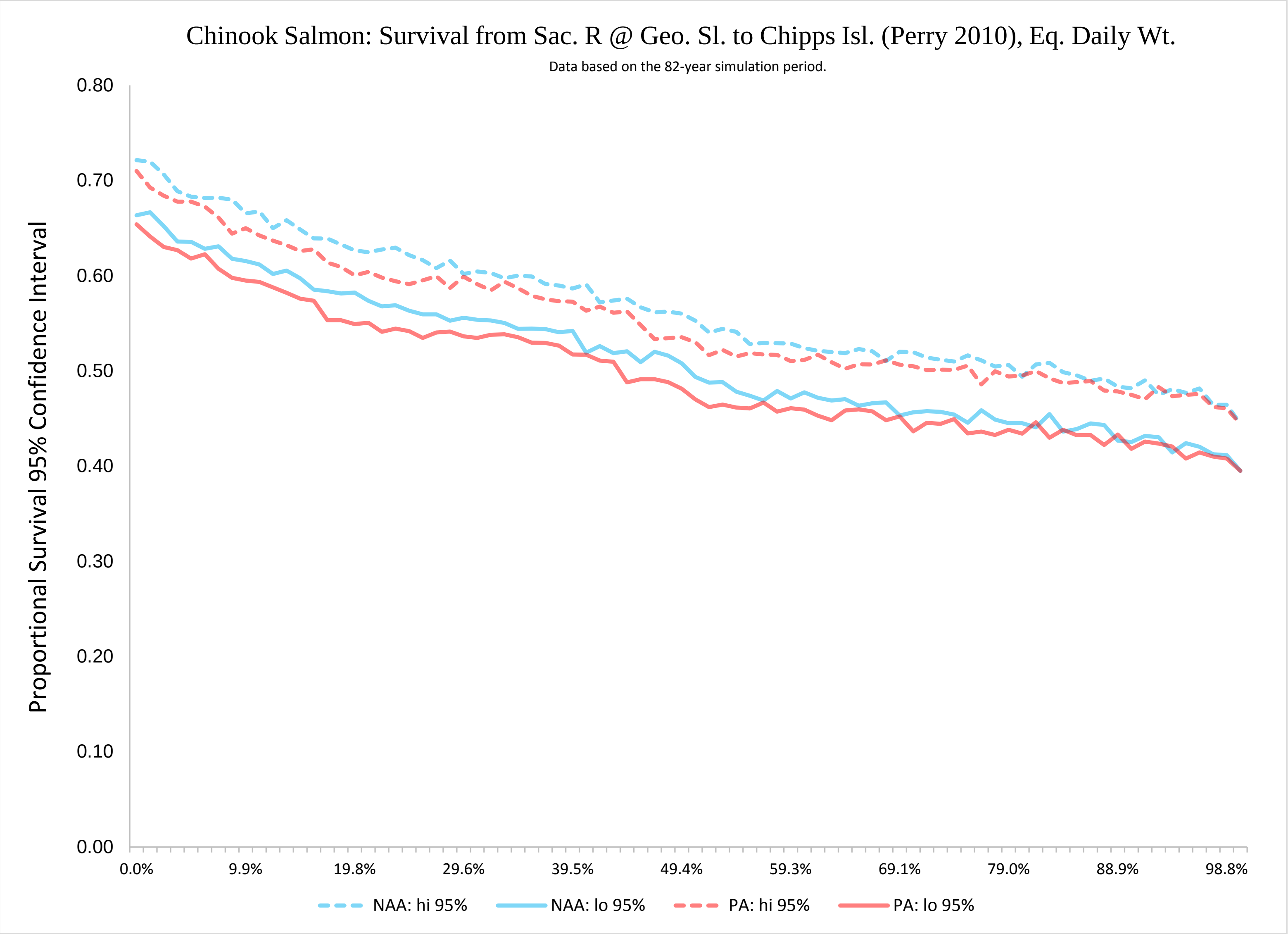
WY	Pulse protection flows			Level 1 bypass flows			Level 2 bypass flows			Level 3 bypass flows			Total		
	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
W	0.04	0.04	0.00 (0%)	0.12	0.12	0.00 (-4%)	0.06	0.06	0.00 (-3%)	0.39	0.38	-0.01 (-3%)	0.62	0.60	-0.02 (-3%)
AN	0.03	0.03	0.00 (-1%)	0.15	0.15	0.00 (-3%)	0.07	0.07	0.00 (-2%)	0.32	0.31	-0.01 (-4%)	0.57	0.55	-0.02 (-3%)
BN	0.03	0.03	0.00 (0%)	0.25	0.24	-0.01 (-2%)	0.16	0.16	-0.01 (-4%)	0.06	0.05	0.00 (-5%)	0.50	0.48	-0.01 (-3%)
D	0.02	0.02	0.00 (-1%)	0.27	0.27	-0.01 (-3%)	0.16	0.15	0.00 (-3%)	0.04	0.04	0.00 (-6%)	0.49	0.48	-0.01 (-3%)
C	0.02	0.02	0.00 (-2%)	0.39	0.39	-0.01 (-1%)	0.04	0.04	0.00 (-2%)	NA	NA	NA	0.45	0.45	-0.01 (-1%)

Note: Survival for a given flow level is weighted by the proportion of the juvenile population occurring during that flow level. NA indicates there were no level 3 bypass flows in critical years.



Note: Plot only includes annual mean responses and does not consider model uncertainty.

Figure 5.4-22. Box Plots of Juvenile Chinook Salmon Annual Total Survival from the Sacramento River at Georgiana Slough to Chipps Island, Estimated from the Analysis Based on Perry (2010), Grouped by Water Year Type, Assuming Equal Daily Weighting from December to June.



Note: Data are sorted by mean estimate, with only 95% confidence intervals shown.

Figure 5.4-23. Exceedance Plot of Juvenile Chinook Salmon Annual Total Survival from the Sacramento River at Georgiana Slough to Chipps Island, Estimated from the Analysis Based on Perry (2010), Assuming Equal Daily Weighting from December to June.

Table 5.4-19. Mean Annual Juvenile Chinook Salmon Weighted Survival from the Sacramento River at Georgiana Slough to Chipps Island By Water Year Type, Estimated from the Analysis Based on Perry (2010), Divided into Each NDD Bypass Flow Level, Assuming Equal Daily Weighting from December to June.

WY	Pulse protection flows			Level 1 bypass flows			Level 2 bypass flows			Level 3 bypass flows			Total		
	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
W	0.04	0.04	0.00 (0%)	0.12	0.12	0.00 (-4%)	0.06	0.06	0.00 (-3%)	0.39	0.38	-0.01 (-3%)	0.62	0.60	-0.02 (-3%)
AN	0.03	0.03	0.00 (-1%)	0.15	0.15	0.00 (-3%)	0.07	0.07	0.00 (-2%)	0.32	0.31	-0.01 (-4%)	0.57	0.55	-0.02 (-3%)
BN	0.03	0.03	0.00 (0%)	0.25	0.24	-0.01 (-2%)	0.16	0.16	-0.01 (-4%)	0.06	0.05	0.00 (-5%)	0.50	0.48	-0.01 (-3%)
D	0.02	0.02	0.00 (-1%)	0.27	0.27	-0.01 (-3%)	0.16	0.15	0.00 (-3%)	0.04	0.04	0.00 (-6%)	0.49	0.48	-0.01 (-3%)
C	0.02	0.02	0.00 (-2%)	0.39	0.39	-0.01 (-1%)	0.04	0.04	0.00 (-2%)	NA	NA	NA	0.45	0.45	-0.01 (-1%)

Note: Survival for a given flow level is weighted by the proportion of the juvenile population occurring during that flow level. NA indicates there were no level 3 bypass flows in critical years.

5.4.1.3.1.2.1.3.4 Life Cycle Models (IOS and OBAN): Winter-run Chinook Salmon

The winter-run Chinook salmon life cycle models IOS and OBAN were also run to provide perspective on potential PA effects with respect to both in-Delta and upstream conditions. Methods and results are presented in Appendix 5.D, *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale*, Section 5.D.3, *Life Cycle Models*. In both models, ocean conditions were assumed not to differ between the NAA and PA, in order to focus the analysis on potential PA effects.

As described in Section 5.4.2, *Upstream Hydrologic Changes*, upstream differences in environmental stressors between the NAA and PA were found to be small, so the main driver of differences in escapement between NAA and PA was differences in Delta survival. IOS's in-Delta component is the DPM, although with one important difference from the DPM results previously discussed in Section 5.4.1.3.1.2.1.3.1, *Delta Passage Model: Winter-Run and Spring-Run Chinook Salmon*: Delta entry in IOS consists of a unimodal peak, the timing of which depends on upstream fry/egg rearing, in contrast to the fixed nature of Delta entry for the standalone DPM; the unimodal peak generally occurs between the bimodal peaks from the fixed entry distribution (Appendix 5.D, *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale*, Section 5.D.3.1.1.5, *Delta Passage*). Whereas the DPM results showed that the 95% confidence intervals of annual through-Delta survival estimates for NAA and PA did not overlap in 10 of 81 years, the through-Delta survival confidence intervals overlapped in all but one year for IOS. This may have reflected a greater proportion of the through-Delta migration occurring earlier in the migration season for IOS, when NDD bypass flow restrictions would have been greater, with the result that there was greater overlap in survival estimates between NAA and PA for IOS compared to DPM.

In IOS, as with the DPM, in-Delta channel flow-survival relationships tend to have a greater effect on survival than the export-survival effect, as discussed in Section 5.4.1.3.1.2.1.3, *Through-Delta Survival*, for spring-run Chinook salmon. In contrast, OBAN's through-Delta survival component includes Yolo Bypass inundation (which was assumed the same for NAA and PA, based on both scenarios having a notched Fremont Weir) and south Delta exports, which would be appreciably less under the PA than NAA. In order to represent potential adverse effects of the NDD on through-Delta survival in OBAN, sensitivity analyses of additional mortality (1%, 5%, 10%, and 50%) were applied to the estimates of survival derived from Yolo Bypass inundation and south Delta exports. The OBAN results demonstrated that early ocean survival and the spreading of effects between age 3 and age 4 maturing adults has a significant buffering effect on through-Delta survival effects[33], so that estimates of escapement between sensitivity analysis scenarios did not directly reflect proportional differences in through-Delta survival. The sensitivity analysis results suggested that at 5% additional mortality because of the NDD, the number of years having greater than 50% probability of *equal or greater* escapement under the

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[33] As discussed further in Appendix 5.D, *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale*, Section 5.D.3.2.8, *Results*, OBAN includes a lower bound on escapement to avoid numerical instability, which also contributed to less than expected differences between sensitivity analysis scenarios when escapement was low.

PA relative to the NAA would be the same as the number of years having less than 50% probability of *lower* escapement under the PA relative to the NAA. In simpler terms, 5% additional mortality because of the NDD[34] would cancel out the gains from south Delta export reductions under the PA, judged from the probability of having escapement equal to or less than NAA.

In contrast to OBAN, which suggested that the benefits of less south Delta exports could offset additional mortality from the NDD, the IOS escapement estimates suggested that lower through-Delta survival would result in increasing divergence of PA and NAA escapement estimates, resulting in a median 25% lower escapement for the PA over the 81 years simulated. However, the variability in through-Delta survival estimates across the 75 randomized iterations of IOS meant that as median escapement diverged, so too did the 95% confidence intervals, so that the escapement confidence intervals for the PA and NAA overlapped in all years; in the years with greatest differences in escapement between PA and NAA, the 95% confidence intervals spread over two orders of magnitude. This likely reflects the uncertainty in the underlying model parameters (e.g., flow-survival and export-survival relationships), as well extrapolation beyond the range of the data upon which the model parameters were based. OBAN was similar to IOS in that the differences in escapement between NAA and PA scenarios usually were within 90% probability intervals[35]. For both life cycle models, the uncertainty in the relationships between environmental parameters and fish survival, coupled with extrapolation beyond the data from which the relationships were established, gave wide variation in the range of escapement estimates.

5.4.1.3.1.2.1.3.5 SalSim Through-Delta Survival Function: San Joaquin River Basin Spring-Run Chinook Salmon

Through-Delta survival for spring-run Chinook salmon from the San Joaquin River basin was estimated using the survival function from the Juvenile Delta Module of the Salmon Simulator (SalSim; AD Consultants 2014). Whereas SalSim is a standalone life cycle modeling tool, the coefficients of the survival function from its Delta Module were used in a spreadsheet to compare potential survival differences between NAA and PA. The details of the method as applied for fall-run Chinook salmon are described in the *SalSim Through-Delta Survival Function: Fall-Run Chinook Salmon* subsection of Appendix 5.E., *Essential Fish Habitat*, Section 5.E.5.3.1.2.1.2.1, *Indirect Mortality within the Delta*. The DPM timing for spring-run Chinook salmon entering the Delta from the Sacramento River basin was assumed for this analysis to be representative of the timing for entry of San Joaquin River spring-run Chinook salmon.

The results of the analysis based on the SalSim through-Delta survival function suggested that the through-Delta survival of San Joaquin River spring-run Chinook salmon under the PA would be greater under the PA than NAA (Figure 5.4-24 and Figure 5.4-25, and Table 5.4-20;). This is the result of the implementation of the HOR gate, which was modeled to be 50% closed during the main period of spring-run Chinook salmon migration, with the result that flow into the

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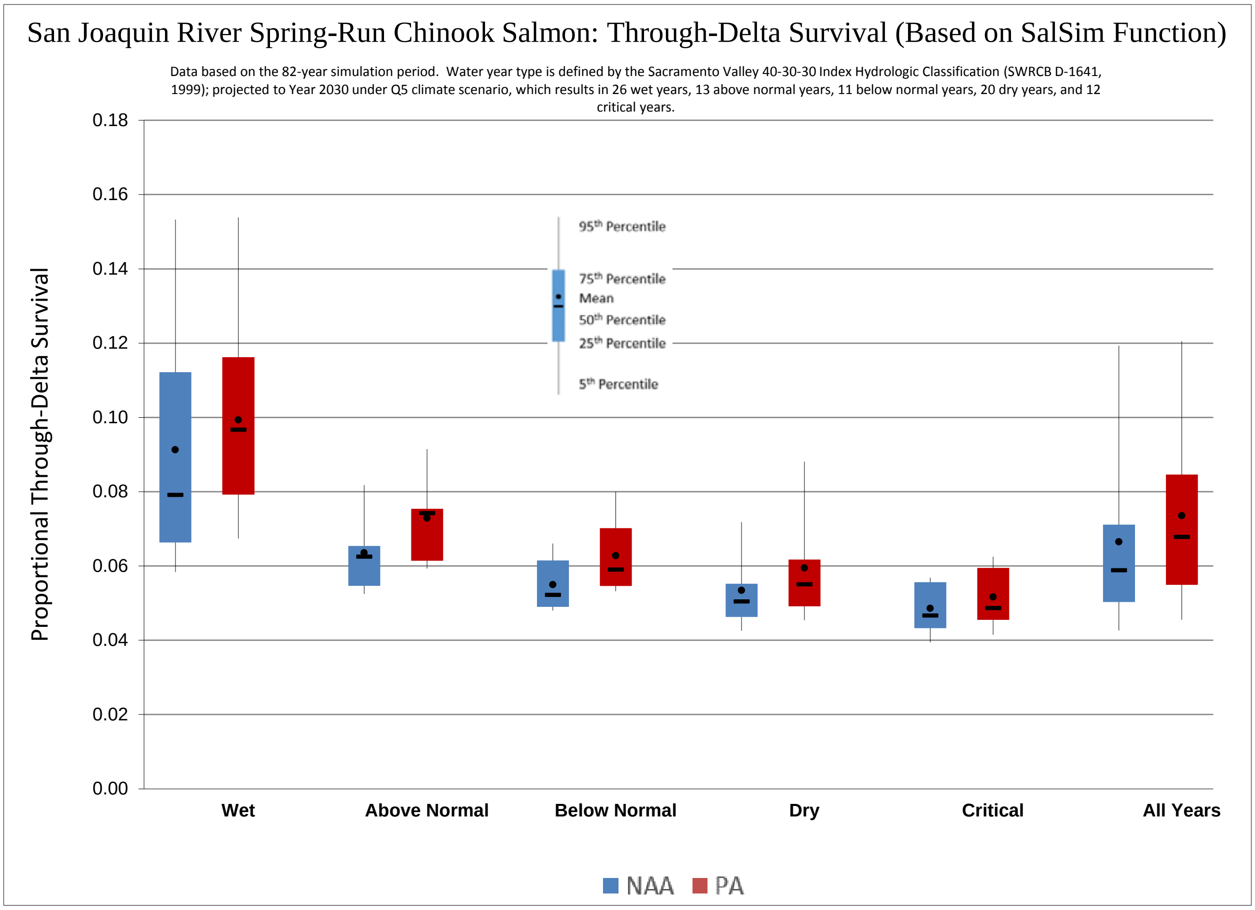
[34] That is, (PA Delta survival)*0.95 (i.e., 5% lower Delta survival)

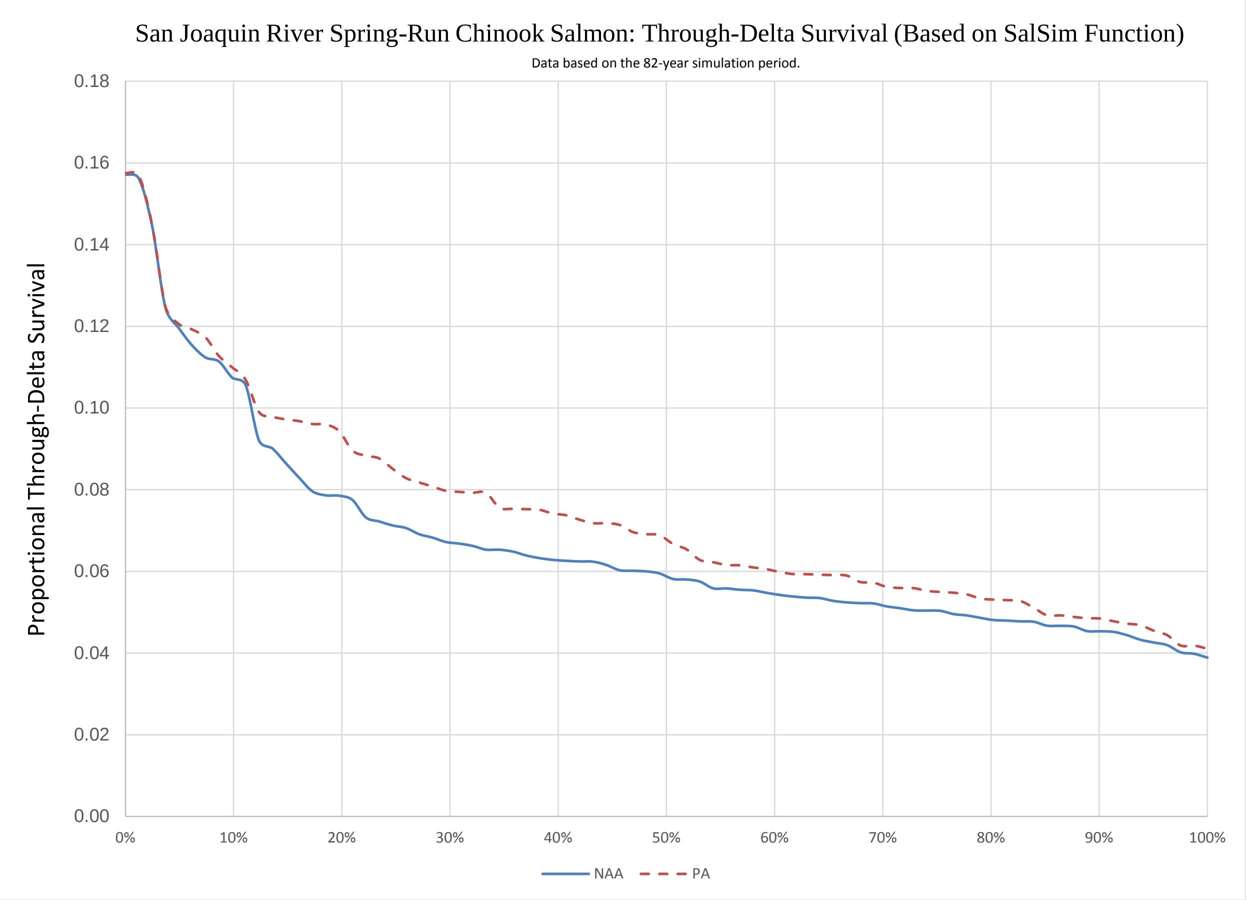
[35] The exception was one year in which the PA with 50.0% additional NDD mortality had lower escapement than the NAA, and the percentage difference did not include zero within the 90% probability interval.

Stockton Deepwater Ship Channel is considerably greater under the PA (Table 5.4-20). The relative differences in survival between NAA and PA were greatest in intermediate water-year types (above normal, below normal, and dry), as a result of two factors. First, the HOR gate would not be closed when Vernalis flow is greater than 10,000 cfs; this results in the top 5% of survival estimates being identical between NAA and PA (Figure 5.4-25.), which limits the overall differences in wet years. Second, in critical years when flows are very low and water temperature would be high, the rate of change in survival is considerably less than with more flow and lower temperature, as shown in the flatness of the flow-survival curve in Appendix 5.E, *Essential Fish Habitat*. Overall, the analysis based on the SalSim Juvenile Delta Module survival function suggested that the PA would likely have a positive effect on San Joaquin River spring-run Chinook salmon in the Delta.



Note: Plot only includes annual mean responses and does not consider model uncertainty.

Figure 5.4-24. Box Plots of San Joaquin River Spring-Run Chinook Salmon Smolt Annual Through-Delta Survival Estimated from the Juvenile Delta Module Survival Function of SalSim, Grouped by Water Year Type.



Note: Plot only includes annual mean responses and does not consider model uncertainty.

Figure 5.4-25. Exceedance Plot of San Joaquin River Spring-Run Chinook Salmon Smolt Annual Through-Delta Survival Estimated from the Juvenile Delta Module Survival Function of SalSim.

Table 5.4-20. Mean Annual San Joaquin River Spring-Run Chinook Salmon Smolt Annual Through-Delta Survival Estimated from the Juvenile Delta Module Survival Function of SalSim, Together with Weighted-Mean Flow into the Stockton Deepwater Ship Channel, Grouped by Water Year Type.

Water Year Type	Through-Delta Survival Probability				Flow into Stockton Deepwater Ship Channel (cfs) Weighted by Proportion of Fish Entering the Delta		
	NAA	PA	PA vs. NAA		NAA	PA	PA vs. NAA
W	0.091	0.099	0.008 (9%)		4,568	5,380	811 (18%)
AN	0.064	0.073	0.009 (15%)		2,305	3,386	1,081 (47%)
BN	0.055	0.063	0.008 (14%)		1,471	2,456	986 (67%)
D	0.053	0.059	0.006 (11%)		1,124	1,883	759 (68%)
C	0.049	0.052	0.003 (6%)		483	929	446 (92%)

5.4.1.3.1.2.2 Habitat Suitability

5.4.1.3.1.2.2.1 Bench Inundation

Channel margin habitat in the Delta, and in much of the Sacramento/San Joaquin Rivers in general, has been considerably reduced because of the construction of levees and the armoring of their banks with riprap (Williams 2009). This has reduced the extent of high-value rearing habitat for rearing Chinook salmon juveniles, for such shallow-water habitat provides refuge from unfavorable hydraulic conditions and predation, as well as foraging habitat. Although the benefits of such habitat are most often associated with smaller, rearing individuals (McLain and Castillo 2009; H.T. Harvey & Associates with PRBO Conservation Science 2011), good quality channel margin habitat also functions as holding areas during downstream migration (Burau et al. 2007; Zajanc et al. 2013), thereby improving connectivity between higher value habitats along the migration route. Whereas, historically, riverbank protection from erosion was undertaken with riprap alone, in recent years there has been an emphasis from DWR and USACE to install bank protection that incorporates riparian and wetland benches, as well as other habitat features, to restore habitat function (HT Harvey and PRBO Conservation Science 2011). These benches are shallow areas along the channel margins that have relatively gentle slopes (e.g., 10:1 instead of the customary 3:1) and are designed to be wetted or flooded during certain parts of the year to provide habitat for listed species of fish and other species. Wetland benches are at lower elevations where more frequent wetting and inundation may be expected, and riparian benches occupy higher portions of the slope where inundation is restricted to high-flow events. These benches were planted and often secured with riprap or other materials.

5.4.1.3.1.2.2.1.1 Operational Effects

Several levee improvements projects along the Sacramento River have been implemented by the USACE and others, and have included the restoration of benches intended to be inundated under specific flows during certain months to provide suitable habitat for listed species of fish. Restored benches in the north Delta could potentially be affected by the PA because of changes in water level; for example, less water in the Sacramento River below the NDD could result in riparian benches being inundated less frequently. This possibility was examined by calculating bench inundation indices for juvenile Chinook salmon (see detailed method description in Appendix 5.D, *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale*, Section 5.D.1.3.1, *Bench Inundation*). These indices range from 0 (no availability of bench habitat) to 1 (water depth on the bench is optimal for juvenile Chinook salmon all of the time). The analysis was undertaken for a number of riparian and wetland benches in five geographic locations within the north Delta, by linking bench elevation data to DSM2-HYDRO-simulated water surface elevation.

The bench inundation analysis suggested that the effects of changes in water surface elevation caused by PA operations would vary by location and bench type (Table 5.4-21). As noted above, wetland benches are located at lower elevation than riparian benches and are intended to be inundated much of the time; this results in relatively high bench inundation indices in all water year types, and makes them less susceptible to differences in water levels that could be caused by the NDD, as reflected by the small differences between NAA and PA in all locations and water year types. In the Sacramento River above the NDD, the wetland bench inundation indices were greater in drier than wetter years, reflecting the water depth becoming shallower and therefore moving toward the optimum for juvenile Chinook salmon (i.e., 2.2-2.5 feet; see Appendix 5.D, *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale*, Section 5.D.1.3.1, *Bench Inundation*).

In contrast to wetland benches, riparian benches are at higher elevations and are intended to be inundated only for portions of winter/spring. Riparian bench inundation indices were higher in wetter years and smaller in drier years, particularly in spring (Table 5.4-21). Although there were some large *relative* differences in bench inundation indices between NAA and PA (e.g., ~40–90% lower under PA in below normal to critical years in the Sacramento River below the NDD to Sutter/Steamboat sloughs), these differences occurred in drier years when there was little habitat value under either PA or NAA. The greatest differences during the periods when the riparian benches would provide more than minimal habitat value (assumed here, based on best professional judgement, to be a bench inundation index > 0.05[36]) were:

- 29% lower riparian bench inundation index under PA in the Sacramento River from Sutter Steamboat sloughs to Rio Vista in spring of above normal years;
- 24% lower riparian bench inundation index under PA in the Sacramento River below the NDD to Sutter/Steamboat sloughs in spring of above normal years
- 19% lower riparian bench inundation index under PA in Sutter/Steamboat Sloughs in spring of wet years.

Channel margin enhancement would be implemented to offset these deficits, as described in the following section.

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[36] A bench inundation index of 0.05 equates to optimal depth (suitability = 1) 5% of the time within a season (with no other inundation occurring); or equates to poor depth (suitability = 0.05) 100% of the time within a season; or in reality, equates to a combination of time and depth between these ranges. The choice of an index of 0.05 was based on best professional judgement of an index demarcating little value to no value from some value.

Table 5.4-21. Mean Bench Inundation Index by Location, Bench Type, Water Year Type, and Season, for NAA and PA.

Location	Bench Type (Total Length)	Water Year Type	Winter (December-February)				Spring (March-June)		
			NAA	PA	PA vs. NAA		NAA	PA	PA vs. NAA
Cache Slough	Riparian (2,950 ft)	W	0.011	0.010	-0.001 (-6%)		0.003	0.003	0.000 (-9%)
		AN	0.004	0.004	0.000 (-6%)		0.001	0.001	0.000 (-8%)
		BN	0.003	0.003	0.000 (-4%)		0.000	0.000	0.000 (-7%)
		D	0.002	0.002	0.000 (-8%)		0.000	0.000	0.000 (-6%)
		C	0.002	0.002	0.000 (-4%)		0.000	0.000	0.000 (-4%)
	Wetland (3,992 ft)	W	0.232	0.229	-0.003 (-1%)		0.189	0.186	-0.003 (-2%)
		AN	0.202	0.199	-0.003 (-2%)		0.158	0.157	-0.001 (-1%)
		BN	0.181	0.178	-0.002 (-1%)		0.135	0.134	-0.001 (-1%)
		D	0.176	0.173	-0.003 (-2%)		0.139	0.138	-0.001 (-1%)
		C	0.158	0.157	-0.002 (-1%)		0.132	0.132	0.000 (0%)
Sacramento River above NDD	Riparian (18,521 ft)	W	0.170	0.186	0.016 (9%)		0.186	0.180	-0.007 (-4%)
		AN	0.162	0.169	0.007 (4%)		0.105	0.103	-0.001 (-1%)
		BN	0.100	0.100	0.000 (0%)		0.015	0.009	-0.005 (-35%)
		D	0.111	0.112	0.000 (0%)		0.023	0.017	-0.006 (-28%)
		C	0.038	0.038	0.000 (0%)		0.004	0.003	-0.001 (-27%)
	Wetland (3,766 ft)	W	0.360	0.364	0.004 (1%)		0.398	0.412	0.014 (3%)
		AN	0.398	0.396	-0.002 (-1%)		0.471	0.470	0.000 (0%)
		BN	0.447	0.450	0.003 (1%)		0.493	0.492	-0.001 (0%)
		D	0.424	0.429	0.005 (1%)		0.489	0.489	0.000 (0%)
		C	0.475	0.466	-0.009 (-2%)		0.393	0.391	-0.002 (-1%)
Sacramento River below NDD to Sutter/Steamboat Sl.	Riparian (3,037 ft)	W	0.247	0.227	-0.020 (-8%)		0.180	0.142	-0.039 (-21%)
		AN	0.210	0.175	-0.035 (-17%)		0.084	0.064	-0.020 (-24%)
		BN	0.116	0.098	-0.018 (-15%)		0.002	0.000	-0.002 (-77%)
		D	0.144	0.123	-0.020 (-14%)		0.008	0.005	-0.003 (-40%)
		C	0.041	0.036	-0.004 (-11%)		0.000	0.000	0.000 (0%*)
	Wetland (3,115 ft)	W	0.318	0.331	0.013 (4%)		0.357	0.343	-0.014 (-4%)
		AN	0.319	0.322	0.003 (1%)		0.289	0.280	-0.009 (-3%)
		BN	0.281	0.276	-0.006 (-2%)		0.203	0.192	-0.011 (-5%)
		D	0.281	0.278	-0.003 (-1%)		0.212	0.199	-0.014 (-6%)
		C	0.226	0.221	-0.005 (-2%)		0.171	0.168	-0.003 (-2%)
Sacramento River from Sutter/Steamboat Sl. to Rio Vista	Riparian (1,685 ft)	W	0.257	0.219	-0.039 (-15%)		0.171	0.126	-0.045 (-26%)
		AN	0.206	0.159	-0.047 (-23%)		0.075	0.053	-0.022 (-29%)
		BN	0.118	0.092	-0.025 (-22%)		0.002	0.000	-0.001 (-75%)
		D	0.146	0.115	-0.031 (-21%)		0.006	0.004	-0.003 (-43%)
		C	0.044	0.036	-0.008 (-18%)		0.000	0.000	0.000 (0%**)
	Wetland (2,430 ft)	W	0.410	0.421	0.011 (3%)		0.437	0.420	-0.017 (-4%)
		AN	0.412	0.409	-0.003 (-1%)		0.362	0.350	-0.013 (-3%)
		BN	0.361	0.354	-0.007 (-2%)		0.265	0.254	-0.012 (-4%)
		D	0.365	0.360	-0.005 (-1%)		0.276	0.262	-0.014 (-5%)
		C	0.295	0.290	-0.005 (-2%)		0.230	0.226	-0.003 (-1%)

Location	**Bench Type (Total Length)**	**Water Year Type**	**Winter (December-February)**				**Spring (March-June)**		
			NAA	**PA**	**PA vs. NAA**		**NAA**	**PA**	**PA vs. NAA**
Sutter/Steamboat Sloughs	Riparian (5,235 ft)	W	0.262	0.233	-0.028 (-11%)		0.196	0.159	-0.037 (-19%)
		AN	0.220	0.186	-0.034 (-15%)		0.103	0.085	-0.018 (-17%)
		BN	0.138	0.117	-0.020 (-15%)		0.024	0.021	-0.003 (-12%)
		D	0.160	0.135	-0.025 (-16%)		0.030	0.026	-0.004 (-14%)
		C	0.066	0.059	-0.007 (-11%)		0.019	0.018	-0.001 (-4%)
	Wetland (2,670 ft)	W	0.515	0.528	0.014 (3%)		0.562	0.548	-0.014 (-2%)
		AN	0.528	0.526	-0.001 (0%)		0.499	0.486	-0.013 (-3%)
		BN	0.488	0.482	-0.006 (-1%)		0.401	0.387	-0.014 (-3%)
		D	0.487	0.483	-0.004 (-1%)		0.414	0.397	-0.017 (-4%)
		C	0.420	0.415	-0.005 (-1%)		0.356	0.352	-0.004 (-1%)

Notes: *Value was changed from -92% because absolute change was extremely small. **Value was changed from -80% because absolute change was extremely small.

5.4.1.3.1.2.2.1.2 Channel Margin Enhancement

As described above, PA operations have the potential to reduce riparian bench inundation, which would reduce habitat suitability for juvenile Chinook salmon from the Sacramento River basin. Channel margin enhancement would be undertaken in order to mitigate for deficits created by PA operations. Channel margin enhancement would be coordinated with NMFS, would occur at sites currently containing poor habitat, and would accommodate the range of water stage elevations necessary to provide appropriate water depth and other habitat features for juvenile Chinook salmon. Additional discussion of channel margin enhancement is provided in Section 5.5.1, *Tidal, Channel Margin, and Riparian Habitat Protection and Restoration*.

5.4.1.3.1.2.2.2 Water Temperature (DSM2-QUAL)

Kimmerer (2004: 19-20) noted that the water temperature in the San Francisco Estuary depends mainly on air temperature, and that even in the Delta the relationship between air and water temperature is only slightly affected by freshwater inflow. He further noted that at Freeport high inflow reduces water temperature on cool days, presumably because water reaches the Delta before its temperature equilibrates with air temperature; at Antioch low inflow increases water temperature on cool days, probably because of the moderating effect of warmer estuarine water moving farther upstream. USFWS (2008: 194) suggested, based on Kimmerer (2004) that water temperatures at Freeport can be cooled up to about 3°C by high Sacramento River flows, but only by very high river flows that cannot be sustained by CVP/SWP operations. In general, flow-related effects on Delta water temperature are expected to be minor (Wagner *et al.* 2011). However, operational changes under the PA with respect to less south Delta export pumping and less Sacramento River inflow because of the proposed NDD mean that it is prudent to investigate whether water temperature is expected to differ between the NAA and the PA, and if so, why. DSM2-QUAL modeling was undertaken to examine water temperature differences between NAA and PA scenarios at four locations, in response to requests from NMFS and USFWS for locations with biological relevance to listed fishes based on likely occurrence: Sacramento River at Rio Vista, San Joaquin River at Prisoners Point, Stockton Deep Water Ship Channel, and San Joaquin River at Brandt Bridge. Detailed methods are presented in Attachment 5.B.A.4 of Appendix 5.B, *DSM2 Methods and Results,* and results are presented in Section 5.B.5 of that appendix. In general, DSM2-QUAL modeling suggested that there would be only very slight differences in water temperature between NAA and PA. For the Sacramento River at Rio Vista, water temperature differences were most apparent during July to November (see, for example, the temperature exceedance plots in Appendix 5.B, *DSM2 Methods and Results*, Section 5.B.5: Figure 5.B.5.40-1). This period is essentially outside the main juvenile migration period for juvenile spring-run Chinook salmon and steelhead, but may overlap with early (November) occurrence of juvenile winter-run Chinook salmon in the Delta. However, the results suggest small differences in mean temperature may be small even when they are visually apparent, e.g., in November, the greatest difference between NAA and PA scenarios was at the 20% exceedance level, and was ~0.3°C greater under the PA (Appendix 5.B, *DSM2 Methods and Results*, Section 5.B.5: Figure 5.B.5.40-1); such differences may not be of biological significance, whereas a difference of 0.5-1°C would be of more importance. The timing of differences between NAA and PA scenarios could overlap with steelhead upstream migration, but again, the slight differences suggest little effect of the PA in relation to the NAA.

The water temperature results on the San Joaquin River have relevance for San Joaquin River steelhead and spring-run Chinook salmon migrating through the Delta from the San Joaquin River basin. Differences between the NAA and PA scenarios varied by location. At Brandt Bridge, the most upstream station examined (river km 72, i.e., just below the Old River divergence), there was little to no difference in temperature between NAA and PA (see exceedance plots in Appendix 5.B, *DSM2 Methods and Results*, Section 5.B.5: Figure 5.B.5.42-1), as would be expected given that the main source of water is the San Joaquin River under both scenarios. At the Stockton Deep Water Ship Channel, differences were apparent from January to June, which may reflect a greater proportion of warmer San Joaquin River water under the PA as a combined result of the presence of the HOR gate and less south Delta exports. The greatest differences occurred in the cold months of January and February, which suggests that there would be little issue for juvenile or adult steelhead and spring-run Chinook salmon from the San Joaquin River basin at this time because water temperatures are not limiting in these months, whereas slightly higher water temperatures during April-June could result in less suitable habitat conditions for juvenile steelhead, given that temperatures above 15-17°C are above optimal (Moyle et al. 2008). There would be less of an issue for juvenile spring-run Chinook salmon, for which temperatures above 19-20°C are above optimal (Moyle et al. 2008). At Prisoners Point, similar patterns to the Stockton Deep Water Ship Channel were evident for January to April, whereas in May and June, there was little difference between the NAA and PA, which is more similar to the pattern at Rio Vista and reflects general warming and a lesser influence of operations on water temperature with movement downstream. Overall, there appears to be the potential for a small negative effect of greater water temperature on steelhead juveniles, because of slightly higher spring water temperature in the San Joaquin River at the Stockton Deep Water Ship Channel. However, this may have little biological effect on steelhead because of the small magnitude of temperature differences between the PA and NAA scenarios and the high frequency of May and June temperatures that exceed the optimal temperature range for both the PA and NAA, indicating temperatures would be above optimal under both scenarios. As previously noted, in general it is expected that air temperature is the main driver on water temperature in the Delta, as shown by detailed temperature modeling that does not include the effects of flow and has higher correspondence with observed temperatures than DSM2-QUAL estimates (Wagner *et al.* 2011)

5.4.1.3.1.2.2.3 Selenium

The increase in the proportion of San Joaquin River water entering the Delta because of less south Delta exports under the PA would be expected to increase the selenium concentration in Delta water. However, the analyses of potential effects on trophic level 3 species, which are representative of juvenile salmonids, showed essentially no difference between PA and NAA scenarios in particulate, invertebrate, or whole-body estimates of selenium concentration (see Appendix 5.F, *Selenium Analysis*). Therefore, the PA is not likely to increase exposure of salmonids to selenium toxicity.

Olfactory Cues for Upstream Migration

Attraction flows and the importance of olfactory cues to adult Chinook salmon were well described by Marston et al. (2012):

> Chinook salmon rely primarily on olfactory cues to successfully migrate through the Delta's maze of waterways to home back to their natal river (Groves et al.

> 1968; Mesick 2001). Juvenile salmon imprint by acquiring a series of chemical waypoints at every major confluence that enables them to relocate their river of origin (Quinn 1997 ; Williams 2006).

Marston et al. (2012) used recoveries of coded-wire tags from hatchery-origin Chinook salmon to estimate stray rates of adults. Fish released further upstream in-river had considerably lower straying rates than fish released downstream (including in San Francisco Bay) presumably because the fish released downstream had imprinted on fewer waypoints. For the Sacramento River, the stray rate for fish released upstream of the confluence of the Sacramento and San Joaquin Rivers was very low (average 0.1%, range 0 to 6.7%; Marston et al. 2012 [Methods Appendix:10])—If this rate is representative of wild populations spawned upstream, then it suggests a very low rate of straying for fish emigrating from natal tributaries in the Sacramento River basin with the existing flows through the Delta. As noted by Marston et al. (2012:18), Quinn (1997) suggested that background levels of straying for hatchery-origin salmon are 2 to 5%, although few studies have been conducted on wild-origin Chinook salmon; one such study for wild-origin Mokelumne River Chinook salmon—albeit a population with appreciable hatchery influence—reported a stray rate of over 7% (Williams 2006).

Sacramento River flows downstream of the proposed NDD generally would be lower under PA operations relative to NAA, with differences between water-year types because of differences in the relative proportion of water being exported from the NDD and south Delta export facilities. As assessed by DSM2-QUAL fingerprinting analysis, the average percentage of Sacramento River–origin water at Collinsville, where the Sacramento and San Joaquin Rivers converge in the west Delta, was estimated to be always slightly lower under PA than NAA (Table 5.4-22). However, during the fall/winter/spring periods of interest for upstream migrating salmonids, Sacramento River water formed the majority of water in the confluence area, and differences between scenarios were within the 20% change in olfactory cues that adult sockeye salmon detected and behaviorally responded to (Fretwell 1989). Therefore, it is concluded that there would be little potential for an effect from changes in olfactory cues for upstream migrating adults salmonids from the Sacramento River basin.

Less use of the south Delta export facilities under the PA would result in a greater amount of San Joaquin River reaching the confluence area (Table 5.4-23), which may increase the olfactory cues available for upstream migrating adult salmonids from the San Joaquin River basin, including steelhead and spring-run Chinook salmon. As shown by Marston et al. (2012), relatively small changes in the ratio of south Delta exports to San Joaquin River inflow may affect the straying rate of upstream migrating adult fall-run Chinook salmon[37]. The several-fold increase in San Joaquin River flow reaching the confluence area under the PA (Table 5.4-23) has the potential to improve homing of adult salmonids, including steelhead and spring-run Chinook salmon, to the San Joaquin River basin.

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[37] There is uncertainty in the relative or combined importance of San Joaquin River flow and south Delta exports explaining straying rates better (Marston et al. 2012); as noted by Marston et al. (2012), statistically speaking, the results of their analysis suggested San Joaquin River flows were more important than south Delta exports (with the latter not being statistically significant at $P < 0.05$), but because little if any pulse flow leaves the Delta when south Delta exports are elevated, exports in combination with pulse flow may be of importance.

Table 5.4-22. Mean Percentage of Water at Collinsville Originating in the Sacramento River, from DSM2-QUAL Fingerprinting.

Month	Wet				Above Normal				Below Normal				Dry				Critical		
	NAA	PA	PA vs. NAA		NAA	PA	PA vs. NAA		NAA	PA	PA vs. NAA		NAA	PA	PA vs. NAA		NAA	PA	PA vs. NAA
Jan	71.8	71.4	0 (0%)		71.7	70.5	-1 (-2%)		72.8	70.7	-2 (-3%)		72.3	69.4	-3 (-4%)		71.9	71.3	-1 (-1%)
Feb	65.4	59.1	-6 (-11%)		74.4	69.2	-5 (-8%)		80.6	76.2	-4 (-6%)		81.0	78.7	-2 (-3%)		80.1	78.6	-1 (-2%)
Mar	69.2	58.9	-10 (-17%)		77.6	69.1	-9 (-12%)		83.4	76.6	-7 (-9%)		82.1	76.9	-5 (-7%)		80.7	78.4	-2 (-3%)
Apr	70.7	63.0	-8 (-12%)		79.0	70.0	-9 (-13%)		81.9	76.5	-5 (-7%)		81.4	77.5	-4 (-5%)		77.0	75.4	-2 (-2%)
May	73.8	67.3	-6 (-10%)		75.2	68.4	-7 (-10%)		74.5	70.7	-4 (-5%)		73.9	71.8	-2 (-3%)		68.4	66.8	-2 (-2%)
Jun	71.7	60.2	-11 (-19%)		67.4	60.1	-7 (-12%)		67.2	64.0	-3 (-5%)		68.7	66.0	-3 (-4%)		60.4	59.0	-1 (-2%)
Jul	74.3	59.8	-14 (-24%)		75.8	63.2	-13 (-20%)		73.1	63.7	-9 (-15%)		62.3	57.7	-5 (-8%)		54.3	52.3	-2 (-4%)
Aug	67.0	56.3	-11 (-19%)		71.3	62.9	-8 (-13%)		68.5	61.0	-7 (-12%)		60.3	55.4	-5 (-9%)		51.2	48.6	-3 (-5%)
Sep	88.9	83.6	-5 (-6%)		79.8	76.6	-3 (-4%)		58.5	51.0	-8 (-15%)		53.6	48.7	-5 (-10%)		48.9	46.8	-2 (-4%)
Oct	86.6	80.9	-6 (-7%)		76.1	75.0	-1 (-1%)		53.4	56.9	4 (6%)		50.1	54.7	5 (8%)		42.8	46.5	4 (8%)
Nov	86.0	73.7	-12 (-17%)		76.5	70.1	-6 (-9%)		57.6	57.9	0 (0%)		56.4	57.9	1 (3%)		41.4	43.9	3 (6%)
Dec	77.1	70.7	-6 (-9%)		75.5	69.3	-6 (-9%)		67.7	65.0	-3 (-4%)		67.6	65.6	-2 (-3%)		59.4	57.5	-2 (-3%)

Table 5.4-23. Mean Percentage of Water at Collinsville Originating in the San Joaquin River, from DSM2-QUAL Fingerprinting.

Month	Wet				Above Normal				Below Normal				Dry				Critical		
	NAA	PA	PA vs. NAA		NAA	PA	PA vs. NAA		NAA	PA	PA vs. NAA		NAA	PA	PA vs. NAA		NAA	PA	PA vs. NAA
Jan	1.3	3.4	2.1 (63%)		0.1	0.8	0.7 (92%)		0.2	0.5	0.3 (68%)		0.4	1.2	0.7 (63%)		0.2	0.2	0.0 (24%)
Feb	2.1	5.5	3.4 (62%)		1.0	3.0	2.0 (67%)		0.5	2.8	2.3 (83%)		0.3	1.2	0.9 (79%)		0.1	0.3	0.2 (66%)
Mar	4.1	11.4	7.3 (64%)		1.9	6.8	4.9 (72%)		1.4	5.0	3.7 (72%)		0.9	2.7	1.8 (67%)		0.3	1.0	0.7 (71%)
Apr	8.5	15.6	7.0 (45%)		4.2	11.7	7.5 (64%)		2.0	6.0	4.1 (67%)		1.6	3.9	2.4 (61%)		0.6	1.7	1.2 (68%)
May	13.6	19.8	6.3 (32%)		10.0	16.6	6.6 (40%)		5.7	9.7	4.1 (42%)		3.7	6.5	2.8 (43%)		0.9	2.3	1.4 (60%)
Jun	11.3	21.4	10.0 (47%)		8.5	15.1	6.7 (44%)		4.9	8.5	3.6 (43%)		3.3	6.0	2.7 (45%)		1.1	2.4	1.3 (55%)
Jul	5.5	14.5	8.9 (62%)		2.0	6.3	4.3 (68%)		1.3	3.4	2.1 (62%)		0.9	2.4	1.5 (62%)		0.6	1.5	0.9 (58%)
Aug	1.8	6.3	4.5 (71%)		0.2	1.6	1.4 (85%)		0.2	0.9	0.7 (80%)		0.2	0.8	0.6 (75%)		0.2	0.6	0.4 (61%)
Sep	0.2	1.9	1.6 (89%)		0.0	0.5	0.4 (91%)		0.0	0.3	0.3 (86%)		0.1	0.3	0.2 (76%)		0.1	0.3	0.1 (58%)
Oct	0.1	3.1	3.0 (96%)		0.0	0.7	0.7 (98%)		0.0	0.3	0.3 (94%)		0.0	0.2	0.2 (85%)		0.1	0.1	0.1 (53%)
Nov	0.6	9.6	9.0 (94%)		0.1	3.9	3.8 (98%)		0.1	1.2	1.1 (95%)		0.1	0.7	0.6 (89%)		0.1	0.4	0.2 (59%)
Dec	0.8	5.1	4.3 (84%)		0.1	3.2	3.1 (98%)		0.1	0.7	0.6 (89%)		0.2	0.6	0.5 (71%)		0.2	0.3	0.1 (39%)

5.4.1.3.1.2.2.4 Microcystis

The toxic blue-green alga *Microcystis* has been shown to have negative effects on the aquatic foodweb of the Delta (Brooks et al. 2012), principally in the south Delta and the middle to upper portions of the west/central Delta near locations such as Collinsville, Antioch, and Franks Tract (Lehman et al. 2010). *Microcystis* blooms generally occur from June to October, when water temperature is at least 19°C (Lehman et al. 2013). Lehman et al. (2013) suggested that streamflow is probably the most important factor maintaining *Microcystis* blooms, with longer residence times allowing the slow-growing colonies to accumulate into blooms. The summer/fall timing of *Microcystis* generally would be expected to avoid the period of occurrence of juvenile and adult winter-run and spring-run Chinook salmon and juvenile steelhead. *Microcystis* could, however, coincide with the occurrence of upstream-migrating adult steelhead, particularly those returning to the San Joaquin River basin that pass through the channels in the south Delta, where *Microcystis* is often abundant (Lehman et al. 2013). Quantitative analyses presented in detail for Delta Smelt in Section 6.1.3.5.5, *Microcystis*, showed that, based on analysis of flow in the lower San Joaquin River, conditions may be less favorable for *Microcystis* under the PA because of less south Delta exports and greater San Joaquin River flow past Jersey Point (QWEST). However, there are portions of the south Delta where residence time would be greater under the PA, which could give greater potential for *Microcystis* occurrence under the PA, although there has been no detailed study of *Microcystis* occurrence specifically in relation to residence time. Adult steelhead may be migrating through the Delta toward natal tributaries somewhat rapidly and without feeding, so the potential for ingestion of contaminated prey over longer periods would be limited; there is evidence that ingestion of prey contaminated by *Microcystis* can have effects on fish within the Delta (Lehman et al. 2010). Laboratory exposure of yearling rainbow trout to water containing *Microcystis* cell concentrations representative of bloom conditions did not give lethal effects or evidence of liver damage, suggesting that there is negligible entry of toxins through the gills or skin (Tencalla et al. 1994); however, it is possible for the toxins to enter fish guts passively during swimming (De Magalthaes et al. 2001, as cited by Lehman et al. 2010). Overall, this analysis suggests that the potential for negative effects to steelhead from changes in *Microcystis* under the PA relative to the NAA is insignificant. Under the assumption that the migration timing of San Joaquin River spring-run Chinook salmon is similar to that of Sacramento River basin spring-run, this suggests that most individuals would occur in the Delta during winter/spring and therefore would avoid the season of *Microcystis* occurrence. However, yearling juveniles migrating downstream could occur in the fall and therefore have some overlap with *Microcystis*. The risk to yearling San Joaquin River spring-run Chinook salmon associated with the mixed effects of the PA on *Microcystis*, including potential greater occurrence of *Microcystis* in some areas, is uncertain. As described in Section 6.1.3.5.5.5.2 *Population-Level Effects* for Delta Smelt, there is potential to mitigate effects on *Microcystis* through preferential south Delta export pumping: the modeling currently assumes that in the summer months (July–September), the first 3,000 cfs of exports would be from the south Delta, with any additional allowable exports able to be diverted from either the north or the south Delta; it would be possible to shift to additional south Delta pumping as opposed to north Delta pumping in order to reduce water residence time, for example. Subsequent monitoring will confirm to what extent the yearling life history trait occurs for San Joaquin River basin spring-run Chinook salmon.

5.4.1.3.2 Green Sturgeon

5.4.1.3.2.1 Near-Field Effects

5.4.1.3.2.1.1 North Delta Exports

5.4.1.3.2.1.1.1 Entrainment

Green sturgeon eggs, embryos, and larvae occur farther upstream in the Sacramento River than the proposed location of the NDD (Israel and Klimley 2008). Therefore, these life stages would not be entrained by the NDD. NMFS (2009: 119) noted that the lack of a significant proportion of juveniles below 200 mm in length in salvage samples at the south Delta export facilities indicates that juveniles likely hold in the mainstem Sacramento River upstream of the Delta before moving downstream. This would mean that juvenile green sturgeon would be effectively screened, given the 1.75-mm openings in the NDD screens.

5.4.1.3.2.1.1.2 Impingement and Screen Contact

Green sturgeon are demersal (i.e., tend to occupy the bottom of the channel), and therefore less likely to occur near vertical, on-bank fish screens that are off the river bottom, as proposed for the NDD. Preliminary studies at the UC Davis Fish Treadmill facility found that juvenile green sturgeon frequently contacted the fish screen but survival was high and the fish were not injured, with screen contact rate being unrelated to water velocity or time of day (Swanson et al. 2004b). Recent studies with a V-shaped screen in a test flume confirmed that contact with screens was frequent, and in this case screen contact was increased with increasing water velocity and was greater by day than by night (Poletto et al. 2014). There is therefore a potential for adverse effects from screen contact (e.g., injury), although impingement was rarely observed in laboratory studies.

5.4.1.3.2.1.1.3 Predation

NMFS (2009: 350) suggested that predation on juvenile green sturgeon during occurrence in Clifton Court Forebay would be minimal, given their size and protective scutes, but noted that this has never been experimentally verified. If true, the potential for predation at the NDD would be expected to be insignificant because the size and protective scutes of green sturgeon occurring near the NDD and the predators would be similar to that found in Clifton Court Forebay. However, there is uncertainty in the potential and extent of predation of juvenile green sturgeon at the NDD.

5.4.1.3.2.1.2 South Delta Exports

As noted for salmonids in Section 5.4.1.3.1.1.2, *South Delta Exports*, direct entrainment by the south Delta export facilities includes a number of components contributing to loss, including prescreen loss; louver efficiency; collection, handling, trucking, and release; and post-release mortality. However, specific loss estimates for these components generally are unknown for green sturgeon (National Marine Fisheries Service 2009: 341-374). Consistent with the analysis for salmonids, the present analysis for green sturgeon provides quantitative analyses of entrainment differences between NAA and PA, and a qualitative discussion of potential predation differences between NAA and PA. The various components of salvage loss (prescreen loss, etc.) are assumed not to differ between NAA and PA (other than qualitative discussion of potential prescreen loss differences in Clifton Court Forebay), so the differences between NAA and PA are attributable to differences in export pumping.

5.4.1.3.2.1.2.1 Entrainment

5.4.1.3.2.1.2.2 Salvage-Density Method

The salvage-density method was used to assess differences in south Delta exports and resulting entrainment during the periods of occurrence of juvenile green sturgeon in the Delta, based on historical salvage data. Details of the method, together with results by month and water year, are presented in Appendix 5.D, *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale*, Section 5.D.1.1.2, *South Delta Exports*. As noted previously for juvenile salmonids, although this method provides an index of entrainment, it is most appropriately viewed comparatively, and functions primarily to illustrate south Delta export differences between scenarios. The method does not account for differences in salvage that could occur because of other operational effects, e.g., changes in juvenile sturgeon routing because of the NDD or the HOR gate.

The results of the salvage-density method showed that, based on modeled south Delta exports, mean salvage of juvenile green sturgeon at the south Delta export facilities would be lower under PA than NAA in all water year types that salvage had historically occurred (Table 5.4-24); during the historic period providing the salvage-density data for the analysis (1996-2008), there was no observed salvage of green sturgeon in above normal years (CVP), below normal years (CVP/SWP), and critical years (SWP), so this meant the density in these months was zero and therefore there were no differences between the NAA and PA scenarios in salvage estimate. The differences between PA and NAA were greater in wetter water years, as a result of less south Delta export pumping facilitated by operation of the NDD. The differences between scenarios ranged from 0% in the aforementioned periods when no salvage occurred historically, to 65% less under PA at the SWP in wet years (Table 5.4-24).

Table 5.4-24. Estimated Mean Entrainment Index (Number of Fish Salvaged, Based on Nonnormalized Salvage Data) of Juvenile Green Sturgeon for NAA and PA Scenarios at the CVP/SWP Salvage Facilities, By Water Year Type

Water Year Type	State Water Project				Central Valley Project		
	NAA	PA	PA vs. NAA[1]		NAA	PA	PA vs. NAA[1]
Wet	109	38	-71 (-65%)		69	28	-41 (-60%)
Above Normal	12	7	-5 (-41%)		0	0	0 (0%)
Below Normal	0	0	0 (0%)		0	0	0 (0%)
Dry	22	19	-3 (-13%)		51	24	-27 (-53%)
Critical	0	0	0 (0%)		7	5	-1 (-17%)

Notes: [1]Negative values indicate lower entrainment loss under the proposed action (PA) than under the no action alternative (NAA).

5.4.1.3.2.1.2.3 Predation

As previously noted for the NDD, NMFS (2009: 350) suggested that predation on juvenile green sturgeon during occurrence in Clifton Court Forebay would be minimal, given their size and protective scutes, but noted that this has never been experimentally verified. Therefore, reductions in entrainment under the PA would not be expected to lead to anything more than a minimal reduction in entrainment-related predation at the south Delta export facilities. Localized reduction in predatory fishes (Section 5.5.2, *Localized Reduction of Predatory Fishes to*

Minimize Predator Density at North and South Delta Export Facilities) may decrease predatory fish density in Clifton Court Forebay, but given that there is uncertainty in the feasibility of doing so (based on previous studies; Brown et al. 1996) and NMFS's (2009: 350) suggestion that predation is minimal, the action would also be expected to provide no more than a minimal benefit to green sturgeon; the uncertainty in the measure's effectiveness means that for this BA, no effectiveness is assumed.

5.4.1.3.2.1.3 Head of Old River Gate

5.4.1.3.2.1.3.1 Predation

In contrast to juvenile salmonids, for which predation near previously implemented barriers at the HOR has been observed, there is no such information about predation risk near the HOR gate for green sturgeon. Following the logic of NMFS (2009: 350), which suggested that there may be minimal predation in Clifton Court Forebay because of the size of juvenile green sturgeon and their protective body scutes, there may be minimal risk to juvenile green sturgeon from predation at the HOR gate; however, as noted by NMFS (2009: 350) for Clifton Court Forebay, this has not verified experimentally, and the potential for predation of green sturgeon at the head of Old River gate is uncertain.

5.4.1.3.2.1.3.2 Upstream Passage

Passage of green sturgeon at the vertical slot fishway proposed for the HOR gate under the PA would be expected to be limited, as the structure is designed primarily for adult salmonid passage, whereas sturgeon have different requirements for successful passage (Webber et al. 2007). Therefore, green sturgeon intending to migrate to the San Joaquin River main stem from Old River could be confined to Old River until the HOR gate opened again. For the spring operations, this would be an adverse effect relative to the NAA, for which a rock barrier is not always installed. In the fall, operations of the HOR gate again could block passage of green sturgeon intending to move into the San Joaquin River from Old River; however, although the existing fall rock barrier has a 30-foot-wide notch at elevation 2.3 feet NAVD, the demersal nature of green sturgeon means that passage is unlikely under the NAA, based on NMFS' (2013a: 82) observation of passage being unlikely over the weir crests of other temporary barrier in the south Delta. Therefore, during the fall RTO of the HOR gate, passage impediment of green sturgeon in the south Delta would be insignificantly different from the NAA.

5.4.1.3.2.1.4 Delta Cross Channel

Given that the main period of upstream migration of adult green sturgeon is in the winter/spring, it is expected that the DCC gates would be closed and therefore any adult green sturgeon bound for the upper Sacramento River that encounter the gates would need to migrate back down the Mokelumne River and ascend an alternative Delta channel leading to the main stem Sacramento River. Any such delays in migration would be the same under the NAA and PA, given the same operational criteria during this time period (see Table 5.A.6-31 in Appendix 5.A, *CalSim II Modeling and Results*). NMFS (2009: 408) noted that there is little information available regarding juvenile green sturgeon movements in the lower Sacramento River and Delta waterways, and although there is newer available information since the assessment of NMFS (2009)—i.e., the summary by Klimley et al. (2015) of juvenile movements; see Section 5.4.1.3.2.2.1 *Indirect Mortality Within the Delta*—it remains unknown how vulnerable juvenile green sturgeon are to diversion into the DCC or their risk from predation in the Delta. The monthly number of days that the DCC gates would be open generally would be expected to be similar between NAA and PA throughout most of the year, except during fall, as discussed for salmonids. Therefore, differences between NAA and PA in effects on juvenile green sturgeon, which reside in the Delta for several years, are likely to be limited.

5.4.1.3.2.1.5 Suisun Marsh Facilities

5.4.1.3.2.1.5.1 Suisun Marsh Salinity Control Gates

As described by NMFS (2009: 435-436), little is known about adult green sturgeon upstream passage at the SMSCG, with existing studies suggesting that use of Suisun and Honker Bays was greater than Montezuma Slough where the SMSCG are located. NMFS (2009: 435-436) suggested that adult green sturgeon would have the opportunity to pass the SMSCG through the boat locks or gates (when open), as adult salmonids do, but that they could be delayed. However, any delays would not affect access to spawning habitat in the upper Sacramento River because adult green sturgeon tend to spawn in deeper water (Poytress et al. 2015) that would not be affected by temporary changes in flow; in addition, previous concerns from NMFS (2009: 436) regarding delays potentially affecting timing of arrival at Red Bluff Diversion Dam (where passage was previously restricted) no longer apply because of the decommissioning of the RBDD. The potential for predation near the SMSCG that was previously discussed for juvenile salmonids would be of minimal concern for juvenile green sturgeon because they are relatively large and unlikely prey for striped bass and Sacramento pikeminnow (National Marine Fisheries Service 2009: 439). In addition, as noted by NMFS (2009: 436), the multi-year estuarine residence of juvenile green sturgeon often includes long periods of localized, non-directional movement interspersed with occasional long-distance movements (Kelley et al. 2007); such movements are unlikely to be negatively affected by periodic delays of a few hours to a few days at the SMSCG. As discussed for salmonids, operational criteria for the SMSCG would not change under the PA relative to NAA, and operations modeling suggested that there would be little difference between NAA and PA in terms of SMSCG opening (see Table 5.B.5-29 in Appendix 5.B, *DSM2 Methods and Results*). Therefore any effects on green sturgeon from the SMSCG would be similar under NAA and PA.

5.4.1.3.2.1.5.2 Roaring River Distribution System

As previously described for juvenile salmonids, the low screen velocity at the RRDS intake culverts combined with a small screen mesh size are expected to successfully prevent green sturgeon from being entrained (National Marine Fisheries Service 2009: 437).

5.4.1.3.2.1.5.3 Morrow Island Distribution System

NMFS (2009: 438) noted that the MIDS is not on a migratory corridor for green sturgeon and that no green sturgeon had been entrained during DWR studies at the location in 2004-2006. However, seine surveys in Goodyear Slough did collect one juvenile white sturgeon in 2005-2006 (Enos et al. 2007), indicating that sturgeons can be present in the area. Overall, NMFS (2009: 438) considered it unlikely that green sturgeon would be entrained by the MIDS. Any entrainment that does occur would be expected to be similar between NAA and PA, as operations would not differ.

5.4.1.3.2.1.5.4 Goodyear Slough Outfall

NMFS (2009: 438) concluded that it would be unlikely that green sturgeon 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 green sturgeon by improving water quality and increasing foraging opportunities.

5.4.1.3.2.1.6 North Bay Aqueduct

As described for salmonids, pumping rates at the North Bay Aqueduct Barker Slough Intake generally would be similar under the NAA and PA (see Table 5.B.5-35 in Appendix 5.B, *DSM2 Methods and Results*). In addition, NMFS (2009: 417) noted that green sturgeon are expected to be fully screened by the positive barrier screen in place at the pumping facility.

5.4.1.3.2.1.7 Other Facilities

5.4.1.3.2.1.7.1 Contra Costa Canal Rock Slough Intake

As described for salmonids, greater use of the Rock Slough intake under the PA than NAA could increase the potential for adverse effects to green sturgeon; however, resolution of screening effectiveness issues (new rake technology to eliminate aquatic weed problems) would be expected to limit any potential effects.

5.4.1.3.2.1.7.2 Clifton Court Forebay Aquatic Weed Control Program

As noted for salmonids, green sturgeon that occur in Clifton Court Forebay during application of copper-based herbicides would have the potential to be adversely affected from sublethal or lethal effects, although the potential for exposure to such effects would be limited to relatively few days during which chemical treatments would be applied. Mechanical removal of aquatic weeds such as water hyacinth may be unlikely to affect green sturgeon given their demersal position in the water column, which could limit the potential for direct injury from contact with cutting blades, for example.

5.4.1.3.2.2 Far-Field Effects

5.4.1.3.2.2.1 Indirect Mortality Within the Delta

In contrast to juvenile salmonids that are often moving relatively rapidly through the Delta toward the ocean and for which studies have shown that through-Delta survival can be linked to channel flows and south Delta exports, impacts to juvenile and sub-adult green sturgeon from such factors are less clear. As noted by NMFS (2009: 386), juvenile 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, fish are free to migrate throughout the Delta. Entrainment by the net negative export flows in the central and southern delta may cause fish to be pulled into the southern Delta waterways in an unnatural proportion to their normal movements, and acoustic tracking studies have provided more detailed information on the movements of this lifestage in the Delta. Thirty-two juvenile green sturgeon (30–53-cm fork length) fitted with acoustic tags were released at Santa Clara Shoals in the lower San Joaquin River near Fishermans Cut (Klimley et al. 2015). Over the nine-and-a-half-month life of the tags, these juvenile green sturgeon exhibited six behavioral patterns: 1) remained in the Delta, 2) moved into the Carquinez Strait, 3) migrated into San Pablo Bay, 4) moved into San Pablo Bay but returned to the Delta, 5) migrated through the estuary and likely left through the mouth of the bay, and 6) left the estuary only to later return. Thirty of the 32 tagged individuals were detected in the Central Delta, where they were released. Individuals stayed within this region on average 90.6 days and 44.3% of the time. The juveniles also stayed within the East Delta and the region between the East and Central Delta (see Figure 3 of Klimley et al. 2015). Fourteen individuals spent an average of 26.7 days and 28% of the time in the East Delta, and 16 juveniles spent 34.1 days and 31.0% of the time in the Central Delta. The next most inhabited regions were San Pablo Bay (15 individuals spent 26.0 days and 12.0% of their time) and around the Richmond Bridge (14 individuals spent 34.1 days and 13.4% of their time). As many as seven juveniles were detected near the Golden Gate Bridge, where they were present an average of 23.2 days and 9.9% of total days. Overall, these observations suggest the potential for both wide-ranging movements as well as residency in relatively small geographic areas for appreciable periods of time (multiple weeks). As described for juvenile salmonids in the summary of Delta hydrodynamics based on DSM2-HYDRO (Section 5.4.1.3.1.2.1.1, *Channel Velocity (DSM-HYDRO)* and Section 5.4.1.3.1.2.1.2.1, *Flow Routing Into Channel Junctions*, under the PA, channel velocity and flow routing into interior Delta channels generally would be expected to be improved in the south Delta because of less south Delta exports relative to NAA.

5.4.1.3.2.2.2 Habitat Effects

5.4.1.3.2.2.2.1 Delta Outflow

The reproductive success of white sturgeon, as judged by the year-class index of downstream trawl captures, is greatest in wet and above-normal water years when spring flows are high (Kohlhorst et al. 1991; Fish 2010). No similar studies have been conducted for green sturgeon because similar indices of year-class strength are not available. The mechanism behind the importance of higher flows for white sturgeon is not known and may involve both upstream and downstream (Delta) factors. Hypotheses for the mechanism underlying flow effects include higher flows facilitating young white sturgeon dispersal downstream, providing increased freshwater rearing habitat, increasing spawning activity cued by higher upstream flows, increasing nutrient loading into nursery areas, or increasing downstream migration rate and survival through reduced exposure time to predators (U.S. Fish and Wildlife Service 1995; Israel pers. comm.). Higher spring flows also benefit incubating eggs (U.S. Fish and Wildlife Service 1995). Coutant (2004) hypothesized that large recruitment events only happen during years when high spring and early summer outflows occur. This hypothesis was subsequently tested and found to be supported on the Columbia River by van der Leeuw et al. (2006).

As noted by Fish (2010), white sturgeon year-class indices correlate with Delta outflows, which are currently correlated with Delta inflows, at various periods. As described above, it is unclear if year-class strength for white sturgeon is explained best by Delta outflow, Delta inflow, both inflow and outflow, or flow-related changes in upstream areas. NMFS hypothesizes that relationships between white sturgeon year class index and Delta outflow may also be applicable to green sturgeon; year class indices for green sturgeon do not exist to examine these relationships directly.

NMFS provided linear regression relationships between white sturgeon year class indices and Delta outflow for two outflow averaging periods (April/May and March-July) (Marcinkevage pers. comm.). Although the raw data of white sturgeon year class index and Delta outflow suggest that nonlinear regression may be appropriate (Figure 5.4-26), there was no difference in explanatory power between linear and quadratic regressions for either averaging period[38], so the simpler, linear regression approach recommended by NMFS was used. Predicted means and 95% prediction intervals were calculated using PROC GLM and PROC PLM in SAS/STAT software, Version 9.4 of the SAS System for Windows.[39]

The analysis suggested that there would be very little difference in white sturgeon year-class index between NAA and PA with respect to either the April-May (Figure 5.4-29 and Figure 5.4-28) or the March-July (Figure 5.4-29 and Figure 5.4-30) Delta outflow averaging periods. Any differences were small, especially in relation to the magnitude of the 95% prediction intervals around the estimates (Figure 5.4-31 and Figure 5.4-31). Therefore, if white sturgeon is found to be a suitable surrogate species for green sturgeon with respect to Delta outflow, and Delta outflow is found to be a key mechanism affecting year class index, then the modeling results suggest that there would be essentially no difference between NAA and PA for green sturgeon with respect to effects from Delta outflow. This is because PA operations currently include provisions to ensure that Delta outflow in the spring is nearly equal to Delta outflow under NAA (see discussion in Appendix 5.A, *CALSIM Methods and Results*, Section 5.A.5.2.4.3)[40]. As explained previously, this analysis does not account for the results of the research and monitoring under the Adaptive Management Program and real time operational adjustments.

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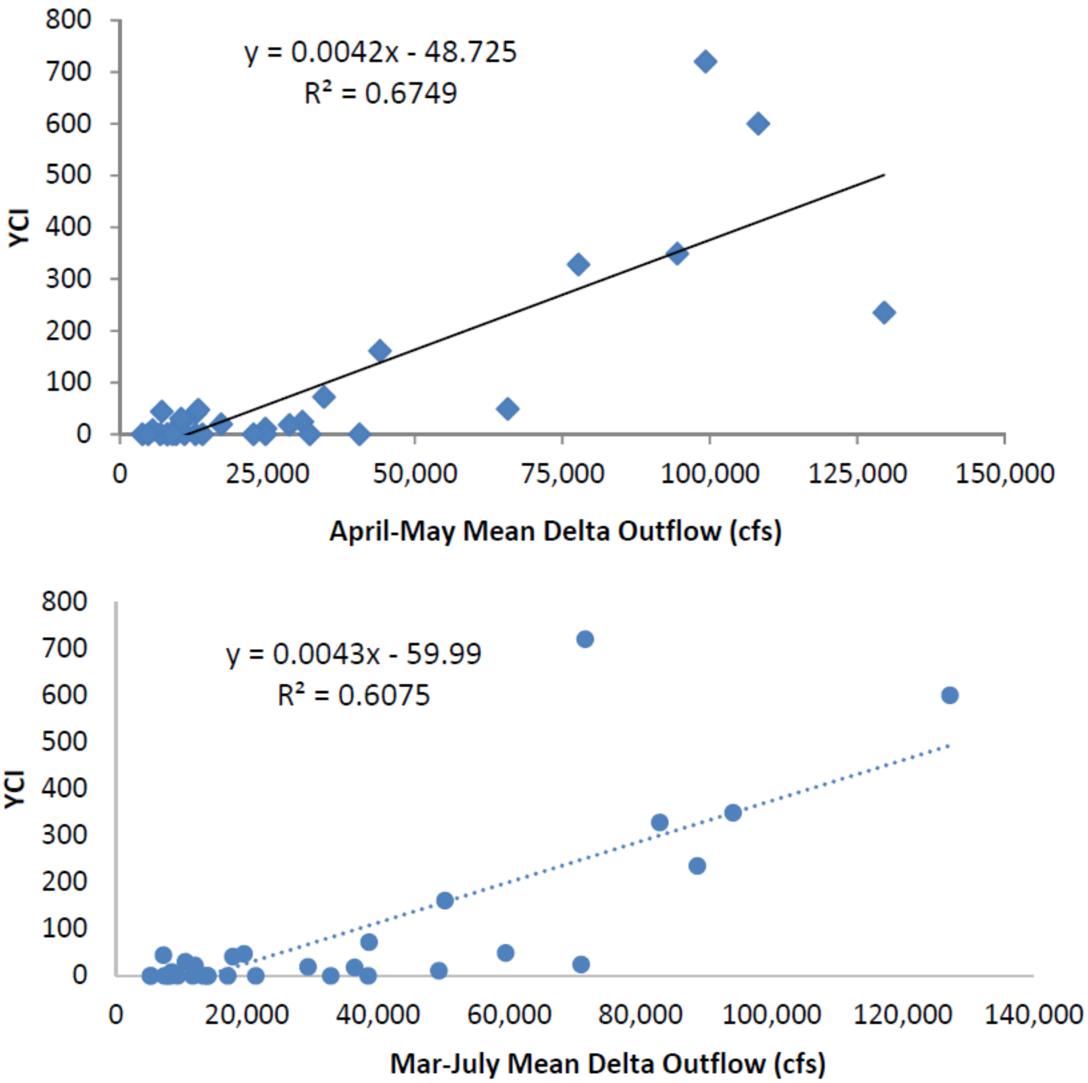
[38] Akaike's information criterion corrected for small sample sizes [AIC_C] was less than two units different for both comparisons of linear vs. quadratic regressions.

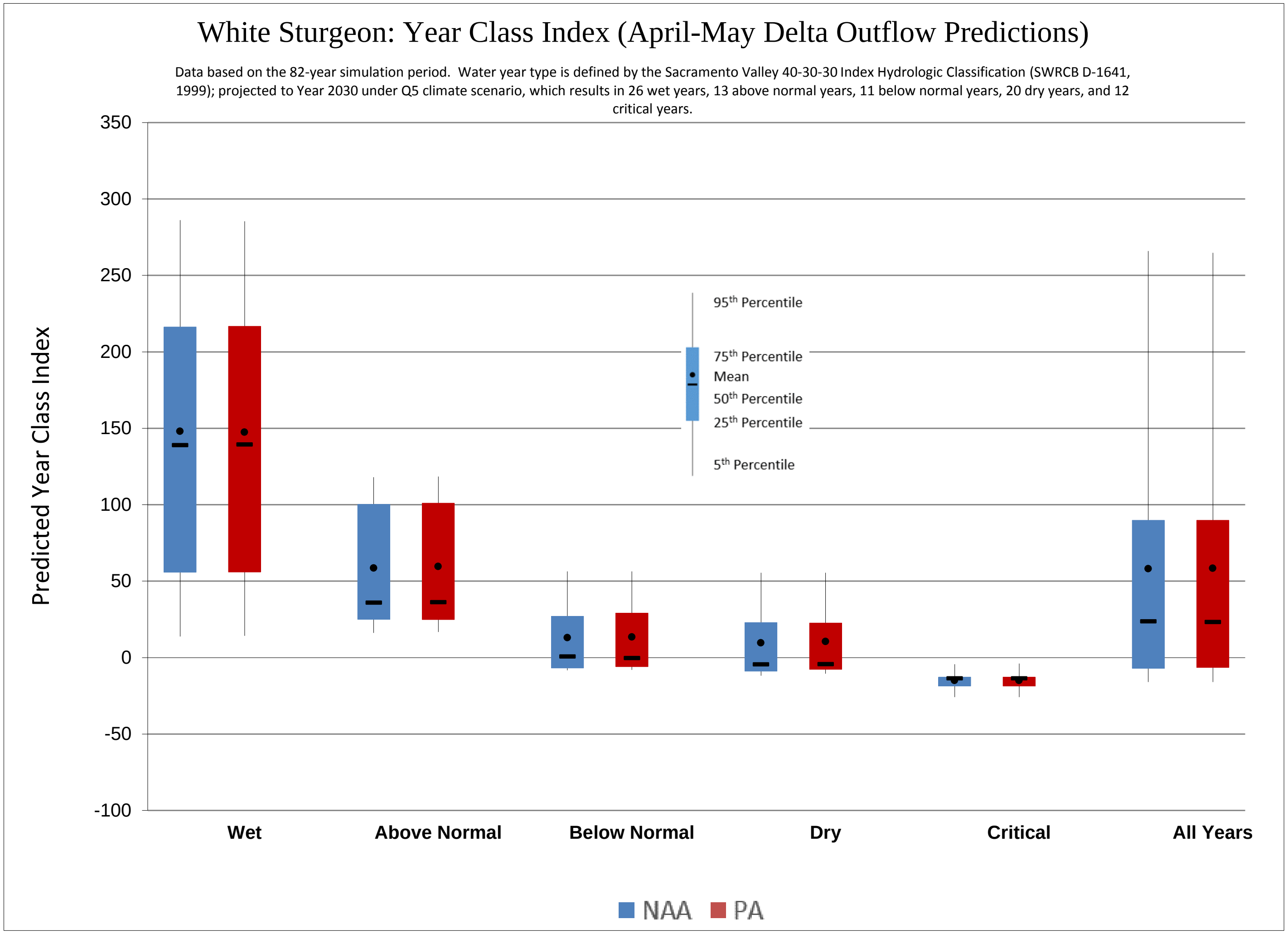
[39] Copyright 2002-2010, SAS Institute Inc. SAS and all other SAS Institute Inc. product or service names are registered trademarks or trademarks of SAS Institute Inc., Cary, NC, USA

[40] As previously noted for analyses in Section 5.4.1.3.1.2.1.3.1 *Delta Passage Model: Winter-Run and Sacramento River Basin Spring-Run Chinook Salmon*, the independent review panel report for the working draft BA suggested that it is possible that the true annual values could lie near the bottom boundary of the prediction interval for PA and near the top boundary of the prediction interval for NAA (Simenstad et al. 2016). This would result in greater differences than suggested by the comparison of annual mean values. By the same rationale, it is also possible that the true annual values could lie near the top boundary of the confidence intervals for both PA and NAA, in which case the differences would be more similar to the differences between means.



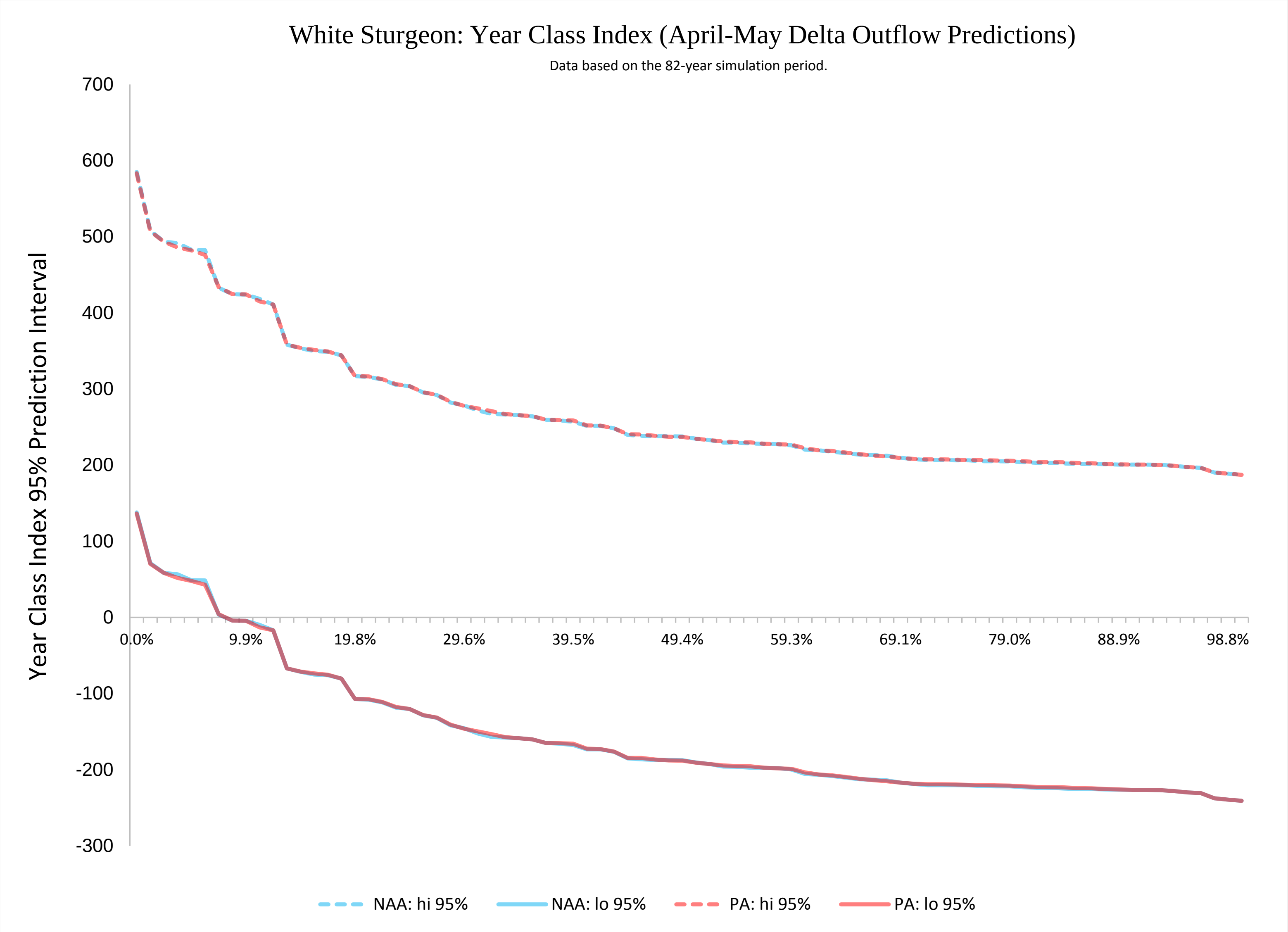
Source: Marcinkevage (pers. comm.)

Figure 5.4-26. White Sturgeon Year-Class Index (YCI) for 1980-2011 as function of Mean April-May Delta Outflow (Upper Panel) and Mean March-July Delta Outflow (Lower Panel).



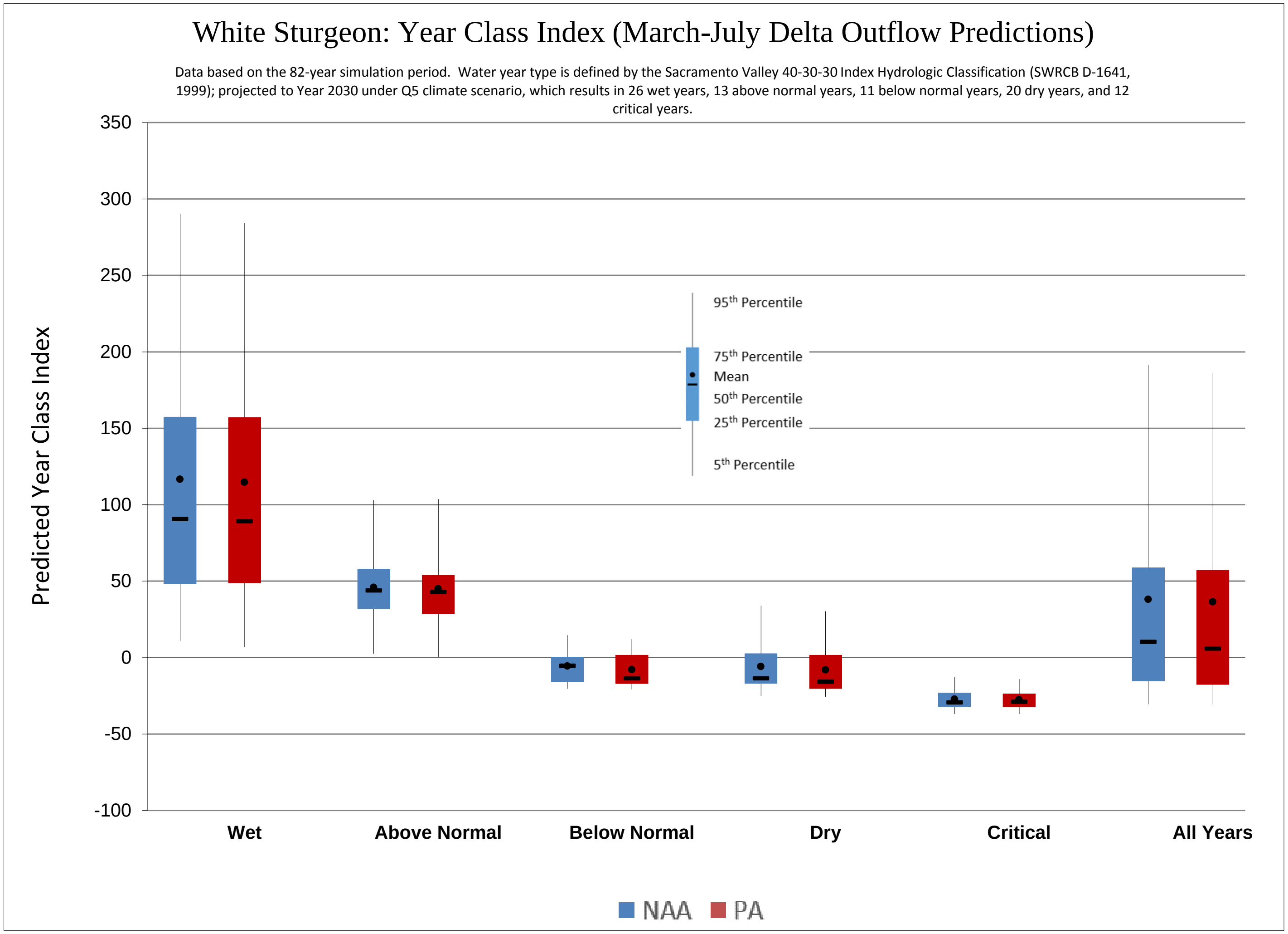
Note: Plot only includes annual mean responses and does not consider model uncertainty.

Figure 5.4-27. Box Plots of White Sturgeon Year Class Index from the Mean April-May Delta Outflow Regression, Grouped by Water Year Type.



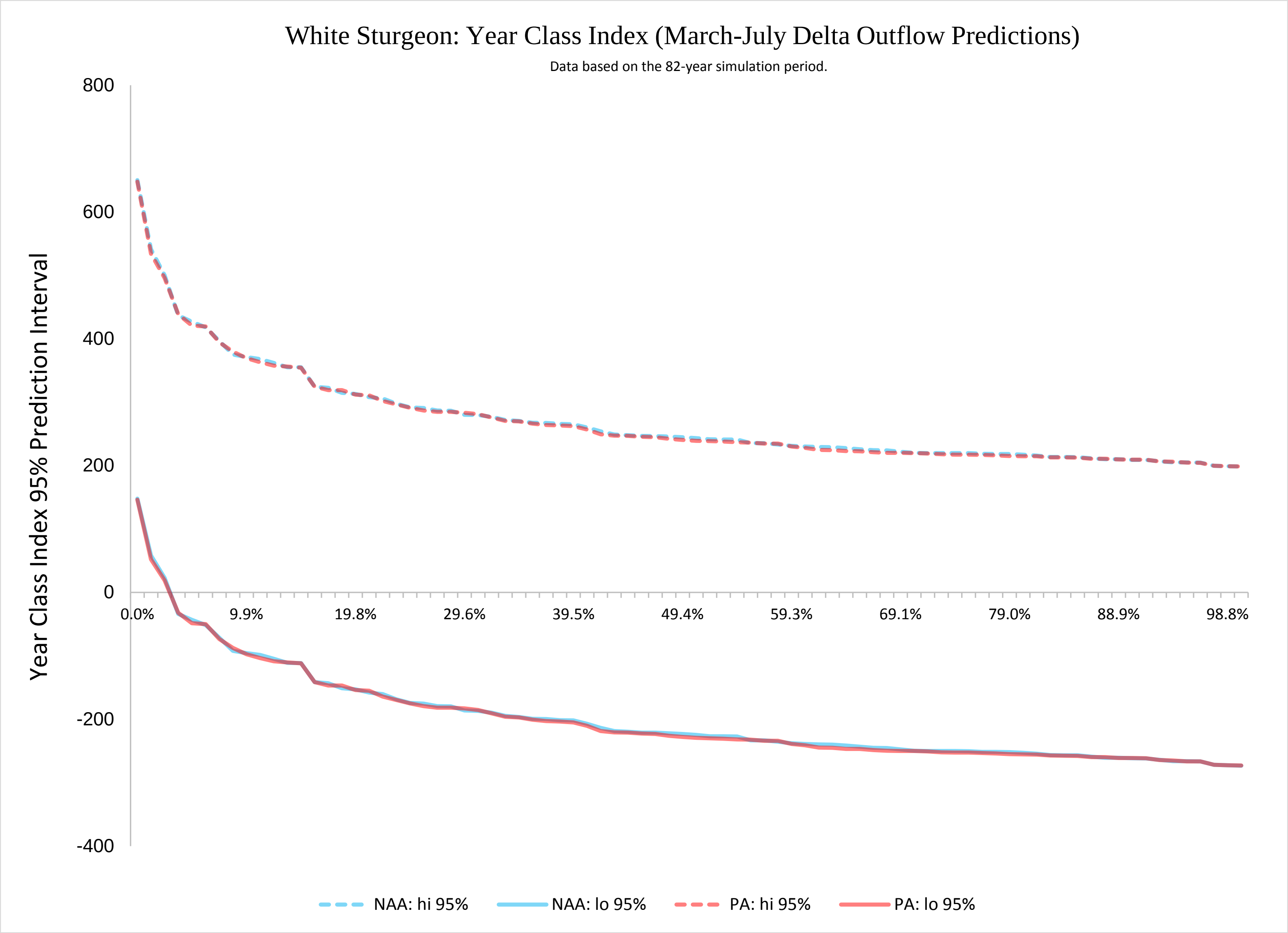
Note: Data are sorted by mean estimate, with only 95% prediction intervals shown.

Figure 5.4-28. Exceedance Plot of White Sturgeon Year Class Index from the Mean April-May Delta Outflow Regression.



Note: Plot only includes annual mean responses and does not consider model uncertainty.

Figure 5.4-29. Box Plots of White Sturgeon Year Class Index from the Mean March-July Delta Outflow Regression, Grouped by Water Year Type.



Note: Data are sorted by mean estimate, with only 95% prediction intervals shown.

Figure 5.4-30. Exceedance Plot of White Sturgeon Year Class Index from the Mean March-July Delta Outflow Regression.

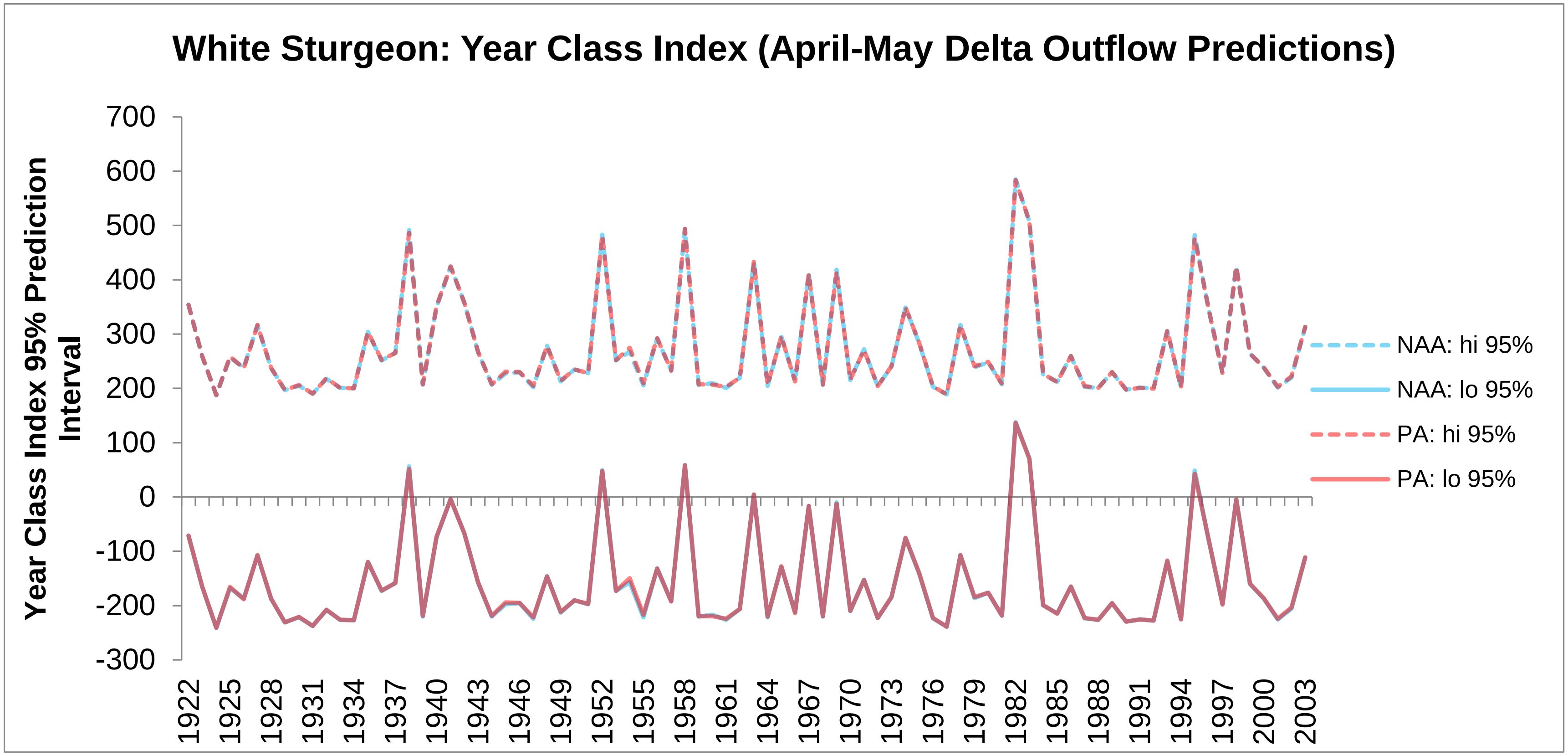


Figure 5.4-31. Time Series of 95% Prediction Interval Annual White Sturgeon Year Class Index, Estimated from the Mean April-May Delta Outflow Regression.

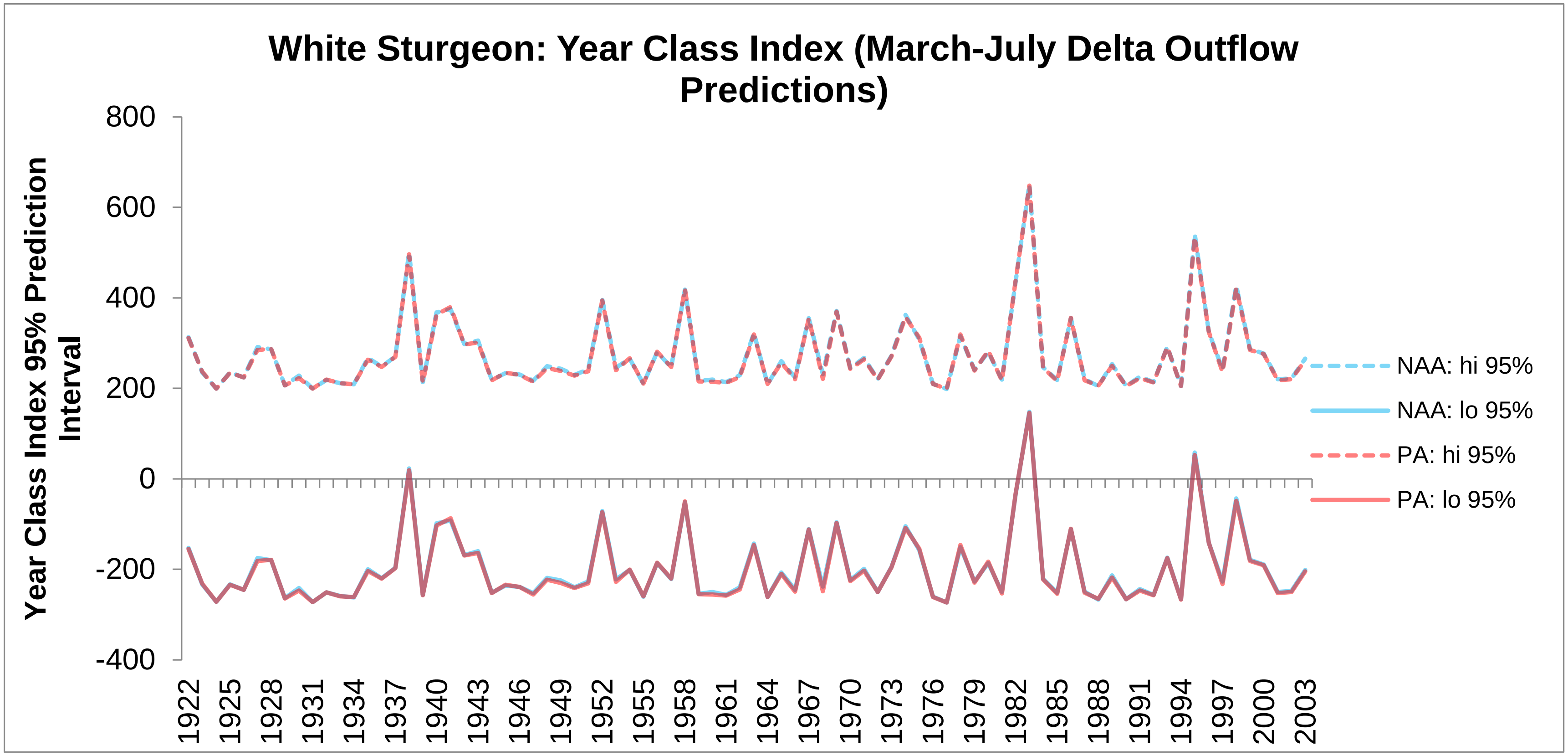


Figure 5.4-32. Time Series of 95% Prediction Interval Annual White Sturgeon Year Class Index, Estimated from the Mean March-July Delta Outflow Regression.

5.4.1.3.2.2.2.2 Selenium

As previously discussed for salmonids, the increase in the proportion of San Joaquin River water entering the Delta because of less south Delta exports under the PA would be expected to increase the selenium concentration in Delta water. A detailed analysis of the potential for effects is provided in Appendix 5.F, *Selenium Analysis*. The analysis presented therein concluded the following:

- Based on the selenium analysis for reproductive effects in green sturgeon (the most sensitive life-stage), no risks to individual green sturgeon or populations are predicted at two locations (Sacramento River upstream of Delta Cross Channel and San Joaquin River near San Andreas Landing).

- Risks to green sturgeon (individuals and populations) at the Old River at Clifton Court Forebay Radial Gates (West Canal) location are considered possible but unlikely (i.e., all dietary concentrations are below the benchmark of 8.2 mg/kg; although there are some exceedances of the whole-body benchmark of 3.3 mg/kg, there are no predicted exceedances of the 5 mg/kg benchmark).

- Modeled green sturgeon whole-body concentrations at the two western Delta locations may present a risk to sturgeon (i.e., all whole-body concentrations exceeded the 3.3 mg/kg threshold and 50 to 70 percent of whole-body concentrations exceeded the less conservative 5 mg/kg threshold). The 3.3 mg/kg threshold is an EC_{05} and the 5 mg/kg threshold is an EC_{10}, which suggests a small percentage of individuals may experience reproductive effects that could translate into a small population effect (under both the NAA and PA). However, it is important to note that there is very little predicted difference under the PA in comparison to the NAA.

- Possible risks identified for green sturgeon would be most likely to occur during dry or critical years.

5.4.1.3.2.2.2.3 Microcystis

As described for salmonids in Section 5.4.1.3.1.2.2.5, *Microcystis*, the PA could have mixed effects on the occurrence of *Microcystis* principally in the south Delta as a result of flow and residence time changes caused by less south Delta export pumping. Juvenile green sturgeon occur in the Delta year-round and therefore could be exposed to *Microcystis* or prey items containing *Microcystis*. The potential effects are uncertain because no studies have been made of *Microcystis* on green sturgeon, although there is evidence for Delta fish species being adversely affected by consumption of *Microcystis*-contaminated food (Lehman et al. 2010; Acuna et al. 2012). During workshops convened in August 2013 to discuss potential effects of the previously proposed BDCP, agency biologists felt that the high mobility of sturgeon juveniles (and adults) would allow movement away from adverse conditions caused by *Microcystis*, although this opinion was made with low certainty.

5.4.1.4 Assess Risk to Individuals

5.4.1.4.1 Salmonids

5.4.1.4.1.1 Risk to Salmonids from Near-Field Effects

5.4.1.4.1.1.1 Risk to Salmonids from North Delta Exports

As described in Section 5.4.1.2.1.4 *Exposure to North Delta Exports*, juvenile salmonids emigrating from the Sacramento River basin could be exposed to the near-field effects of the NDD, with the only individuals not passing through this reach being the proportion of the population entering the Yolo Bypass (estimated to be an average of ~8% in dry and critical water years and ~16% in wet and above normal years for winter-run and spring-run Chinook salmon; Table 5.4-2, Roberts et al. 2013, Acierto et al. 2014). As described in Section 5.4.1.3.1.1.1, the main near-field effects of the NDD on juvenile salmonids may include screen contact (resulting in risk of injury), long screen passage times (increasing the risk of screen contact or predation), and predation (giving risk of mortality). These effects pose some risk to juvenile salmonids, although there is uncertainty in the extent of the risk. As noted in in Section 5.4.1.3.1.1.1.3, indicators of the risk of predation vary between the lower estimates suggested by previous bioenergetics modeling (e.g., 0.3% for winter-run Chinook salmon) to higher estimates (5%) from the study conducted at the GCID fish screen (Vogel 2008b), although in neither case did these estimates consider the baseline rate of predation that might occur without the NDD. Juvenile salmonids from the San Joaquin basin would not be exposed to near-field effects of the NDD. Risk would be minimized by real-time operational adjustments to reduce north Delta exports to coincide with expected or observed pulses of juvenile salmonids into the Delta, as well by screen design (e.g., low approach velocity, small screen opening size per fish agency criteria, on-bank design; see Section 5.4.1.3.1.1.1 *North Delta Exports* and Section 3.2.2 *Fish Screen Design* in Chapter 3, *Description of the Proposed Action*).

5.4.1.4.1.1.2 Risk to Salmonids from South Delta Exports

As described in Section 5.4.1.2.1.5 *Exposure to South Delta Exports*, exposure to entrainment and associated predation at the south Delta exports would be expected to be greater for juvenile steelhead and spring-run Chinook salmon emigrating from the San Joaquin River basin, than for the ~10-30% entering the interior Delta through Georgiana Slough or the Delta Cross Channel that could subsequently move towards the south Delta. As illustrated in Section 5.4.1.3.1.1.2, the near-field effects of the south Delta export facilities present a risk from mortality by entrainment, either through associated predation (e.g., prescreen loss) or other effects (passing through screening louvers); this results in survival of entrained fish being less than 17% at the SWP and ~65% at the CVP. On the basis of less south Delta export pumping under the PA than NAA, analyses presented in Section 5.4.1.3.1.1.2 demonstrate that there is potential for less risk to juvenile salmonids from south Delta entrainment and associated predation under the PA than NAA, particularly in wetter years when a greater proportion of overall export pumping would be undertaken by the NDD under the PA. Since implementation of the NMFS (2009) BiOp, the risk to juvenile salmonids has been limited by export and OMR restrictions. These restrictions have limited loss of juvenile winter-run Chinook salmon entering the Delta to 1.4% to 66% of the permitted incidental take, equating to ~0.03% to 1.3% of the juvenile population entering the Delta (Islam et al. 2015). This loss, and the risk to juvenile Chinook salmon as a result, would be expected to be lower under the PA than the NAA. Analogous estimates of the percentage of other runs of juvenile salmonids lost at the south Delta export facilities are not made[41], but regardless, the loss would be expected to be less under the PA than NAA

For juvenile steelhead and spring-run Chinook salmon from the San Joaquin River basin, the risk of entrainment and associated predation at the south Delta export facilities would be expected to be further reduced under the PA by the operation of the HOR gate.

5.4.1.4.1.1.3 Risk to Salmonids from Head of Old River Gate

As described in Section 5.4.1.2.1.6 *Exposure to Head of Old River Gate Operations*, only juvenile and adult steelhead and spring-run Chinook salmon from the San Joaquin River basin would be expected to be exposed to HOR gate operations. As described in Section 5.4.1.3.1.1.3.1 *Predation*, there is risk to juvenile salmonids from near-field predation at the barrier. This risk is the result of predation that could occur close to the gate when closed, e.g., because of predatory fishes associating with the gate's in-water structure or capitalizing on longer residence times of juvenile salmonids caused by hydrodynamic eddies created by the position of the gate in Old River downstream of the junction (as shown for the 2012 rock barrier; Figure 5.4-33). Enhanced predation could also occur when the gate is open, if predators are able to use the structure as ambush habitat to attack juvenile salmonids passing close to structure near the channel bottom. In addition, the presence of a gate would be expected to guide juvenile salmonids toward a high-predation area in the scour hole in the San Joaquin River just downstream of the HOR. Based on data assessing the effects of the 2012 rock barrier on acoustically tagged juvenile Chinook salmon, the risk of predation at the junction can be high, as an estimated 39% of juveniles were preyed upon (DWR 2015a). In contrast, only 10% of juveniles were preyed upon in 2011 when no barrier was present. However, flows were much higher in 2011 and 2012, which led to considerably faster travel times through the HOR area in 2011 and possibly led to a lower risk of predation in that year. In addition, the density of predatory fishes at the junction was much lower in 2011 (possibly because of greater flow reducing habitat suitability). As described in Section 5.4.1.3.1.1.3.1 *Predation*, the extent to which the risk from any near-field predation at the HOR gate would offset the anticipated beneficial effects of a greater proportion of fish and flow remaining in the San Joaquin River is unclear, although the available data for fall-run juvenile Chinook salmon suggest that in general the presence of a barrier improves through-Delta survival (Hankin et al. 2010, Brandes and Buchanan 2016; however, see Anderson et al. 2012).

As described in Section 5.4.1.3.1.1.3.2 *Upstream Passage*, the HOR gate has the potential to delay upstream-migrating adult steelhead and spring-run Chinook salmon when closed. However, it is expected that there would be no risk to adults from the gate because of the provision of a fish passage structure meeting NMFS and USFWS guidelines in order to allow passage of upstream migrating salmonids, including steelhead and Chinook salmon.

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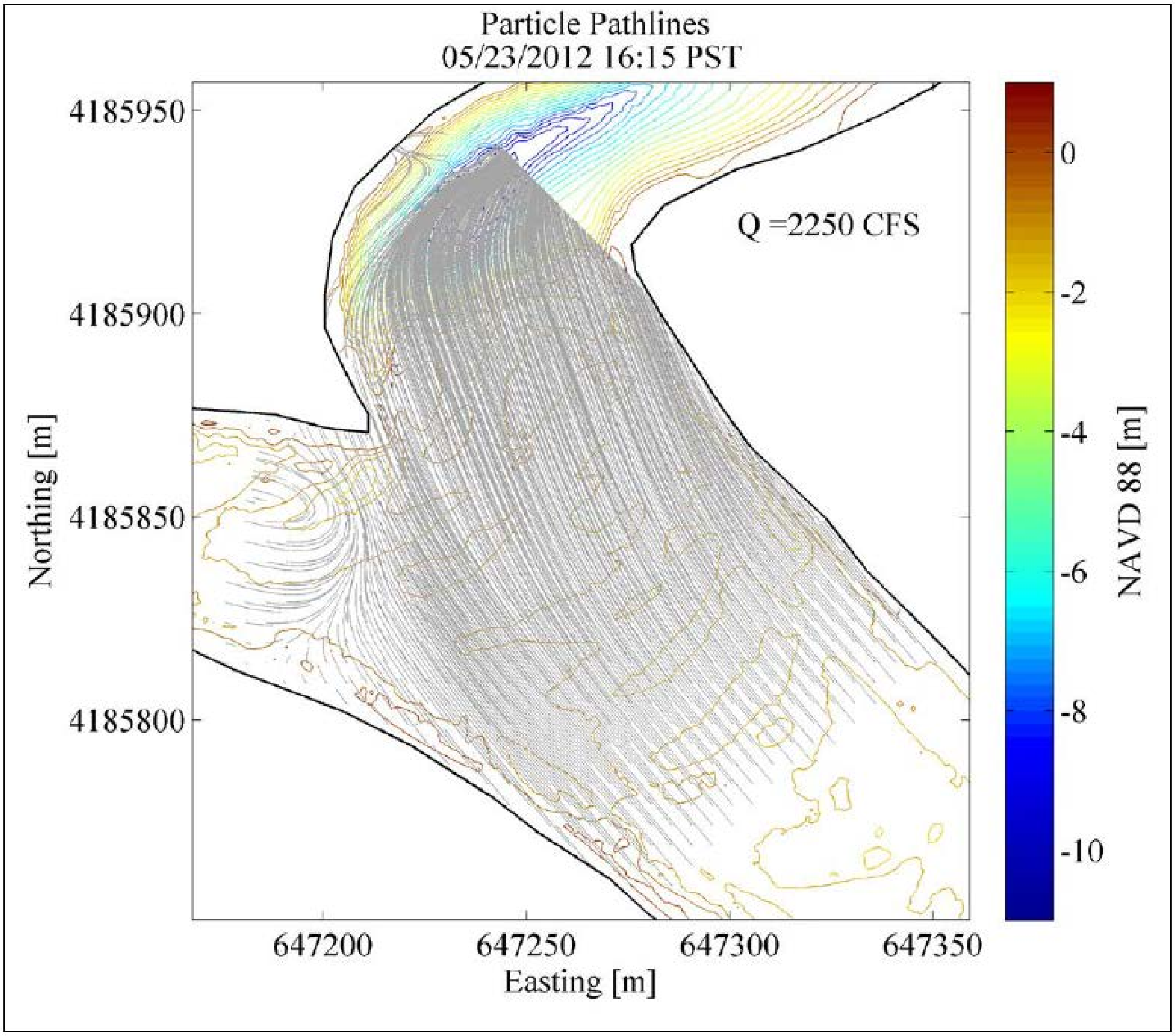
[41] The partial exception being estimates of the loss of hatchery-reared late fall-run Chinook salmon that are surrogates for the small percentage of Sacramento River basin spring-run Chinook salmon entering the Delta as yearlings.



Source: DWR (2015a). Note: The rock barrier is not shown in the diagram, but was just to the left (downstream) of the apparent eddy at the Head of Old River.

Figure 5.4-33. Two-Dimensional Near-Surface Particle Pathlines Estimated from Data Collected with a Side-Looking Acoustic Doppler Current Profiler at the Head of Old River, 5/23/2012, 1615 PST, with River Discharge in the San Joaquin River near Lathrop (Q) of 2,250 cfs.

5.4.1.4.1.1.4 Risk to Salmonids from Delta Cross Channel

As described in Section 5.4.1.2.1.7 *Exposure to Delta Cross Channel*, most juvenile salmonids approaching the DCC from the Sacramento River basin would encounter the DCC gates in the closed position, whereas primarily adult spring-run Chinook salmon and steelhead could encounter the gates in a mixture of open and closed configurations because of the seasonality of their upstream migrations. Section 5.4.1.3.1.1.4 illustrated that only for the adult steelhead migration period would the operations of the DCC potentially differ between the NAA and PA, and that there could be potential for greater delay under the PA in some years because of a greater frequency of multi-day opening and subsequent closure. The extent to which this would constitute a risk to steelhead adults is unknown without further study of the extent to which adult steelhead could find an alternative pathway through the Delta, or how long they may hold below the gates until they are reopened.

5.4.1.4.1.1.5 Risk to Salmonids from Suisun Marsh Facilities

As described in Section 5.4.1.2.1.8 *Exposure to Suisun Marsh Facilities*, the October–May operational period of the SMSCG coincides with the upstream and downstream migration periods of listed Central Valley salmonids, with the full extent of exposure depending on entry into Montezuma Slough. Salmonids could also encounter the RRDS in Montezuma Slough, but would be less likely to be exposed to the MIDS and the Goodyear Slough outfall. As described in Section 5.4.1.3.1.1.5.1, adult salmonids are at risk of delay if encountering closed SMSCG but could backtrack around the structure. The proportion of individuals that would do so is not known, and as described by NMFS (2009: 436) delays to spring-run Chinook salmon and steelhead could result in greater effects than to winter-run Chinook salmon, because spring-run and steelhead may be more reliant on short-term high flow events in smaller tributaries to access spawning habitat in these tributaries. With respect to juvenile salmonids migrating downstream, near-field predation and passage obstruction for migrants are not expected to cause considerable risk at the SMSCG (NMFS 2009L 436-437), and in any case there would be little difference in the number of days that the SMSCG would be operated between the PA and the NAA (see Table 5.B.5-29 in Appendix 5.B, DSM2 Methods and Results). The risk to juvenile salmonids at the RRDS because of the screened intakes would be insignificant (see Section 5.4.1.3.1.1.5.2 *Roaring River Distribution System*).

5.4.1.4.1.1.6 Risk to Salmonids from North Bay Aqueduct

As described in Section 5.4.1.2.1.9 *Exposure to North Bay Aqueduct*, listed salmonids could occur in the vicinity of the NBA's Barker Slough pumping plant, but as assessed in Section 5.4.1.3.1.1.6 *North Bay Aqueduct*, the screens at the facility are designed to protect juvenile salmonids per NMFS criteria. In addition, the location of the facility is well off the typical migration corridor of juvenile salmonids (NMFS 2009: 417). These factors indicate that the risk to listed salmonids from the NBA intake is insignificant.

5.4.1.4.1.1.7 Risk to Salmonids from Other Facilities

5.4.1.4.1.1.7.1 Risk to Salmonids from Contra Costa Canal Rock Slough Intake

As noted in Section 5.4.1.2.1.10.1, juvenile salmonids are present in the south Delta near the Rock Slough intake in winter/spring, and adult salmonids can also occur in the area. As described in Section 5.4.1.3.1.1.7.1 *Contra Costa Canal Rock Slough Intake*, there have been recent fouling issues with the fish screens at the Rock Slough intake, with a new mechanical rake system being tested to resolve these issues. DSM2 modeling suggested that PA pumping at the Rock Slough intake generally would be expected to be similar to the NAA, with the exception of April and May, when diversions were modeled to be greater under the PA (see Table 5.B.5-36 in Appendix 5.B, DSM2 Methods and Results). Resolution of the screening issue described above is expected to improve screen efficiency, reduce predation of juvenile salmonids by vegetation-associated predatory fishes, and reduce adult salmonid mortality during screen maintenance (NMFS 2015b: 4). This, coupled with the intake's location off the main migratory route (NMFS 2015a: 4), suggests that the risk to listed salmonids from the Rock Slough intake therefore would be insignificant.

5.4.1.4.1.1.7.2 Risk to Salmonids from Clifton Court Forebay Aquatic Weed Control Program

As noted in Section 5.4.1.2.1.10.2, exposure to the July/August herbicide application within Clifton Court Forebay would be expected to be minimal for listed salmonids because of their temporal occurrence within the Delta, whereas exposure to mechanical removal could occur as it would be done on an as-needed basis. The species response analysis (Section 5.4.1.3.1.1.7.2) showed that the small amount of entrainment that could occur in July/August would be expected to be less under the PA than the NAA. Mechanical removal could pose some risk to juvenile salmonids in Clifton Court Forebay from injury because of contact with cutting blades, but the reduction in aquatic weeds in the Forebay may provide an offsetting benefit and reduction in risk of predation by vegetation-associated fishes. Overall, the risk to salmonids from the Clifton Court Forebay Aquatic Weed Control Program is concluded to be insignificant.

5.4.1.4.1.2 Risk to Salmonids from Far-Field Effects

5.4.1.4.1.2.1 Risk to Salmonids from Indirect Mortality Within the Delta

As described in Section 5.4.1.3.1.2.1 *Indirect Mortality Within the Delta*, the PA has the potential to change important factors that influence survival of juvenile salmonids in the Delta, namely channel velocity and flow routing into the interior Delta. In the north Delta, the risk to juvenile salmonids generally would be expected to increase because of less flow leading to lower survival, as a result of flow-survival relationships (see Section 5.4.1.3.1.2.1.3 *Through-Delta Survival*) and a slightly greater percentage of flow entering the interior Delta at Georgiana Slough (see Section 5.4.1.3.1.2.1.2 *Entry into Interior Delta*). As described in Section 5.4.1.4.1.1.1 *Risk to Salmonids from North Delta Exports*, these potential effects would be of risk to all juvenile salmonids passing the NDD from the Sacramento River basin, which would constitute all the juveniles entering the Delta via the Sacramento River, but would exclude juveniles entering the Delta via the Yolo Bypass (~8-16% depending on water-year type). The risk to juvenile salmonids entering the Delta from the Sacramento River basin would be minimized by operational criteria and coordinated monitoring and research under the Adaptive Management Program, and real-time operational adjustments that would be made in response to fish presence, which would seek to maximize water supplies while limiting potential adverse effects as appropriate to avoid jeopardy. In addition, installation of a nonphysical fish barrier at the Georgiana Slough junction would minimize the potential for increased entry of fish into the junction caused by hydrodynamic changes because of the NDD, which would lessen the risk of individual fish entering the low-survival interior Delta. As described in Section 5.4.1.3.1.2.1.2.2 *Nonphysical Fish Barrier at Georgiana Slough*, pilot studies of barrier effectiveness have suggested that a BAFF has more potential than an FFGS at this location, with the BAFF reducing entry of acoustically tagged test Chinook salmon into Georgiana Slough by half or more.

For juvenile salmonids from the San Joaquin River basin, risks to individuals related to through-Delta survival generally would be expected to be lower under the PA than NAA as a result of less south Delta exports and the HOR gate (previously discussed in Section 5.4.1.4.1.1.3 *Risk to Salmonids from Head of Old River Gate*). As described in Section 5.4.1.3.1.2.1.3.5 *SalSim Through-Delta Survival Function: San Joaquin River Basin Spring-Run Chinook Salmon*, there could be appreciably greater through-Delta survival for juvenile San Joaquin River spring-run Chinook salmon under the PA, for example.

It is important to note that the risks to individuals from indirect mortality within the Delta are based mostly on the conclusions of studies related to larger juveniles, generally at least smolt-sized (e.g., the DPM is focused on fish of 70 mm and greater; see Appendix 5.D, *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale,* Section 5.D.1.2.2, *Delta Passage Model*). Smaller juveniles also migrate through the Delta (Miller et al. 2010), but quantitative data such as flow-survival relationships from which to draw conclusions regarding the risk to these juveniles do not exist. It is possible that these small juveniles would also experience far-field risk from PA operations, although it is unclear whether this risk would be greater or less than the risk for larger juveniles.

5.4.1.4.1.2.2 Risk to Salmonids from Changes in Habitat Suitability

Of the potential changes in habitat suitability that could occur because of the PA that were analyzed in Section 5.4.1.3.1.1.2.2 *Habitat Suitability,* there is discountable risk to salmonids from differences between PA and NAA in water temperature, selenium, olfactory cues, and *Microcystis*. The main potential risk to salmonids is less restored bench inundation for Sacramento River basins because of the far-field effects of the NDD, as described in Section 5.4.1.3.1.2.2.1.1 *Operational Effects*, which could result in less available habitat for rearing or resting during migration. This risk, which is estimated to result in up to ~20-30% less restored riparian bench habitat availability in some years at these restored bench locations, would be compensated for by restoration of channel margin habitat, as described in Section 3.4.4 *Fish Species Conservation* of Chapter, *Description of the Proposed Action*.

5.4.1.4.2 Green Sturgeon

5.4.1.4.2.1 Risk to Green Sturgeon from Near-Field Effects

5.4.1.4.2.1.1 Risk to Green Sturgeon from North Delta Exports

The near-field effects of the NDD create a potential risk to juvenile green sturgeon, which are present year-round in the Delta (see Section 5.4.1.2.2 *Exposure to North Delta Exports*). As described in Section 5.4.1.3.2.1.1, there is potential for adverse effects (e.g., injury) from screen contact should juvenile green sturgeons occur off the river bottom and encounter the screens, although laboratory studies did not find screen contact to result in injury (Swanson et al. 2004b). The extent of this risk is uncertain, whereas the risk of entrainment is none because of the size of the juveniles compared to the 1.75-mm screen openings. The risk of predation at the NDD may be low because of the size and protective scutes of green sturgeon, based on the analysis conducted for risk of predation in Clifton Court Forebay (NMFS 2009: 350), although this is uncertain.

5.4.1.4.2.1.2 Risk to Green Sturgeon from South Delta Exports

As described in Section 5.4.1.3.2.1.2, *South Delta Exports*, entrainment of green sturgeon can occur at the south Delta export facilities, with salvage efficiency generally not known. There has been little salvage of green sturgeon in recent years: between January 1, 2009, and June 20, 2016, for example, 12 green sturgeon were salvaged at the Skinner facility (all in 2011) and 6 green sturgeon were salvaged at the Tracy facility (2 in 2011, 4 in 2016)[42]. It is unknown what

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[42] http://www.dfg.ca.gov/delta/apps/salvage/SalvageExportChart.aspx?Species=3&SampleDate=6%2f2%2f2016&Facility=1, accessed June 23, 2016.

percentage of the green sturgeon population this represents, so that the overall risk is uncertain. As shown in Section 5.4.1.3.2.1.2.2 *Salvage-Density Method*, the risk to green sturgeon from south Delta entrainment under the PA generally would be expected to be less than for the NAA as result of less south Delta export pumping under the PA, with the salvage-density method suggesting the potential for 60-65% less entrainment in wet years, with less difference in drier years, as a result of little observed historical salvage in drier years. As previously noted in Section 5.4.1.3.2.1.2.5 *Predation*, NMFS's (2009: 350) suggestion that predation on juvenile green sturgeon during occurrence in Clifton Court Forebay is minimal—given juvenile green sturgeon size relative to predators, and their protective scutes—means that reductions in risk of entrainment under the PA would possibly lead to an insignificant change in risk of entrainment-related predation at the south Delta export facilities.

5.4.1.4.2.1.3 Risk to Green Sturgeon from Head of Old River Gate

As described in Section 5.4.1.2.2.5 *Exposure to Head of Old River Gate Operations*, some green sturgeon could occur in the vicinity of the HOR gate and be exposed to operational effects, although captures by anglers in the vicinity of that area are relatively low compared to other areas (see Section 5.4.1.2.2.4 *Spatial Occurrence*). As described in Section 5.4.1.3.2.1.3.1 *Predation*, there is uncertainty in the extent to which there could be predation risk to juvenile green sturgeon near the HOR gate. The risk of delay from passage at the HOR gate's vertical slot fishway, in contrast, is likely for any individuals migrating upstream through Old River to reach the San Joaquin River during spring (Section 5.4.1.3.2.1.3.2 *Upstream Passage*). Based on capture reports from the sturgeon report card, this risk may be limited to relatively few individuals (Table 5.4-4). These individuals therefore would be at risk of being negatively affected by the PA relative to the NAA, given that a rock barrier is not always installed in spring under the NAA. During the fall RTO of the HOR gate, the risk of passage impediment of green sturgeon in the south Delta would be insignificant, because of the installation of a rock barrier under the NAA, which is also likely to create passage delays.

5.4.1.4.2.1.4 Risk to Green Sturgeon from Delta Cross Channel

As described in Section 5.4.1.3.2.1.5 *Delta Cross Channel*, the upstream migration period of adult green sturgeon coincides with the winter/spring closure period for the DCC under both the NAA and PA, so that adult green sturgeon bound for the upper Sacramento River that encounter the closed DCC gates would need to migrate back down the Mokelumne River and ascend an alternative Delta channel leading to the main stem Sacramento River; any such delays in migration would be the same under the NAA and PA and therefore there would be no difference in the risk to green sturgeon adults from the DCC. It is unknown how vulnerable juvenile green sturgeon are to diversion into the DCC or their risk from predation in the Delta, but given that the monthly number of days that the DCC gates would be open generally would be expected to be similar between NAA and PA throughout most of the year, except during fall, as discussed for salmonids in Section 5.4.1.3.1.1.4, the differences in between NAA and PA are likely to be insignificant.

5.4.1.4.2.1.5 Risk to Green Sturgeon from Suisun Marsh Facilities

As described in Section 5.4.1.3.2.1.5 *Suisun Marsh Facilities*, screening at the RRDS intake, the low likelihood of entrainment by the unscreened MIDS, and the possible beneficial effects of the Goodyear Slough outfall indicate that the risk to green sturgeon from these three facilities is insignificant. In addition, although there may be greater potential of effects to green sturgeon from operations of the SMSCG than from the other Suisun Marsh facilities, the risk may also be insignificant. This is because delays to upstream adult migration would not affect access to deep spawning habitat in the upper Sacramento River—such habitat being available regardless of temporary changes in flow, unlike some spawning habitat for steelhead and spring-run Chinook salmon in smaller tributaries, for example—and any delays to juvenile green sturgeon would not be expected to adversely affect their long periods of localized, non-directional movements and occasional long-distance movements. In addition, the difference in operations between NAA and PA would be minimal, so the difference in risk between NAA and PA would be insignificant.

5.4.1.4.2.1.6 Risk to Green Sturgeon from North Bay Aqueduct

The similar pumping rates for NAA and PA and full screening of the North Bay Aqueduct Barker Slough Intake indicate that the risk to green sturgeon from this facility would be insignificant (Section 5.4.1.3.2.1.6 *North Bay Aqueduct*).

5.4.1.4.2.1.7 Risk to Green Sturgeon from Other Facilities

5.4.1.4.2.1.7.1 Risk to Green Sturgeon from Contra Costa Canal Rock Slough Intake

Although Rock Slough is not part of designated critical habitat for green sturgeon, individuals could still occur in that location and be exposed to the Rock Slough intake (Section 5.4.1.2.2.9.1 *Contra Costa Canal Rock Slough Intake*). Although pumping may be somewhat greater under the PA than NAA, resolution of the screening effectiveness issues would result in insignificant risk to green sturgeon from the Rock Slough intake.

5.4.1.4.2.1.7.2 Risk to Green Sturgeon from Clifton Court Forebay Aquatic Weed Control Program

Year-round potential occurrence of green sturgeon juveniles and sub-adults in Clifton Court Forebay means that there could be exposure to both chemical and mechanical elements of the weed control program (Section 5.4.1.2.2.9.2 *Clifton Court Forebay Aquatic Weed Control Program*). The risk from chemical treatments would be limited to a few days, whereas the risk from as-required mechanical removal may be limited because of the demersal position of sturgeons that could limit the potential for injury (Section 5.4.1.3.2.1.7.2). NMFS (2009: 390-391) noted that few green sturgeon would be expected to be exposed to herbicide application in Clifton Court Forebay, but indicated that the relative percentage of the population this would represent is unknown. NMFS (2009: 391) likewise noted that the number of green sturgeon that reside in the Forebay at any given time is unknown, with this uncertainty complicating the assessment of both population and individual exposure risks; NMFS (2009: 391) suggested that this area of green sturgeon life history needs further resolution to make an accurate assessment. A summary of recent studies of the movements of 33 acoustically tagged juvenile green sturgeon in the Delta did not indicate that any individuals moved to Clifton Court Forebay (Klimley et al. 2015). It is uncertain the extent to which the movements of these 33 fish is representative of the population as a whole, but if representative, this would indicate that the risk to green sturgeon from the weed control program is discountable as the probability of occurrence of green sturgeon in the Forebay would be very low, and the probability of encountering a weed control action while in the Forebay would also be very low.

5.4.1.4.2.2 Risk to Green Sturgeon from Far-Field Effects

5.4.1.4.2.2.1 Risk to Green Sturgeon from Indirect Mortality Within the Delta

As described in the discussion presented in Section 5.4.1.3.2.2.1 *Indirect Mortality Within the Delta*, the risk to green sturgeon from indirect mortality in the Delta is less clear than for juvenile salmonids. Because juvenile green sturgeon can range widely throughout the Delta, the risks from changes in north Delta hydrodynamics because of the NDD or in the south Delta because of less south Delta exports under the PA are uncertain.

5.4.1.4.2.2.2 Risk to Green Sturgeon from Habitat Effects

As described in Section 5.4.1.3.2.2.2 *Habitat Effects*, potential habitat effects on green sturgeon from the PA include changes in Delta outflow, selenium exposure, and *Microcystis* exposure. Under the assumption that green sturgeon could respond in a similar manner to Delta outflow as white sturgeon, the analysis presented in Section 5.4.1.3.2.2.1 *Delta Outflow* demonstrated that the risk to green sturgeon from PA operations relative to the NAA would be insignificant, as there would be very little difference in the surrogate white sturgeon year-class index between NAA and PA with respect to either the April-May or the March-July outflow averaging periods.

As described in Section 5.4.1.3.2.2.2.2 *Selenium*, the increased proportion of San Joaquin River water entering the Delta because of less south Delta exports under the PA would not be expected to result in any risk to green sturgeon individuals or populations in the Sacramento River upstream of DCC and San Joaquin River near San Andreas Landing, i.e., the north and central Delta. There would be potential risks at Old River at Clifton Court Forebay Radial Gates (West Canal), i.e., the south Delta, and in the west Delta, although with little difference between NAA and PA. Risks would be most likely to occur in dry or critical years.

The risk to green sturgeon associated with the mixed effects of the PA on *Microcystis*, including potential greater occurrence in some areas, is uncertain (Section 5.4.1.3.2.2.2.3). The considerable mobility of green sturgeon (Klimley et al. 2015) suggests that they could move away from affected areas, although this is uncertain. As described in Section 6.1.3.5.5.5.2 *Population-Level Effects* for Delta Smelt, there is potential to mitigate effects on *Microcystis* through preferential south Delta export pumping: the modeling currently assumes that in the summer months (July–September), the first 3,000 cfs of exports would be from the south Delta, with any additional allowable exports able to be diverted from either the north or the south Delta; it would be possible to shift to additional south Delta pumping as opposed to north Delta pumping in order to reduce water residence time, for example. This would reduce the difference in the risk of south Delta entrainment between the NAA and PA (see Section 5.4.1.4.2.1.2 *Risk to Green Sturgeon from South Delta Exports*).

5.4.1.5 Effects of the Action on Designated Critical Habitat

5.4.1.5.1 Salmonids

5.4.1.5.1.1 North Delta Exports

The principal effects of NDD operations on critical habitat for listed salmonids would be near-field and far-field effects on juvenile salmonids in the north Delta. As described previously in Section 5.4.1.3.1.1.1, *North Delta Exports*, the near-field effects include potential for impingement, screen contact, long passage times, and predation at the NDD. Design and operational criteria of the NDD would minimize the potential for adverse effects on the downstream access (winter-run Chinook salmon) and freshwater migration corridor/estuarine areas (spring-run Chinook salmon and steelhead) PBFs of critical habitat. These design and operational features of the NDD include frequent screen cleaning and approach and sweeping velocity criteria providing protection to minimize screen surface impingement of juvenile Chinook salmon and steelhead. The smooth screen surface also would serve to reduce the risk of abrasion and scale loss for any fish that does come into contact with the screens. Operational criteria would also minimize potential for far-field effects to these PBFs with respect to through-Delta survival, by having bypass flow criteria that adjust NDD exports downward coincident with juvenile salmonid entry into the Delta (Section 3.3.3.1, *North Delta Diversion*); as described in Section 5.4.1.3.1.2.1, *Indirect Mortality Within the Delta*, potential changes in channel velocity and entry into the interior Delta through Georgiana Slough/DCC could affect critical habitat, with the Georgiana Slough nonphysical fish barrier intended to be designed and installed to minimize these potential effects. As discussed in Section 5.4.1.3.1.2.1.2.2 *Nonphysical Fish Barrier at Georgiana Slough*, if an NPB reduced the probability of juvenile Chinook salmon taking the interior Delta pathway through Georgiana Slough by 50%, this could result in ~5-17% greater through-Delta survival based on the elasticity analysis by Perry et al. (2013); this could minimize the effects to the PBFs of concern in the Delta because of hydrodynamic effects on entry into the interior Delta or flow-survival effects.

As described in Section 5.4.1.3.1.2.2.1, *Bench Inundation*, NDD operations have the potential to reduce access to riparian bench areas, which could reduce riparian habitat and downstream access PBF for winter-run Chinook salmon and the estuarine areas PBF for spring-run Chinook salmon and steelhead. Compensation for this potential effect would be provided by channel margin enhancement of areas currently including poor habitat (see Section 3.4, *Conservation Measures*). NMFS (2009: 385-386) noted that the effects of the SWP/CVP on the rearing qualities of the Delta are related to the removal or reduction of potential forage species from the Delta environment (e.g., by entrainment of salmonid invertebrate prey or entrainment of the invertebrate's phytoplankton prey), which affects the estuarine areas PBF, for example. As described in the analysis of entrainment of food web materials by the NDD for Delta Smelt (see Section 6.1.3.5.4, *Entrainment of Food Web Materials*), it is estimated that the NDD would seldom entrain more than 5% of the Delta's standing stock of phytoplankton in any given month; there also would be less entrainment of phytoplankton at the south Delta export facilities (discussed below), as well as in situ production within the Delta (downstream of the NDD), that could offset the effects of entrainment at the NDD.

5.4.1.5.1.2 South Delta Exports

Reductions in south Delta exports under the PA compared to NAA have a potential to beneficially affect the estuarine areas PBF of critical habitat for spring-run Chinook salmon and Central Valley steelhead in the central and south Delta[43]. The risk of entrainment would be lower, as illustrated by the salvage-density analysis (see Section 5.4.1.3.1.1.2.1.1, *Salvage-Density Method: Winter-Run Chinook Salmon, Spring-Run Chinook Salmon, and Steelhead*), and hydrodynamic conditions would be expected to be more favorable because of reduced south Delta exports (see Section 5.4.1.3.1.2.1, *Indirect Mortality Within the Delta*). Reduced south

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[43] Critical habitat for winter-run Chinook salmon in the Delta is limited to the main stem Sacramento River, which is essentially unaffected by south Delta export operations (Cavallo et al. 2015).

Delta exports would increase the olfactory cues available for adult steelhead returning to the San Joaquin River basin (see Section 5.4.1.3.1.2.2.4, *Olfactory Cues for Upstream Migration*), thus improving the critical habitat for this life stage in the Delta. Although the PA would have a potential to reduce adverse effects on south Delta and interior Delta critical habitat, to the extent that the south Delta export facilities remain in use and have effects on water movement, there is a potential for adverse effects on critical habitat. Additionally, reduced Delta exports could increase the concentration of selenium in the Delta, but the risk to critical habitat for juvenile salmonids would be low, as indicated by the quantitative analyses previously discussed (see Section 5.4.1.3.1.2.2.3, *Selenium*). Any differences in *Microcystis* occurrence between the NAA and PA would be unlikely to affect the estuarine area PBF for adult steelhead, as discussed in Section 5.4.1.3.1.2.2.5, *Microcystis*.

5.4.1.5.1.3 Head of Old River Gate Operations

In conjunction with reduced south Delta exports, HOR gate operations have a potential to beneficially affect the estuarine area PBF for juvenile steelhead emigrating from the San Joaquin River basin by keeping flow in the mainstem San Joaquin River and reducing the proportion of fish moving into Old River. However, as described in Section 5.4.1.3.1.1.3.1, *Predation*, the extent to which any near-field predation at the HOR gate would offset the anticipated beneficial effects of a greater proportion of fish and flow remaining in the San Joaquin River is unclear, although the available data for juvenile Chinook salmon suggest that in general the presence of a barrier improves through-Delta survival (see review by Hankin et al. 2010 and comparison of 2012 [rock barrier] versus 2013 [no barrier] by Brandes and Buchanan 2016; however, see also comments by Anderson et al. [2012] with specific reference to the uncertainty in the effectiveness of the 2012 HOR rock barrier implementation in protecting out-migrating salmonid smolts).Upstream passage for adult steelhead would be provided with a fish passage structure, so the risk of adverse effects on the estuarine areas PBF for this life stage would be small (see Section 5.4.1.3.1.1.3, *Head of Old River Gate*).

5.4.1.5.1.4 Delta Cross Channel

As discussed by NMFS (2009: 410), for both winter-run and spring-run Chinook salmon, designated critical habitat lies adjacent to the location of the DCC gates. In the case of designated critical habitat for the winter-run Chinook salmon (58 FR 33212) the DCC is specifically not included because the biological opinions issued by NMFS in 1992 and 1993 concerning winter-run Chinook salmon included measures on the operations of the gates that were designed to exclude winter-run Chinook salmon from the channel and the waters of the Central Delta. For spring-run Chinook salmon, designated critical habitat (70 FR 52488) includes the DCC from its point of origin on the Sacramento River to its terminus at Snodgrass Slough, including the location of the gates. Designated critical habitat for Central Valley steelhead includes most of the Delta and its waterways; however, the DCC waterway was not included in the text or maps of the Federal Register notice as being part of the Delta waters designated as critical habitat. Nevertheless, actions of the DCC gates affect the critical habitat PBFs designated for the spring-run Chinook salmon and CV steelhead populations. Primarily, DCC gate operations interfere with the performance of the Sacramento River as a migratory corridor for spring-run Chinook salmon and Central Valley steelhead by preventing access downstream from the spawning grounds to San Francisco Bay and the Pacific Ocean. Fish entrained into the DCC and the Mokelumne River systems are at a greater risk of mortality than their counterparts who have remained in the mainstem of the Sacramento River. The operations of the gates permit fish to enter habitat and waterways they would not normally have access to with substantially higher predation risks than the migratory corridor available in the Sacramento River channel. Operations of the gates have a direct effect on the entrainment rate and hence the functioning of the Sacramento River as a migratory corridor.

However, during the downstream migration period of listed juvenile salmonids, the DCC gates would be closed, operational criteria not differing between NAA and PA during winter/spring. As described in Section 5.4.1.3.1.1.4, *Delta Cross Channel*, there may be minor differences between NAA and PA in terms of the number of days that the DCC is open during the adult steelhead upstream migration period in fall, but given that the differences between NAA and PA in the number of days open generally were not considerable, and adult salmonids that are migrating to the Sacramento River basin have the ability to swim around the DCC gates using other Delta channels (National Marine Fisheries Service 2009: 406). As such, DCC operations are not expected to result in adverse effects on adult steelhead critical habitat.

5.4.1.5.1.5 Suisun Marsh Facilities

As described in Chapter 3, Section 3.3.2.5, *Operational Criteria for the Suisun Marsh Facilities*, there are no proposed changes to operations of the Suisun Marsh facilities under the PA, in relation to what would occur under the NAA, so that effects of the PA on critical habitat would be expected to be similar to the effects under the NAA. This is described for each facility in the following sections.

5.4.1.5.1.5.1 Suisun Marsh Salinity Control Gates

As described by NMFS (2009: 437), Montezuma Slough is designated critical habitat for endangered winter-run Chinook salmon, with PBFs of designated critical habitat including water quality and quantity, foraging habitat, natural cover including large substrate and aquatic vegetation, and migratory corridors free of obstructions. As discussed in Section 5.4.1.3.1.1.5.1, *Suisun Marsh Salinity Control Gates*, fish passage could be affected by the operation of the SMSCG, with the gates potentially delaying upstream-migrating adult salmonids that have entered Montezuma Slough and are seeking to exit the slough at its eastward end. Adult salmonids that do not continue upstream past the SMSCG are expected to return downstream by backtracking through Montezuma Slough to Suisun Bay, and they likely find the alternative upstream route to their natal Central Valley streams through Suisun and Honker Bays (National Marine Fisheries Service 2009: 435). The tidally-operated gates are also expected to influence water currents and tidal circulation periodically during the 10 to 20 days of annual operation. However, these changes in water flow will be limited to the flood portion of the tidal cycle and will generally be limited to a few days during each periodic operational episode. Overall, the short-term changes to tidal flow patterns in Montezuma Slough due to operation of the SMSCG are not expected to significantly change habitat availability or suitability for rearing of listed anadromous salmonids (National Marine Fisheries Service 2009: 437).

5.4.1.5.1.5.2 Roaring River Distribution System

As discussed in the previous section, Montezuma Slough is designated critical habitat for endangered winter-run Chinook salmon. As described by NMFS (2009: 438), the operation of the RRDS may affect some PBFs of designated critical habitat. Fish passage and the migration corridor will not be affected, because the RRDS intakes are properly screened. However, water withdrawals at RRDS could influence flow, water quality, and food resources. The water surface elevation and water circulation at this location on Montezuma Slough is dominated by tides. The diversion is also tidally-operated by filling the intake pond at the RRDS during high tide. Since high tide conditions raise the water surface elevation throughout Montezuma Slough, water withdrawals at the RRDS intake do not reduce the quantity of available habitat and are not expected to negatively affect the condition of estuarine habitat for listed salmonids in Montezuma Slough (National Marine Fisheries Service 2009: 438).

5.4.1.5.1.5.3 Morrow Island Distribution System

Goodyear Slough, the location of the Morrow Island Distribution System, is not designated critical habitat for winter-run Chinook salmon, spring-run Chinook salmon, or Central Valley steelhead.

5.4.1.5.1.5.4 Goodyear Slough Outfall

As previously noted, Goodyear Slough, the location of the Goodyear Slough Outfall, is not designated critical habitat for winter-run Chinook salmon, spring-run Chinook salmon, or Central Valley steelhead.

5.4.1.5.1.5.5 North Bay Aqueduct

The following account of the potential effects on critical habitat because of the NBA was adapted from that of NMFS (2009: 418). The location of the Barker Slough Pumping Plant lies within the regional waterways designated as critical habitat for both spring-run Chinook salmon and Central Valley steelhead. The Federal Register (September 2, 2005, 70 FR 52488) identifies the upstream tidal limits of Cache Slough and Prospect Slough, as well as Miner Slough and the Yolo Bypass within the Sacramento Delta Hydrologic Unit 5510 as critical habitat. Barker Slough and Lindsey Slough are interconnected with the Cache Slough complex of waterways and were not specifically excluded as critical habitat, as was the Sacramento DWSC. Designated critical habitat for winter-run Chinook salmon is more ambiguous, as only the Sacramento River was named as critical habitat (58 FR 33212) and not any of the tributaries or side channels and sloughs associated with the north Delta system.

As described by NMFS (2009: 418), the footprint of the Barker Slough Pumping Plant is relatively small and located approximately 7 to 10 miles upstream from Cache Slough on Barker Slough. Barker Slough is a dead-end Slough without any significant sources of inflow. It does not physically block a migratory corridor, nor does it occur in habitat that appears to be utilized extensively by Chinook salmon or steelhead, based on monitoring surveys. The primary effects of the NBA and the Barker Slough Pumping Plant are related to the entrainment of water from the Cache Slough complex of waterways. The entrainment of water from these waterways can redirect or delay listed salmonids present in those waterways. This can affect the PBF concerned with the preservation of the functionality of the migratory corridors for listed salmonids. However the effect the Barker Slough Pumping on this PBF is believed to be insignificant due to the relatively small magnitude of the diversion (National Marine Fisheries Service 2009: 418). As shown in the analysis described in Section 5.4.1.3.1.1.6, *North Bay Aqueduct*, there would be expected to be little difference in pumping between NAA and PA.

5.4.1.5.1.6 Other Facilities

5.4.1.5.1.6.1 Contra Costa Canal Rock Slough Intake

Rock Slough is not part of designated critical habitat for winter-run Chinook salmon, spring-run Chinook salmon, or Central Valley steelhead.

5.4.1.5.1.6.2 Clifton Court Forebay Aquatic Weed Control Program

Clifton Court Forebay is not part of the designated critical habitat for winter-run Chinook salmon, spring-run Chinook salmon, or Central Valley steelhead and thus actions taken within the Forebay itself do not affect PBFs in the Delta for rearing habitat or migratory corridors (National Marine Fisheries Service 2009: 391). Chemical treatments for aquatic weeds would occur with the radial gates closed, so no herbicide would exit the forebay into the south Delta. After the exposure period, residual herbicide would be pulled into the California Aqueduct via the pumps when the radial gates are opened to let in fresh water from the Delta (National Marine Fisheries Service 2009: 391). The flushing of the forebay with external Delta water should reduce any remaining herbicide to insignificant levels and move the treated water volume into the aqueduct system of the SWP, and therefore there should be no discernable effects on designated critical habitat outside the forebay (National Marine Fisheries Service 2009: 391).

5.4.1.5.2 Green Sturgeon

5.4.1.5.2.1 North Delta Exports

As described in Section 5.4.1.3.2.1, *Near-Field Effects*, the potential for near-field effects (entrainment, impingement, and predation) on green sturgeon from the NDD is small. Therefore, the effects on designated green sturgeon critical habitat PBFs such as migratory corridor in the Sacramento River is small. As discussed for listed salmonid critical habitat in Section 5.4.1.5.1.1, *North Delta Exports*, direct entrainment of forage base items (e.g., zooplankton and phytoplankton) by water diversions has the potential to adversely affect critical habitat for green sturgeon. However, as demonstrated in the analysis of entrainment of food web materials by the NDD for Delta Smelt (see Section 6.1.3.5.4, *Entrainment of Food Web Materials*), it is estimated that the NDD would seldom entrain more than 5% of the Delta's standing stock of phytoplankton in any given month; there also would be less entrainment of phytoplankton at the south Delta export facilities under the PA, as well as in situ production within the Delta (downstream of the NDD), that could offset the effects of entrainment at the NDD.

5.4.1.5.2.2 South Delta Exports

As described by NMFS (2009: 386), impacts to the migratory corridor function of juvenile and sub-adult 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. Net negative export flows in the central and southern delta may cause fish to be entrained into the southern Delta waterways, which is not typical of their normal movements. Should this be the case, then the PA would be expected to have a lesser effect in this regard compared to the NAA, as indicated by results of the salvage-density analysis (see Section 5.4.1.3.2.1.2.2, *Salvage-Density Method*) and analysis of hydrodynamic conditions (see Section 5.4.1.3.2.2.1, *Indirect Mortality Within the Delta*). Reduced Delta exports would increase the concentration of selenium in the Delta, although this is not expected to have substantial effects on green sturgeon (see Section 5.4.1.3.2.2.2.2, *Selenium*). As discussed in Section 5.4.1.3.2.2.2.3, *Microcystis*, south Delta operations could influence the potential for occurrence of *Microcystis* under the PA, with greater flow and lower residence time compared to NAA in the lower San Joaquin River, but greater residence time in portions of the south Delta. These flow changes are not expected to adversely affect green sturgeon critical habitat because the PBF for water flow refers to Sacramento River for attraction of upstream migrants, which would not be affected by south Delta exports, and the PBF for water quality (principally temperature, salinity, and dissolved oxygen) would not be greatly altered by the PA (see water temperature analysis in Section 5.4.1.3.1.2.2.2, *Water Temperature (DSM2-QUAL)*; see summaries of salinity [electrical conductivity] in Appendix 5.B, *DSM2 Methods and Results*; see qualitative discussion of dissolved oxygen effects of Alternative 4A on pp. 4.3.4-19 to 4.3.4-22 in the Bay Delta Conservation Plan/California WaterFix RDEIR/SDEIS, available at http://baydeltaconservationplan.com/RDEIRS/4_New_Alternatives.pdf).

5.4.1.5.2.3 Head of Old River Gate Operations

Operations of the HOR gate would have the potential to affect the migratory corridor PBF of green sturgeon critical habitat. As described in Section 5.4.1.3.2.1.3.2, *Upstream Passage*, the proposed vertical slot fishway designed for adult salmonids could confine green sturgeon to Old River until the gate was opened again. Under the NAA, a physical (rock) barrier is not always installed at HOR during the spring upstream migration period of green sturgeon, so this would represent a temporary effect on the migration PBF for green sturgeon critical habitat. In addition, it is possible that near-field predation effects could occur to smaller juvenile green sturgeon at the HOR gate, therefore potentially affecting the migratory corridor PBF.

5.4.1.5.2.4 Delta Cross Channel

The DCC is included in designated critical habitat for green sturgeon. As described in Section 5.4.1.3.2.1.4, *Delta Cross Channel*, the DCC gates would be expected to be closed during the upstream migration period of adult green sturgeon, therefore affecting the migratory corridor PBF of critical habitat; however, this would not differ between NAA and PA. As noted in the analysis by NMFS (2009: 408), the extent to which the DCC affects juvenile green sturgeon is uncertain, given their long residence time in the Delta. Although the DCC gates could be open more often under the PA than NAA, the differences are not considerable and so any differences in critical habitat effects would be insignificant, in light of juvenile green sturgeon spending several years in the Delta.

5.4.1.5.2.5 Suisun Marsh Facilities

As described in Chapter 3, Section 3.3.2.5, *Operational Criteria for the Suisun Marsh Facilities*, and as noted previously for listed salmonids, there are no proposed changes to operations of the Suisun Marsh facilities under the PA, in relation to what would occur under the NAA, so that effects of the PA on critical habitat would be expected to be similar to the effects under the NAA. This is described for each facility in the following sections.

5.4.1.5.2.5.1 Suisun Marsh Salinity Control Gates

The SMSCG are located on Montezuma Slough, which is designated critical habitat for green sturgeon. The specific PBFs of proposed critical habitat for the Southern DPS of green sturgeon in estuarine areas include food resources, water flow, water quality, migratory corridor, water depth, and sediment quality. As discussed in Section 5.4.1.3.2.1.5.1, *Suisun Marsh Salinity Control Gates*, fish passage will be affected by the operation of the SMSCG, although operations under the NAA and PA would be very similar. The tidally-operated gates are also expected to influence water currents and tidal circulation periodically during the up to 20 days of annual operation. However, as noted by NMFS (2009: 437), these changes in water flow will be limited to the flood portion of the tidal cycle and will generally be limited to a few days during each periodic operational episode. Overall, the short-term changes to tidal flow patterns in Montezuma Slough due to operation of the SMSCG would result in insignificant changes to habitat availability or suitability for rearing of green sturgeon, and the effects of the NAA and PA would be similar.

5.4.1.5.2.5.2 Roaring River Distribution System

As discussed in the previous section, Montezuma Slough, the location of the RRDS, is designated critical habitat for green sturgeon. As discussed by NMFS (2009: 437-438), the operation of the RRDS may affect some PBFs of critical habitat. Fish passage and the migration corridor will not be affected, because the RRDS intakes are properly screened. However, water withdrawals at RRDS could influence flow, water quality, and food resources. The water surface elevation and water circulation at this location on Montezuma Slough is dominated by tides. The diversion is also tidally-operated by filling the intake pond at the RRDS during high tide. Because high tide conditions raise the water surface elevation throughout Montezuma Slough, water withdrawals at the RRDS intake do not reduce the quantity of available habitat and are not expected to negatively affect the condition of estuarine habitat for green sturgeon in Montezuma Slough (National Marine Fisheries Service 2009: 437-438); any effects would be similar between NAA and PA.

5.4.1.5.2.5.3 Morrow Island Distribution System

Goodyear Slough, the location of the MIDS, is designated as critical habitat for green sturgeon. As described by NMFS (2009: 438), the slough is subject to tidal influence and the MIDS intake is also tidally operated. High tide conditions raise the water surface elevation throughout the area and, thus, the withdrawal of water at MIDS during high tide does not reduce the volume of aquatic habitat in the marsh. Low water intake velocities minimize the loss of aquatic organisms to entrainment. Overall, the quality of habitat, foraging of prey organisms by juvenile sturgeon, and the other specific PBFs for green sturgeon critical habitat are not likely to be negatively affected by the operation of MIDS, with any effects being similar between NAA and PA.

5.4.1.5.2.5.4 Goodyear Slough Outfall

As noted by NMFS (2009: 438), improved water circulation from operation of the Goodyear Slough Outfall likely benefits juvenile green sturgeon in Suisun Marsh by improving water quality and increasing foraging opportunities. Therefore, the PBFs of critical habitat for green sturgeon are not likely to be negatively affected by the operation of the Goodyear Slough Outfall (National Marine Fisheries Service 2009: 438), and any effects would be similar between NAA and PA.

5.4.1.5.2.6 North Bay Aqueduct

As described by NMFS (2009: 418), the footprint of the Barker Slough Pumping Plant is relatively small and located approximately 7 to 10 miles upstream from Cache Slough on Barker Slough, which is part of designated critical habitat for green sturgeon. Barker Slough is a dead-end slough without any significant sources of inflow. It does not physically block a migratory corridor, nor does it occur in habitat that appears to be utilized extensively by green sturgeon based on the monitoring surveys mentioned previously. The primary effects of the NBA and the

Barker Slough Pumping Plant are related to the entrainment of water from the Cache Slough complex of waterways. The entrainment of water from these waterways can affect the PBF concerned with preservation of the functionality of the migratory corridors for green sturgeon. However the effect the Barker Slough Pumping on this PBF is believed to be insignificant because of the relatively small magnitude of the diversion (National Marine Fisheries Service 2009: 418), and there would be relatively little difference in diversions between the NAA and PA (see Table 5.B.5-35 in Appendix 5.B, *DSM2 Methods and Results*).

5.4.1.5.2.7 Other Facilities

5.4.1.5.2.7.1 Contra Costa Canal Rock Slough Intake

Rock Slough is not part of designated critical habitat for green sturgeon.

5.4.1.5.2.7.2 Clifton Court Forebay Aquatic Weed Control Program

Critical habitat for green sturgeon does not include Clifton Court Forebay. As previously described for salmonids, application of herbicides would be done in such a way that critical habitat outside the Forebay would not be affected.

5.4.2 Upstream Hydrologic Changes

For purposes of this analysis, “upstream” refers to waterways upstream of the legal Delta where flows, reservoir storage, and water temperatures and, as a result, listed fish species or critical habitat for such species may be affected by implementation of the PA. Therefore, this section assesses potential effects on listed aquatic species and critical habitat in the American River and Sacramento River upstream of the Delta. The potential effects on listed aquatic species and critical habitat in the Delta resulting from the proposed action (PA) are described in Section 5.4.1, *Proposed Delta Exports and Related Hydrodynamics*.

A preliminary screening analysis was conducted using model outputs of exceedance plots and mean reservoir storage, monthly flows, and water temperatures, where available, in the Trinity, Sacramento, American, San Joaquin, and Stanislaus Rivers and Clear Creek to determine whether modeled flows, storage, and water temperatures in any of these waterways would be clearly not affected by the PA and, therefore, no further analyses of effects on listed aquatic species or critical habitat for such species would be necessary in the waterway.

Results of this preliminary analysis indicated that there would be no effect of the PA on operations in the Trinity, San Joaquin, and Stanislaus Rivers and on Clear Creek (Appendix 5.C, *Upstream Water Temperature Methods and Results*). Accordingly, it was concluded that these areas are not part of the Action area (Chapter 4, *Action Area and Environmental Baseline*). As such, the following listed species or their critical habitat in these waterways are not evaluated in this effects analysis.

- Trinity River: Southern Oregon/Northern California Coastal coho salmon.
- San Joaquin River upstream of the Delta: California Central Valley (CCV) steelhead distinct population segment (DPS), Central Valley spring-run Chinook salmon.
- Stanislaus River: CCV steelhead DPS.

- Clear Creek: Central Valley spring-run Chinook salmon, CCV steelhead DPS.

This preliminary analysis indicates that there is the potential for changes in reservoir operations, instream flows, and water temperatures in the Sacramento River and American River. Therefore, the analysis of potential effects in each of these rivers is described in detail here.

5.4.2.1 Sacramento River

5.4.2.1.1 Deconstruct the Action

The PA could cause changes in cold-water pool storage in Shasta Reservoir and in operations of Shasta Dam, which could cause changes to instream flows and water temperatures in the Sacramento River. Changes under the PA in the magnitude, duration, frequency, timing, and rate of change of flows in the Sacramento River can all affect habitat characteristics of the life stages of winter- and spring- run Chinook salmon, steelhead, and green sturgeon that are present.

For spawning, egg incubation, and alevins, this analysis evaluates flow-related effects on weighted usable area (WUA) of spawning habitat, redd dewatering, and redd scour. Changes in flow rates can affect the amount of WUA of spawning habitat, which is characterized by velocity, depth, and substrate type (U.S. Fish and Wildlife Service 2003b, 2005a, 2006). Redd dewatering occurs when flows are reduced while eggs and alevins are still in the gravel after a spawning event (U.S. Fish and Wildlife Service 2006). Redd scour and entombment can occur when flood flows are of a high enough magnitude to mobilize the gravel, although attempts are made to spread out flood control releases when possible.

For fry and juveniles, this analysis evaluates flow-related effects on WUA of rearing habitat and juvenile stranding. Changes in flow rates can affect the amount of WUA of rearing habitat, which is characterized by velocity, depth, and substrate type (U.S. Fish and Wildlife Service 2005b). Juvenile stranding can occur when flows are reduced rapidly and individuals are unable to escape an area that becomes isolated from the main channel or dewatered, often leading to mortality (U.S. Fish and Wildlife Service 2006). Appendix 5.D, *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale,*[44] provides detail on the methods used to evaluate flow effects of the PA.

As cold-water species, salmonids and sturgeon are sensitive to water temperatures. Changes to water temperatures may influence the suitability of habitat for each life stage present in the Sacramento River and can lead to sublethal impairments that include reduced growth, inhibited smoltification, altered migration, disease, and ultimately death. Appendix 5.D provides detail on the methods used to evaluate water temperature effects of the PA.

5.4.2.1.2 Assess Species Exposure

The species in the Sacramento River upstream of the Delta that could be affected by implementation of the PA include winter-run and spring-run Chinook salmon, CCV steelhead, and green sturgeon.

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[44] For brevity, this appendix is cited as Appendix 5.D throughout.

5.4.2.1.2.1 Winter-Run Chinook Salmon

Implementation of the PA has the potential to expose winter-run Chinook salmon to different flows and water temperatures than those predicted to occur under the NAA throughout their presence in the Sacramento River upstream of the Delta. Table 5.4-25 presents the timing of the upstream presence of each life stage for winter-run Chinook salmon in the Sacramento River upstream of the Delta. The months included in this table (and in tables for other races and species of fish presented below) represent the periods during which the majority (more than approximately 90%) of fish in a life stage are present.

Table 5.4-25. Temporal Occurrence of Winter-Run Chinook Salmon by Life Stage, Sacramento River Upstream of the Delta.

Life Stage	J	F	M	A	M	J	J	A	S	O	N	D
Spawning, egg incubation, and alevins[1]				░	▨	■	■	■	■	░		
Fry and Juvenile rearing[2]							▨	▨	▨	▨	▨	
Juvenile emigration[3]	░	░	░				░	▨	■	■	▨	▨
Adult immigration[4]	▨	■	■	■	▨	░	░	░				░
Adult holding[5]	░	▨	▨	■	■	■	▨	░				
	■	High			▨	Med			░	Low		

Sources: [1] Vogel and Marine 1991; [2] Gaines and Martin 2002; [3] Vogel and Marine 1991; Poytress et al. 2014; [4] National Marine Fisheries Service 1997, Hallock and Fisher 1985, specific to Red Bluff Diversion Dam; [5] Inferred based on immigration and spawning timing

Winter-run Chinook salmon spawn in the Sacramento River and eggs and alevins are in the gravel primarily between April and October with a peak during June through September. Based on CDFW aerial redd surveys from 2003 through 2014, the vast majority (99.3%) of winter-run Chinook salmon spawning between 2003 and 2014 occurred upstream of Airport Road Bridge (RM 284; Table 5.4-26).

Table 5.4-26. Spatial Distribution of Spawning Redds in the Sacramento River Based on Aerial Redd Surveys, Winter-Run Chinook Salmon, 2003–2014 (Source: CDFW)

Reach	Mean Annual Percent of Total Redds Sighted
Keswick Dam to ACID Dam	45.0
ACID Dam to Highway 44 Bridge	42.1
Highway 44 Bridge to Airport Road Bridge	12.2
Airport Road Bridge to Balls Ferry Bridge	0.3
Balls Ferry Bridge to Battle Creek	0.1
Battle Creek to Jelly's Ferry Bridge	0.1
Jelly's Ferry Bridge to Bend Bridge	0.1
Bend Bridge to Red Bluff Diversion Dam	0.0
Downstream of Red Bluff Diversion Dam	0.1

ACID = Anderson-Cottonwood Irrigation District

Juvenile winter-run Chinook salmon rear in the Sacramento River primarily between July and November. Fry and juvenile rearing occurs from Keswick Dam to the Delta. Many juveniles apparently rear in the Sacramento River below Red Bluff Diversion Dam for several months before they reach the Delta (Williams 2006). Juveniles begin moving downstream towards the ocean beginning in July and continue until March, with a peak migration period of September and October observed at Red Bluff Diversion Dam. The peak of winter run juvenile emigration at Knights Landing is November through February, although this is not reflected in Table 5.4-25.

Adult winter-run Chinook salmon migrate upstream primarily during December through August, with a peak during February through April. Adults then hold from approximately January through August until they spawn, with a peak holding period of April through June. Some adults have been shown to stray into the Colusa Basin Drain from the Sacramento River: for example, around 300 individuals (5% of the adult population) entered the Drain in 2012 (NMFS 2015c: 80) and were lost to the population because there is no pathway to return to the river; this situation will be largely remedied with construction and operation of a picket weir fence (NMFS 2015c). Adult salmonids, including winter-run Chinook, can also stray into the Colusa Basin Drain when flows are sufficiently high to allow passage via the Tule Canal and Knights Landing Ridge Cut from the south; replacement of the existing Wallace Weir with a permanent operable structure and fish rescue facility are planned to reduce losses of winter-run Chinook by this mechanism[45].

5.4.2.1.2.2 Spring-Run Chinook Salmon

Implementation of the PA has the potential to expose spring-run Chinook salmon to different flows and water temperatures than those predicted to occur under the NAA throughout their presence in the Sacramento River upstream of the Delta. Table 5.4-27 presents the timing of the upstream presence of each life stage for spring-run Chinook salmon in the Sacramento River upstream of the Delta.

Table 5.4-27. Temporal Occurrence of Spring-Run Chinook Salmon by Life Stage, Sacramento River Upstream of the Delta.

Life Stage	J	F	M	A	M	J	J	A	S	O	N	D
Spawning, egg incubation, and alevins[1]								▓	■	■	▓	░
Fry and Juvenile rearing[2]	▓	▓	▓	▓	▓	▓	▓	▓	▓	▓	■	■
Juvenile emigration[3]	▓	░	▓	■	▓					■	■	■
Adult immigration[4]			▓	▓	■	■	▓	▓	░			
Adult holding[5]				▓	■	■	■	■	░			
	■ High			▓ Med				░ Low				

Sources: [1] Moyle 2002; CDFW aerial redd surveys; [2] Snider and Titus 2000; Poytress et al 2014; [3] California Department of Fish and Game 1998, Snider and Titus 2000; Poytress et al 2014; specific to Red Bluff Diversion Dam;[4] Yoshiyama et al. 1998, Moyle 2002; [5] Inferred based on timing of adjacent life stages

Spring-run Chinook salmon may spawn in the Sacramento River between RBDD and Keswick Dam in very low densities with only a total of 449 redds documented from 2001 through 2014 (average 35/year; range= 0-105; no data available for 2009 or 2011) in CDFW aerial redd surveys. Eggs and alevins remain in the gravel primarily between August and December, with a peak between September and October. The vast majority (more than 91%) of spawning between 2003 and 2014 occurred upstream of Battle Creek (River Mile 272; Table 5.4-28).

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[45] http://resources.ca.gov/docs/ecorestore/projects/Wallace_Weir_Modification.pdf

Table 5.4-28. Spatial Distribution of Spawning Redds in the Sacramento River Based on Aerial Redd Surveys, Spring-Run Chinook Salmon, 2003–2014 (Source: CDFW)

Reach	Mean Annual Percent of Total Redds Sighted
Keswick Dam to ACID Dam	12.4
ACID Dam to Highway 44 Bridge	32.8
Highway 44 Bridge to Airport Road Bridge	27.7
Airport Road Bridge to Balls Ferry Bridge	10.9
Balls Ferry Bridge to Battle Creek	7.3
Battle Creek to Jelly's Ferry Bridge	1.5
Jelly's Ferry Bridge to Bend Bridge	2.6
Bend Bridge to Red Bluff Diversion Dam	0.8
Downstream of Red Bluff Diversion Dam	4.1

ACID = Anderson-Cottonwood Irrigation District

Juvenile spring-run Chinook salmon rear in the Sacramento River year-round, with a peak between November and December. Fry and juvenile rearing occur from Keswick to the Delta. Juveniles begin moving downstream towards the ocean beginning in October and continue until May, with peak migration periods of April and October through December. The peak of spring run juvenile emigration at Knights Landing is February through May (Snider and Titus 2000), although this is not reflected in Table 5.4-27.

Adult spring-run Chinook salmon migrate upstream primarily as early as March with a peak between May and June. Temperatures in the mainstem and Delta are likely too warm for migrating salmon by summer, although holding spring-run Chinook likely hold and move throughout the upper Sacramento once they have ascended the river. Adults display these behaviors from approximately April through September until they spawn in September. It is uncertain how late into summer spring-run Chinook salmon migrate into the Sacramento River. On tributaries, typically spring-run Chinook salmon cannot ascend to cooler water later than May or early June. On the Feather River, hatchery spring run Chinook salmon are identified as fish entering the ladder no later than June. While Red Bluff Diversion Dam once blocked spring-run Chinook passage and significantly delay migration of spring run Chinook such that they passed throughout the summer, this broad migration pattern is likely not natural given spring-run Chinook migration patterns from Northern Valley tributaries and the Feather River.

5.4.2.1.2.3 California Central Valley Steelhead

Implementation of the PA has the potential to expose CCV steelhead to different flows and water temperatures than those predicted to occur under the NAA throughout their presence in the Sacramento River upstream of the Delta. Table 5.4-29 presents the timing of the upstream presence of each life stage for steelhead in the Sacramento River upstream of the Delta.

Table 5.4-29. Temporal Occurrence of California Central Valley Steelhead by Life Stage, Sacramento River Upstream of the Delta.

Life Stage	J	F	M	A	M	J	J	A	S	O	N	D
Spawning, egg incubation, and alevins[1]	▨	▨	▨	▨							▨	▨
Kelt emigration[2]		▨	▨	▨	▨							
Juvenile rearing[3]	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Smolt emigration[3,4]	■	■	■	▨	▨	▨					░	░
Adult immigration[5]	░	░	░					▨	■	■	■	▨
Adult holding[6]									▨	▨	▨	
	■	High			▨	Med			░	Low		

Sources:; [1] Reclamation 2008; [2] inferred from spawning period; [3] Gaines and Martin 2002; [4] Does not include migrant parr; [5] CDFW unpublished counts at RBDD 1966–1994; [6] Inferred from adjacent life stages

CCV steelhead may spawn in the Sacramento River and eggs and alevins remain in the gravel primarily between December and May. Recent steelhead monitoring data are scarce for the Upper Sacramento River system but numbers are considered low, and there is a strong resident component to the population (referred to as rainbow trout) that interacts with and produces both resident and anadromous offspring. Little is known about steelhead spawning locations in the Sacramento River, although it was assumed for this analysis that, because of constraints on water temperature and other habitat features, individuals spawn between Keswick Dam and Red Bluff Diversion Dam, where nearly all Chinook salmon spawn. After spawning, steelhead adults either die or kelts emigrate back to the ocean between February and May.

Juvenile steelhead rear for 1 to 3 years in the Sacramento River from Keswick Dam to the Delta. Therefore, individuals are present in the river throughout the year. Smolts begin migrating downstream towards the ocean beginning in November and continue until June, with a peak migration period of January through March.

Adult CCV steelhead migrate upstream during August and March with a peak between September and November. Adults then hold from September through November until they spawn.

5.4.2.1.2.4 Green Sturgeon

Implementation of the PA has the potential to expose green sturgeon to different flows and water temperatures than those predicted to occur under the NAA throughout their presence in the Sacramento River upstream of the Delta. Table 5.4-30 presents the timing of the upstream presence of each life stage for green sturgeon in the Sacramento River upstream of the Delta.

Table 5.4-30. Temporal Occurrence of Green Sturgeon by Life Stage, Sacramento River Upstream of the Delta

Life Stage	J	F	M	A	M	J	J	A	S	O	N	D
Spawning, egg incubation[1]			░	■	■	■	░					
Pre- and post-spawn adult holding[2]		░	▦	▦	▦	▦	▦	▦	▦	▦	▦	▦
Post-spawn emigration[3]	▦			▦	▦	▦	▦	▦	▦	▦	▦	▦
Larval to juvenile rearing and emigration[4]	░	░	░	░	▦	■	■	▦	▦	░	░	░
Adult immigration[5]		░	▦	▦	▦	▦						

■ High ▦ Med ░ Low

Sources: [1]; Poytress et al. 2009, 2010, 2011, 2012; [2] Israel and Klimley 2008; [3] Heublein et al. 2009; [4] National Marine Fisheries Service 2009; Poytress et al. 2014; [5] Reclamation 2008

Green sturgeon spawn and eggs incubate in the Sacramento River upstream of Hamilton City (RM 200) to as far upstream as Ink's Creek confluence (RM 281) and possibly up to the Cow Creek confluence (RM 280) (Brown 2007; Poytress et al. 2013) between March and July, with a peak between April and June. Larvae and juveniles rear and migrate year-round in much of the spawning reach and downstream. Therefore, individuals are present in this reach of the river throughout the year.

Adult green sturgeon migrate upstream primarily during February and June. Adults hold near spawning reaches beginning in February until they spawn and then after spawning until December. Post-spawning emigration occurs between April and January of the following year.

5.4.2.1.3 Assess Species Response to the Proposed Action

5.4.2.1.3.1 Winter-Run Chinook Salmon

5.4.2.1.3.1.1 Spawning, Egg Incubation, and Alevins

5.4.2.1.3.1.1.1 Flow-Related Effects

Estimated mean monthly flow rates and reservoir storage volumes were examined for the PA and NAA in the Sacramento River at the Keswick Dam to Red Bluff locations during the April through October spawning and egg incubation period, with peak occurrence during July through September, for winter-run Chinook salmon (Table 5.4-25). Changes in flow can affect the instream area available for spawning and egg incubation, along with the quality of the habitat, and can result in dewatering or scour of the redds. Shasta Reservoir storage volume at the end of May can influence flow rates below the dam during much of the winter-run salmon spawning and egg incubation period. Mean Shasta May storage volume under the PA would be similar (less than 5% difference) to storage under NAA for all water year types (Appendix 5.A, *CALSIM Methods and Results*, Table 5.A.6-3). During the majority of months and water year types of the winter-run spawning period, the PA would result in insignificant changes (less than 5% difference) in mean flow in the Sacramento River at the Keswick Dam to Red Bluff locations (Appendix 5.A, *CALSIM Methods and Results*, Table 5.A.6-10, Table 5.A.6-35). However, at both locations, flows under the PA would be 5% to 7% higher than the NAA during May of dry years and June of all water year types except wet years, and would be up to 17% higher in October of below normal and dry years. Flows under the PA would be 5% to 11% lower than the NAA in September of all except wet water year types, October of wet years, and August of below normal water years. The flow reductions in August and September occur within the peak winter-run spawning period (July through September). The results given here indicate that the PA would reduce flow in some months and water year types, although this does not consider real-time operational management described in Section 3.1.5, *Real-Time Operations Upstream of the Delta*, and Section 3.3.3, *Real-Time Operational Decision-Making Process*, that would be used to avoid and minimize any modeled effects. Further discussion regarding flow-related effects during the June through November period is provided in Section 5.4.2.3, *Summary of Upstream Effects*.

5.4.2.1.3.1.1.1.1 Spawning WUA

Spawning weighted usable area (WUA) provides a metric of spawning habitat availability that accounts for the spawning requirements of the fish with respect to water depth, flow velocity, and substrate. Spawning WUA for winter-run Chinook salmon was determined by USFWS (2003a, 2006) for a range of flows in three segments of the Sacramento River between Keswick Dam and the Battle Creek confluence (Appendix 5.D, Section 5.D.2.2, *Spawning Flows Methods*). Segment 4 stretches 8 miles from Battle Creek to the confluence with Cow Creek; Segment 5 reaches 16 miles from Cow Creek to the A.C.I.D. Dam; and Segment 6 covers 2 miles from A.C.I.D. Dam to Keswick Dam. The Cow Creek confluence is about midway between the Airport Road Bridge and Balls Ferry and, therefore, based on CDFW aerial survey results (Table 5.4-26), 45% of winter-run Chinook salmon redds occur within Segment 6 and most of the remainder are found within Segment 5. To estimate changes in spawning WUA that would result from the PA, the flow-versus-spawning habitat WUA relationship developed for each of these segments was used with mean monthly CALSIM II flow estimates for the midpoint of each segment under the PA and the NAA during the winter-run spawning and egg incubation period. Further information on the WUA analysis methods is provided in Appendix 5.D, Section 5.D.2.2, *Spawning Flows Methods*.

Differences in winter-run spawning WUA under the PA and NAA were examined using exceedance plots of monthly mean WUA for the winter-run spawning period in each of the river segments for each water year type and all water year types combined. The exceedance curves for the PA generally match those of the NAA for all water year types in all three segments (Figure 5.4-30–Figure 5.4-51).

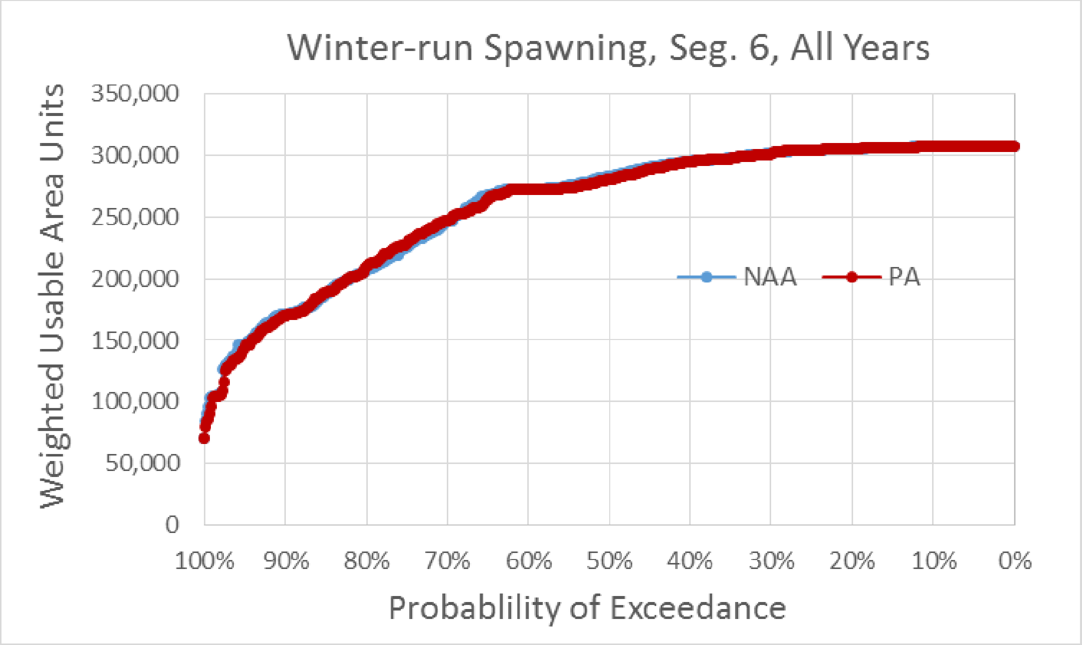

Figure 5.4-34. Exceedance Plot of Winter-Run Chinook Salmon Spawning Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 6, All Water Years

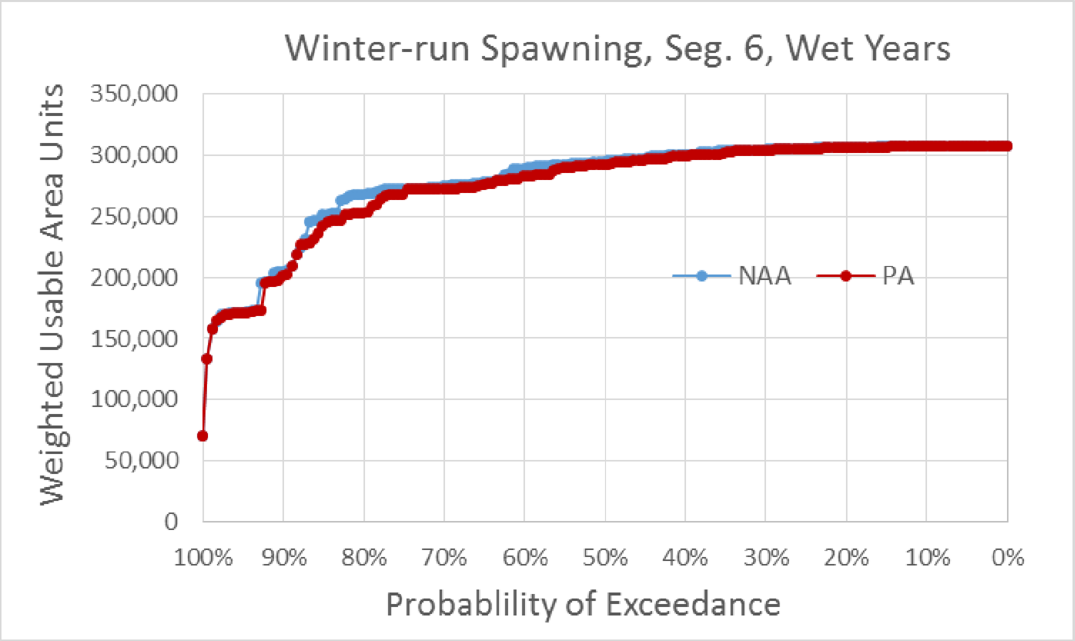

Figure 5.4-35. Exceedance Plot of Winter-Run Chinook Salmon Spawning Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 6, Wet Water Years

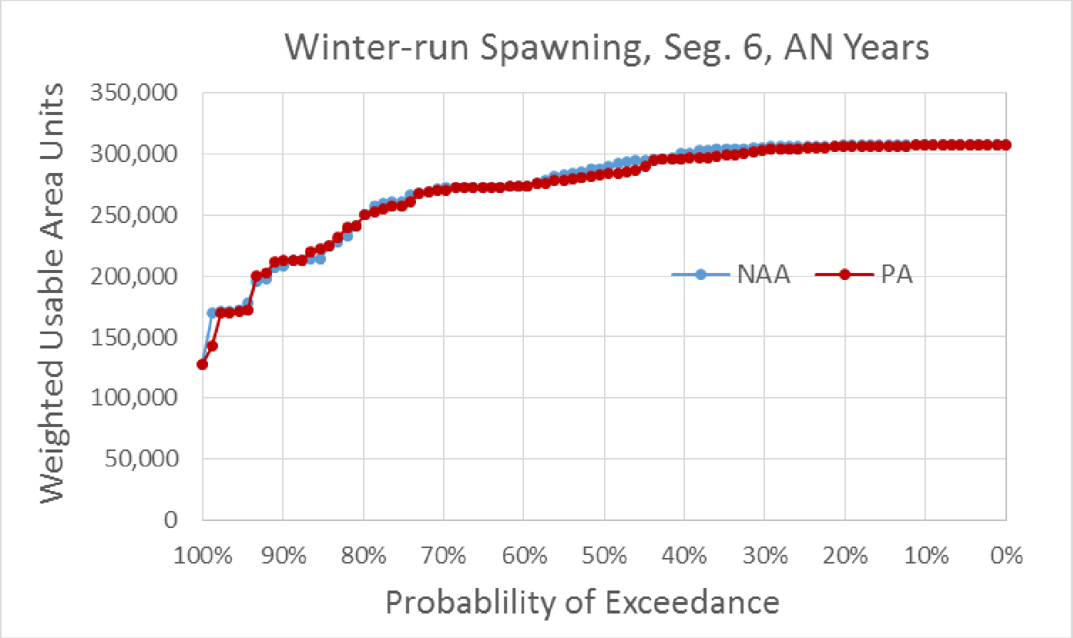

Figure 5.4-36. Exceedance Plot of Winter-Run Chinook Salmon Spawning Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 6, Above Normal Water Years

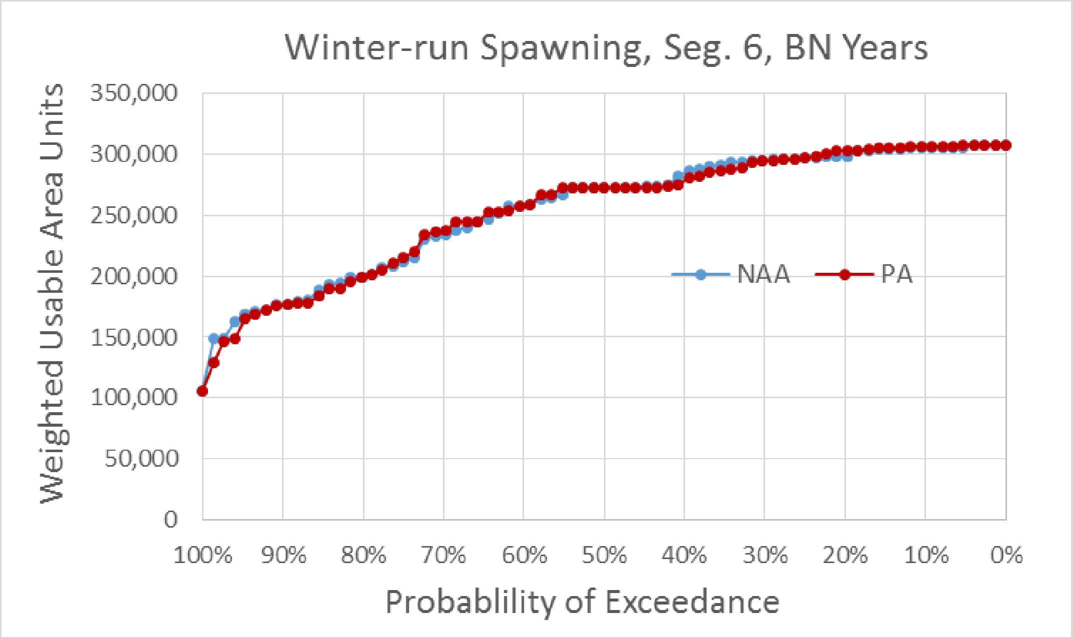

Figure 5.4-37. Exceedance Plot of Winter-Run Chinook Salmon Spawning Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 6, Below Normal Water Years

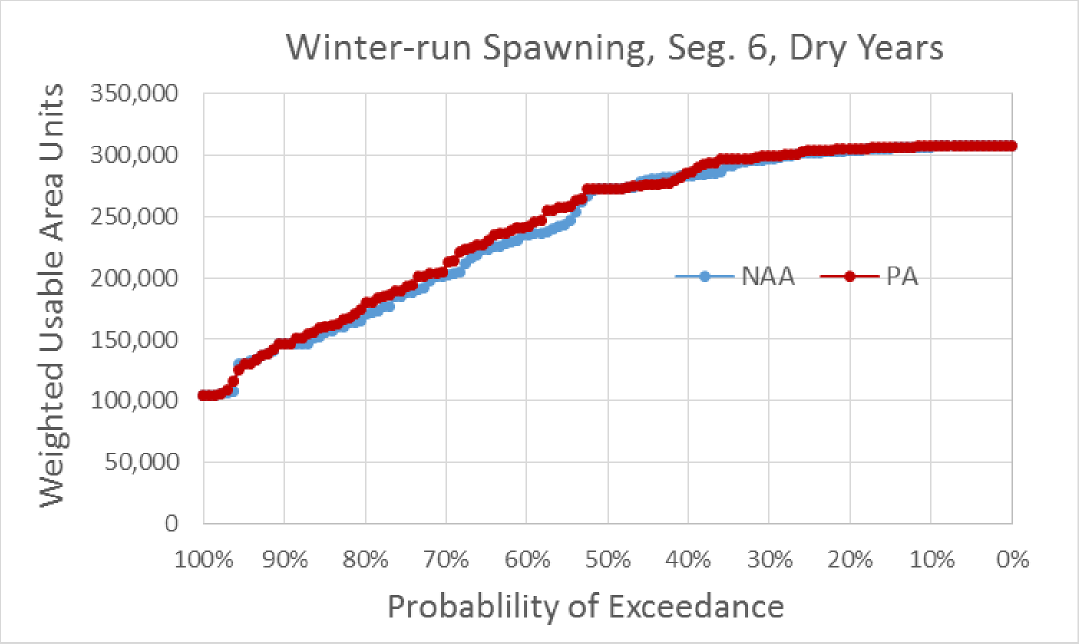

Figure 5.4-38. Exceedance Plot of Winter-Run Chinook Salmon Spawning Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 6, Dry Water Years

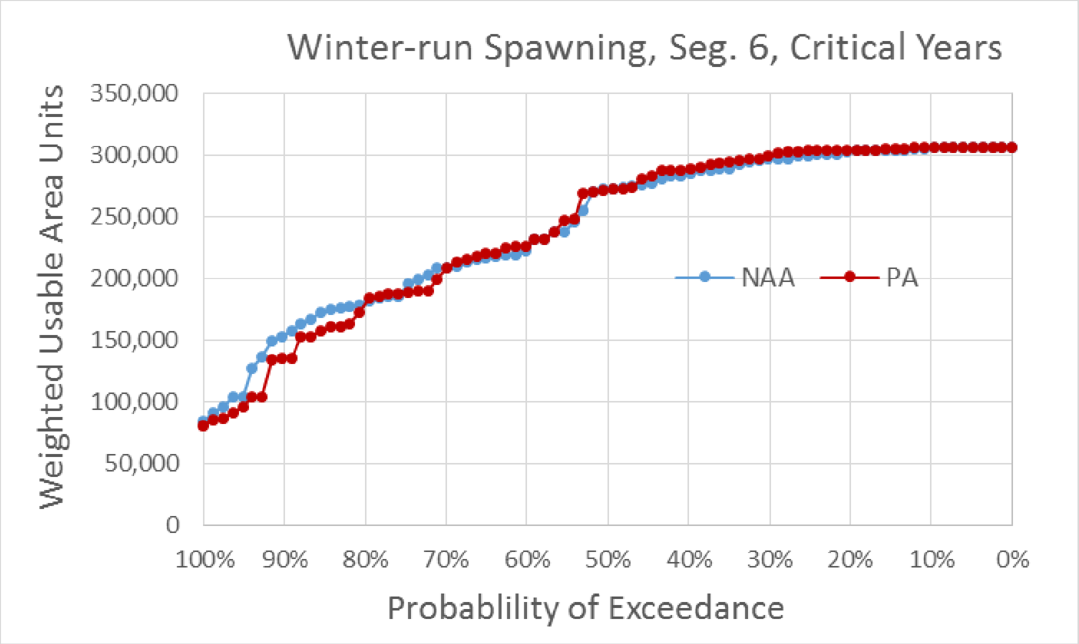

Figure 5.4-39. Exceedance Plot of Winter-Run Chinook Salmon Spawning Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 6, Critical Water Years

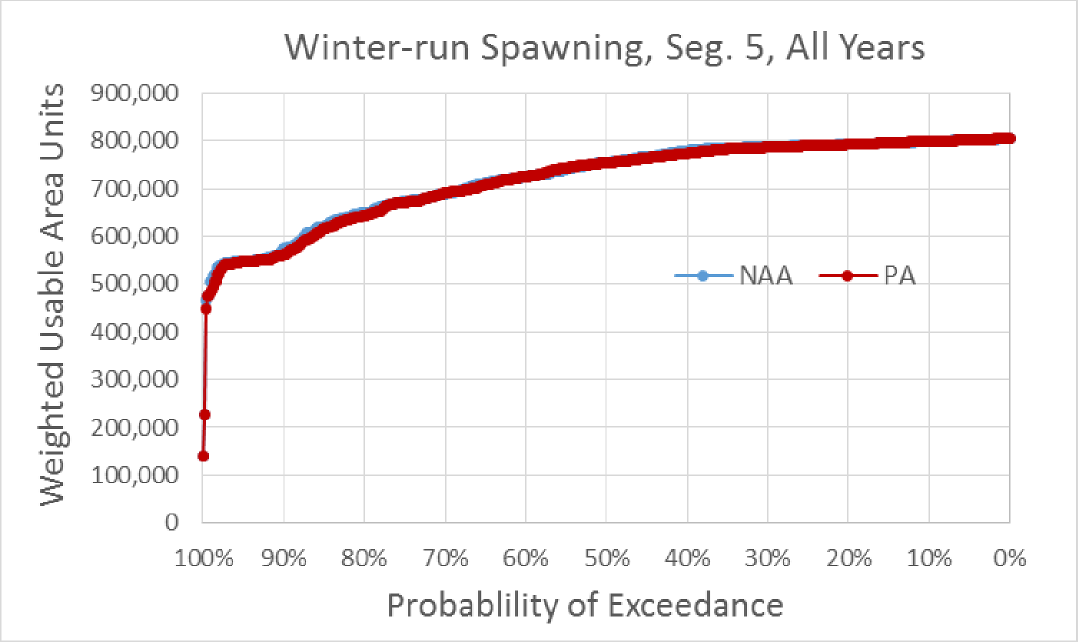

Figure 5.4-40. Exceedance Plot of Winter-Run Chinook Salmon Spawning Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 5, All Water Years

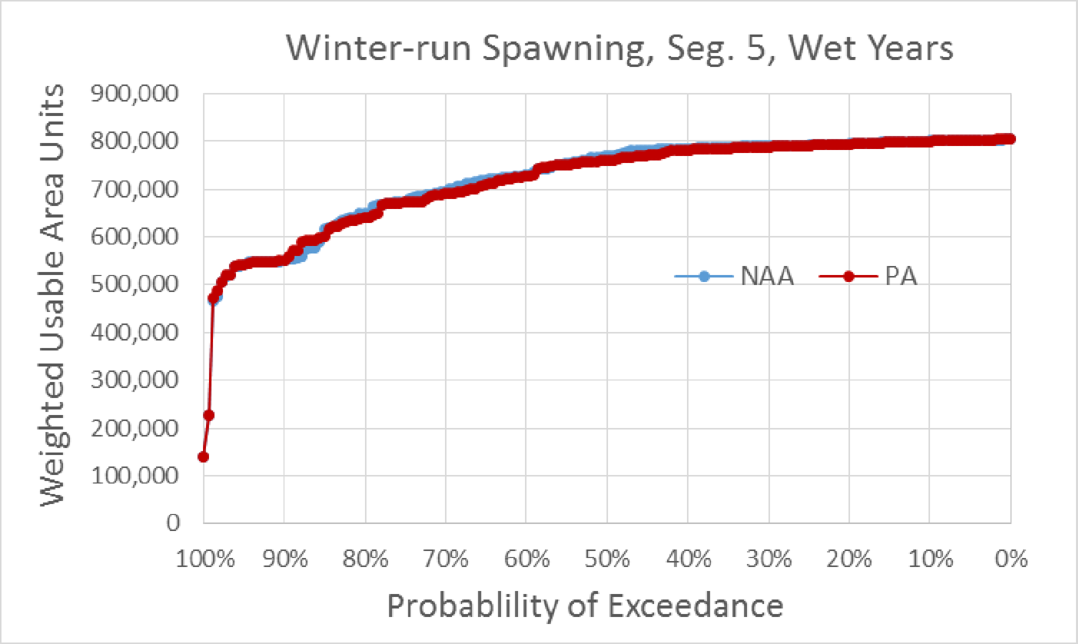

Figure 5.4-41. Exceedance Plot of Winter-Run Chinook Salmon Spawning Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 5, Wet Water Years

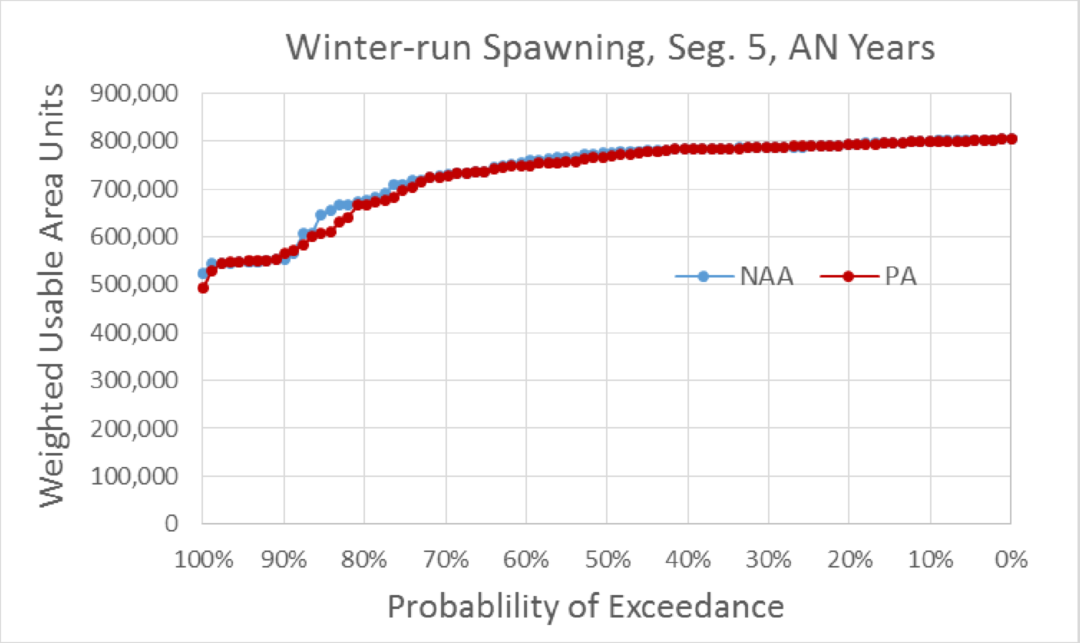

Figure 5.4-42. Exceedance Plot of Winter-Run Chinook Salmon Spawning Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 5, Above Normal Water Years

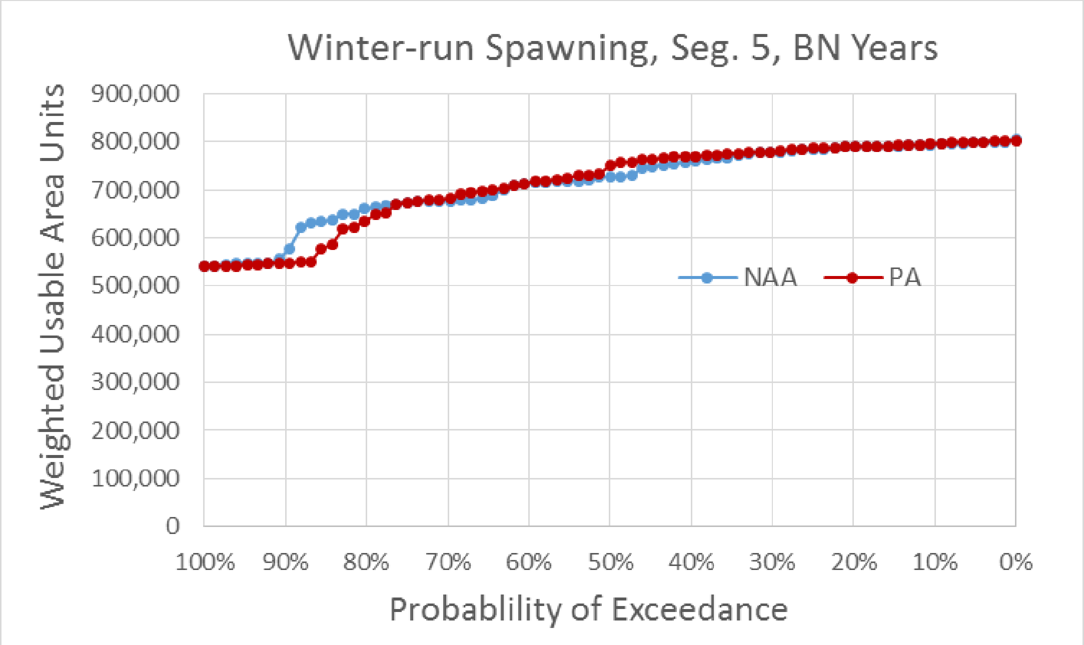

Figure 5.4-43. Exceedance Plot of Winter-Run Chinook Salmon Spawning Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 5, Below Normal Water Years

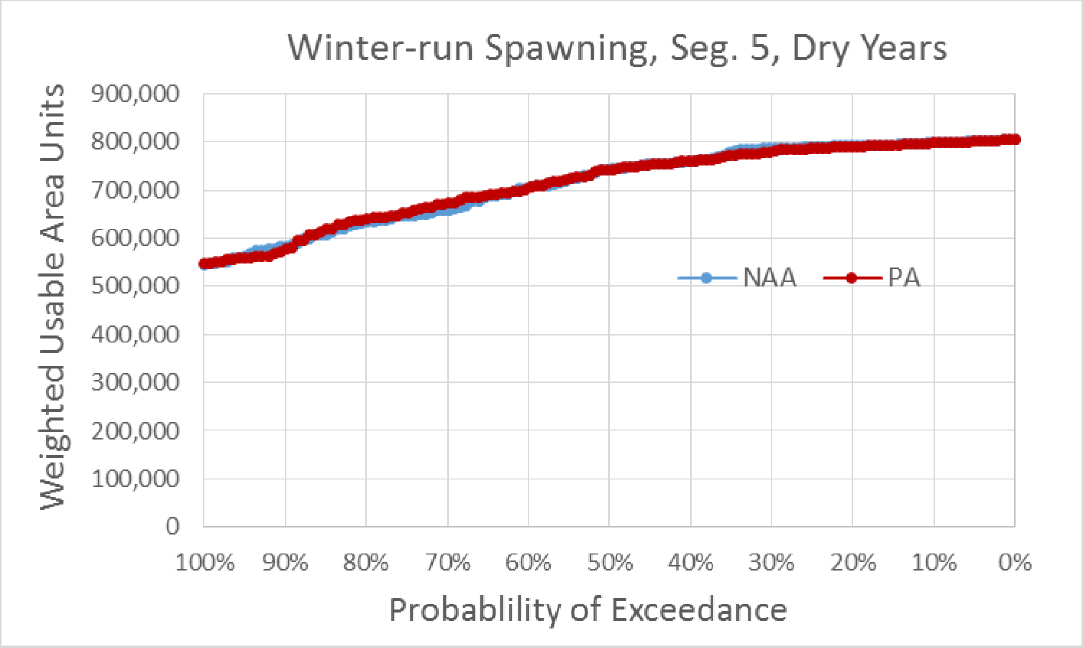

Figure 5.4-44. Exceedance Plot of Winter-Run Chinook Salmon Spawning Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 5, Dry Water Years

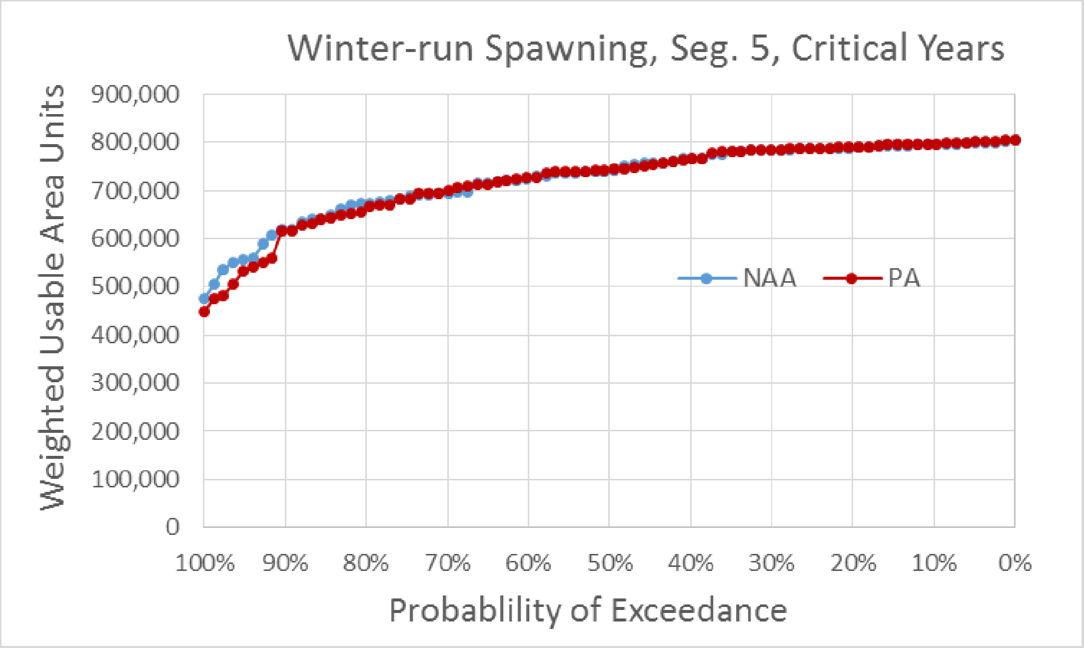

Figure 5.4-45. Exceedance Plot of Winter-Run Chinook Salmon Spawning Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 5, Critical Water Years

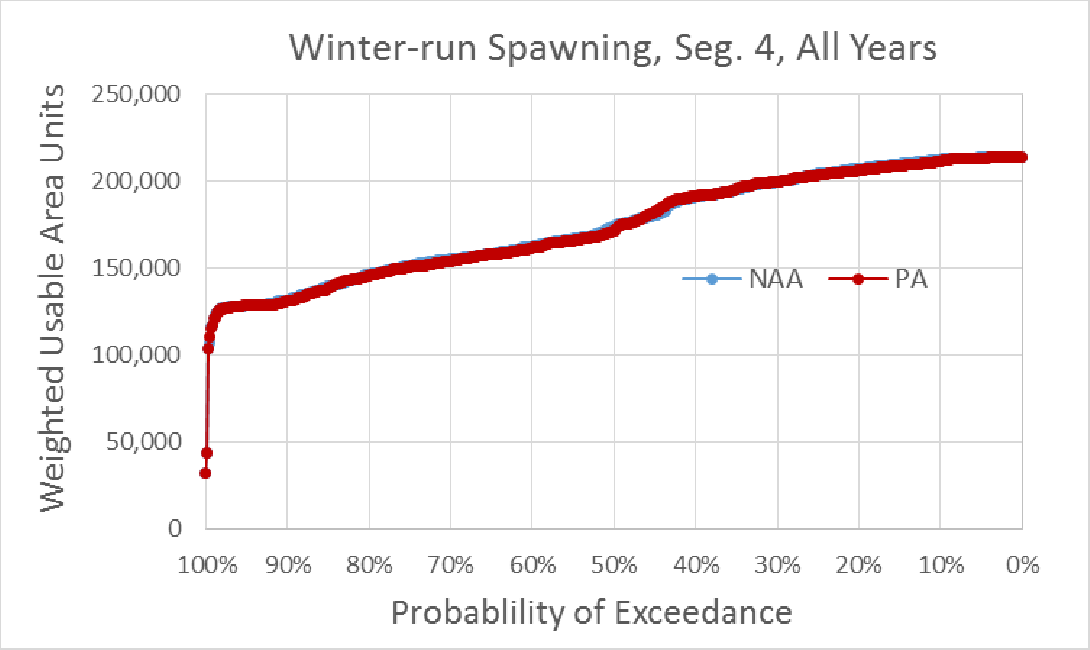

Figure 5.4-46. Exceedance Plot of Winter-Run Chinook Salmon Spawning Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 4, All Water Years

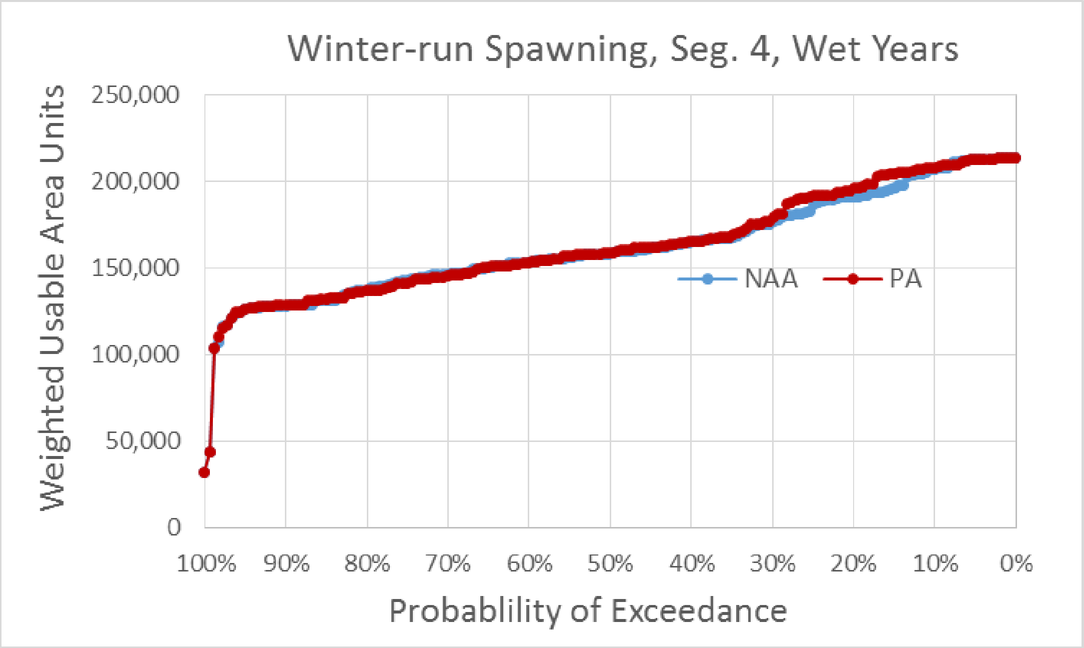

Figure 5.4-47. Exceedance Plot of Winter-Run Chinook Salmon Spawning Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 4, Wet Water Years

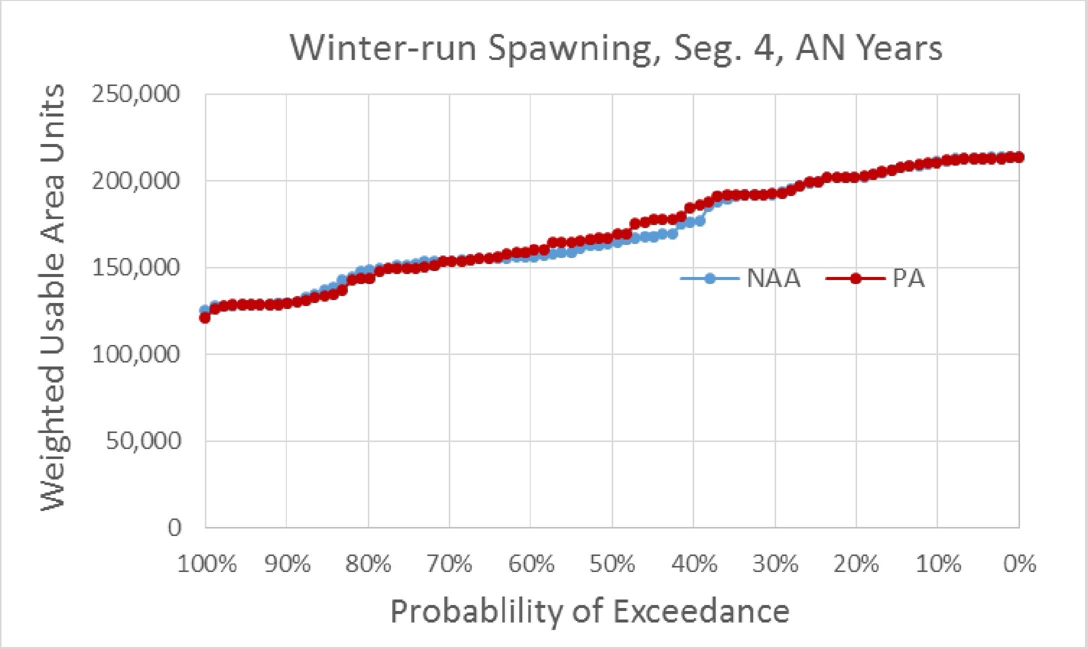

Figure 5.4-48. Exceedance Plot of Winter-Run Chinook Salmon Spawning Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 4, Above Normal Water Years

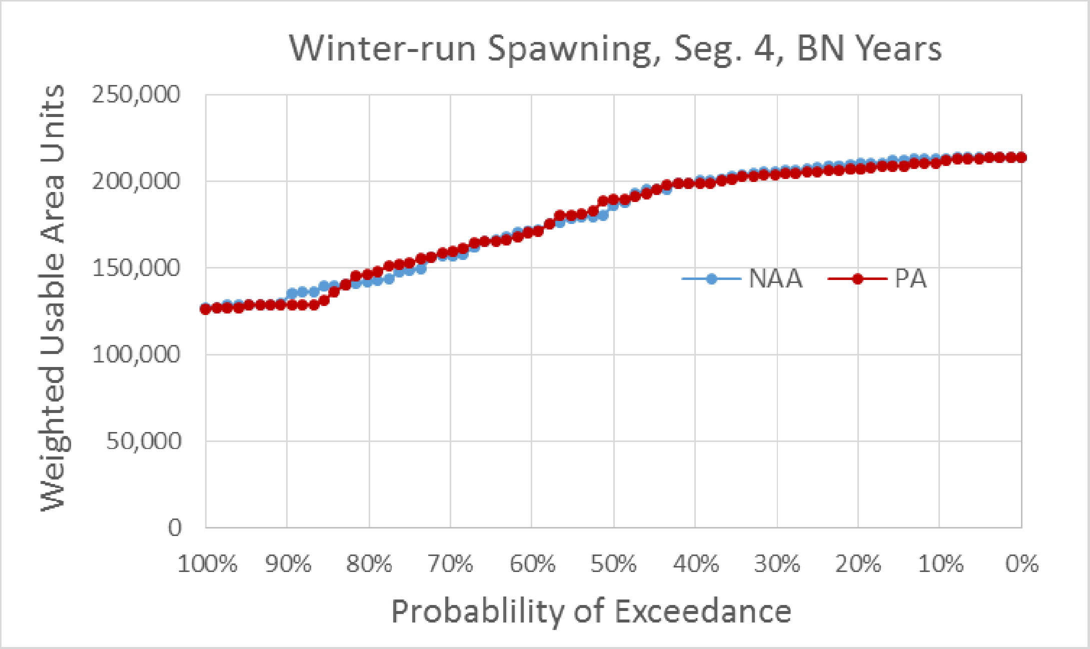

Figure 5.4-49. Exceedance Plot of Winter-Run Chinook Salmon Spawning Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 4, Below Normal Water Years

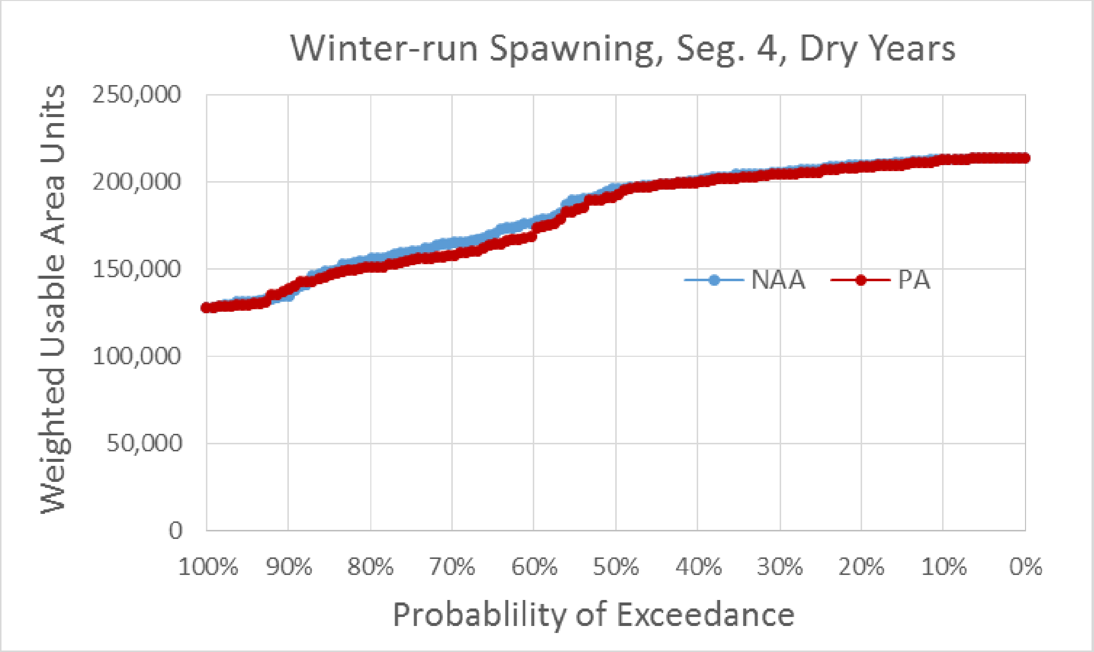

Figure 5.4-50. Exceedance Plot of Winter-Run Chinook Salmon Spawning Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 4, Dry Water Years

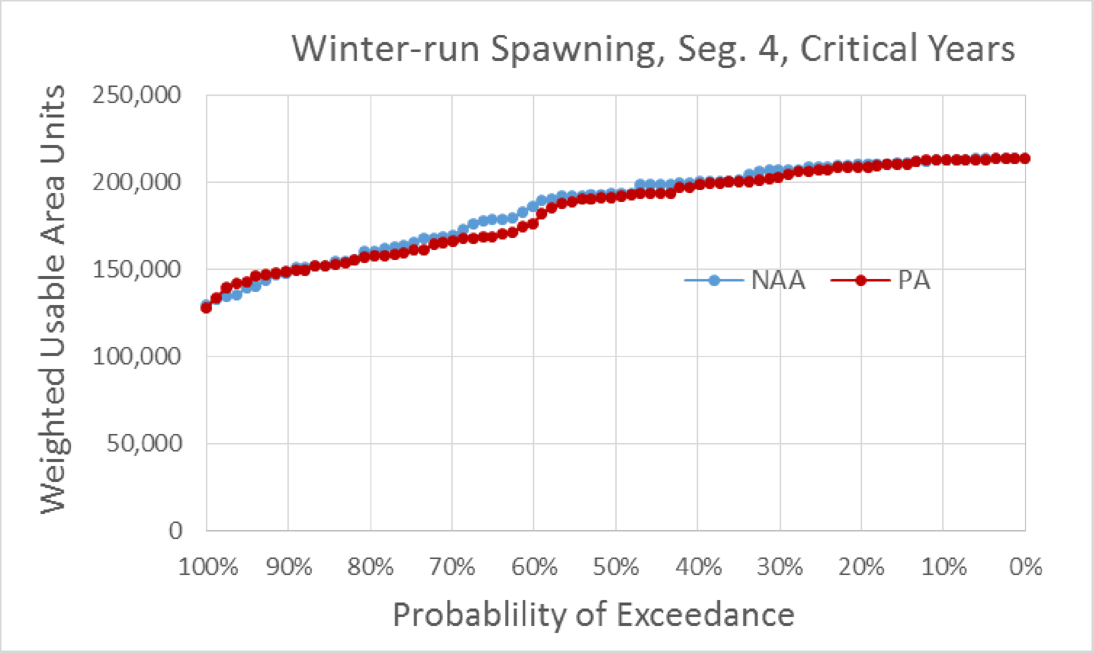

Figure 5.4-51. Exceedance Plot of Winter-Run Chinook Salmon Spawning Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 4, Critical Water Years

Differences in spawning WUA in each segment under the PAA and NAA were also examined using the grand mean spawning WUA for each month of the spawning period under each water year type and all water year types combined (Table 5.4-31 to Table 5.4-33). The means differed by less than 5% for most months and water year types, but mean WUA in Segment 6 under the

PA was up to 12% lower than that under the NAA in September (below normal years) and up to 15% higher in October (below normal years). In the other two segments, the largest differences in mean WUA between the PA and NAA were 6%, except for an 8% higher WUA for the PA in Segment 4 in September of above normal years. Further discussion regarding flow-related effects during the June through November period is provided in Section 5.4.2.3, *Summary of Upstream Effects*.

Table 5.4-31. Winter-Run Chinook Salmon Spawning Weighted Usable Area (WUA) and Differences (Percent Differences) in River Segment 6 between Model Scenarios (green indicates PA is at least 5% higher [raw difference] than NAA; red indicates PA is at least 5% lower)

Month	WYT	NAA	PA	PA vs. NAA
April	Wet	216,522	217,519	997 (0.5%)
	Above Normal	221,764	222,044	280 (0.1%)
	Below Normal	215,429	211,200	-4,229 (-2%)
	Dry	178,104	184,522	6,418 (4%)
	Critical	227,592	231,978	4,386 (2%)
	All	209,456	211,457	2,001 (1%)
May	Wet	276,320	275,628	-692 (-0.3%)
	Above Normal	262,042	263,867	1,825 (1%)
	Below Normal	265,550	264,156	-1,394 (-1%)
	Dry	245,321	253,132	7,812 (3%)
	Critical	244,786	248,484	3,699 (2%)
	All	260,436	262,766	2,330 (1%)
June	Wet	300,750	299,713	-1,037 (-0.3%)
	Above Normal	303,673	299,032	-4,641 (-1.5%)
	Below Normal	299,363	292,133	-7,230 (-2%)
	Dry	300,122	298,338	-1,785 (-1%)
	Critical	298,345	300,412	2,067 (1%)
	All	300,522	298,355	-2,167 (-1%)
July	Wet	288,622	287,598	-1,024 (-0.4%)
	Above Normal	275,604	276,013	408 (0.1%)
	Below Normal	281,204	278,891	-2,313 (-1%)
	Dry	289,472	291,323	1,851 (1%)
	Critical	295,595	299,558	3,964 (1%)
	All	286,791	287,252	461 (0.2%)
August	Wet	304,239	304,335	96 (0.03%)
	Above Normal	305,230	306,481	1,252 (0.4%)
	Below Normal	299,726	304,102	4,376 (1%)
	Dry	296,651	299,775	3,124 (1%)
	Critical	289,022	286,724	-2,298 (-1%)
	All	299,713	300,955	1,241 (0.4%)

Month	WYT	NAA	PA	PA vs. NAA
September	Wet	285,342	288,294	2,952 (1%)
	Above Normal	293,397	283,485	-9,912 (-3%)
	Below Normal	202,678	178,020	-24,658 (-12%)
	Dry	176,018	164,981	-11,038 (-6%)
	Critical	172,765	156,462	-16,303 (-9%)
	All	232,391	223,370	-9,021 (-4%)
October	Wet	272,932	253,563	-19,368 (-7%)
	Above Normal	249,434	248,612	-822 (-0.3%)
	Below Normal	215,956	248,266	32,310 (15%)
	Dry	205,448	223,098	17,650 (9%)
	Critical	166,658	160,394	-6,264 (-4%)
	All	229,306	230,785	1,479 (0.6%)

Table 5.4-32. Winter-Run Chinook Salmon Spawning Weighted Usable Area (WUA) and Differences (Percent Differences) in River Segment 5 between Model Scenarios (green indicates PA is at least 5% higher [raw difference] than NAA; red indicates PA is at least 5% lower)

Month	WYT	NAA	PA	PA vs. NAA
April	Wet	668,066	669,812	1,746 (0.3%)
	Above Normal	723,965	724,219	255 (0.04%)
	Below Normal	721,025	716,821	-4,204 (-1%)
	Dry	673,244	680,144	6,900 (1%)
	Critical	728,344	733,481	5,137 (1%)
	All	694,116	696,581	2,465 (0%)
May	Wet	764,672	764,118	-554 (-0.07%)
	Above Normal	760,631	762,898	2,266 (0.3%)
	Below Normal	772,514	771,235	-1,279 (-0.2%)
	Dry	746,462	754,220	7,758 (1%)
	Critical	758,547	760,080	1,533 (0.2%)
	All	759,746	761,874	2,128 (0.3%)
June	Wet	770,985	761,269	-9,715 (-1%)
	Above Normal	755,863	719,160	-36,703 (-5%)
	Below Normal	732,040	690,204	-41,836 (-6%)
	Dry	747,713	717,986	-29,728 (-4%)
	Critical	767,702	758,858	-8,844 (-1%)
	All	757,207	734,150	-23,056 (-3%)
July	Wet	641,046	634,097	-6,949 (-1%)
	Above Normal	565,302	568,741	3,440 (1%)
	Below Normal	591,210	582,317	-8,893 (-2%)
	Dry	651,436	662,086	10,650 (2%)
	Critical	700,751	729,890	29,139 (4%)

Month	WYT	NAA	PA	PA vs. NAA
	All	633,624	637,635	4,011 (1%)
August	Wet	777,517	775,814	-1,702 (-0.2%)
	Above Normal	782,416	788,046	5,630 (1%)
	Below Normal	739,346	785,280	45,935 (6%)
	Dry	784,795	785,457	662 (0.1%)
	Critical	781,243	776,562	-4,681 (-0.6%)
	All	775,493	781,485	5,991 (0.8%)
September	Wet	640,986	653,779	12,793 (2%)
	Above Normal	788,726	783,990	-4,736 (-1%)
	Below Normal	710,530	681,581	-28,949 (-4%)
	Dry	673,713	659,064	-14,649 (-2%)
	Critical	669,275	642,375	-26,900 (-4%)
	All	685,859	677,772	-8,088 (-1%)
October	Wet	776,954	764,281	-12,674 (-2%)
	Above Normal	762,221	759,184	-3,036 (-0.4%)
	Below Normal	734,311	764,065	29,754 (4%)
	Dry	716,970	739,011	22,041 (3%)
	Critical	662,073	642,143	-19,930 (-3%)
	All	737,150	739,163	2,012 (0.3%)

Table 5.4-33. Winter-Run Chinook Salmon Spawning Weighted Usable Area (WUA) and Differences (Percent Differences) in River Segment 4 between Model Scenarios (green indicates PA is at least 5% higher [raw difference value] than NAA; red indicates PA is at least 5% lower)

Month	WYT	NAA	PA	PA vs. NAA
April	Wet	173,839	173,836	-4 (0%)
	Above Normal	193,016	192,951	-65 (-0.03%)
	Below Normal	202,334	203,129	796 (0.4%)
	Dry	205,148	203,986	-1,162 (-0.6%)
	Critical	195,967	195,628	-339 (-0.2%)
	All	191,577	191,339	-238 (-0.1%)
May	Wet	174,435	174,717	281 (0.2%)
	Above Normal	191,050	190,875	-176 (-0.09%)
	Below Normal	191,405	192,361	956 (0.5%)
	Dry	194,209	189,802	-4,408 (-2%)
	Critical	201,976	200,657	-1,319 (-0.7%)
	All	188,199	187,121	-1,078 (-0.6%)
June	Wet	158,988	157,577	-1,411 (-0.9%)
	Above Normal	152,276	147,609	-4,667 (-3%)
	Below Normal	153,552	148,988	-4,564 (-3%)
	Dry	155,038	149,189	-5,849 (-4%)

Month	WYT	NAA	PA	PA vs. NAA
	Critical	168,125	161,557	-6,568 (-4%)
	All	157,569	153,381	-4,187 (-3%)
July	Wet	138,521	137,705	-816 (-0.6%)
	Above Normal	130,498	130,695	197 (0.2%)
	Below Normal	133,324	132,329	-995 (-0.7%)
	Dry	140,847	141,830	983 (0.7%)
	Critical	150,931	155,376	4,445 (3%)
	All	138,936	139,465	529 (0.4%)
August	Wet	161,112	160,047	-1,065 (-0.7%)
	Above Normal	159,962	159,092	-869 (-0.5%)
	Below Normal	156,705	165,699	8,994 (6%)
	Dry	176,037	171,523	-4,514 (-3%)
	Critical	177,817	174,836	-2,980 (-2%)
	All	166,423	165,617	-806 (-0.5%)
September	Wet	141,651	142,325	675 (0.5%)
	Above Normal	172,658	186,364	13,706 (7.9%)
	Below Normal	207,388	207,314	-74 (-0.04%)
	Dry	204,489	203,147	-1,343 (-0.7%)
	Critical	204,682	200,279	-4,404 (-2%)
	All	179,935	181,341	1,405 (0.8%)
October	Wet	185,912	195,946	10,034 (5.4%)
	Above Normal	199,651	197,487	-2,164 (-1.1%)
	Below Normal	207,180	199,433	-7,747 (-4%)
	Dry	205,507	206,168	661 (0.3%)
	Critical	202,654	198,392	-4,262 (-2%)
	All	198,154	199,534	1,380 (0.7%)

5.4.2.1.3.1.1.1.2 Redd scour

The probability of flows occurring under the PA and the NAA that would be high enough to mobilize sediments and scour winter-run Chinook salmon redds was estimated from CALSIM II estimates of mean monthly flows, using a relationship determined from the historical record between actual mean monthly flow and maximum daily flow (Appendix 5.D, Section 5.D.2.2, *Spawning Flows Methods*). The actual monthly and daily flow data used in the analysis are from gage records just below Keswick Dam and at Bend Bridge, and the CALSIM II estimates used to compare probabilities of redd scour for the PA and the NAA are for the Keswick Dam and Red Bluff locations. As discussed in Appendix 5.D, Section 5.D.2.2, *Spawning Flow Methods*, 40,000 cfs is treated as the minimum daily flow at which redd scour occurs in the Sacramento River. The analysis of the Keswick Dam gage data shows that for months with a mean monthly flow of at least 27,300 cfs, the maximum daily flow in that month is always at least 40,000 cfs. The Bend Bridge gage data show that for months with a mean flow of at least 21,800 cfs, the maximum daily flow in that month is always 40,000 cfs. Therefore, redd scour probabilities for the PA and the NAA were evaluated by comparing frequencies of CALSIM II flows greater than 27,300 cfs at Keswick Dam or greater than 21,800 cfs at Red Bluff during the winter-run April through October spawning and incubation period. Further information on the redd scour analysis methods is provided in Appendix 5.D, Section 5.D.2.2, *Spawning Flows Methods*.

Table 5.4-34 shows that less than 1% of months in the CALSIM II record during the April through October spawning and incubation period of winter-run Chinook salmon would have flows of more than 27,300 cfs at Keswick Dam or more than 21,800 cfs at Red Bluff. This was expected, given that none of the months of the spawning and incubation period usually experiences such high flows. Only one water year and month with mean monthly flow greater than 27,300 cfs was predicted at Keswick Dam for the winter-run spawning and incubation period (Table 5.4-35), and several water years and months with mean monthly flow greater than 21,800 cfs were predicted at Red Bluff (Table 5.4-36) under both the NAA and PA. For winter-run Chinook salmon, there would be no differences between the PA and the NAA in the percentage of scouring flows at either location.

Table 5.4-34. Percent of Months during Spawning and Incubation Periods with CALSIM II Flow Greater than Redd Scouring Threshold Flow at Keswick Dam (27,300 cfs) and Red Bluff (21,800 cfs) between Model Scenarios

	Keswick Dam			Red Bluff		
Species/Race	**NAA**	**PA**	**PA vs. NAA**	**NAA**	**PA**	**PA vs. NAA**
Winter-run Chinook salmon	0.2	0.2	0 (0%)	0.7	0.7	0 (0%)
Spring-run Chinook salmon	0.7	0.5	-0.2 (-25%)	2.6	2.8	0.2 (7%)
CCV Steelhead	5.3	5.3	0 (0%)	14.6	15.7	1 (7%)

Table 5.4-35. Water Year and Month with Mean Flow > 27,300 cfs at Keswick Dam during the Winter-run Chinook Salmon Spawning and Incubation Period

			Flow (cfs)	
Water Year	**Month**	**WYT**	**NAA**	**PA**
1963	April	Wet	30,893	30,893

Table 5.4-36. Water Years and Months with Mean Flow > 21,800 cfs at Red Bluff during the Winter-run Chinook Salmon Spawning and Incubation Period

			Flow (cfs)	
Water Year	**Month**	**WYT**	**NAA**	**PA**
1941	April	Wet	24,464	24,464
1958	April	Wet	22,228	22,228
1963	April	Wet	42,184	42,182
1982	April	Wet	33,884	33,885

Note that SALMOD also predicts redd scour risk for winter-run Chinook salmon in the Sacramento River, although it is combined with redd dewatering and the combination is reported as “Incubation” mortality. Please see Table 5.4-38 below for these results.

5.4.2.1.3.1.1.1.3 Redd dewatering

The percentage of winter-run Chinook salmon redds dewatered by reductions in Sacramento River flow was estimated from CALSIM II estimates of mean monthly flows during the 3 months following each of the months that winter-run salmon spawn (Appendix 5.D, Section 5.D.2.2, *Spawning Flows Methods*, Table 5.D-54). This analysis employed functional relationships developed in field studies by USFWS (2006) that predicted percentages of redds dewatered from an array of paired spawning and dewatering flows. The field studies were conducted in the Sacramento River between Keswick Dam and Battle Creek at the same locations as the spawning WUA studies, and one relationship was developed for the entire river reach (Segments 4 – 6). As noted in Section 5.4.2.1.3.1.1.1.1, *Spawning WUA*, winter-run spawning has peaked, on average, in river Segment 5 based on recent redd surveys, so the Segment 5 CALSIM II flows were used for the effects analysis to estimate redd dewatering under the PA and NAA, using the CALSIM II flow for each month of spawning together with the minimum flow during the 3 months following the spawning month. Because the CALSIM II flows for Segments 4 and 6 are similar to those for Segment 5, redd dewatering estimates using the Segment 4 and Segment 6 flows differ little from those for Segment 5 (Appendix 5.D, Section 5.D.2.6, *Redd Dewatering Results, Sacramento River Segments 4 and 6*). Further information on the redd dewatering analysis methods is provided in Appendix 5.D, Section 5.D.2.2, *Spawning Flows Methods*.

Differences in winter-run redd dewatering under the PA and NAA were examined using exceedance plots of mean monthly percent of redds dewatered for the April through August months during which winter-run spawn. The exceedance curves for the PA generally show higher redd dewatering percentages than those for the NAA for all water year types combined and for all individual water year types except critical years (Figure 5.4-52–Figure 5.4-57). The biggest differences in the dewatering curves are predicted for above normal water years, with about 25% of all months having greater than 10% of redds dewatered under the NAA, but about 38% of all months having greater than 10% of redds dewatered under the PA (a 13% increase). Other differences are smaller than this (up to 11% increase for below normal years at greater than 30% of redds dewatered) but, except for critical years, had consistently higher redd dewatering for the PA. Further discussion regarding flow-related effects during the June through November period is provided in Section 5.4.2.3, *Summary of Upstream Effects*.

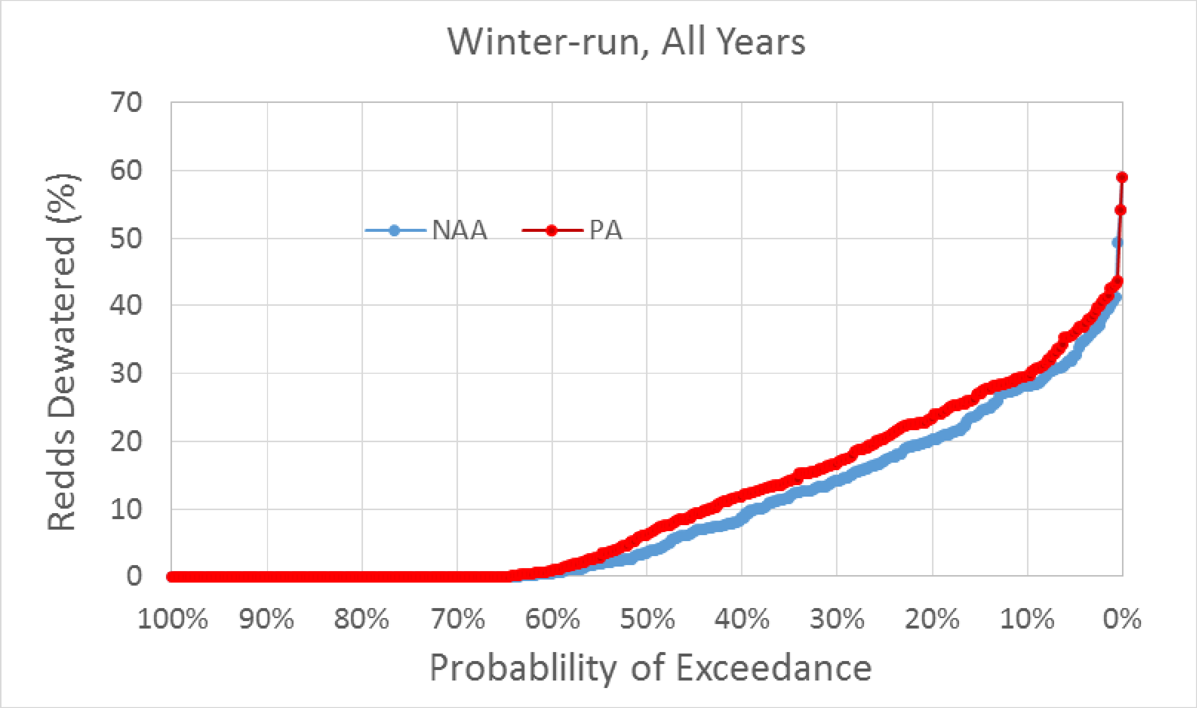

Figure 5.4-52. Exceedance Plot of Winter-Run Chinook Salmon Percent of Redds Dewatered for NAA and PA Model Scenarios, All Water Years

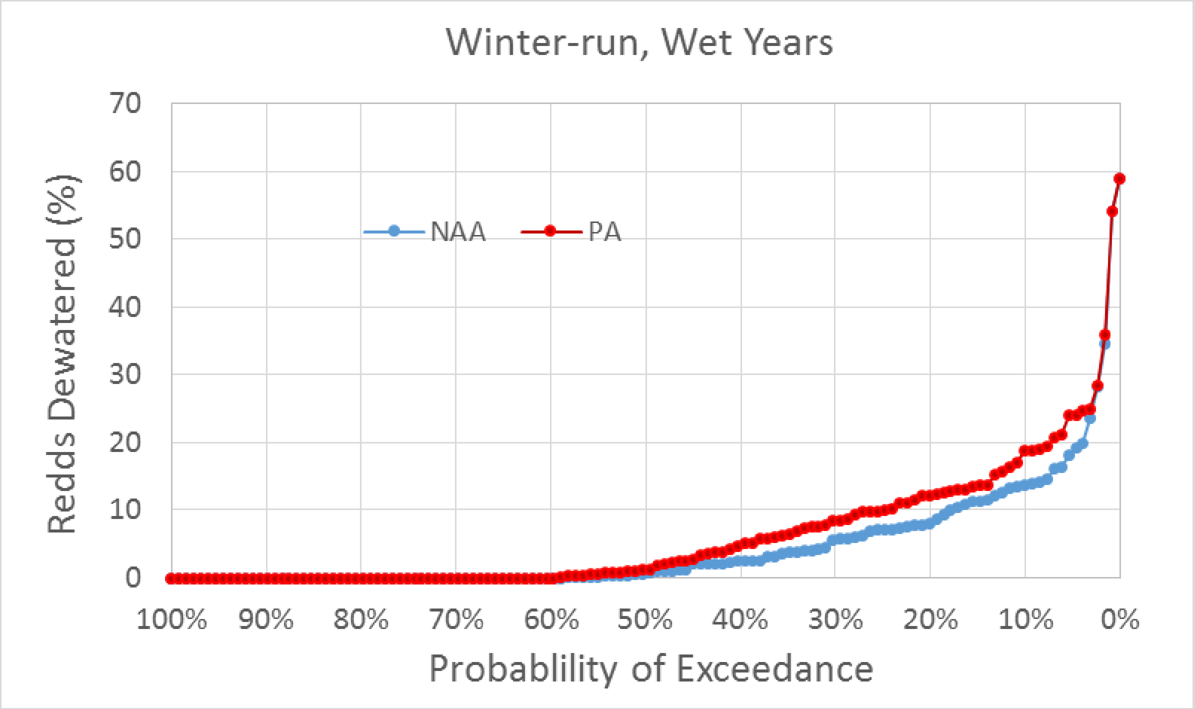

Figure 5.4-53. Exceedance Plot of Winter-Run Chinook Salmon Percent of Redds Dewatered for NAA and PA Model Scenarios, Wet Water Years

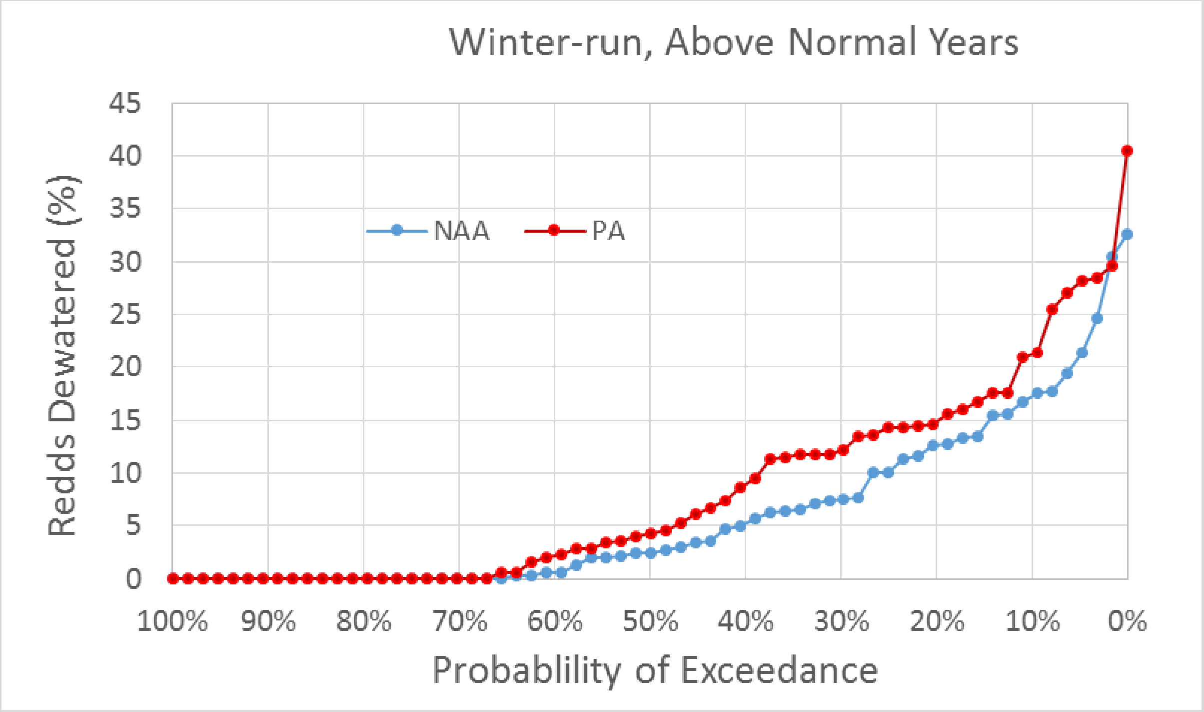

Figure 5.4-54. Exceedance Plot of Winter-Run Chinook Salmon Percent of Redds Dewatered for NAA and PA Model Scenarios, Above Normal Water Years

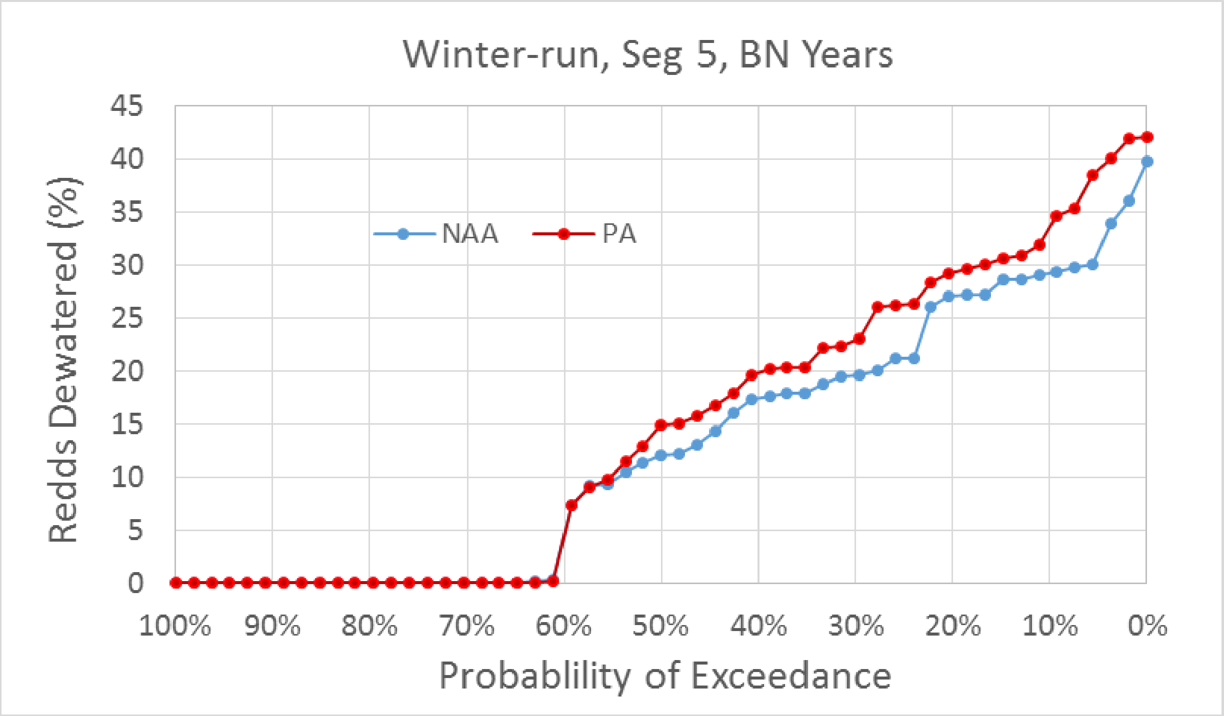

Figure 5.4-55. Exceedance Plot of Winter-Run Chinook Salmon Percent of Redds Dewatered for NAA and PA Model Scenarios, Below Normal Water Years

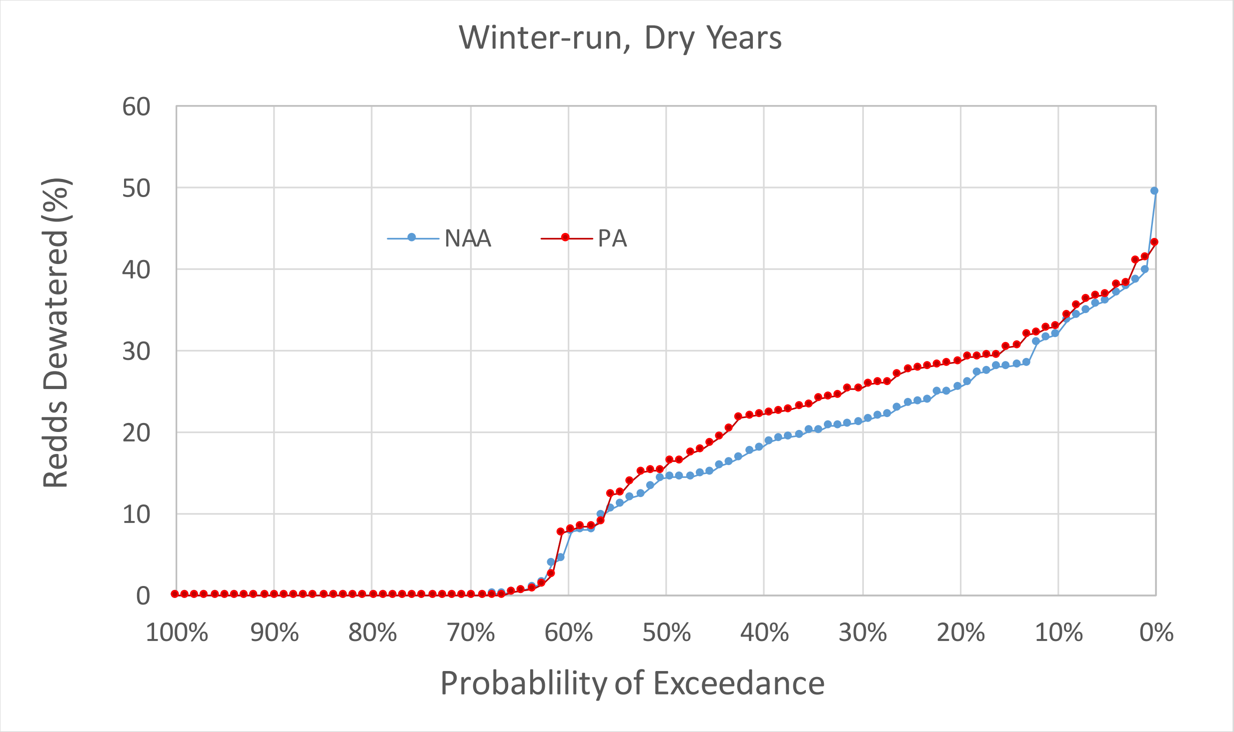

Figure 5.4-56. Exceedance Plot of Winter-Run Chinook Salmon Percent of Redds Dewatered for NAA and PA Model Scenarios, Dry Water Years

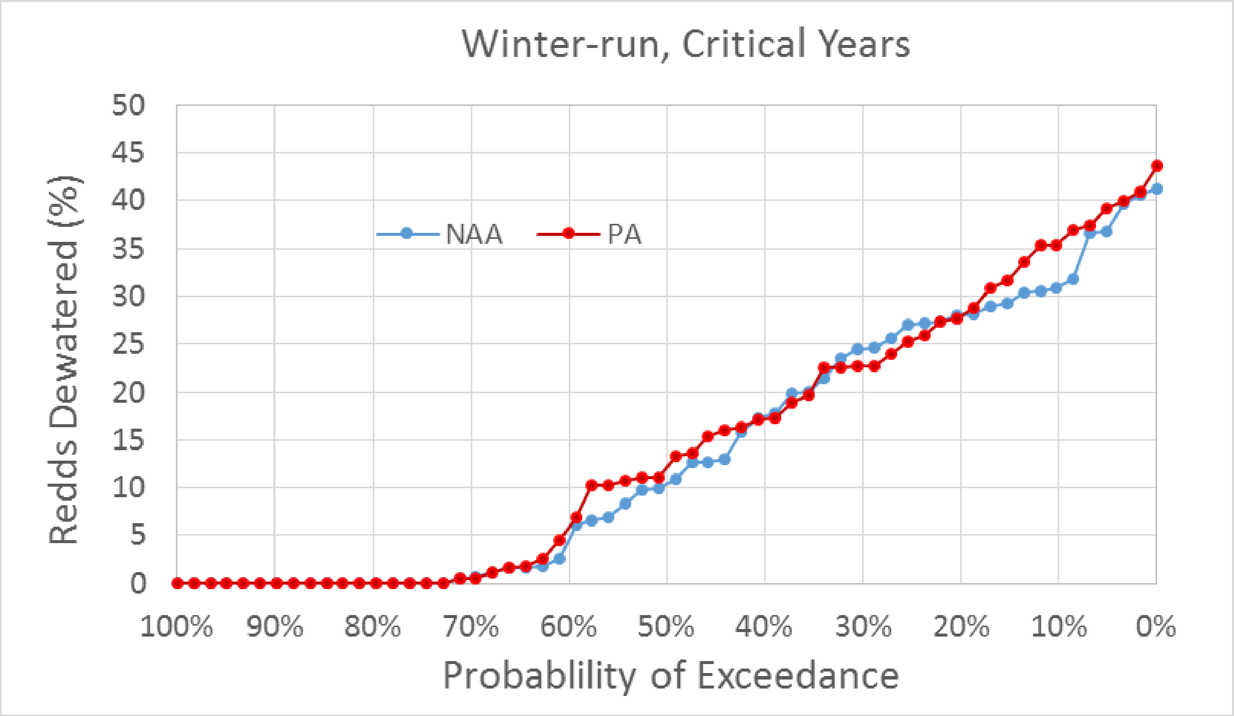

Figure 5.4-57. Exceedance Plot of Winter-Run Chinook Salmon Percent of Redds Dewatered for NAA and PA Model Scenarios, Critical Water Years

Differences in redd dewatering between the PAA and NAA were also examined using the grand mean percentages of redds dewatered for each month of spawning under each water year type and all water year types combined (Table 5.4-37). The mean percent redds dewatered under the PA is predicted to range between 3 and 7% greater than the means under the NAA during June of all water year types except wet years, and to be 3 and 6% greater during August of wet and above normal years, respectively. The percent change (relative change rather than raw change) in the means for these months and water year types ranged from 26% to 89% greater under the PA than under the NAA. The large percentages for many of the months and water year types are artifacts of the low percentages of redds dewatered under both scenarios that were used in computing the percent changes. During April and May, redd dewatering would differ insignificantly between the PA and NAA. Further discussion regarding flow-related effects during the June through November period is provided in Section 5.4.2.3, *Summary of Upstream Effects*.

Table 5.4-37. Winter-Run Chinook Salmon Percent of Redds Dewatered (Percent of Total Redds) and Differences (Percent Differences) between Model Scenarios (green indicates PA is at least 5% lower [raw difference] than NAA; red indicates PA is at least 5% higher)

Month	WYT	NAA	PA	PA vs. NAA
April	Wet	6.1	6.0	0 (0%)
	Above Normal	0.8	0.9	0.14 (19%)
	Below Normal	0.0	0.0	0 (-61%)
	Dry	0.4	0.2	-0.2 (-53%)
	Critical	1.4	1.3	-0.1 (-9%)
	All	2.4	2.3	-0.1 (-2%)
May	Wet	0.4	0.4	0 (1%)
	Above Normal	0.3	0.4	0.1 (31%)
	Below Normal	0.0	0.0	0 (0%)
	Dry	0.7	0.6	-0.2 (-22%)
	Critical	0.2	0.2	0 (10%)
	All	0.4	0.4	0 (-6%)
June	Wet	1.1	1.2	0.1 (9%)
	Above Normal	3.5	6.3	2.8 (79%)
	Below Normal	16.1	22.9	6.8 (43%)
	Dry	20.5	25.8	5.3 (26%)
	Critical	16.5	21.8	5.3 (32%)
	All	10.5	13.9	3.5 (33%)
July	Wet	10.8	14.3	3.5 (32.4%)
	Above Normal	17.5	18.2	0.6 (4%)
	Below Normal	28.5	31.8	3.3 (12%)
	Dry	29.8	30.9	1.1 (4%)
	Critical	27.7	28.0	0.3 (0.9%)
	All	21.4	23.3	2 (9%)

August	Wet	5.5	8.5	3 (55%)
	Above Normal	7.1	13.4	6.3 (89%)
	Below Normal	18.9	17.9	-1 (-5%)
	Dry	16.5	18.5	2 (12%)
	Critical	21.7	20.6	-1.1 (-5%)
	All	12.6	14.8	2.2 (17%)

5.4.2.1.3.1.1.1.4 SALMOD Flow-related Outputs

The SALMOD model provides predicted flow-related mortality of winter-run Chinook salmon eggs and alevins in the Sacramento River (see Attachment 5.D.2, *SALMOD Model* for a full description). The SALMOD results for this type of mortality are presented in Table 5.4-38, together with results for the other sources of mortality of winter-run Chinook salmon predicted by SALMOD and discussed in other sections of this document. The flow-related mortality of winter-run Chinook salmon eggs and alevins is split up as “incubation” (which refers to redd dewatering and scour) and “superimposition” (of redds) mortality. The annual exceedance plot of flow-related mortality of winter-run Chinook salmon eggs and alevins is presented in Figure 5.4-58. These results indicate that there would be increases in flow-related mortality of winter-run Chinook salmon eggs and alevins from incubation-related factors under the PA relative to the NAA for all water year types (increase in average annual mortality of 61,712 eggs and alevins, or 17%, for all water year types combined). Note, however, that the increase for all years combined under the PA would be largely offset by a 7% reduction in temperature-related mortality of the life stage, yielding an increase in average annual total mortality for the life stage of 29,958 eggs and alevins, or 4% (Table 5.4-38). No mortality is predicted from redd superimposition for either scenario. It should be noted that SALMOD predicts redd superimposition for each race of salmon without consideration of redd densities of the other races. SALMOD predicts no superimposition mortality for winter-run because numbers of winter-run spawners are low. Fall-run and late fall–run Chinook salmon are currently the only races of salmon abundant enough in the upper Sacramento River for redd superimposition to be a mortality factor according to SALMOD. However, there is little temporal or spatial overlap of winter-run spawning with that of fall-run or late fall–run Chinook salmon, so the SALMOD prediction of low superimposition for winter-run can be considered reliable. The incubation-related mortality factors in Table 5.4-38 comprise redd dewatering and redd scour (Attachment 5.D.2, *SALMOD Model*). Redd scour, as described in Section 5.4.2.1.3.1.1.1.2, *Redd Scour*, is expected to have little effect on winter-run Chinook salmon under either project scenario, but redd dewatering (Section 5.4.2.1.3.1.1.1.3, *Redd Dewatering*) is predicted to increase under the PA for June and August egg cohorts of some water year types (Table 5.4-37). Therefore, the increase in incubation-related mortality is attributable primarily to the predicted increase in redd dewatering. Further discussion regarding flow-related effects during the June through November period is provided in Section 5.4.2.3, *Summary of Upstream Effects*.

Table 5.4-38. Mean Annual Winter-Run Chinook Salmon Mortality[1] (# of Fish/Year) Predicted by SALMOD

	Spawning, Egg Incubation, and Alevins							Fry and Juvenile Rearing									
	Temperature-Related Mortality			Flow-Related Mortality				Temperature-Related Mortality				Flow-Related Mortality					
Analysis Period	Pre-Spawn	Eggs	Subtotal	Incubation	Super-imposition	Subtotal	Life Stage Total	Fry	Pre-smolt	Immature Smolt	Subtotal	Fry	Pre-smolt	Immature Smolt	Subtotal	Life Stage Total	Grand Total
All Water Year Types[2]																	
NAA	9,092	423,231	432,323	368,939	0	368,939	801,262	5,343	2,391	0	7,734	123,789	115	0	123,904	131,638	932,900
PA	9,119	391,450	400,568	430,651	0	430,651	831,220	5,495	2,125	0	7,620	120,680	104	0	120,784	128,404	959,624
Difference	27	-31,781	-31,755	61,712	0	61,712	29,958	152	-266	0	-114	-3,109	-11	0	-3,120	-3,234	26,723
Percent Difference[3]	0	-8	-7	17	0	17	4	3	-11	0	-1	-3	-10	0	-3	-2	3
Water Year Types[4]																	
Wet (32.5%)																	
NAA	8,774	806	9,580	167,602	0	167,602	177,182	0	0	0	0	173,745	36	0	173,781	173,781	350,962
PA	8,890	670	9,560	244,211	0	244,211	253,771	0	0	0	0	154,086	27	0	154,113	154,113	407,884
Difference	116	-136	-19	76,609	0	76,609	76,589	0	0	0	0	-19,659	-9	0	-19,667	-19,667	56,922
Percent Difference	1	-17	0	46	0	46	43	0	0	0	NA	-11	-25	0	-11	-11	16
Above Normal (12.5%)																	
NAA	9,001	457	9,459	316,112	0	316,112	325,570	0	0	0	0	159,631	24	0	159,655	159,655	485,225
PA	9,001	376	9,378	369,936	0	369,936	379,313	0	0	0	0	139,838	16	0	139,854	139,854	519,167
Difference	0	-81	-81	53,824	0	53,824	53,743	0	0	0	0	-19,793	-8	0	-19,801	-19,801	33,942
Percent Difference	0	-18	-1	17	0	17	17	0	0	0	NA	-12	-32	0	-12	-12	7
Below Normal (17.5%)																	
NAA	7,909	8,021	15,930	587,438	0	587,438	603,368	10	1	0	11	95,189	127	0	95,316	95,327	698,696
PA	8,455	12,730	21,184	714,331	0	714,331	735,515	11	1	0	12	105,939	117	0	106,056	106,068	841,584
Difference	545	4,709	5,254	126,893	0	126,893	132,147	1	0	0	1	10,749	-10	0	10,740	10,741	142,888
Percent Difference	7	59	33	22	0	22	22	15	-8	0	12	11	-8	0	11	11	20
Dry (22.5%)																	
NAA	9,789	29,678	39,467	610,519	0	610,519	649,986	24	6	0	30	106,542	246	0	106,788	106,818	756,803
PA	9,474	21,650	31,123	648,552	0	648,552	679,676	25	4	0	29	122,973	182	0	123,155	123,184	802,859
Difference	-316	-8,028	-8,344	38,034	0	38,034	29,690	1	-2	0	-1	16,431	-64	0	16,367	16,366	46,056
Percent Difference	-3	-27	-21	6	0	6	5	5	-33	0	-3	15	-26	0	15	15	6
Critical (15%)																	
NAA	9,853	2,764,994	2,774,847	275,207	0	275,207	3,050,054	35,573	15,929	0	51,502	33,235	160	0	33,395	84,897	3,134,950
PA	9,779	2,561,888	2,571,667	290,273	0	290,273	2,861,940	36,581	14,162	0	50,743	39,024	223	0	39,247	89,990	2,951,930
Difference	-74	-203,106	-203,180	15,066	0	15,066	-188,113	1,008	-1,767	0	-759	5,789	63	0	5,852	5,093	-183,021
Percent Difference	-1	-7	-7	5	0	5	-6	3	-11	0	-1	17	40	0	18	6	-6

[1] Mortality values do not include base mortality

[2] Based on the 80-year simulation period

[3] Relative difference of the Annual average

[4] As defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (State Water Resources Control Board 1995). Water years may not correspond to the biological years in SALMOD.

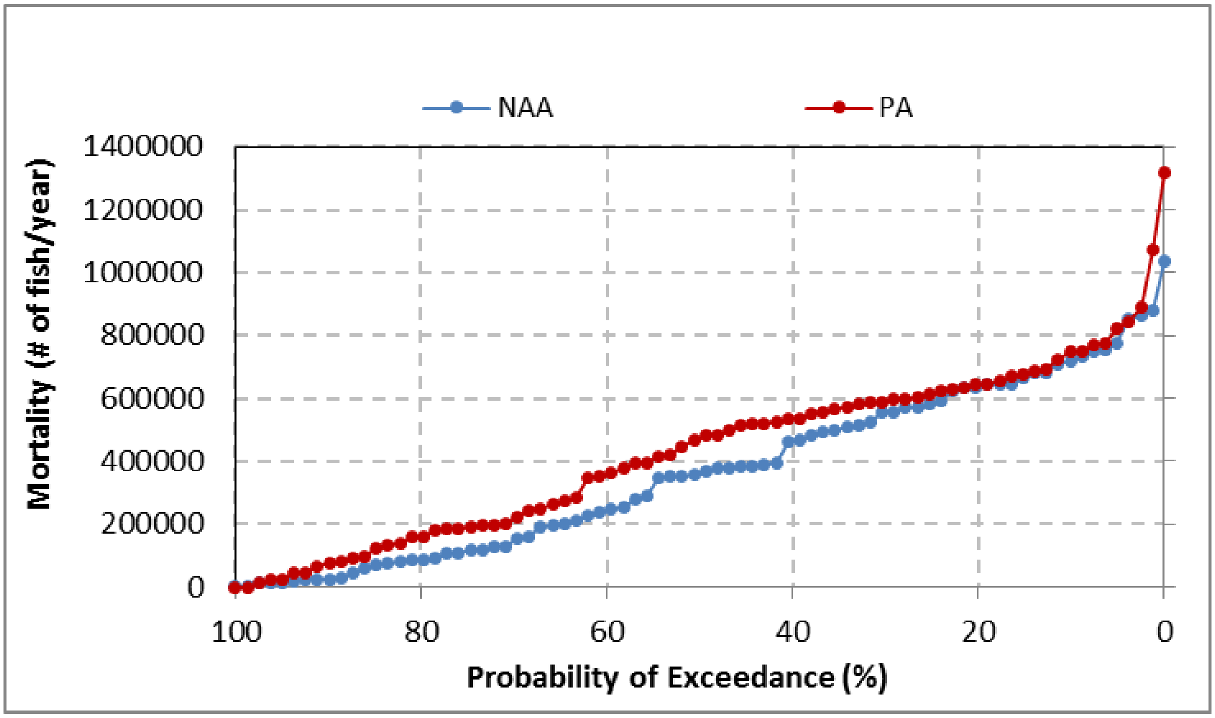

Figure 5.4-58. Exceedance Plot of Annual Flow-Based Mortality (#of Fish/Year) of Winter-Run Chinook Salmon Spawning, Egg Incubation, and Alevins

5.4.2.1.3.1.1.2 Water Temperature-Related Effects

Modeled mean monthly water temperatures during the April through October spawning and incubation period for winter-run Chinook salmon, with peak presence of July through September (Table 5.4-25) are presented in Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results*, Table 5.C.7-3, Table 5.C.7-4, Table 5.C.7-5, Table 5.C.7-7, Table 5.C.7-8. Overall, the PA would change mean water temperatures very little (predominantly less than 1°F, or approximately a 1% change) throughout the spawning reach of Keswick Dam to Red Bluff in all months of the period and water year types. The largest increase in mean monthly water temperatures under the PA relative to the NAA would be 0.6°F, or up to 1.1%, and would occur at Red Bluff in above normal water years during August and in above- and below normal years during September; and at Bend Bridge in below normal years during September. These largest increases would occur during the period of peak presence of spawners, eggs, and alevins.

Exceedance plots of monthly mean water temperatures were examined during each month throughout the spawning and incubation period (Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results*, Figure 5.C.7.3-7, Figure 5.C.7.4-7, Figure 5.C.7.5-7, Figure 5.C.7.7-7, Figure 5.C.7.8-7). The values for the PA in these exceedance plots generally overlap those of the NAA. Further examination of above normal water years during August (Figure 5.4-59) and September (
Figure 5.4-60) at Red Bluff, below normal years during September at Red Bluff (Figure 5.4-61), and in below normal years during September at Bend Bridge (Figure 5.4-62), where the largest increases in mean monthly water temperatures were modeled, reveals that there is a general trend towards marginally higher temperatures under the PA.

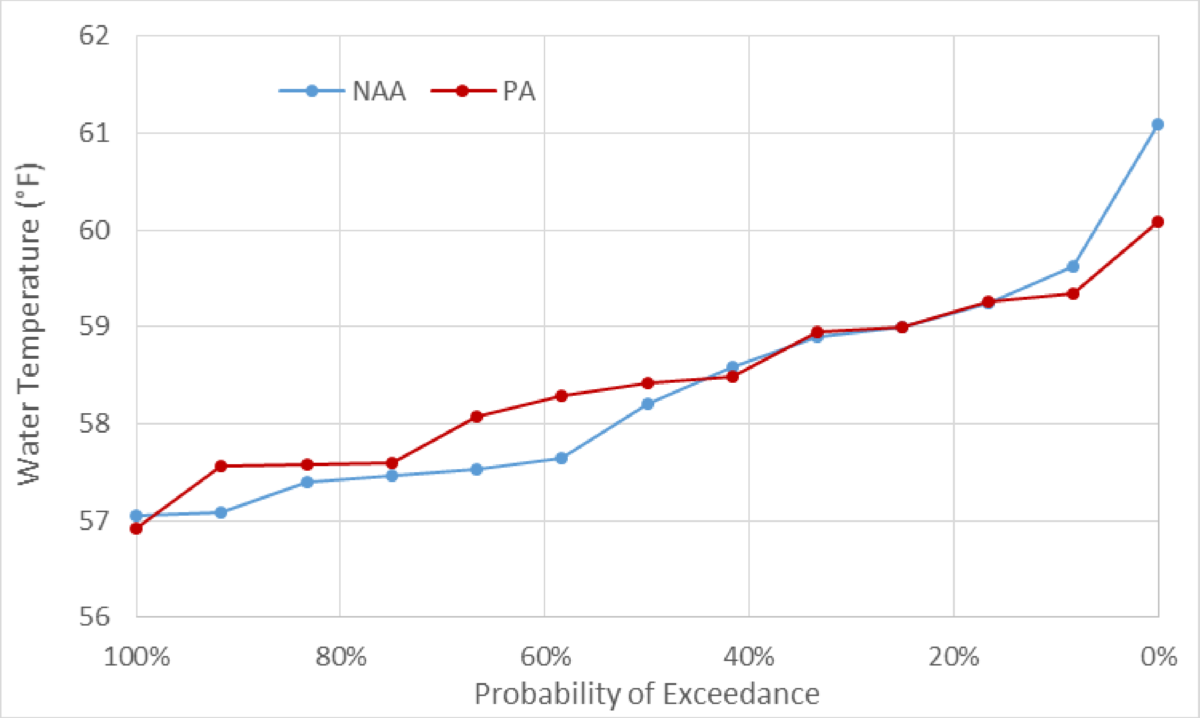

Figure 5.4-59. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the Sacramento River at Red Bluff in August of Above Normal Water Years

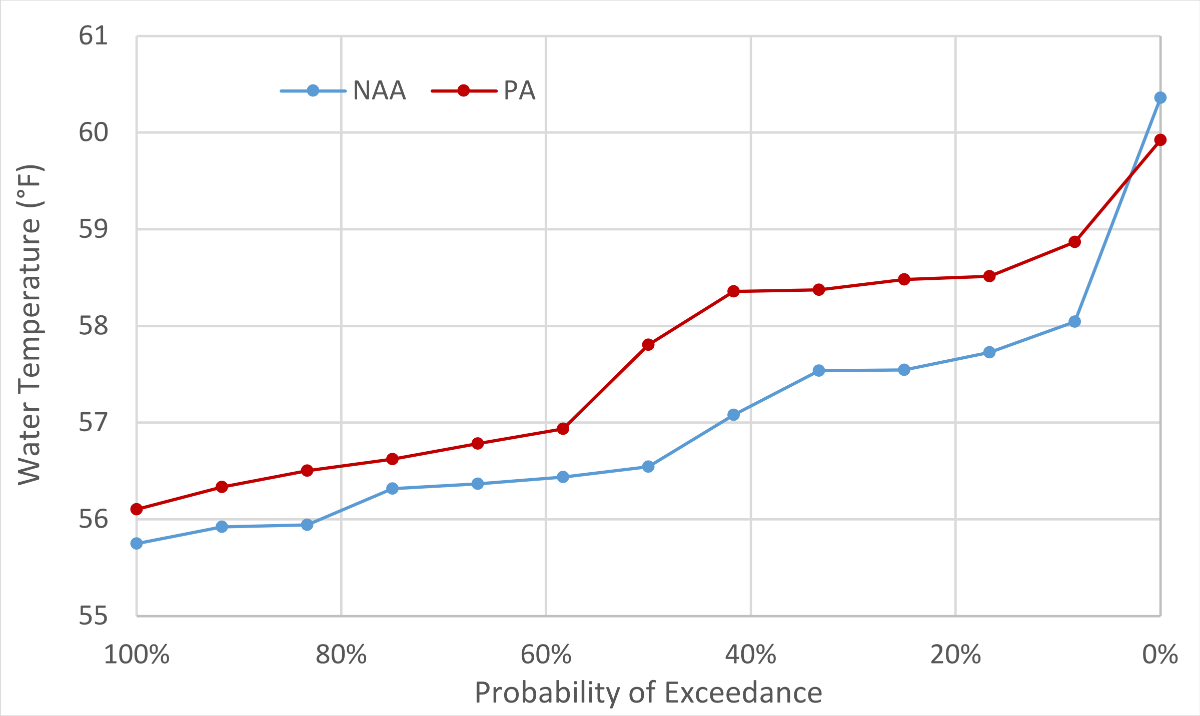

Figure 5.4-60. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the Sacramento River at Red Bluff in September of Above Normal Water Years

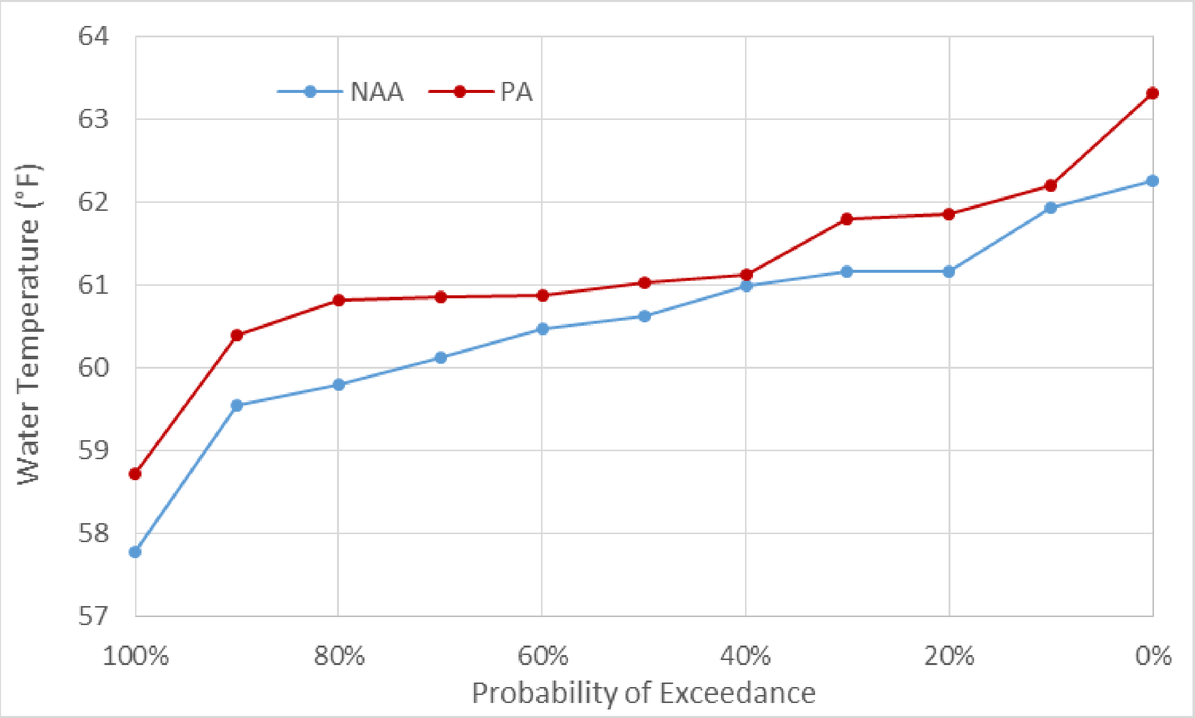

Figure 5.4-61. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the Sacramento River at Red Bluff in September of Below Normal Water Years

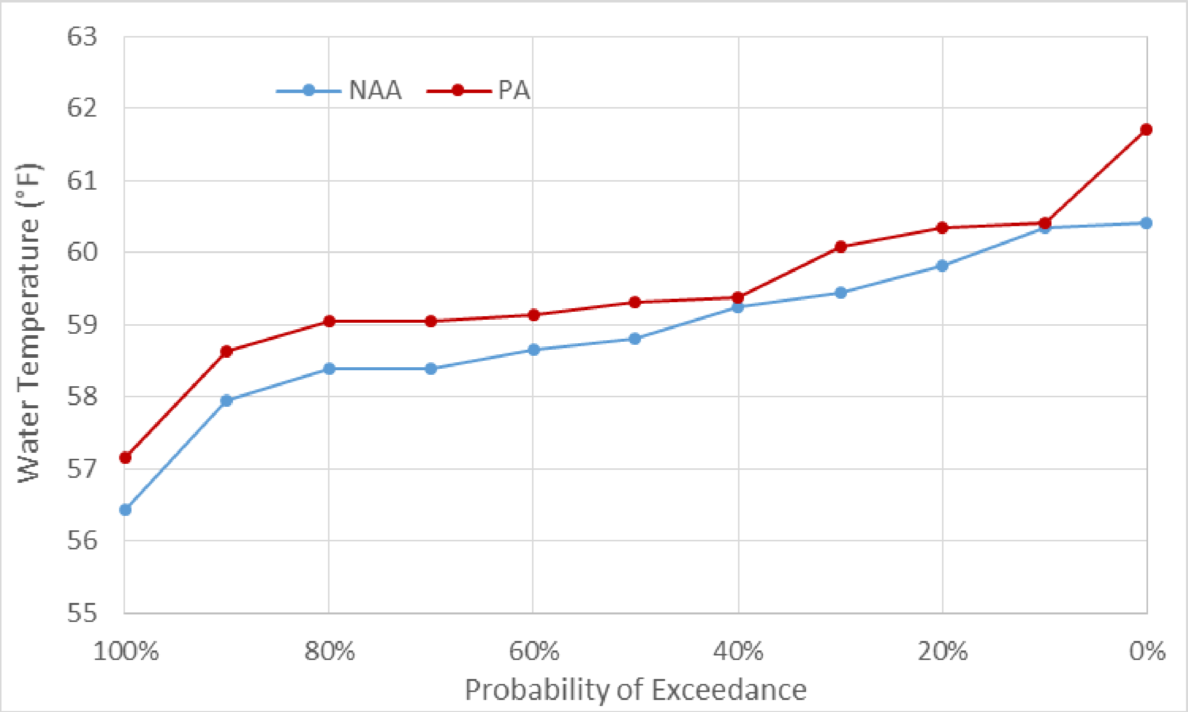

Figure 5.4-62. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the Sacramento River at Bend Bridge in September of Below Normal Water Years

The exceedance of temperature thresholds in the Sacramento River presented in Appendix 5.D, Section 5.D.2.1, *Water Temperature Analysis Methods*, Table 5.D-49 by modeled daily water temperatures were evaluated according to temperature thresholds identified from the literature including the USEPA's temperature water quality guidance (U.S. Environmental Protection Agency 2003). As described in Section 5.D.2.1.2.2, *Water Temperature Threshold Analysis*, the analysis evaluates both the frequency and magnitude of exceedance above a threshold. A *biologically meaningful* effect for the water temperature threshold analysis was defined as the months and water year types in which water temperature results met two criteria: (1) the difference between NAA and PA in frequency of exceedance of the threshold was greater than 5%, and (2) the difference between NAA and PA in average daily exceedance was greater than 0.5°F. The 5% criterion was based on best professional judgment of fisheries biologists from NMFS, CDFW, DWR, and Reclamation. The 0.5°F criterion was based on: (1) a review of the water temperature-related mortality rates for steelhead eggs and juveniles (D. Swank, pers. comm.), and (2) a reasonable water temperature differential that could be resolved through real-time reservoir operations.

For spawning and egg/alevin incubation, the threshold used was from the USEPA's 7-day average daily maximum (7DADM) value of 55.4°F, converted by month to function with daily model outputs for each month separately (Appendix 5.D, Section 5.D.2.1, *Water Temperature Analysis Methods*, Table 5.D-51).

Results of the water temperature thresholds analysis are presented in Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-63 through Table 5.D-67. At Keswick Dam, there would be no months or water year types in which there would be 5% more days under the PA compared to the NAA on which temperatures would exceed the threshold and no more-than-0.5°F difference in the magnitude of average daily exceedance (Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-63).

In the Sacramento River at Clear Creek, the percent of days exceeding the 55.4°F 7DADM threshold under the PA would be more than 5% higher than under the NAA during May (6.2%), August (7.6%), and September (6.4%) of below normal years, and October of dry years (7.3%) (Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-64). There would be a concurrent difference between the NAA and PA in average daily exceedance of more than 0.5°F during May of below normal years only (1.3°F). It was concluded that there would be no biologically meaningful effect in these other months based on the criteria described in Appendix 5.D, Section 5.D.2.1.2.2, *Water Temperature Threshold Analysis*. For May of below normal years, a closer examination of the exceedance plot (Figure 5.4-63) reveals that this appears to be due to CALSIM II attempting to balance storage levels among the CVP reservoirs. This effect is due entirely to 1 year (1923) during which temperatures would be much higher, and there is no practical reason why actual operations under the PA would be different from those under the NAA in this 1 year. Therefore, it was concluded that this result is due to modeling limitations.

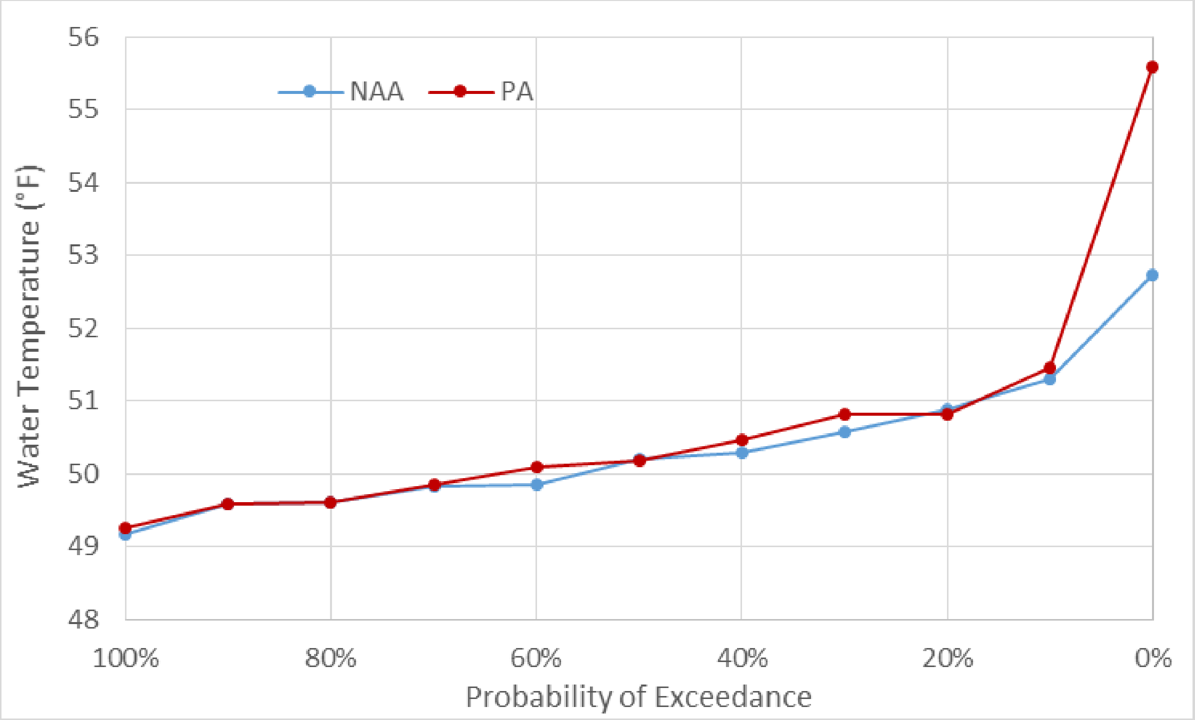

Figure 5.4-63. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the Sacramento River above Clear Creek in May of Below Normal Water Years

At Balls Ferry, the percent of days exceeding the 55.4°F 7DADM threshold under the PA would be more than 5% higher than under the NAA during May of below normal years (6.2%), and July (5.5%), August (7.4%) and September (16.7%) of above normal years (Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-65). There would also be a reduction in exceedance of 9.2% in June of dry years. Among these months and water year types, only May of below normal water years would also have a more-than-0.5°F increase in the magnitude of average daily exceedance (0.55°F). Similar to the Sacrament River at Clear Creek, a closer examination of the exceedance plot (Figure 5.4-64) reveals that this effect is due entirely to 1 year (1923) during which temperatures would be much higher.

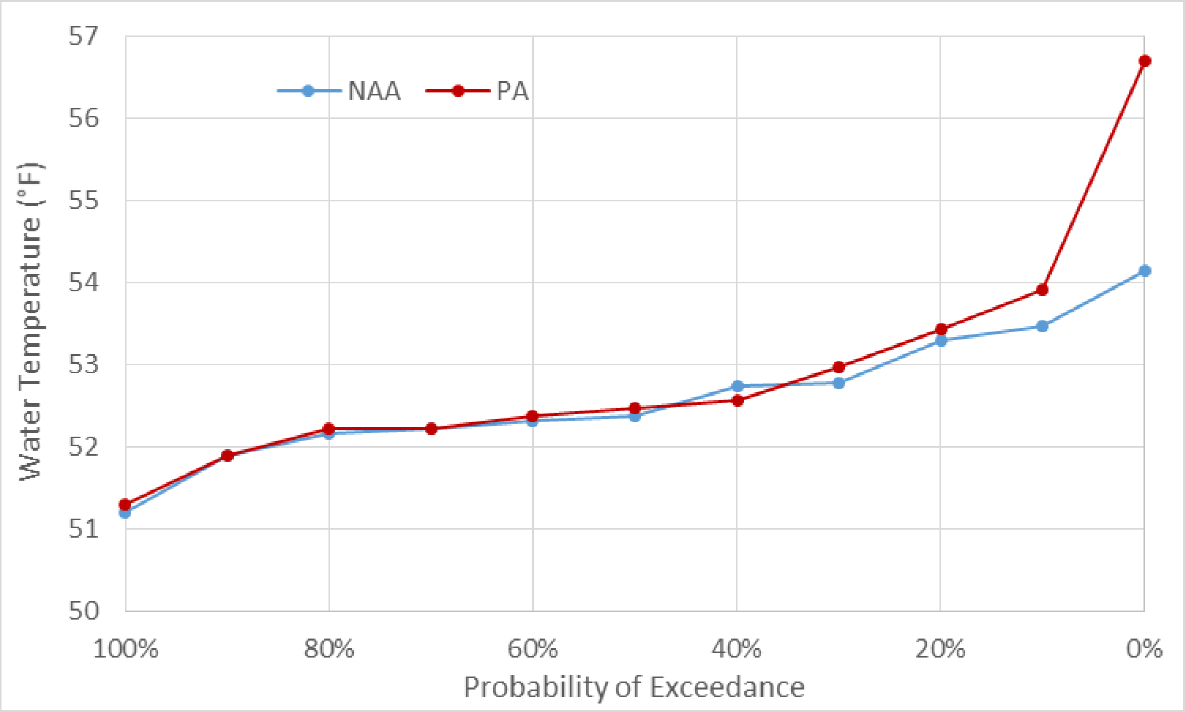

Figure 5.4-64. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the Sacramento River at Balls Ferry in May of Below Normal Water Years

At Bend Bridge, the percent of days exceeding the 55.4°F 7DADM threshold under the PA would be more than 5% higher than under the NAA during September of above normal years and the percent of days exceeding the 55.4°F 7DADM threshold under the PA would be more than 5% lower than under the NAA during June of above normal years (Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-66). However, in neither of these situations would there also be a more-than-0.5°F difference in the magnitude of average daily exceedance. Therefore, it was concluded that there would be no biologically meaningful effect at Bend Bridge.

At Red Bluff, there would be no months or water year types in which there would be 5% more days under the PA compared to the NAA on which temperatures would exceed the threshold and no more-than-0.5°F difference in the magnitude of average daily exceedance (Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-67).

Overall, the thresholds analysis indicates that there would be more exceedances (5% or greater) under the PA in certain months and water year types compared to the NAA. In all but two cases, these exceedances would not result in biologically meaningful water temperature-related effects on winter-run spawning, egg incubation, and alevins, as defined in Appendix 5.D, Section 5.D.2.1.2.2, *Water Temperature Threshold Analysis*. The two cases where modeled water temperatures under the PA exceed the threshold greater than 5% more often than the NAA and by greater than 0.5°F more than under the NAA (May of below normal water years at Clear Creek and Balls Ferry) appear to be the result of a single year (1923) in which water temperature would be substantially higher (approximately 2°F to 3°F). This appear to be due to CALSIM II attempting to balance storage levels among the CVP reservoirs and there is no practical reason why actual operations under the PA would be different from those under the NAA in this one year. Further, CALSIM modeling results given here do not consider revisions to the OCAP RPA Action Suite 1.2 described in Section 3.1.4.5, *Annual/Seasonal Temperature Management Upstream of the Delta*, to improve egg-to-fry survival. CALSIM modeling also does not include consideration of real-time operational management described in Section 3.1.5, *Real-Time Operations Upstream of the Delta*, and Section 3.3.3, *Real-Time Operational Decision-Making Process*, that would be used to avoid and minimize any modeled effects.

The Reclamation Egg Mortality Model provides temperature-related estimates of winter-run egg mortality in the Sacramento River (see Appendix 5.D, Attachment 1, *Reclamation Egg Mortality Model*, for full model description). As noted in Appendix 5.D, Section 5.D.2.1. *Water Temperature Analysis Methods*, NMFS believes this model underestimates temperature related mortality and is likely not sensitive enough to capture small differences in scenarios or temperature related mortality experienced by recent winter-run brood years and, as a result, results should be viewed with caution until a more accurate model is developed or there is better understanding of temperature effects on juvenile production. Because of this, and the fact that the egg life stage has the highest potential effect on the propagation of population size given the constraint of temperature management, a more conservative value of a more-than-2% difference in percent of total individuals (on a raw scale) between the PA and NAA was considered a biologically meaningful effect (see Appendix 5.D, Section 5.D.2.1.2.3, *Reclamation Egg Mortality Model*, for details). Results of the model are presented in Table 5.4-39 and Figure 5.4-65 through Figure 5.4-70.

These results indicate that there would be no biologically meaningful increases in egg mortality under the PA relative to the NAA. Although large on a relative scale due to low mortality values under the NAA, raw differences in below normal and dry water years are insignificant (less than 1% difference) (Table 5.4-39). Also, the difference between means in below normal water years is driven by a single year (1923), as indicated in Figure 5.4-68, and medians and all other metrics are nearly identical. As discussed above, this appears to be due to CALSIM II attempting to balance storage levels among the CVP reservoirs and there is no practical reason why actual operations under the PA would be different from those under the NAA in this 1 year. Further, CALSIM modeling results given here do not consider revisions to the OCAP RPA Action Suite 1.2 described in Section 3.1.4.5, *Annual/Seasonal Temperature Management Upstream of the Delta*, to improve egg-to-fry survival. CALSIM modeling also does not include consideration of real-time operational management described in Section 3.1.5, *Real-Time Operations Upstream of the Delta*, and Section 3.3.3, *Real-Time Operational Decision-Making Process*, that would be used to avoid and minimize any modeled effects.

Table 5.4-39. Winter-Run Chinook Salmon Egg Mortality (Percent of Total Individuals) and Differences (Percent Differences) between Model Scenarios, Reclamation Egg Mortality Model

WYT	NAA	PA	PA vs. NAA
Wet	0.6	0.6	0 (0%)
Above Normal	0.1	0.1	0.002 (2%)
Below Normal	0.3	1.1	0.7 (220%)
Dry	0.3	0.3	-0.03 (-9%)
Critical	31.8	31.3	-0.5 (-2%)
All	5.0	5.0	0 (0%)

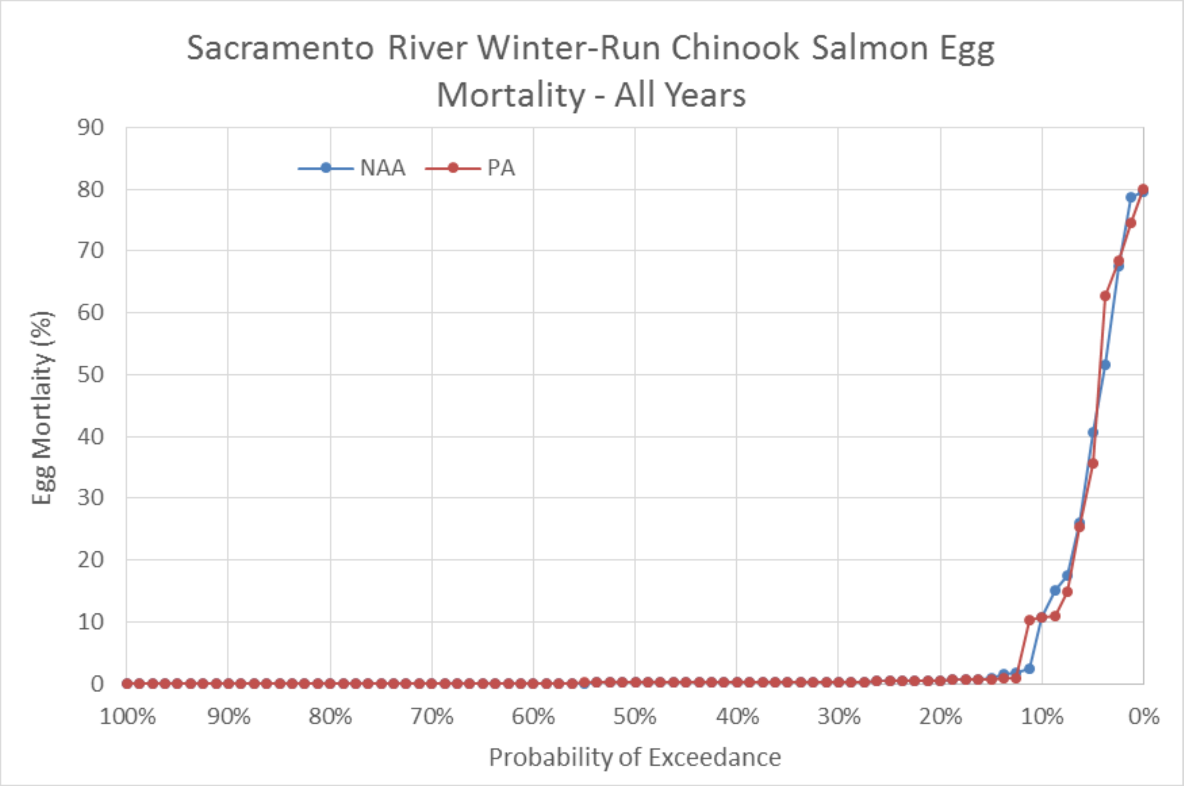

Figure 5.4-65. Exceedance Plot of Winter-Run Chinook Salmon Egg Mortality for NAA and PA Model Scenarios, Reclamation Egg Mortality Model, All Water Years

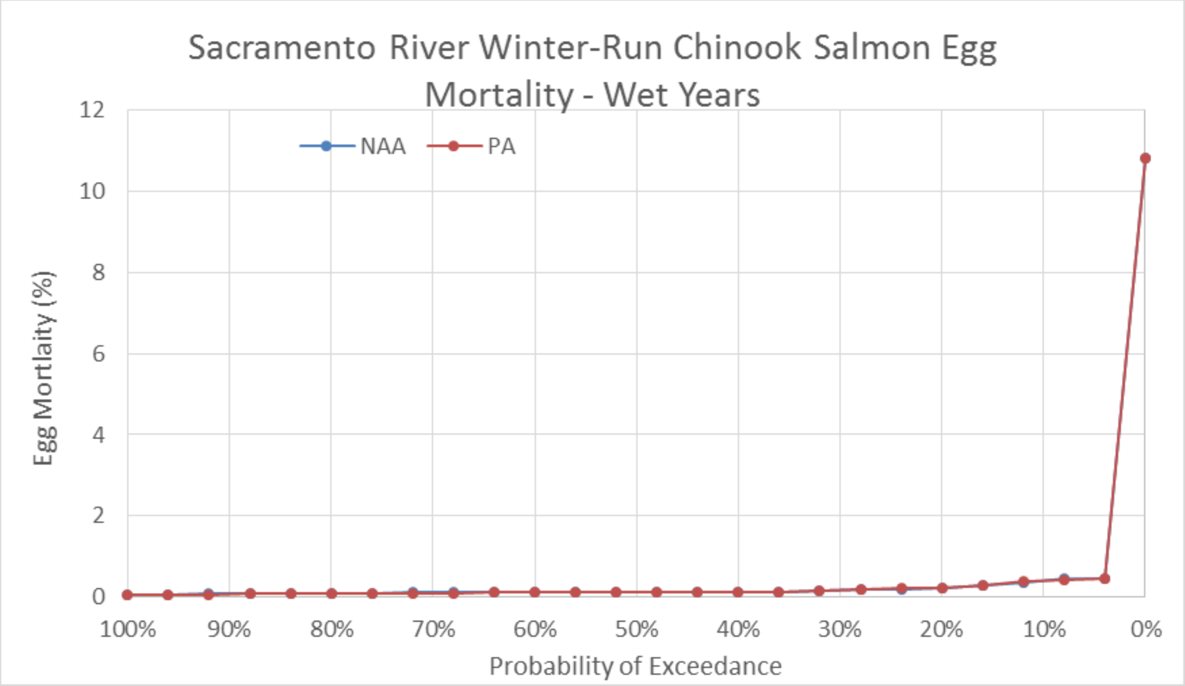

Figure 5.4-66. Exceedance Plot of Winter-Run Chinook Salmon Egg Mortality for NAA and PA Model Scenarios, Reclamation Egg Mortality Model, Wet Water Years

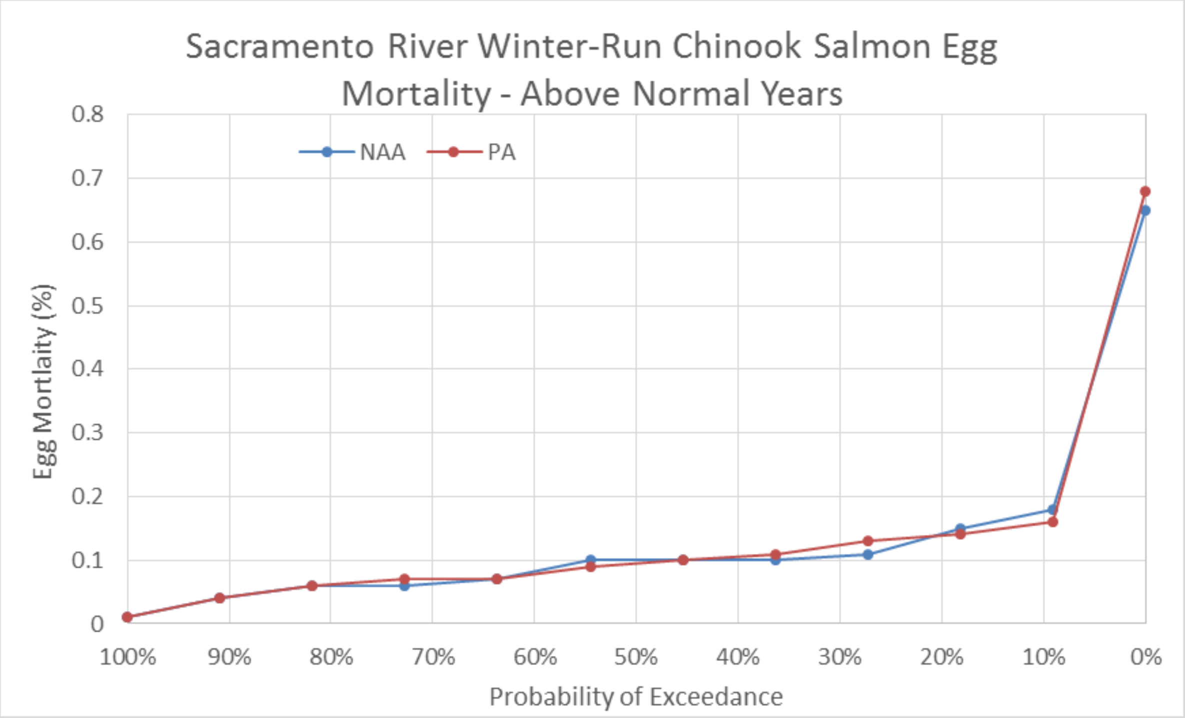

Figure 5.4-67. Exceedance Plot of Winter-Run Chinook Salmon Egg Mortality for NAA and PA Model Scenarios, Reclamation Egg Mortality Model, Above Normal Water Years

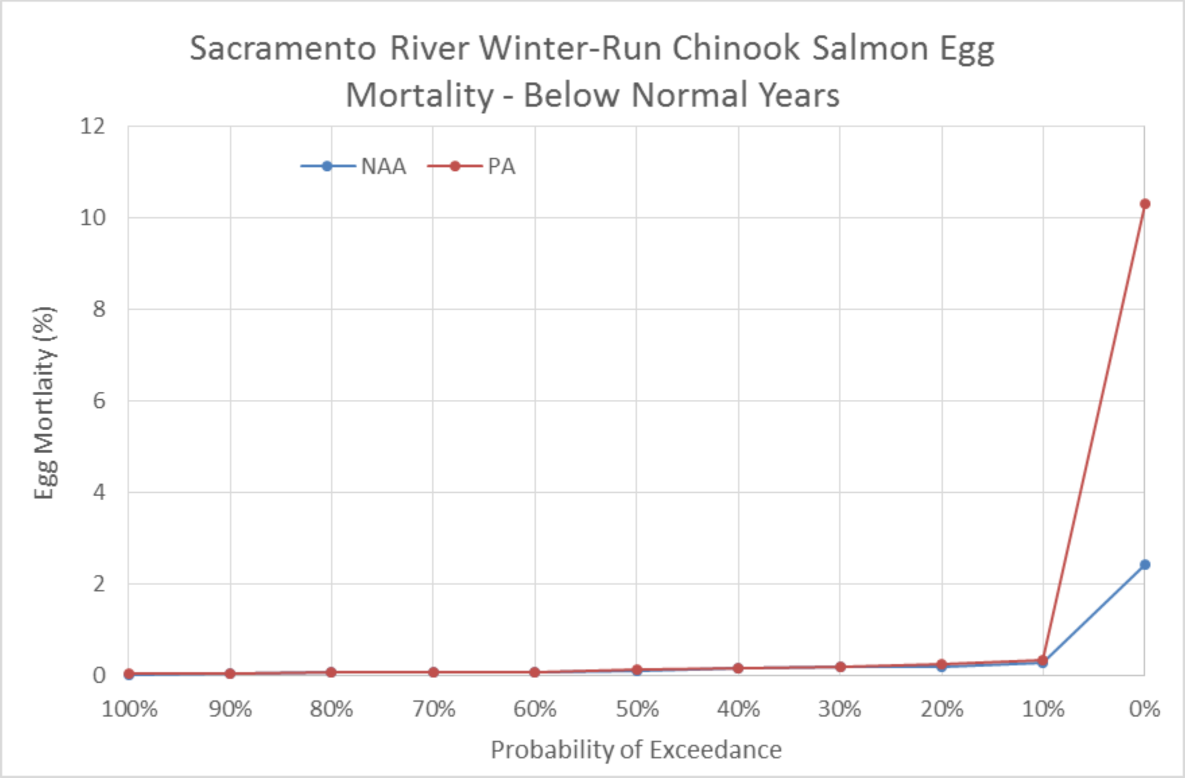

Figure 5.4-68. Exceedance Plot of Winter-Run Chinook Salmon Egg Mortality for NAA and PA Model Scenarios, Reclamation Egg Mortality Model, Below Normal Water Years

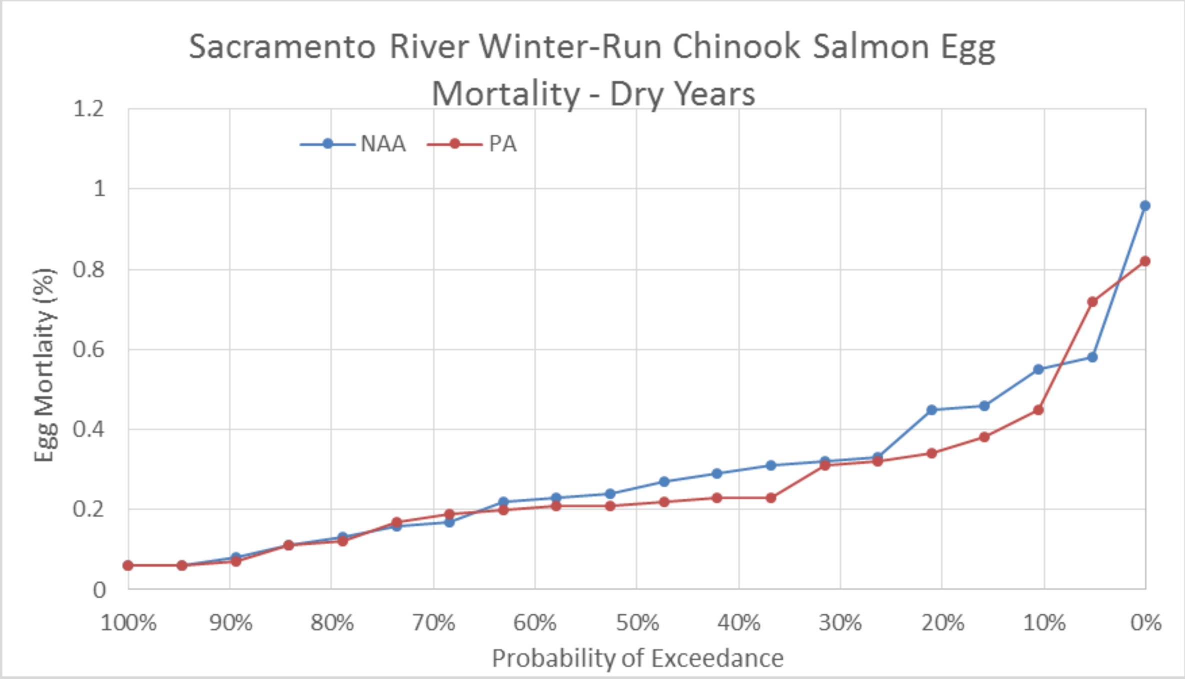

Figure 5.4-69. Exceedance Plot of Winter-Run Chinook Salmon Egg Mortality for NAA and PA Model Scenarios, Reclamation Egg Mortality Model, Dry Water Years

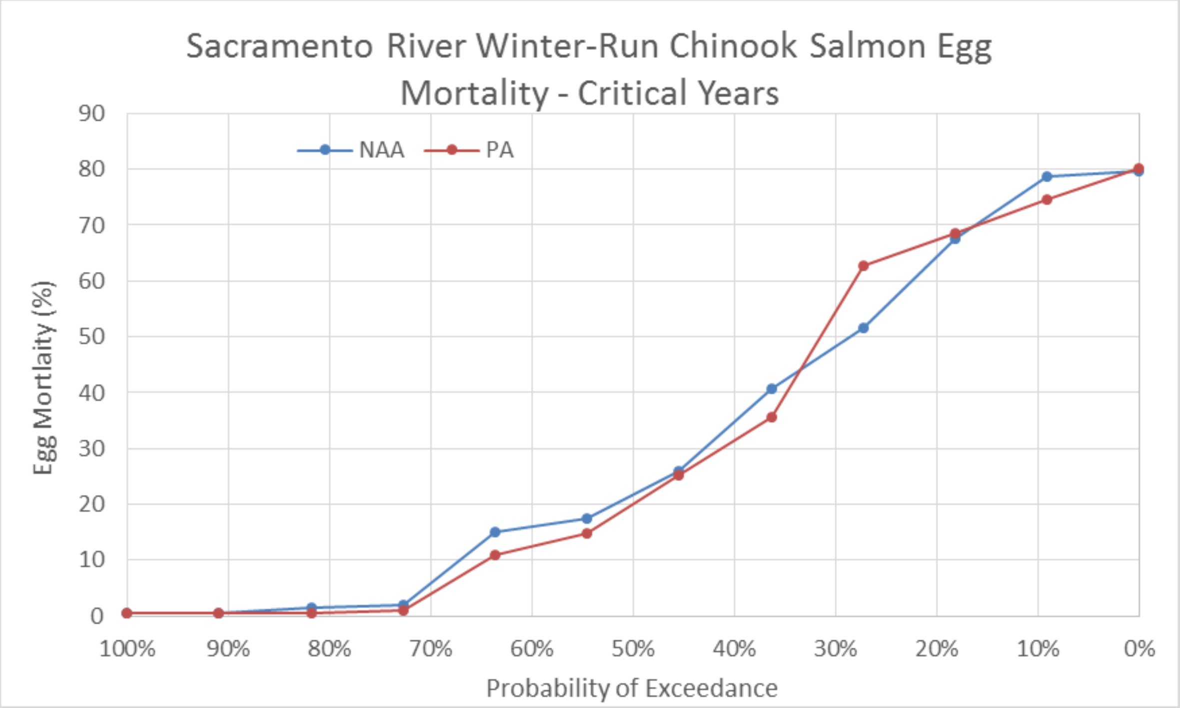

Figure 5.4-70. Exceedance Plot of Winter-Run Chinook Salmon Egg Mortality for NAA and PA Model Scenarios, Reclamation Egg Mortality Model, Critical Water Years

The SALMOD model provides predicted water temperature-related mortality of winter-run Chinook salmon spawning, eggs, and alevins the Sacramento River. This water temperature-related mortality of winter-run Chinook salmon spawning, eggs, and alevins is split up as pre-spawn (in vivo, or in the mother before spawning) and egg (in the gravel) mortality (see Attachment 5.D.2, SALMOD Model, for a full description). Table 5.4-38 presents results for water temperature-related mortality of spawning, eggs, and alevins, in addition to all sources of mortality for winter-run Chinook salmon predicted by SALMOD discussed in other sections of this document. The annual exceedance plot of temperature-related mortality of winter-run Chinook salmon spawning, eggs, and alevins for all water years combined is presented in Figure 5.4-71. These results indicate that, combining all water year types, there would be no increase in temperature-related mortality of winter-run Chinook salmon spawning, eggs, and alevins under the PA relative to the NAA and, in fact, average annual mortality would decrease by 31,755 fish, or 7%, under the PA. For individual water year types, most of the temperature-related mortality (>95%) is predicted to occur in critical years. In this water year type, mortality would average 203,180 fish (7%) lower under the PA relative to the NAA. Almost all of the mortality (>99%) in both the NAA and PA would occur while the eggs are in the gravel and not *in vivo* (pre-spawn).

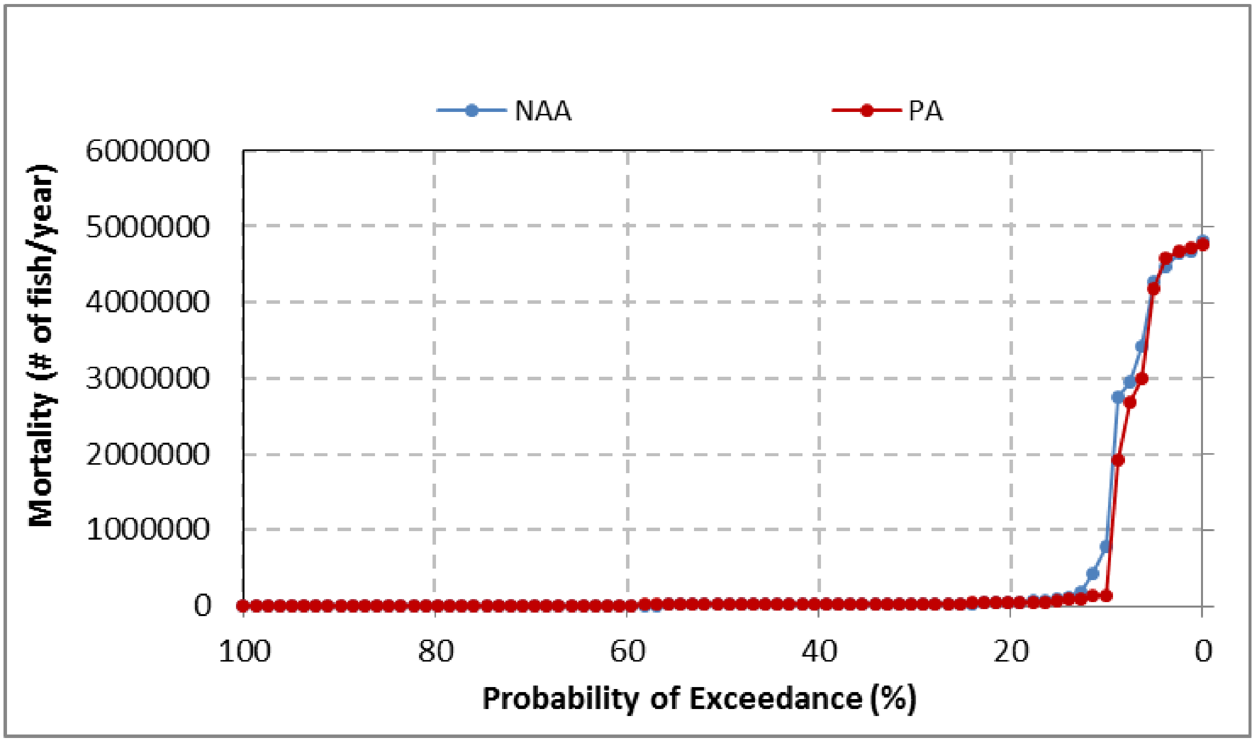

Figure 5.4-71. Exceedance Plot of Annual Water Temperature-Based Mortality (#of Fish/Year) of Winter-Run Chinook Salmon Spawning, Egg Incubation, and Alevins.

5.4.2.1.3.1.2 Fry and Juvenile Rearing

5.4.2.1.3.1.2.1 Flow-Related Effects

As discussed in Appendix 5.D, Section 5.D.2.3, *Rearing Flows Methods*, the stranding of juvenile salmonids is not evaluated in the effects analysis due to limitations of CALSIM modeling. The effect of juvenile stranding on production of Chinook salmon and steelhead populations is not well understood, but stranding is frequently identified as a potentially important mortality factor for the populations in the Sacramento River and its tributaries (Jarret and Killam 2014, 2105, Cramer Fish Sciences 2014, National Marine Fisheries Service 2009, Bureau of Reclamation 2008, Water Forum 2005, California Department of Fish and Game 2001, U.S. Fish and Wildlife Service 2001). Juvenile stranding generally results from reductions in flow that occur over short periods of time, and the CALSIM modeling used to evaluate flow in this effects analysis has a monthly time step, which is too long for any meaningful analysis of juvenile stranding.

Juvenile salmon typically rest in shallow slow-moving water between feeding forays into swifter water. This tendency makes them particularly susceptible to stranding during rapid reductions in flow that dewater and isolate the shallow river margin areas (Jarrett and Killam 2015). Juveniles are most vulnerable to stranding during periods of high and fluctuating flow, when they typically move into side channel habitats that may be extensively inundated. Stranding can lead to direct mortality when these areas drain or dry up, or to indirect mortality from predators or rising water temperatures and deteriorating water quality. High, rapidly changing flows may result from flow release pulses to meet Delta water quality standards and from flood control releases, as well as from tributary freshets following rain events (Jarrett and Killam 2015, Bureau of Reclamation 2008). Stranding may also occur during periods of controlled flow reductions, such as when irrigation demand declines in the fall (National Marine Fisheries Service 2009) or following gate removal at the ACID dam in November and the RBDD dam in September (National Marine Fisheries Service 2009).

As described in Appendix 5.D, Section 5.D.2.3, *Rearing Flows Methods*, the NMFS 2009 BO includes ramping rate restrictions on flow releases from both Keswick Dam and Nimbus Dam to reduce the risk of juvenile stranding and redd dewatering. All ramping restrictions for dams on the Sacramento River and its tributaries would be kept in place for the PA, and, therefore, it is expected that the juvenile stranding risk would be similar for the PA and the NAA.

Estimated mean monthly flow rates and reservoir storage volumes were examined for the PA and NAA in the Sacramento River at the Keswick to Red Bluff locations during the July through November fry and juvenile rearing period for winter-run Chinook salmon (Table 5.4-25, Tables 5.A.6-10, 5.A.6-35). Changes in flow can affect the instream area available for rearing, along with the quality of the habitat for feeding, protective cover, resting, temperature, and other requirements, and can affect stranding of fry and juveniles, especially in side-channel habitats.

Shasta Reservoir storage volume at the end of May can influence flow rates in the Sacramento River below the dam during the first three months of the winter-run salmon rearing period (July – September) and Shasta storage volume at the end of September may influence flow rates during the last two months (October and November). Mean Shasta May storage volume under the PA would be similar (less than 5% difference) to storage under the NAA for all water year types (Appendix 5.A, *CALSIM Methods and Results*, Table 5.A.6-3). Mean Shasta September storage under the PA would also be similar (less than 5% difference) to storage under the NAA for all water year types, except for a 7% higher mean storage volume during critical water years under the PA.

During most months and water year types of the rearing period, mean flow under the PA would be similar (less than 5% difference) or lower than flow under the NAA. Flows at Keswick Dam and Red Bluff in the Sacramento River would be lower under the PA than under the NAA during November of all water year types except critical water years, with 26% lower flows under the PA than under the NAA for wet and above normal water year types at Keswick Dam and 21% lower flows at Red Bluff (Appendix 5.A, *CALSIM Methods and Results*, Table 5.A.6-10, Table 5.A.6-35). Flows under the PA would be 10% lower in August of below normal water years, up to 11% lower in September of above normal and below normal water year types, and up to 11% lower in October of wet years. Mean flows under the PA in October of below normal year types and November of critical years would be up to 17% greater than flows under the NAA. The results given here indicate that the PA would reduce flow in some months and water year types, although this does not consider real-time operational management described in Section 3.1.5, *Real-Time Operations Upstream of the Delta*, and Section 3.3.3, *Real-Time Operational Decision-Making Process*, that would be used to avoid and minimize any modeled effects. Further discussion regarding flow-related effects during the June through November period is provided in Section 5.4.2.3, *Summary of Upstream Effects*.

Rearing weighted usable area (WUA) provides an index of rearing habitat availability that takes into considerations the rearing requirements of the fish with respect to water depth, flow velocity, and cover. Rearing WUA for winter-run Chinook salmon fry and juveniles was determined by USFWS (2005b) for a range of flows in three segments of the Sacramento River between Keswick Dam and the Battle Creek confluence (Appendix 5.D, Section 5.D.2.3, *Rearing Flows Methods*). The three river segments are the same as those used for the spawning habitat WUA studies (U.S. Fish and Wildlife Service 2003a, 2006). Segment 4 stretches 8 miles, from Battle Creek to the confluence with Cow Creek; Segment 5 reaches 16 miles, from Cow Creek to ACID Dam; and Segment 6 covers 2 miles, from ACID Dam to Keswick Dam. To estimate changes in rearing WUA that would result from the PA relative to the NAA, the rearing habitat WUA curve developed for each of these segments was used with mean monthly CALSIM II flow estimates under the PA and the NAA for the midpoint of each segment during each month of the winter-run fry and juvenile rearing periods (Appendix 5.D, Section 5.D.2.3, *Rearing Flows Methods*, Table 5.D-62). For this analysis, fry were defined as fish less than 60 mm, and juveniles were those greater than 60 mm. Further information on the rearing WUA analysis methods is provided in Appendix 5.D, Section 5.D.2.3, *Rearing Flows Methods*.

Differences between the PA and NAA in rearing WUA for winter-run fry and juveniles were examined using exceedance plots of mean monthly WUA for the winter-run fry (Figure 5.4-72–Figure 5.4-89) and juvenile (Figure 5.4-90–Figure 5.4-107) rearing periods in each of the river segments for each water year type and all water year types combined. The PA exceedance curves for fry and juvenile rearing WUA for all water years combined are similar to the NAA exceedance curves for Segments 6 and 5 (Figure 5.4-72, Figure 5.4-78, Figure 5.4-84, Figure 5.4-90, and Figure 5.4-96), but for Segment 4, part of the juvenile exceedance curve for the PA is higher than the NAA curve (Figure 5.4-102). With the curves broken out by water year type, reductions in fry rearing WUA under the PA are evident in Segment 6 during critical water years (Figure 5.4-77) and Segment 5 during below normal years (Figure 5.4-81), while reductions in juvenile rearing WUA under the PA are seen in Segment 6 in above normal years (Figure 5.4-92). Increases in juvenile rearing WUA under the PA are evident in Segment 4 during wet and above normal years (Figure 5.4-103 and Figure 5.4-104) and both increases and reductions in juvenile rearing WUA can be seen in Segment 5 during below normal years (Figure 5.4-99). The WUA modeling indicates that the PA would reduce winter-run Chinook salmon rearing habitat during some months and water year types, especially in Segments 6 and 5, although this does not consider real-time operational management described in Section 3.1.5, *Real-Time Operations Upstream of the Delta*, and Section 3.3.3, *Real-Time Operational Decision-Making Process*, that would be used to avoid and minimize any modeled effects. Further discussion regarding flow-related effects during the June through November period is provided in Section 5.4.2.3, *Summary of Upstream Effects*.

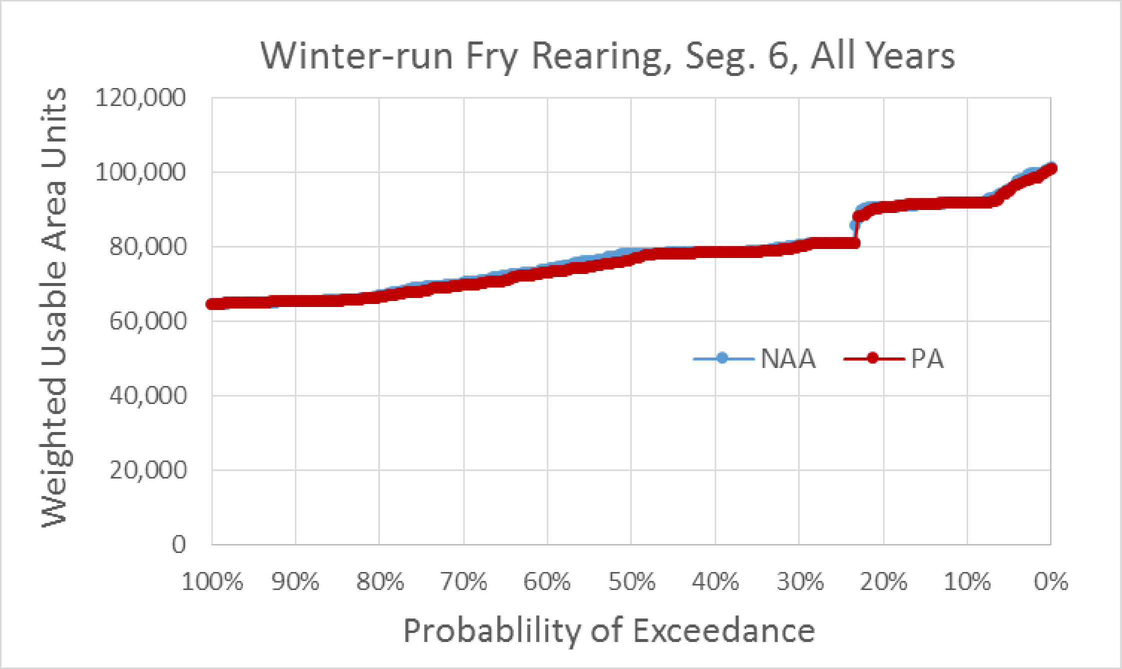

Figure 5.4-72. Exceedance Plot of Winter-Run Chinook Salmon Fry Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 6, All Water Years

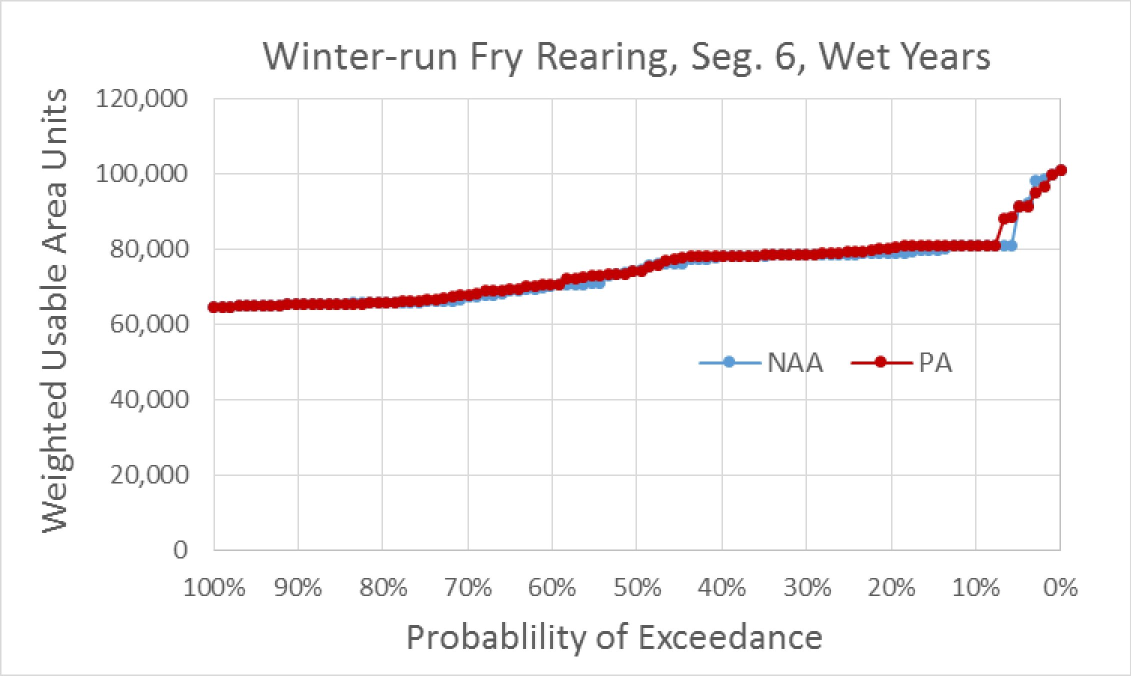

Figure 5.4-73. Exceedance Plot of Winter-Run Chinook Salmon Fry Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 6, Wet Water Years

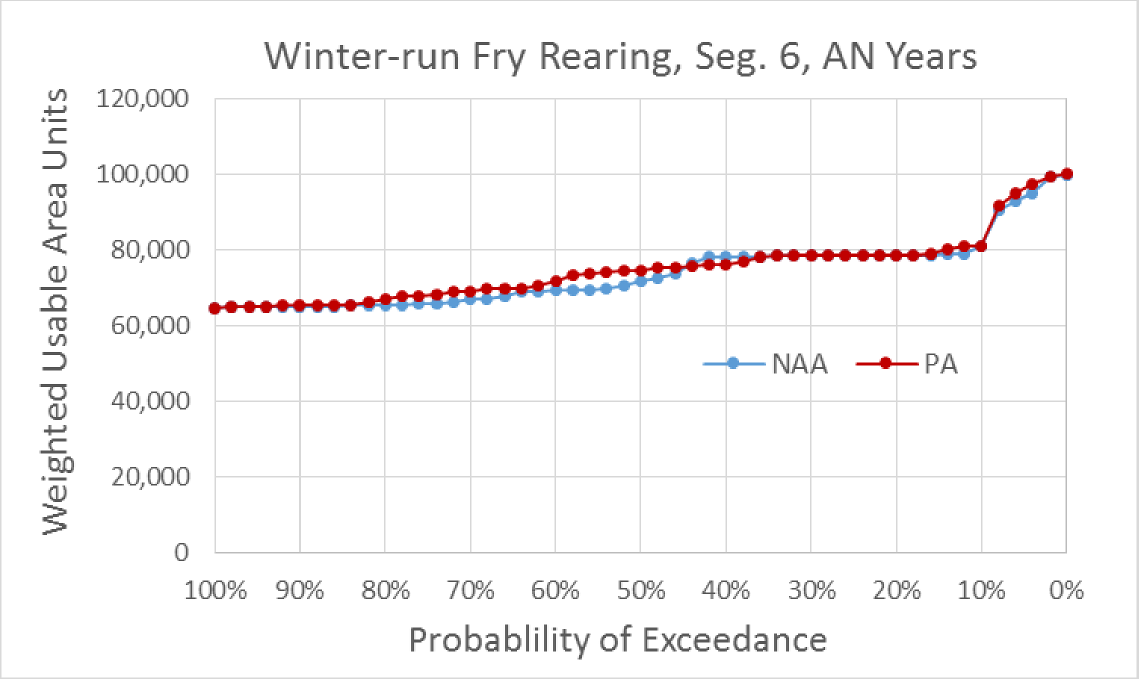

Figure 5.4-74. Exceedance Plot of Winter-Run Chinook Salmon Fry Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 6, Above Normal Water Years

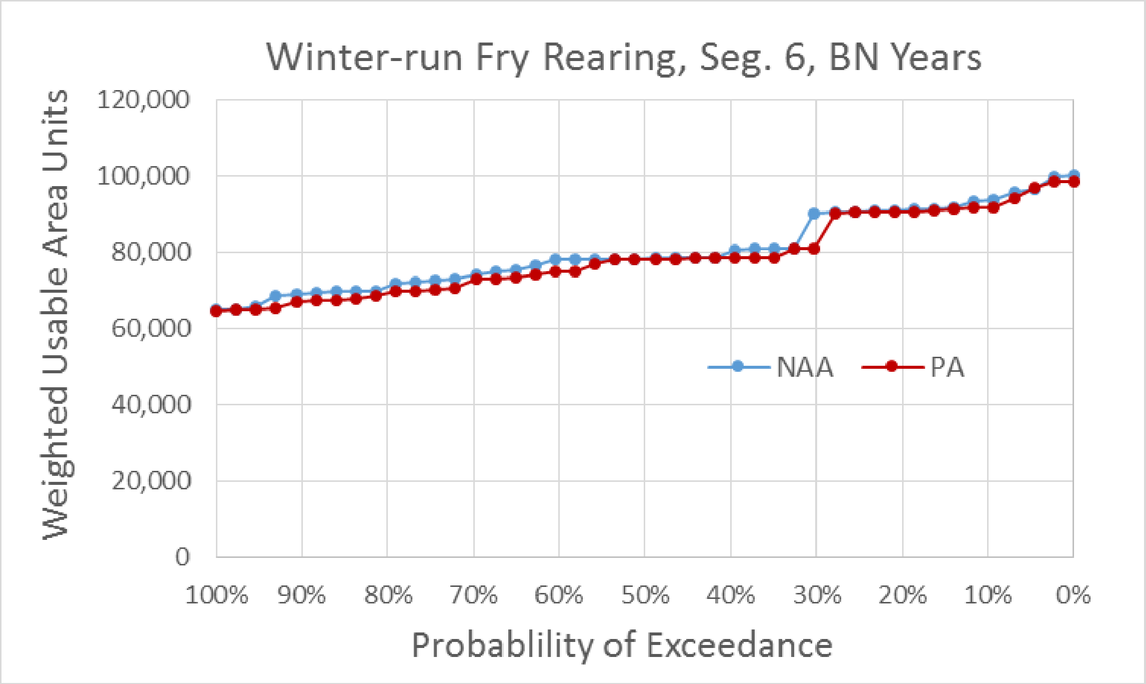

Figure 5.4-75. Exceedance Plot of Winter-Run Chinook Salmon Fry Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 6, Below Normal Water Years

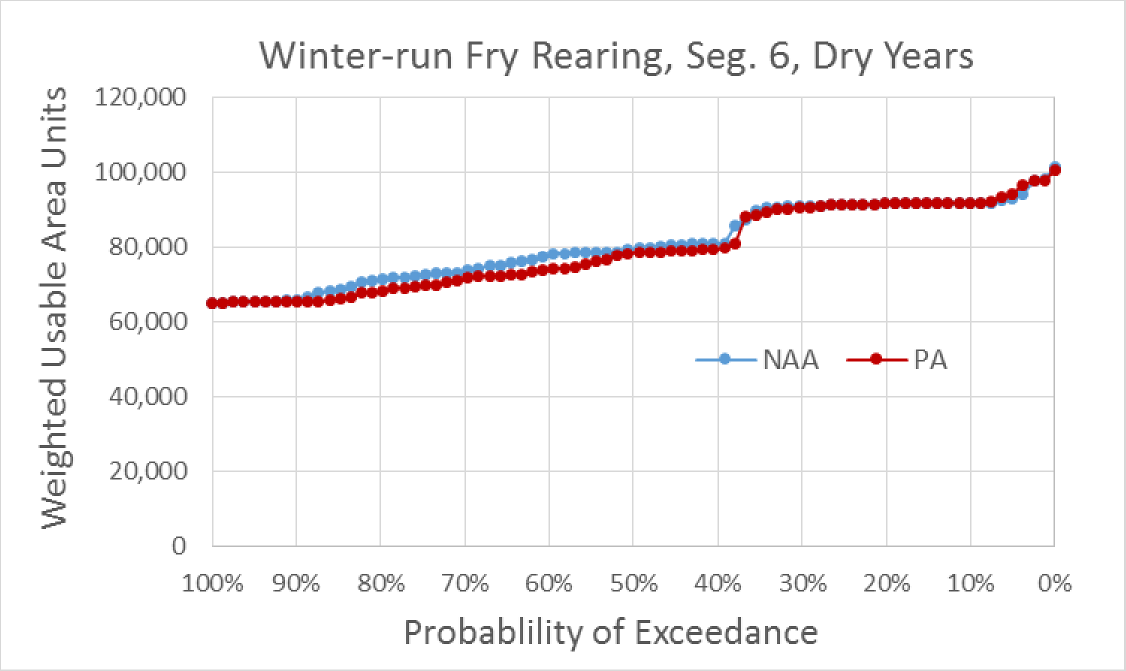

Figure 5.4-76. Exceedance Plot of Winter-Run Chinook Salmon Fry Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 6, Dry Water Years

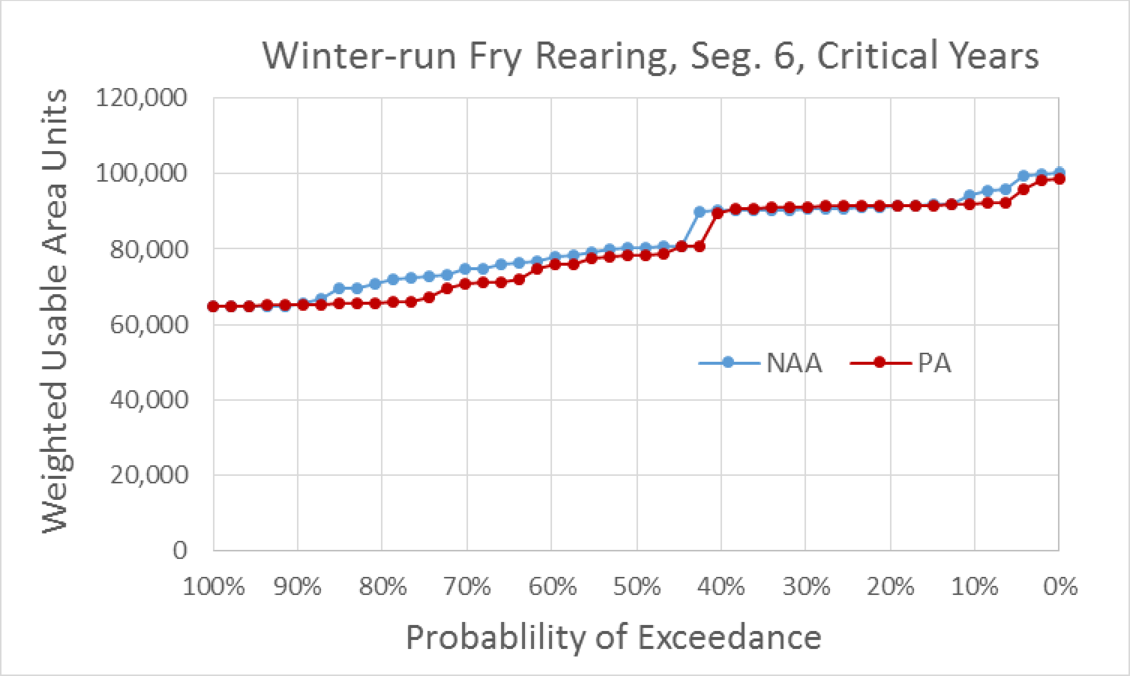

Figure 5.4-77. Exceedance Plot of Winter-Run Chinook Salmon Fry Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 6, Critical Water Years

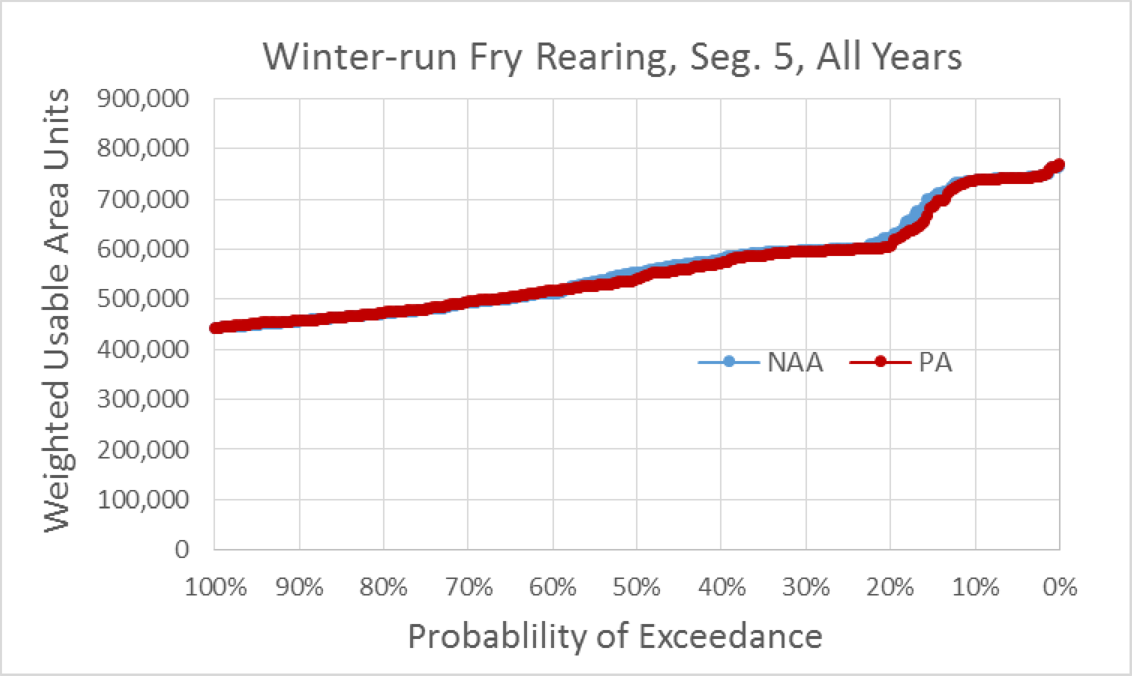

Figure 5.4-78. Exceedance Plot of Winter-Run Chinook Salmon Fry Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 5, All Water Years

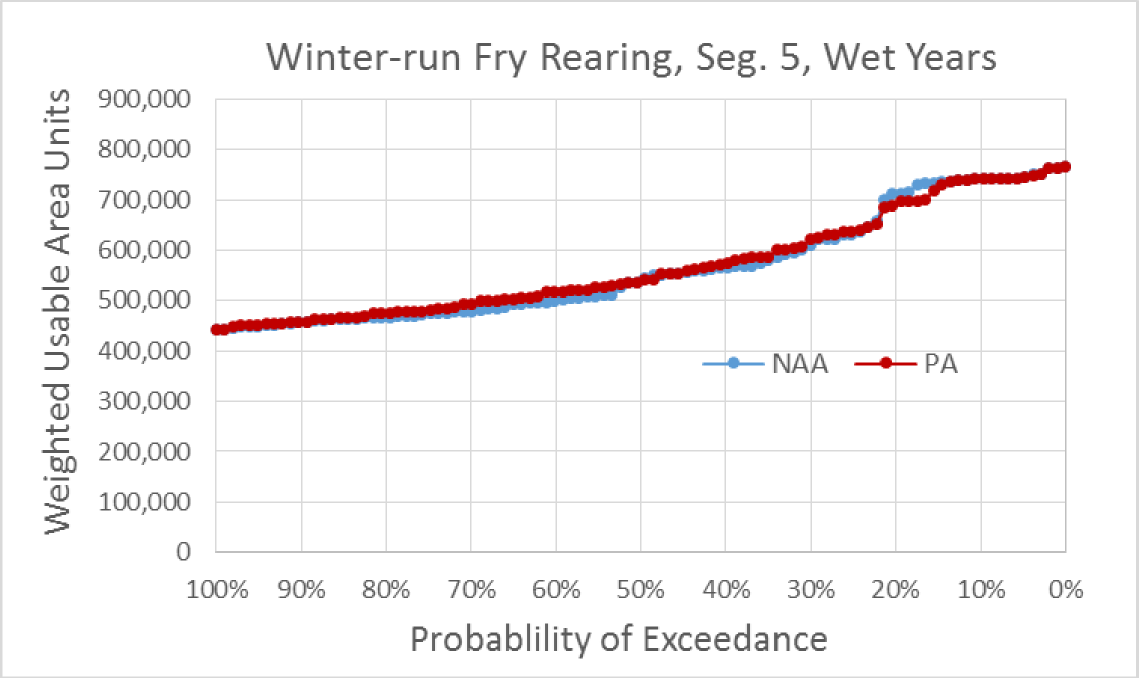

Figure 5.4-79. Exceedance Plot of Winter-Run Chinook Salmon Fry Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 5, Wet Water Years.

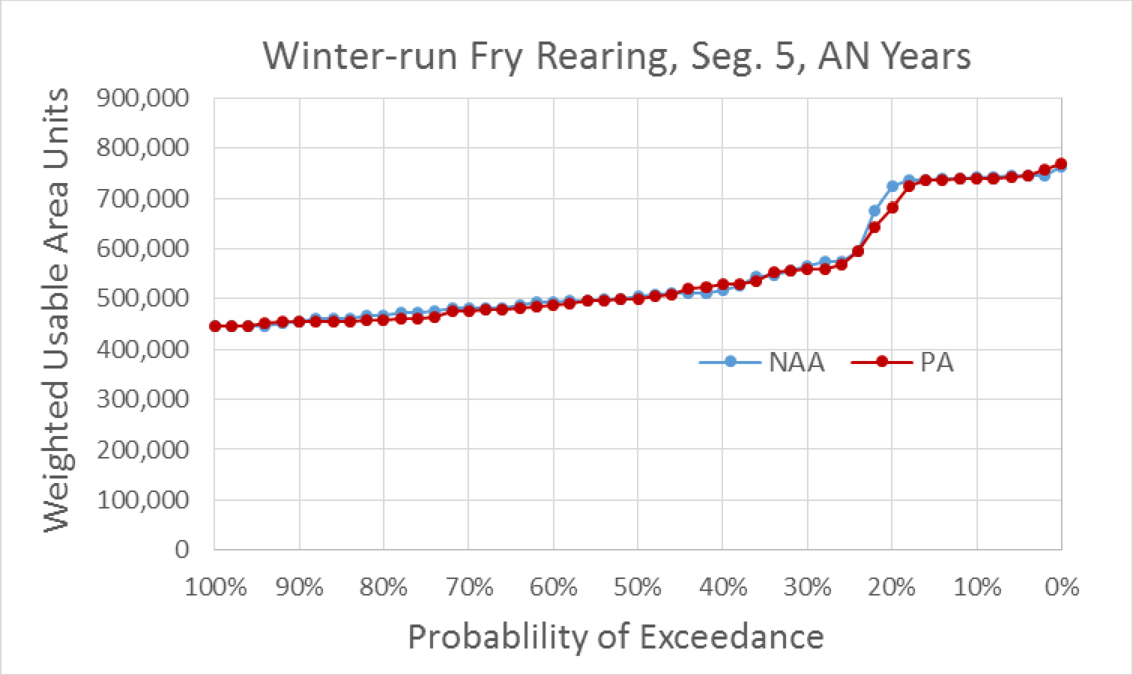

Figure 5.4-80. Exceedance Plot of Winter-Run Chinook Salmon Fry Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 5, Above Normal Water Years

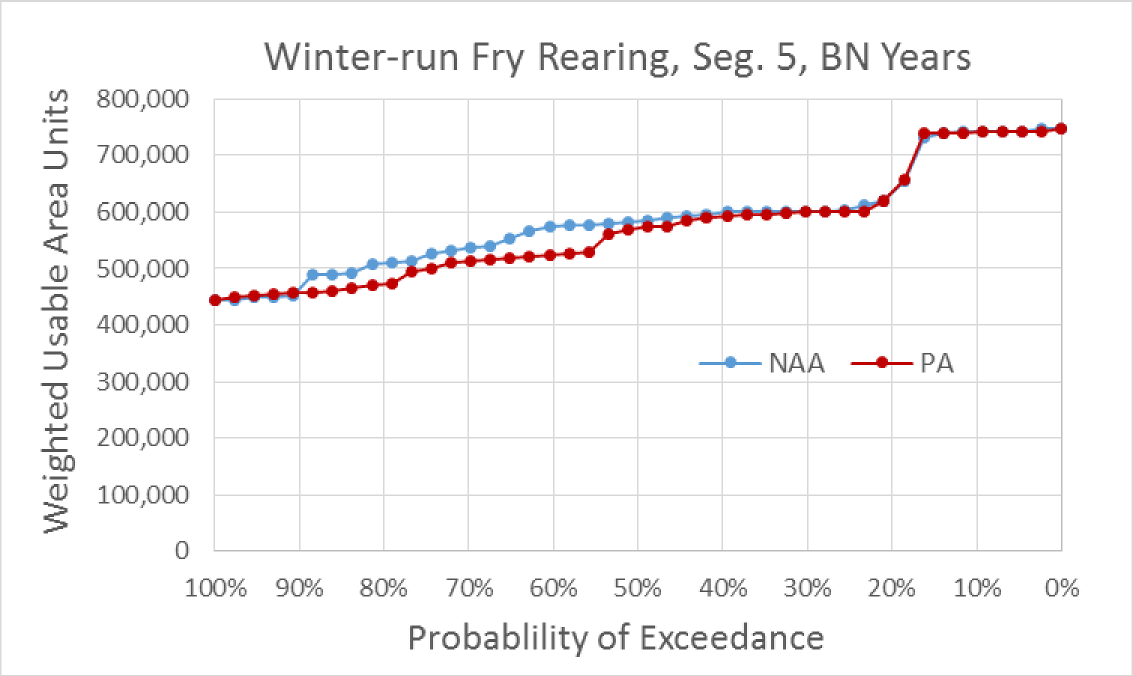

Figure 5.4-81. Exceedance Plot of Winter-Run Chinook Salmon Fry Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 5, Below Normal Water Years

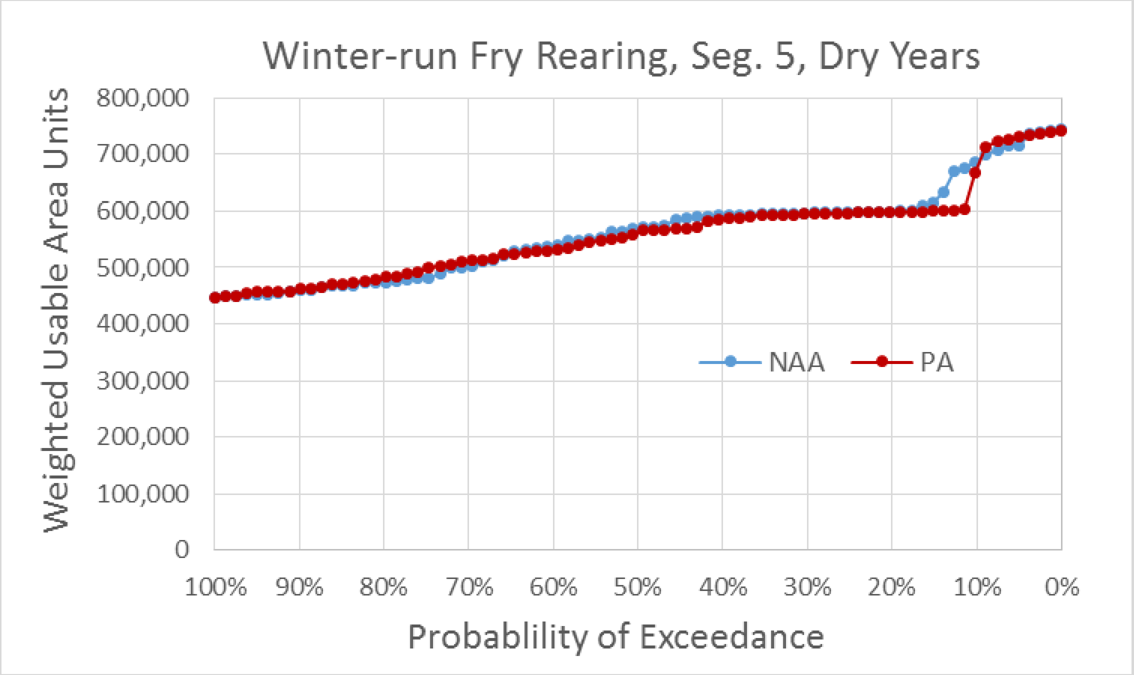

Figure 5.4-82. Exceedance Plot of Winter-Run Chinook Salmon Fry Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 5, Dry Water Years

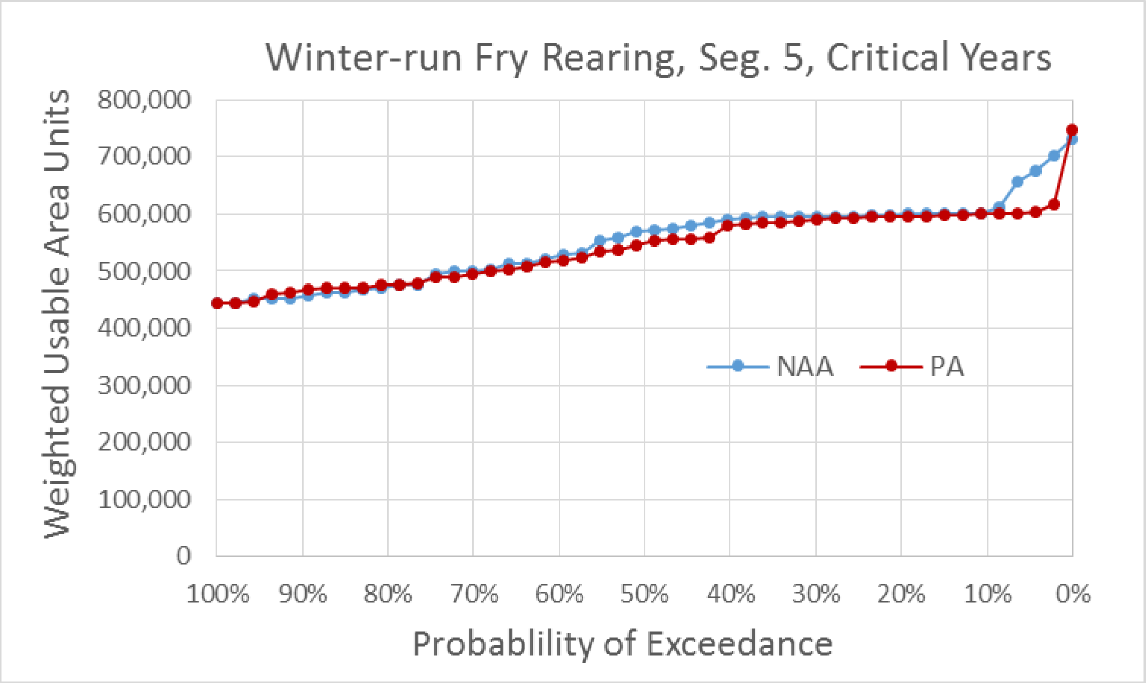

Figure 5.4-83. Exceedance Plot of Winter-Run Chinook Salmon Fry Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 5, Critical Water Years

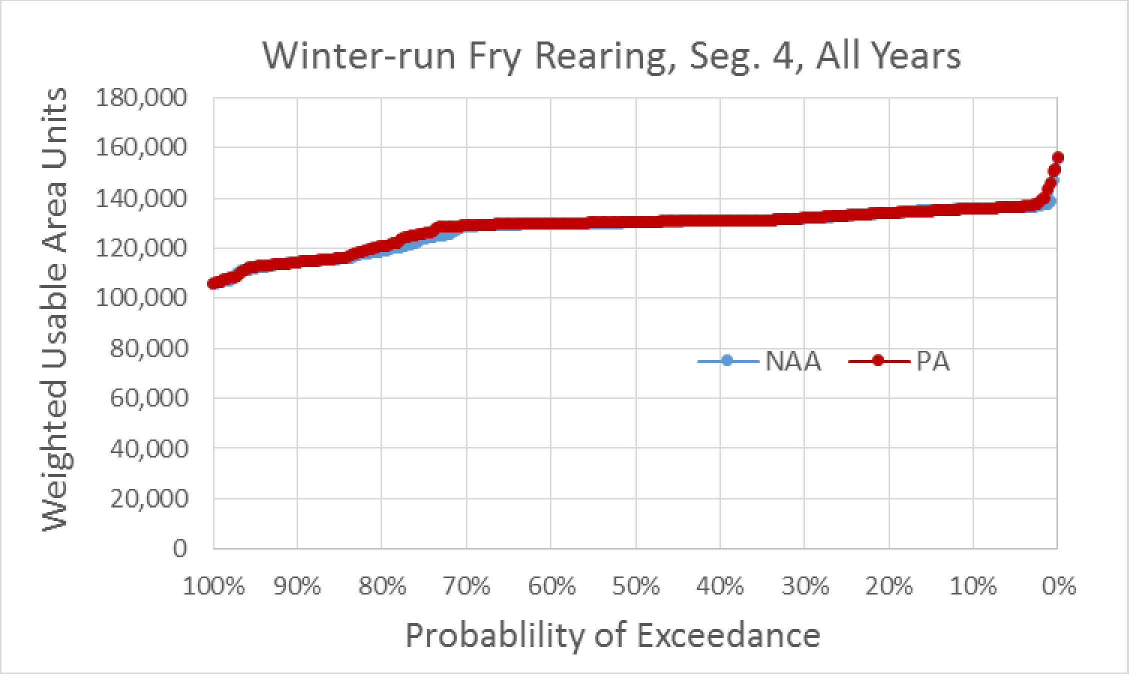

Figure 5.4-84. Exceedance Plot of Winter-Run Chinook Salmon Fry Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 4, All Water Years

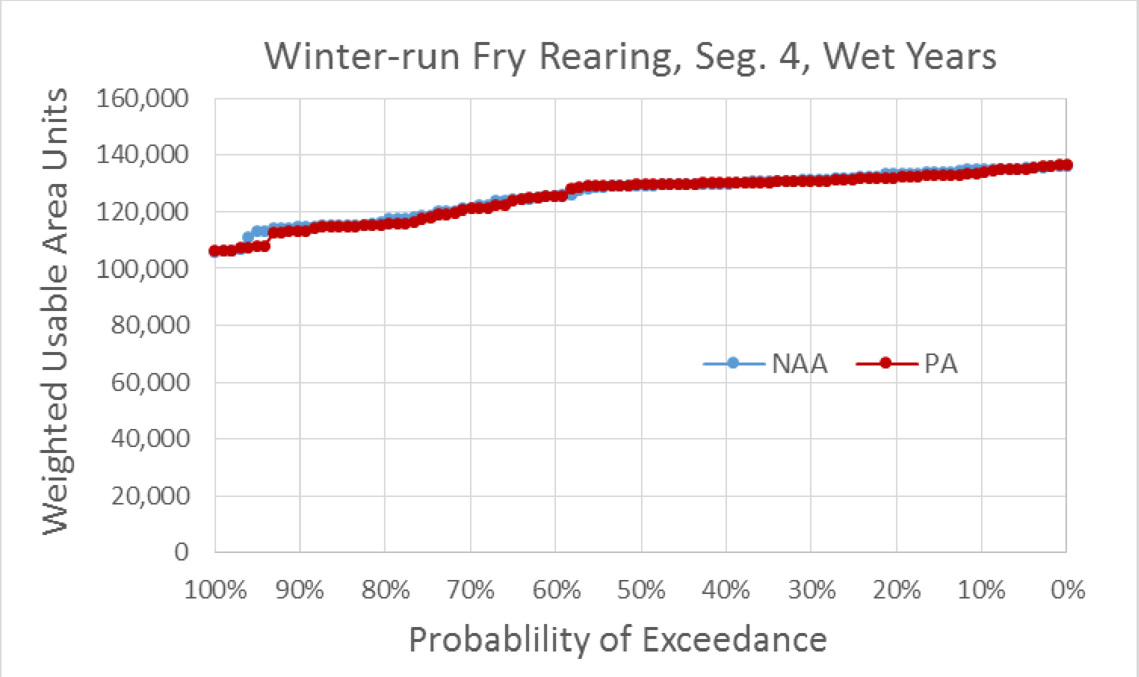

Figure 5.4-85. Exceedance Plot of Winter-Run Chinook Salmon Fry Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 4, Wet Water Years

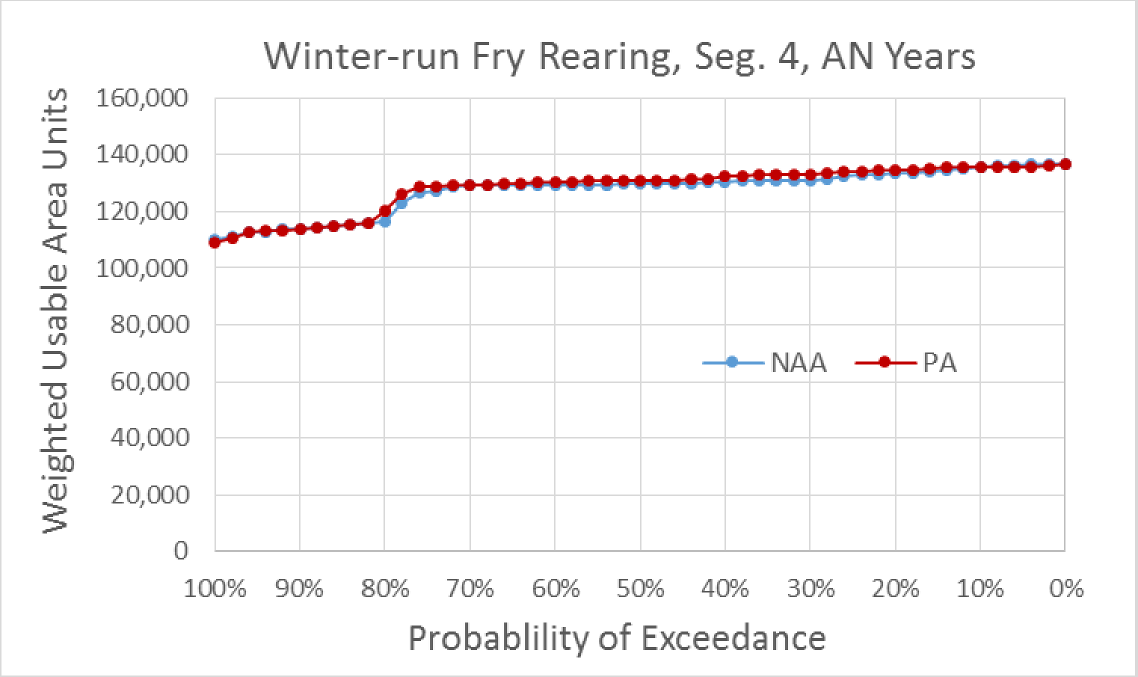

Figure 5.4-86. Exceedance Plot of Winter-Run Chinook Salmon Fry Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 4, Above Normal Water Years

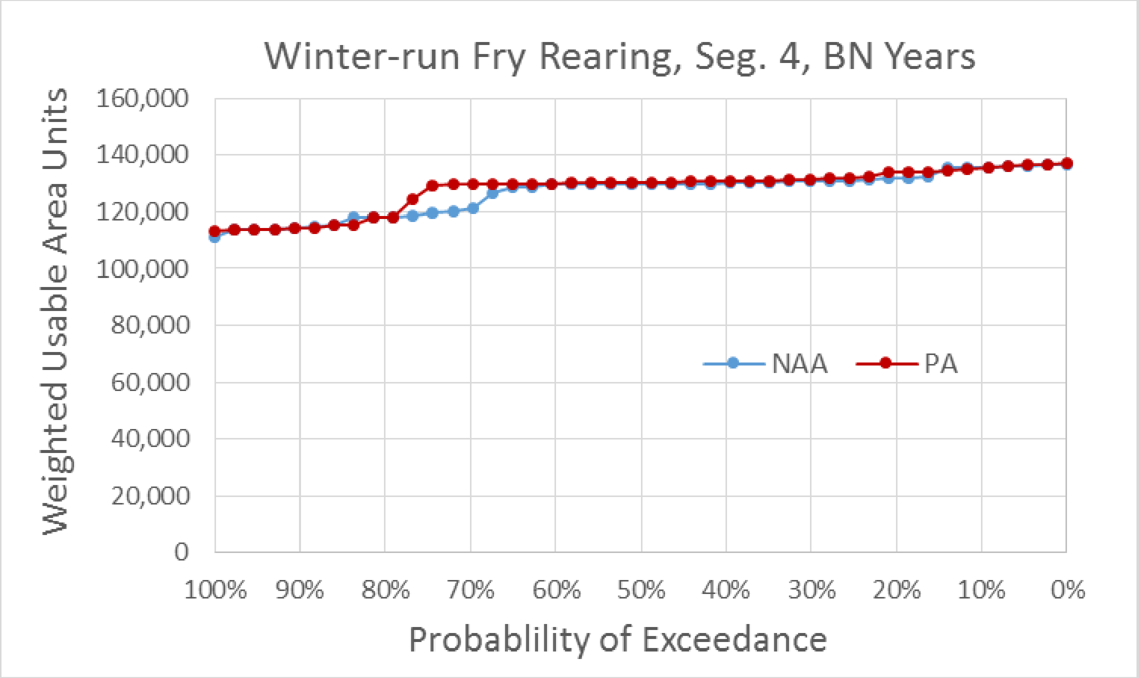

Figure 5.4-87. Exceedance Plot of Winter-Run Chinook Salmon Fry Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 4, Below Normal Water Years

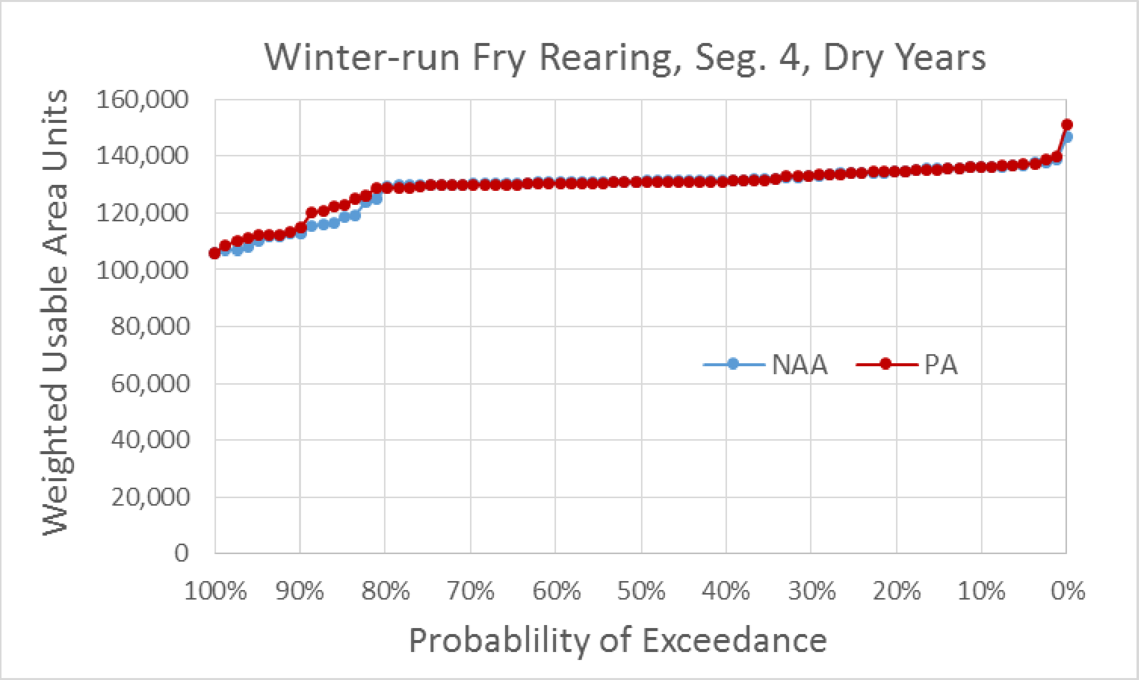

Figure 5.4-88. Exceedance Plot of Winter-Run Chinook Salmon Fry Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 4, Dry Water Years

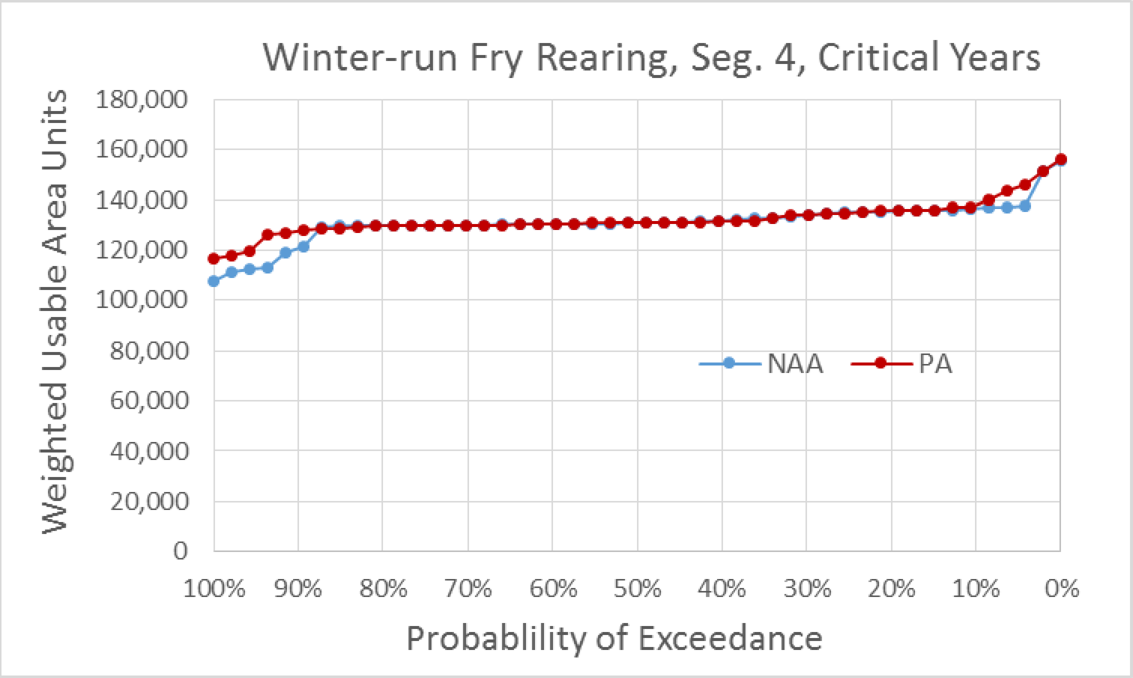

Figure 5.4-89. Exceedance Plot of Winter-Run Chinook Salmon Fry Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 4, Critical Water Years

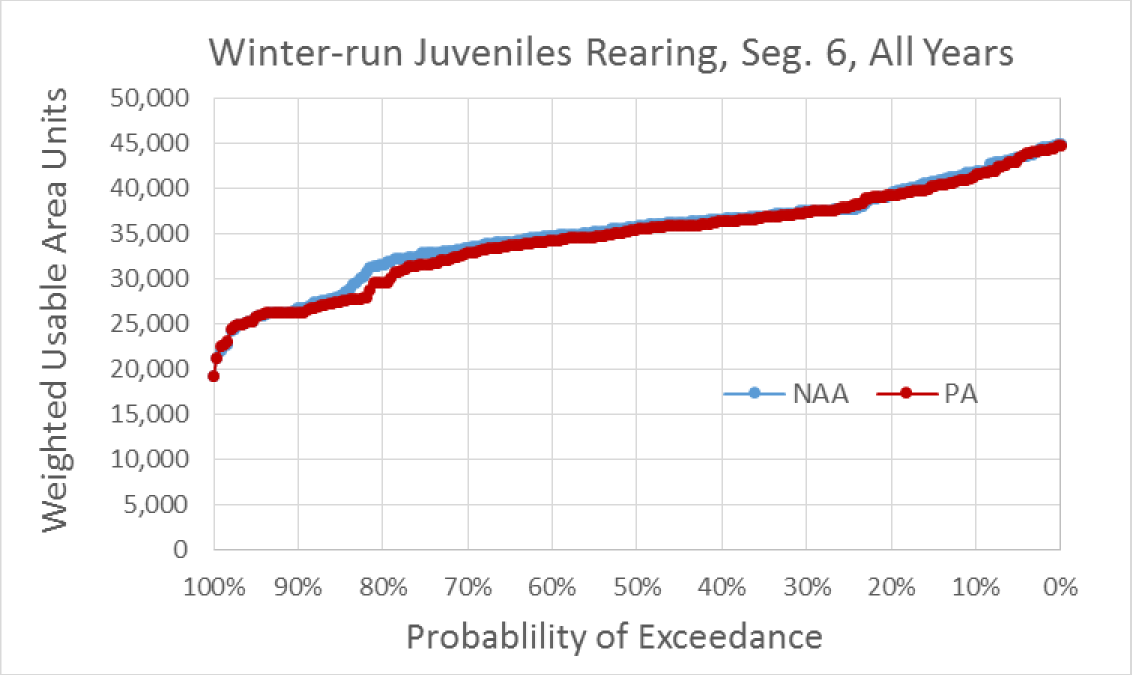

Figure 5.4-90. Exceedance Plot of Winter-Run Chinook Salmon Juvenile Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 6, All Water Years

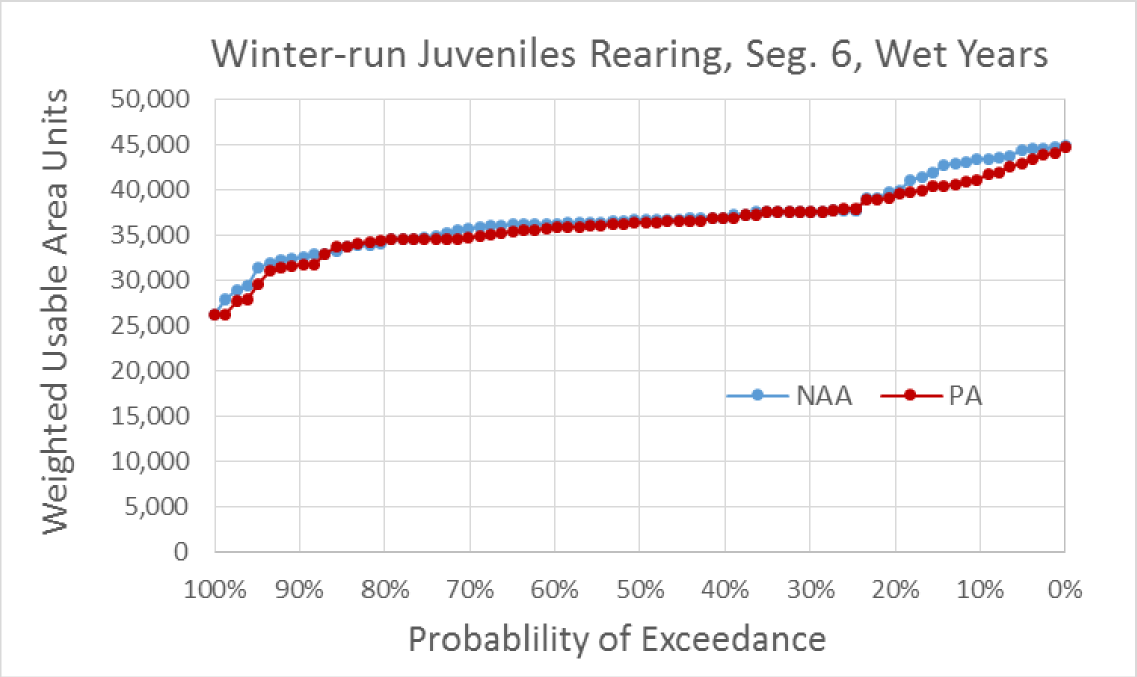

Figure 5.4-91. Exceedance Plot of Winter-Run Chinook Salmon Juvenile Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 6, Wet Water Years

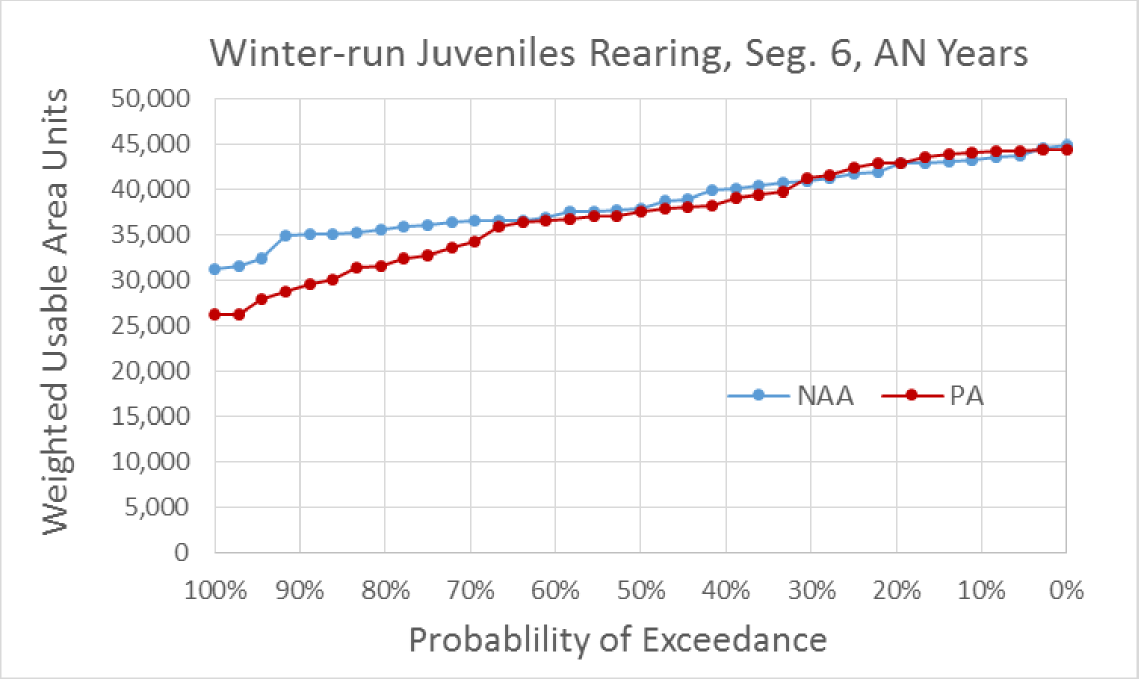

Figure 5.4-92. Exceedance Plot of Winter-Run Chinook Salmon Juvenile Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 6, Above Normal Water Years

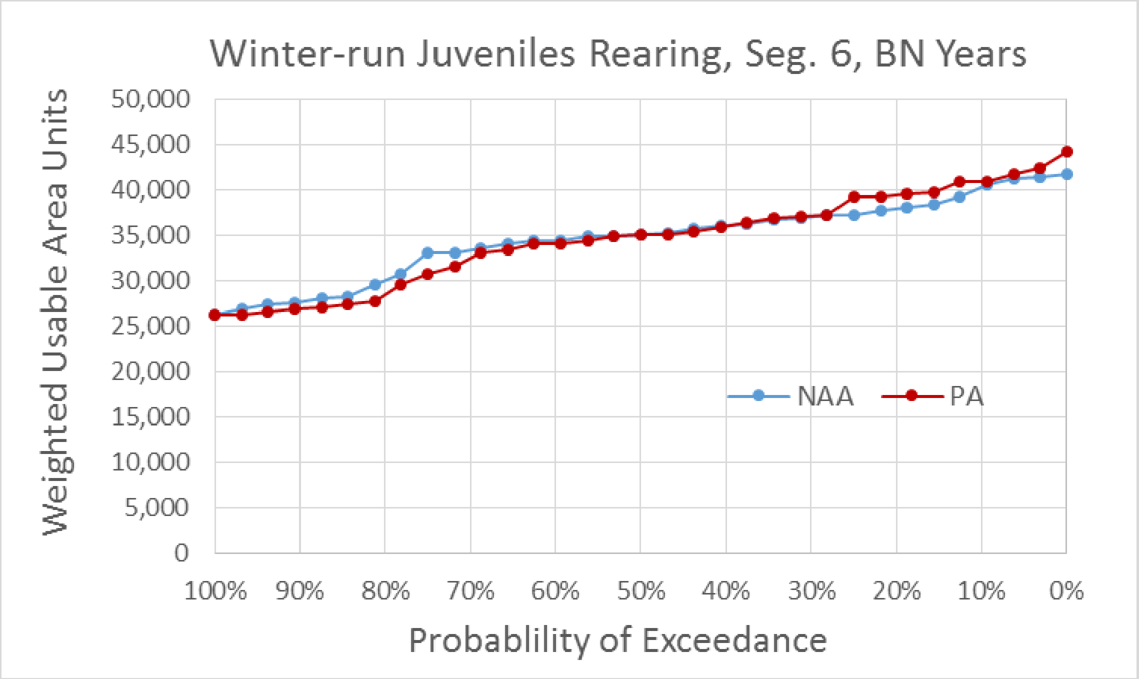

Figure 5.4-93. Exceedance Plot of Winter-Run Chinook Salmon Juvenile Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 6, Below Normal Water Years

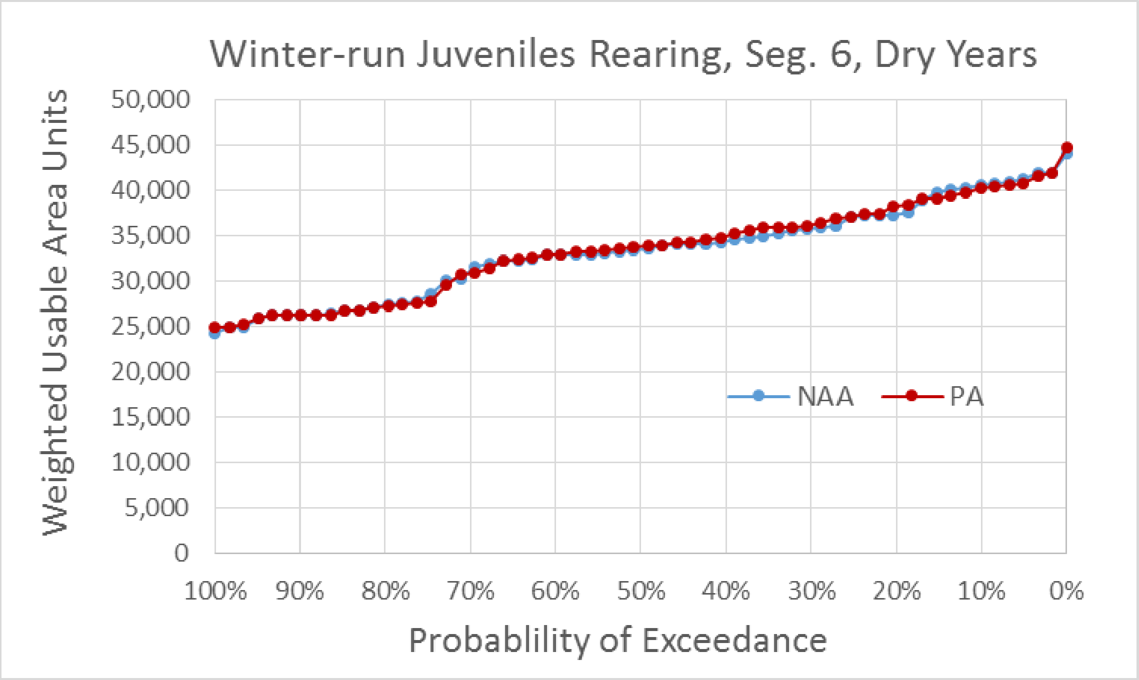

Figure 5.4-94. Exceedance Plot of Winter-Run Chinook Salmon Juvenile Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 6, Dry Water Years

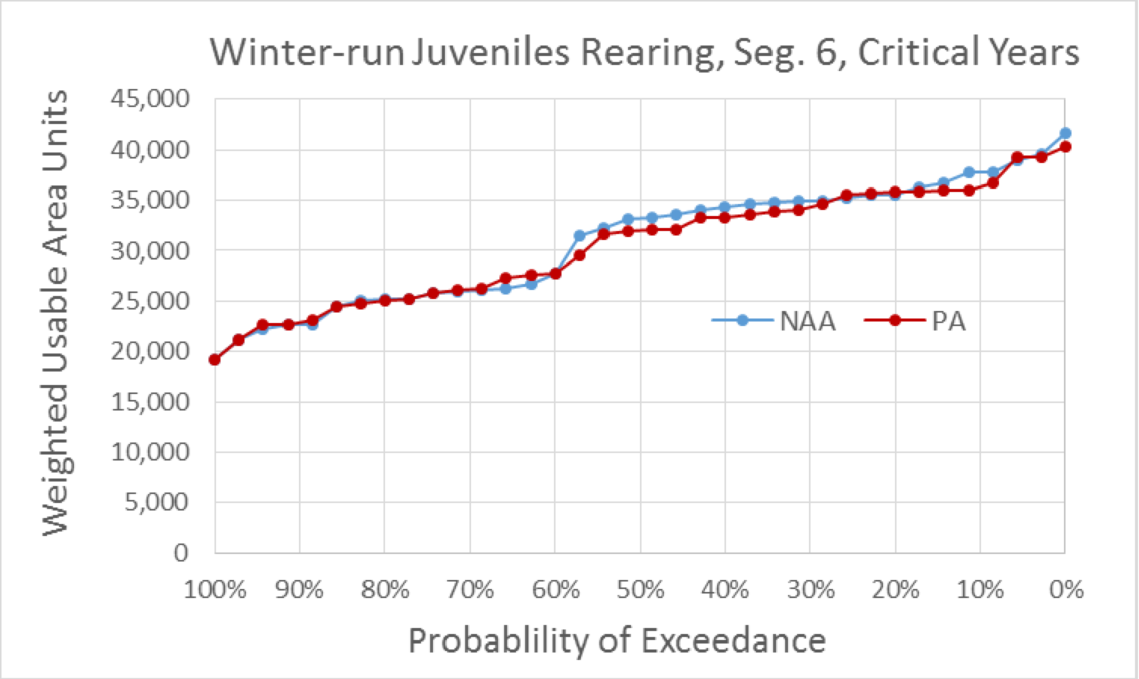

Figure 5.4-95. Exceedance Plot of Winter-Run Chinook Salmon Juvenile Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 6, Critical Water Years

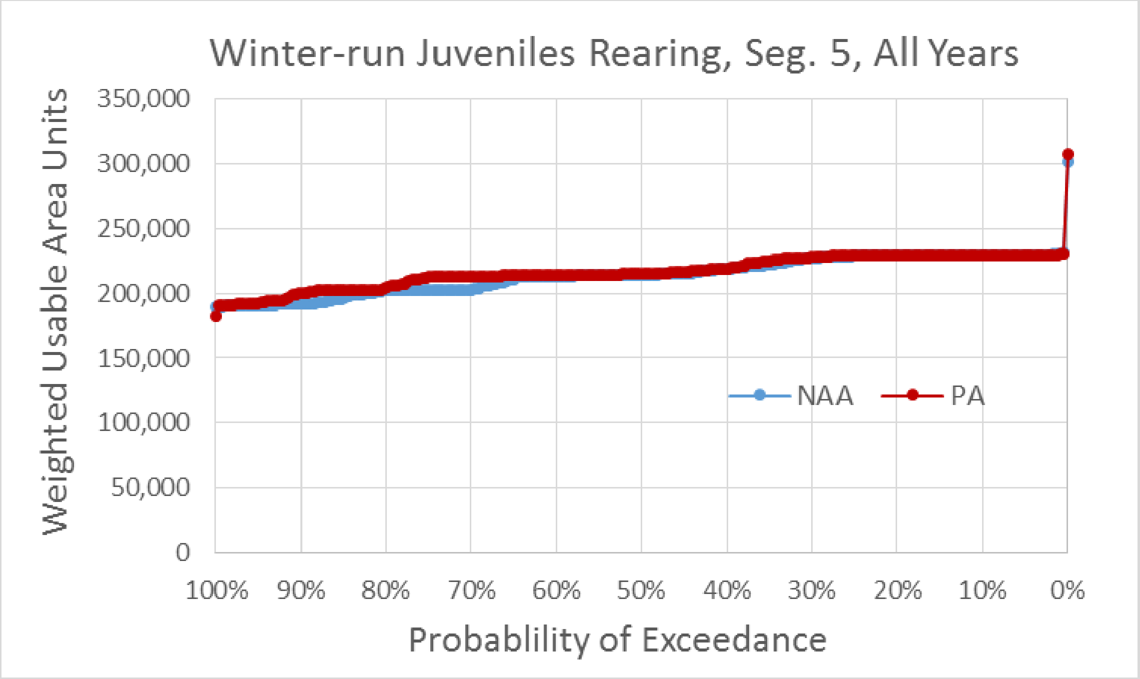

Figure 5.4-96. Exceedance Plot of Winter-Run Chinook Salmon Juvenile Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 5, All Water Years

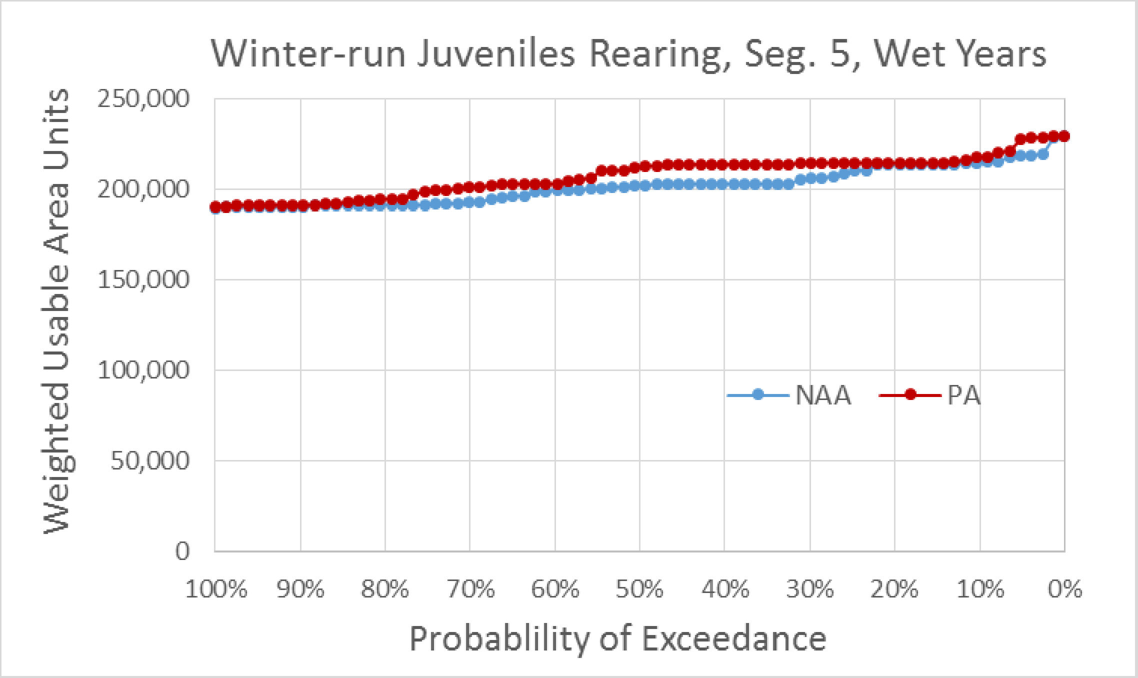

Figure 5.4-97. Exceedance Plot of Winter-Run Chinook Salmon Juvenile Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 5, Wet Water Years

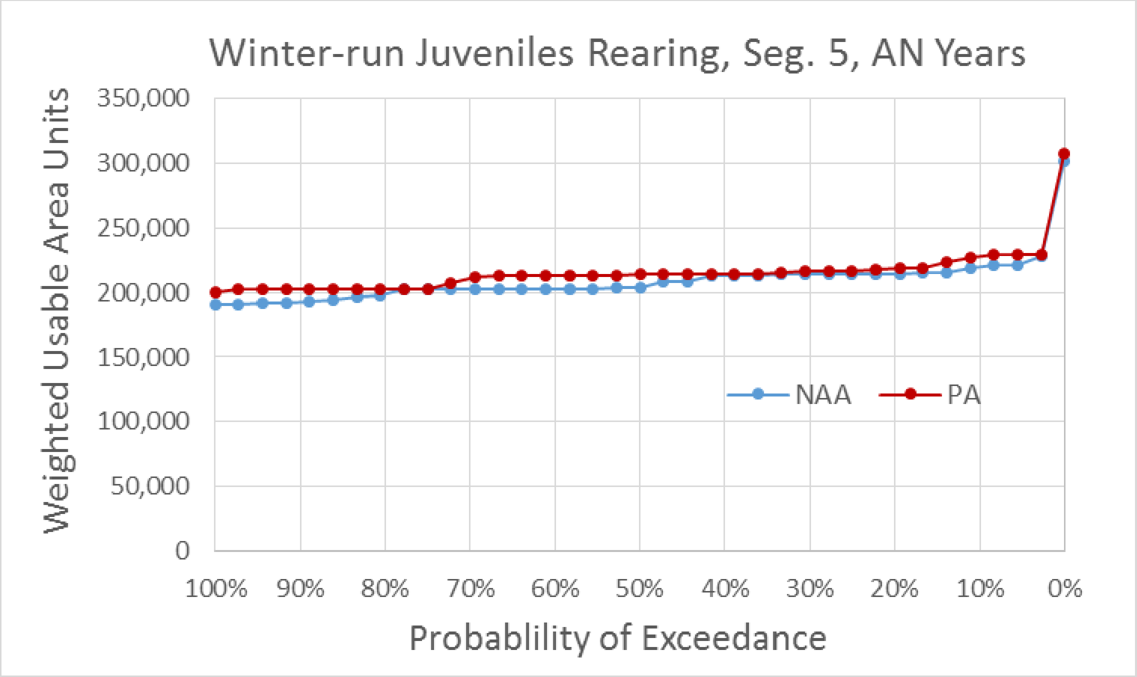

Figure 5.4-98. Exceedance Plot of Winter-Run Chinook Salmon Juvenile Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 5, Above Normal Water Years

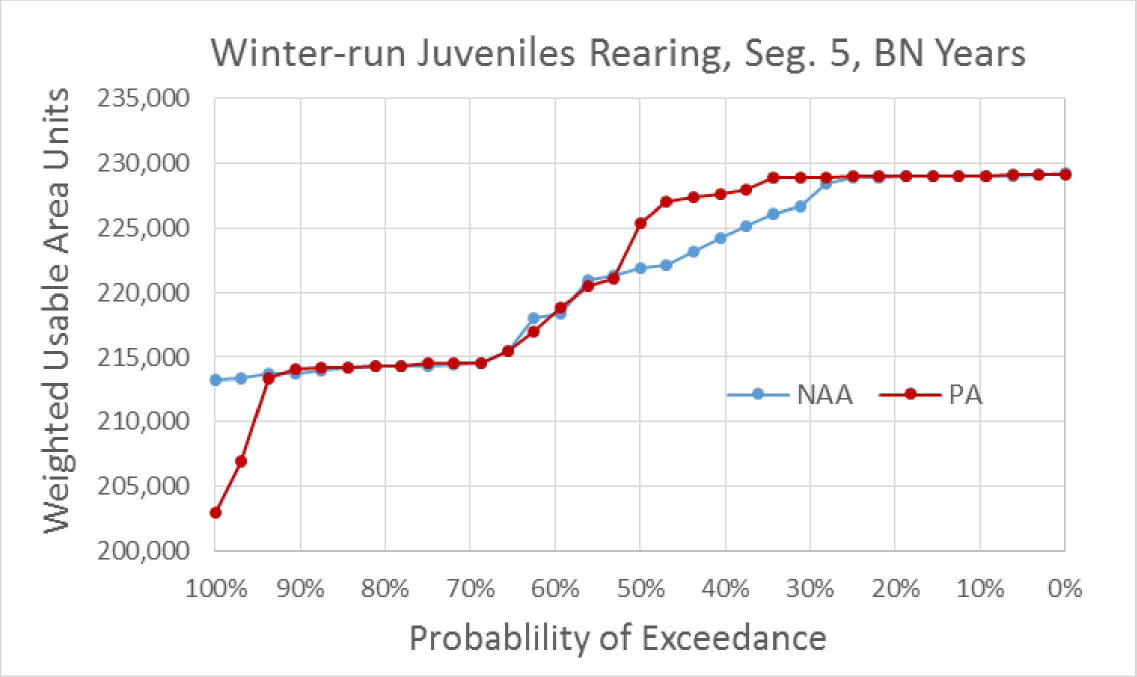

Figure 5.4-99. Exceedance Plot of Winter-Run Chinook Salmon Juvenile Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 5, Below Normal Water Years

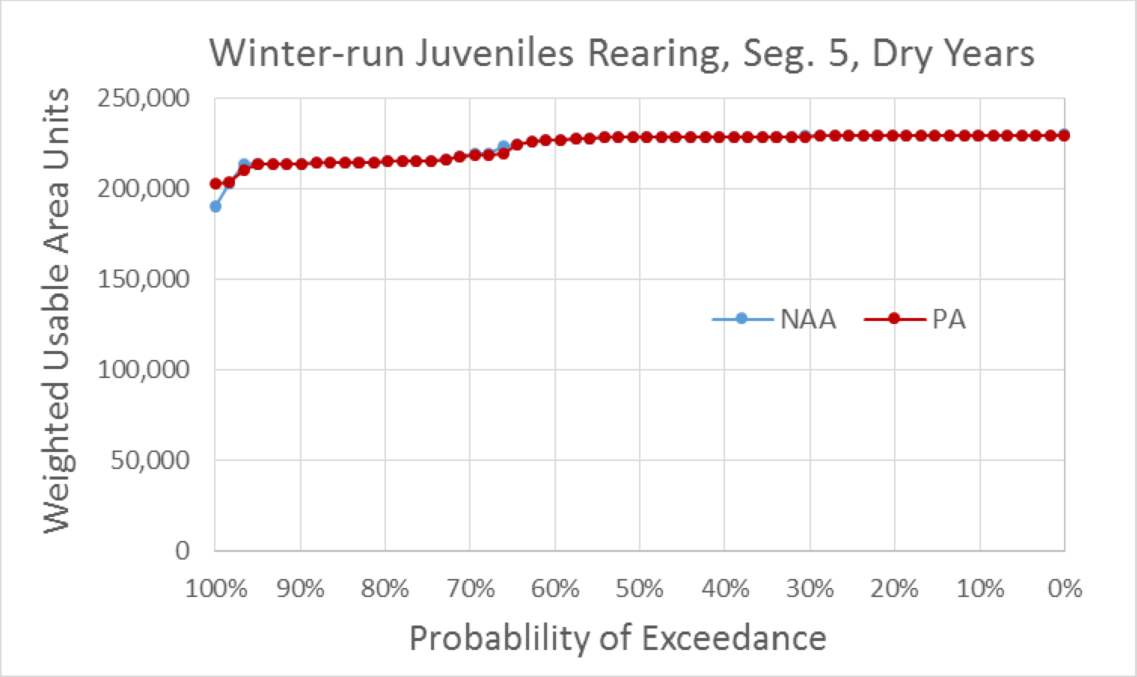

Figure 5.4-100. Exceedance Plot of Winter-Run Chinook Salmon Juvenile Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 5, Dry Water Years

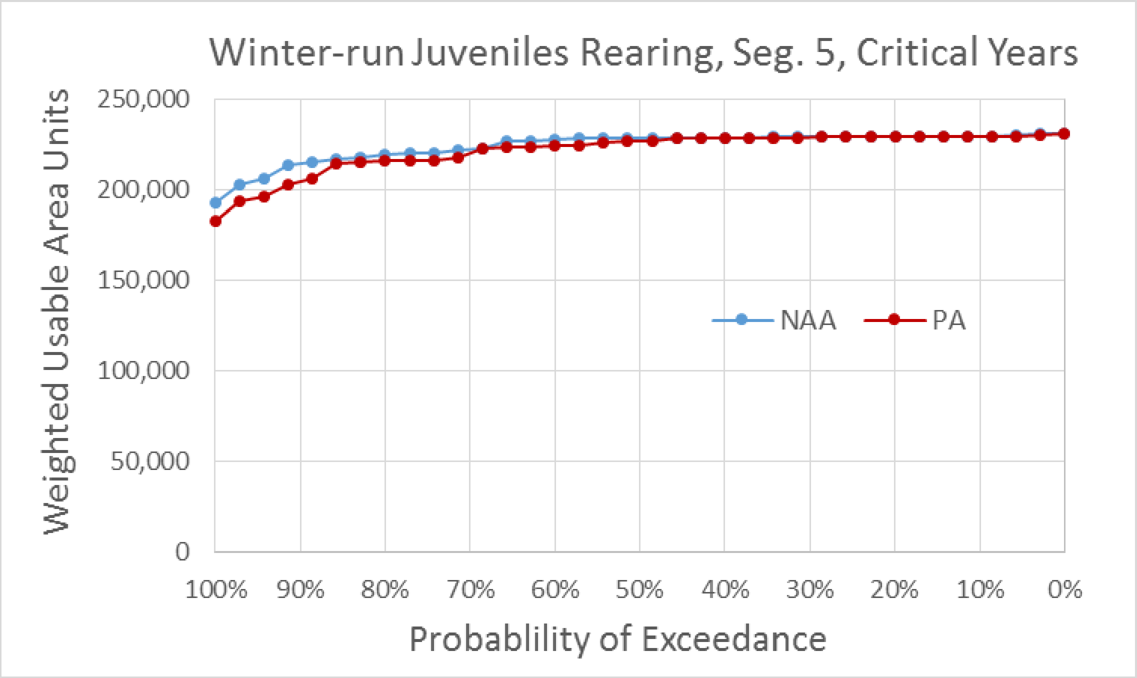

Figure 5.4-101. Exceedance Plot of Winter-Run Chinook Salmon Juvenile Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 5, Critical Water Years

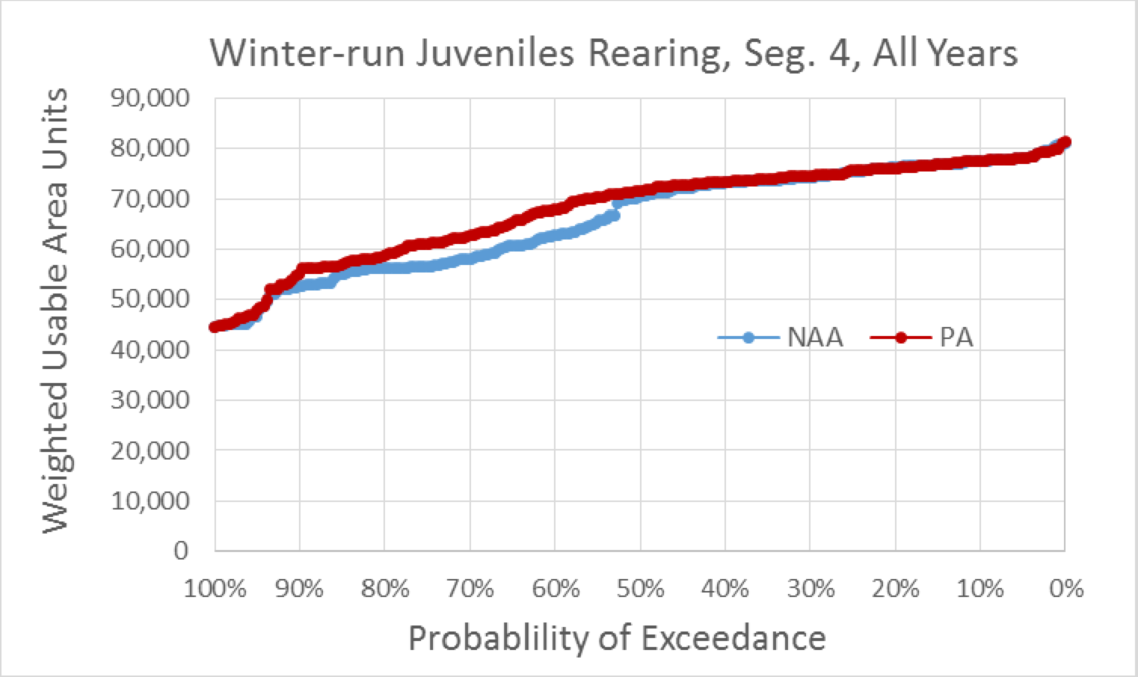

Figure 5.4-102. Exceedance Plot of Winter-Run Chinook Salmon Juvenile Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 4, All Water Years

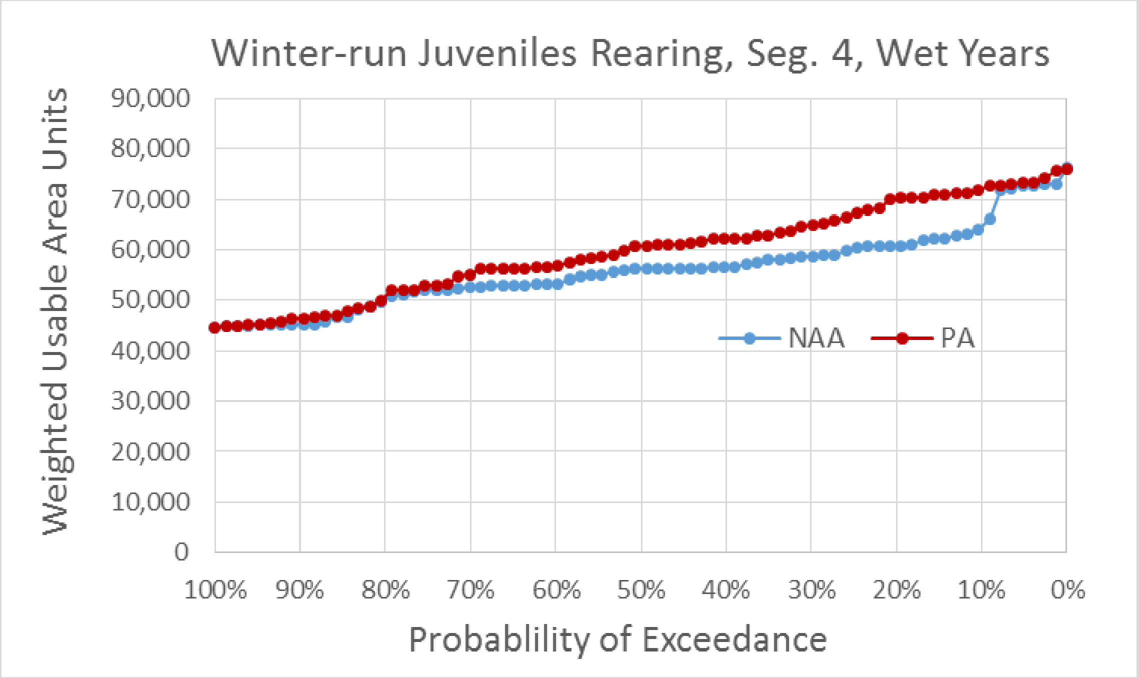

Figure 5.4-103. Exceedance Plot of Winter-Run Chinook Salmon Juvenile Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 4, Wet Water Years

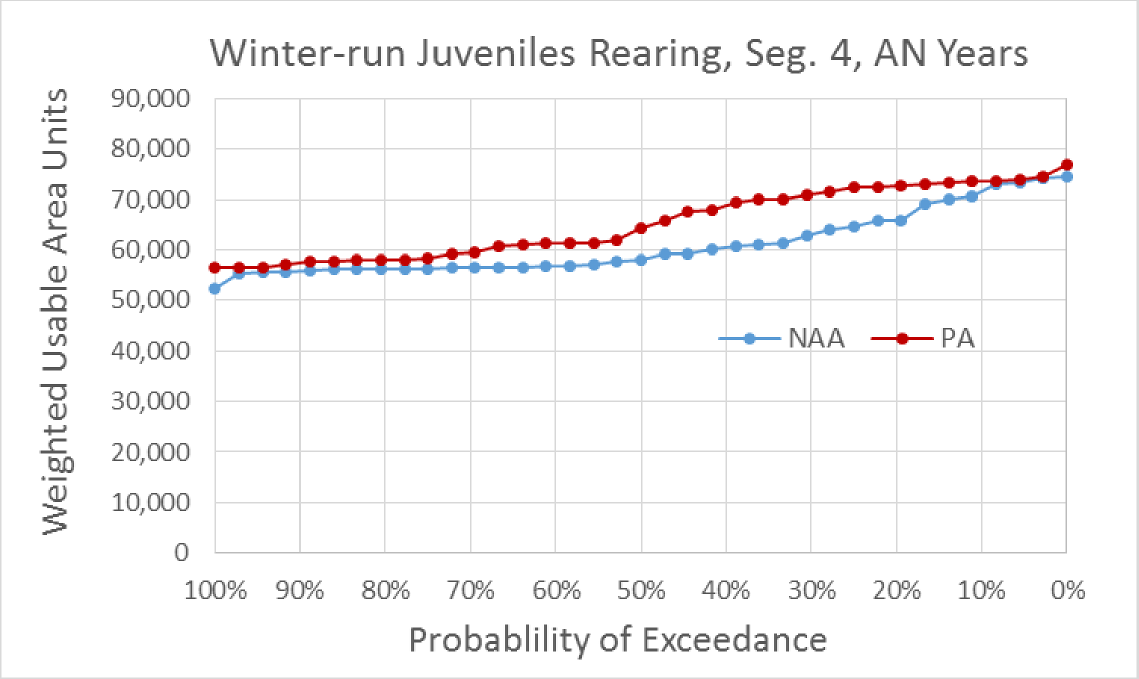

Figure 5.4-104. Exceedance Plot of Winter-Run Chinook Salmon Juvenile Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 4, Above Normal Water Years

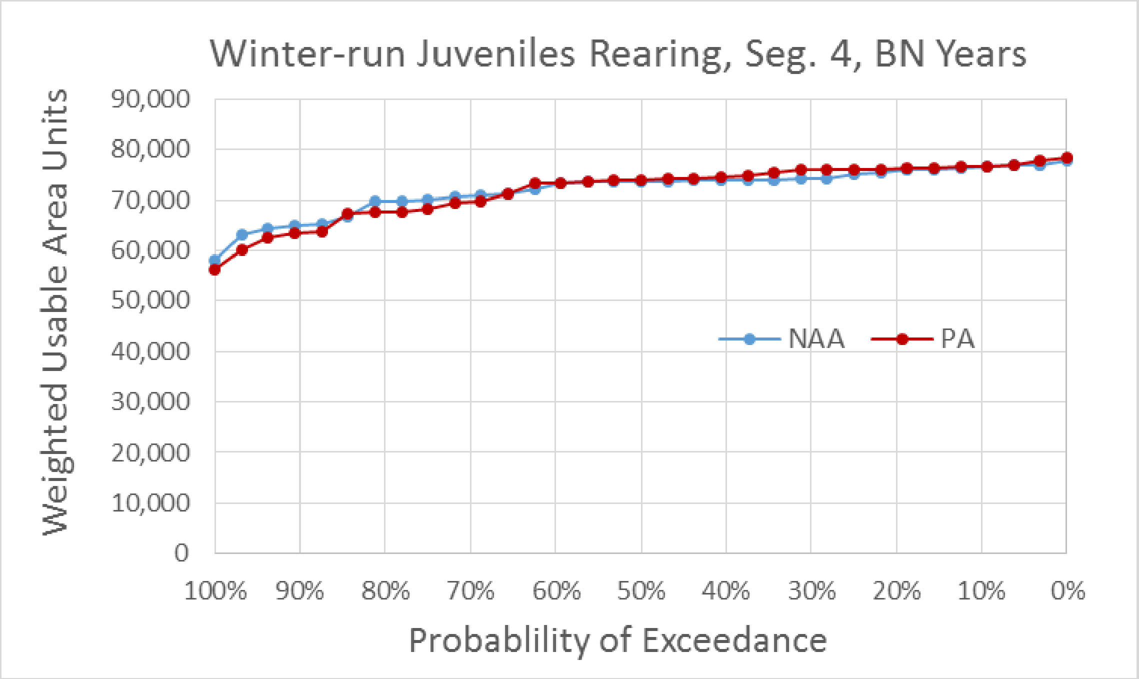

Figure 5.4-105. Exceedance Plot of Winter-Run Chinook Salmon Juvenile Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 4, Below Normal Water Years

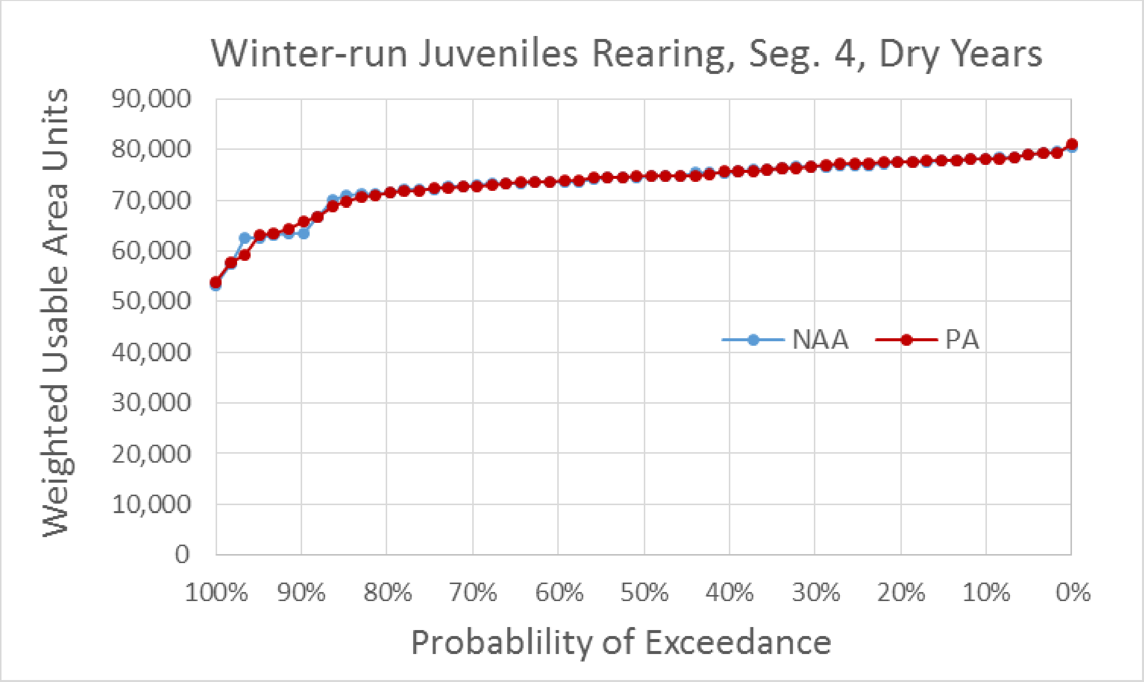

Figure 5.4-106. Exceedance Plot of Winter-Run Chinook Salmon Juvenile Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 4, Dry Water Years

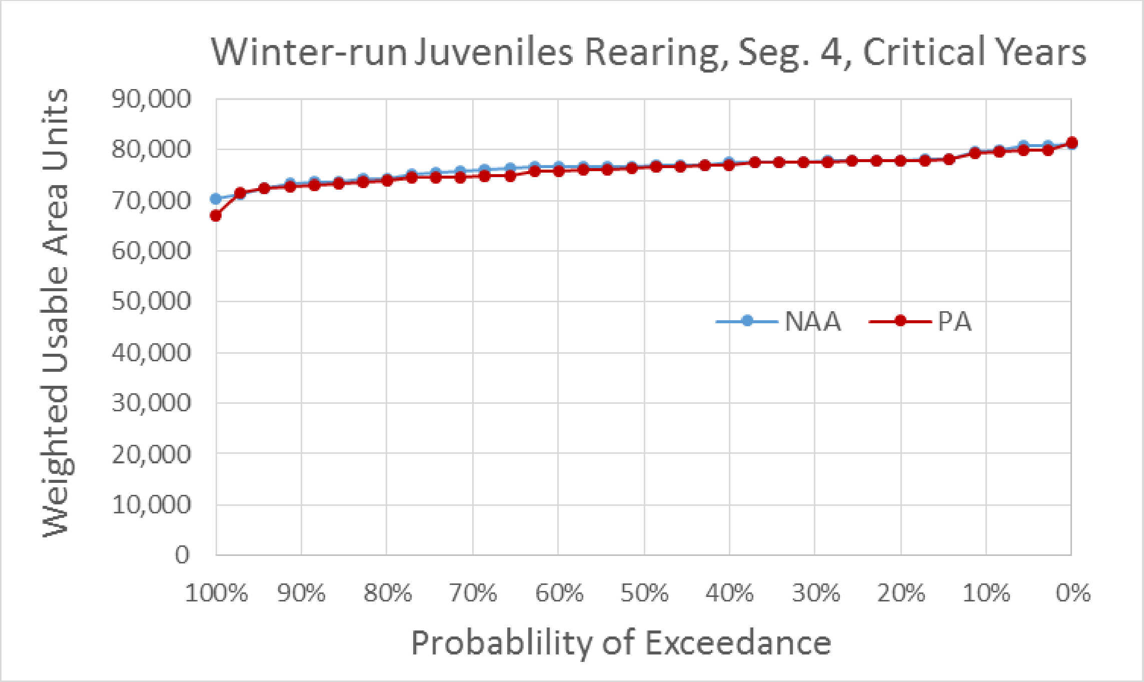

Figure 5.4-107. Exceedance Plot of Winter-Run Chinook Salmon Juvenile Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 4, Critical Water Years

Differences in winter-run Chinook salmon fry and juvenile rearing WUA in each segment under the PA compared to the NAA were also examined using the grand mean rearing WUA for each month of the fry and juvenile rearing periods under each water year type and all water year types combined (Table 5.4-40 to Table 5.4-45). The means for fry rearing WUA differed by less than 5% for most months and water year types, but mean WUA in Segments 6 and 5 under the PA was up to 9% lower than that under the NAA (August and October of below normal years) (Table 5.4-40 and Table 5.4-41). The means for juvenile rearing WUA also differed by less than 5% for most months and water year types, but mean WUA in all three segments differed during November, including a 12% reduction under the PA during above normal years in Segment 6 (Table 5.4-43) and 13% and 18% increases under the PA during wet and above normal years, respectively, in Segment 4 (Table 5.4-45). Mean WUA for juvenile rearing under the PA was 6% lower during October of below normal years and 6% higher during October and/or November in all three segments, depending on the water year type. As indicated above for the WUA exceedance plot results, the grand mean rearing WUA results indicate that the PA would reduce winter-run Chinook salmon rearing habitat in a few months and water year types, although this does not consider real-time operational management described in Section 3.1.5, *Real-Time Operations Upstream of the Delta*, and Section 3.3.3, *Real-Time Operational Decision-Making Process*, that would be used to avoid and minimize any modeled effects.

Table 5.4-40. Winter-Run Chinook Salmon Fry Rearing Weighted Usable Areas (WUA) and Differences (Percent Differences) between Model Scenarios in River Segment 6 (green indicates PA is at least 5% higher [raw difference] than NAA; red indicates PA is at least 5% lower)

Month	Water Year Type	NAA	PA	PA vs. NAA
July	Wet	74,888	75,684	797 (1%)
	Above Normal	77,711	78,038	327 (0.4%)
	Below Normal	78,567	77,632	-934 (-1%)
	Dry	75,180	73,369	-1,811 (-2%)
	Critical	73,844	70,907	-2,937 (-4%)
	All	75,747	75,055	-692 (-0.9%)
August	Wet	68,251	68,063	-188 (-0.3%)
	Above Normal	66,454	65,992	-462 (-0.7%)
	Below Normal	70,946	68,496	-2,450 (-3%)
	Dry	72,100	69,719	-2,381 (-3%)
	Critical	72,995	71,619	-1,376 (-2%)
	All	69,961	68,717	-1,243 (-2%)
September	Wet	74,979	74,387	-592 (-0.8%)
	Above Normal	71,479	74,871	3,392 (5%)
	Below Normal	87,992	92,677	4,685 (5%)
	Dry	89,839	91,748	1,910 (2%)
	Critical	92,093	90,267	-1,825 (-2%)
	All	82,298	83,476	1,177 (1%)

Month	Water Year Type	NAA	PA	PA vs. NAA
October	Wet	78,151	80,199	2,048 (3%)
	Above Normal	81,033	81,921	888 (1%)
	Below Normal	84,215	76,898	-7,317 (-9%)
	Dry	85,753	82,882	-2,871 (-3%)
	Critical	88,010	86,593	-1,417 (-2%)
	All	82,739	81,615	-1,124 (-1%)

Table 5.4-41. Winter-Run Chinook Salmon Fry Rearing Weighted Usable Areas (WUA) and Differences (Percent Differences) between Model Scenarios in River Segment 5 (green indicates PA is at least 5% higher [raw difference] than NAA; red indicates PA is at least 5% lower)

Month	Water Year Type	NAA	PA	PA vs. NAA
July	Wet	641,799	648,643	6,844 (1%)
	Above Normal	722,286	716,128	-6,159 (-0.9%)
	Below Normal	692,543	703,019	10,476 (2%)
	Dry	630,808	620,367	-10,441 (-2%)
	Critical	571,751	541,702	-30,049 (-5%)
	All	648,435	644,090	-4,345 (-0.7%)
August	Wet	490,701	492,357	1,656 (0.3%)
	Above Normal	492,465	483,771	-8,694 (-2%)
	Below Normal	524,955	476,186	-48,770 (-9%)
	Dry	477,850	480,511	2,661 (0.6%)
	Critical	483,342	495,327	11,985 (2%)
	All	491,365	486,372	-4,992 (-1%)
September	Wet	640,883	626,609	-14,274 (-2%)
	Above Normal	476,374	478,456	2,082 (0.4%)
	Below Normal	570,367	590,554	20,186 (4%)
	Dry	581,481	589,147	7,666 (1%)
	Critical	582,039	576,547	-5,491 (-0.9%)
	All	582,243	581,821	-422 (-0.1%)
October	Wet	490,575	512,763	22,188 (5%)
	Above Normal	518,601	515,736	-2,864 (-0.6%)
	Below Normal	555,774	519,724	-36,051 (-6%)
	Dry	556,999	544,318	-12,681 (-2%)
	Critical	567,207	552,775	-14,432 (-3%)
	All	531,335	527,868	-3,467 (-0.7%)

Table 5.4-42. Winter-Run Chinook Salmon Fry Rearing Weighted Usable Areas (WUA) and Differences (Percent Differences) between Model Scenarios in River Segment 4 (green indicates PA is at least 5% higher [raw difference] than NAA; red indicates PA is at least 5% lower)

Month	Water Year Type	NAA	PA	PA vs. NAA
July	Wet	118,256	117,959	-296 (-0.3%)
	Above Normal	115,451	116,105	654 (0.6%)
	Below Normal	116,318	116,358	40 (0.03%)
	Dry	117,865	120,117	2,252 (2%)
	Critical	123,423	127,532	4,109 (3%)
	All	118,212	119,378	1,166 (1%)
August	Wet	130,664	130,806	143 (0.1%)
	Above Normal	130,491	131,348	857 (0.7%)
	Below Normal	128,833	132,838	4,005 (3%)
	Dry	132,484	131,855	-629 (-0.5%)
	Critical	132,698	131,293	-1,404 (-1%)
	All	131,132	131,492	359 (0.3%)
September	Wet	122,118	121,105	-1,013 (-0.8%)
	Above Normal	132,593	133,766	1,173 (0.9%)
	Below Normal	131,285	131,954	669 (0.5%)
	Dry	134,369	135,027	658 (0.5%)
	Critical	133,689	137,226	3,537 (3%)
	All	129,690	130,322	632 (0.5%)
October	Wet	132,910	132,044	-866 (-0.7%)
	Above Normal	131,812	132,659	847 (0.6%)
	Below Normal	130,852	130,849	-3 (-0.002%)
	Dry	131,282	130,998	-284 (-0.2%)
	Critical	134,211	133,427	-784 (-0.6%)
	All	132,259	131,919	-339 (-0.3%)

Table 5.4-43. Winter-Run Chinook Salmon Juvenile Rearing Weighted Usable Areas (WUA) and Differences (Percent Differences) between Model Scenarios in River Segment 6 (green indicates PA is at least 5% higher [raw difference] than NAA; red indicates PA is at least 5% lower)

Month	Water Year Type	NAA	PA	PA vs. NAA
September	Wet	37,175	37,171	-4 (-0.01%)
	Above Normal	41,433	41,844	411 (1%)
	Below Normal	36,591	35,194	-1,398 (-4%)
	Dry	35,386	34,295	-1,091 (-3%)
	Critical	34,640	33,310	-1,330 (-4%)
	All	36,964	36,380	-584 (-2%)
October	Wet	40,426	39,061	-1,365 (-3%)
	Above Normal	39,473	38,542	-931 (-2%)

Month	Water Year Type	NAA	PA	PA vs. NAA
	Below Normal	37,544	39,778	2,235 (6%)
	Dry	36,820	38,173	1,354 (4%)
	Critical	34,103	32,991	-1,112 (-3%)
	All	38,066	37,963	-103 (-0.3%)
November	Wet	33,382	32,986	-396 (-1%)
	Above Normal	34,792	30,646	-4,145 (-12%)
	Below Normal	29,663	28,719	-944 (-3%)
	Dry	27,742	27,794	52 (0.2%)
	Critical	24,017	25,355	1,339 (6%)
	All	30,306	29,648	-658 (-2%)

Table 5.4-44. Winter-Run Chinook Salmon Juvenile Rearing Weighted Usable Areas (WUA) and Differences (Percent Differences) between Model Scenarios in River Segment 5 (green indicates PA is at least 5% higher [raw difference] than NAA; red indicates PA is at least 5% lower)

Month	Water Year Type	NAA	PA	PA vs. NAA
September	Wet	197,659	196,662	-997 (-0.5%)
	Above Normal	201,793	206,800	5,008 (2%)
	Below Normal	222,576	226,548	3,972 (2%)
	Dry	225,400	227,524	2,124 (0.9%)
	Critical	224,334	224,155	-179 (-0.1%)
	All	212,326	213,829	1,503 (0.7%)
October	Wet	208,589	213,299	4,710 (2%)
	Above Normal	213,823	213,959	137 (0.1%)
	Below Normal	219,626	214,288	-5,337 (-2%)
	Dry	220,551	217,706	-2,845 (-1%)
	Critical	221,158	215,703	-5,455 (-2%)
	All	215,679	214,976	-703 (-0.3%)
November	Wet	199,672	212,182	12,510 (6%)
	Above Normal	212,519	226,165	13,647 (6%)
	Below Normal	222,023	224,073	2,050 (0.9%)
	Dry	224,569	225,399	830 (0.4%)
	Critical	226,766	224,475	-2,291 (-1%)
	All	214,772	220,953	6,181 (3%)

Table 5.4-45. Winter-Run Chinook Salmon Juvenile Rearing Weighted Usable Areas (WUA) and Differences (Percent Differences) between Model Scenarios in River Segment 4 (green indicates PA is at least 5% higher [raw difference] than NAA; red indicates PA is at least 5% lower)

Month	Water Year Type	NAA	PA	PA vs. NAA
September	Wet	50,385	50,553	168 (0.3%)
	Above Normal	58,820	61,680	2,860 (5%)
	Below Normal	73,700	76,110	2,410 (3%)
	Dry	76,392	77,247	855 (1%)
	Critical	76,162	77,129	968 (1%)
	All	64,965	66,146	1,180 (2%)
October	Wet	61,807	65,434	3,628 (6%)
	Above Normal	66,065	65,675	-390 (-0.6%)
	Below Normal	70,765	66,612	-4,152 (-6%)
	Dry	71,531	70,120	-1,411 (-2%)
	Critical	75,147	74,092	-1,055 (-1%)
	All	68,032	68,070	38 (0.1%)
November	Wet	55,868	63,204	7,336 (13%)
	Above Normal	58,426	68,808	10,382 (18%)
	Below Normal	71,476	72,794	1,317 (2%)
	Dry	72,396	72,890	495 (0.7%)
	Critical	78,216	76,756	-1,460 (-2%)
	All	65,758	69,736	3,978 (6%)

5.4.2.1.3.1.2.1.1 SALMOD flow-related outputs

The SALMOD model provides predicted flow-related fry and juvenile winter-run Chinook salmon mortality, which is presented as mortality of the fry, pre-smolt, and immature smolt life stages (see Attachment 5.D.2, *SALMOD Model*, for a full description). Results for flow-related mortality of these life stages are presented in Table 5.4-38 and the annual exceedance plot for all water year types combined is presented in Figure 5.4-108. These results indicate that flow-related mortality of winter-run Chinook salmon fry would increase moderately under the PA relative to the NAA for drier water year types (ranging from 11% higher for below normal years to 17% higher for critical years), and would decrease moderately in wet and above normal years (11% and 12% lower, respectively). The flow-related mortality of fry for all water year types combined would be similar between the NAA and PA. The flow-related mortality of winter-run Chinook salmon pre-smolts would be moderately lower under the PA relative to the NAA for all water year types combined and for all water year types separately except critical water years, which would have 40% higher mortality under the PA. SALMOD predicted no mortality for the immature smolt life stage. Almost all of the flow-related mortality predicted for winter-run Chinook salmon fry, pre-smolts and immature smolts consists of fry mortality and, therefore, flow-related mortality for the three life stages combined would be similar to that for fry alone (Table 5.4-38). Accordingly, these results indicate that the PA would increase flow-related mortality of fry and juvenile winter-run Chinook salmon relative to the NAA in drier water years and reduce flow-related mortality in wetter years, but would result in negligible[46] change for all water year types combined. These results are based on CALSIM outputs, which does not consider real-time operational management described in Section 3.1.5, *Real-Time Operations Upstream of the Delta*, and Section 3.3.3, *Real-Time Operational Decision-Making Process*, that would be used to avoid and minimize any modeled effects.

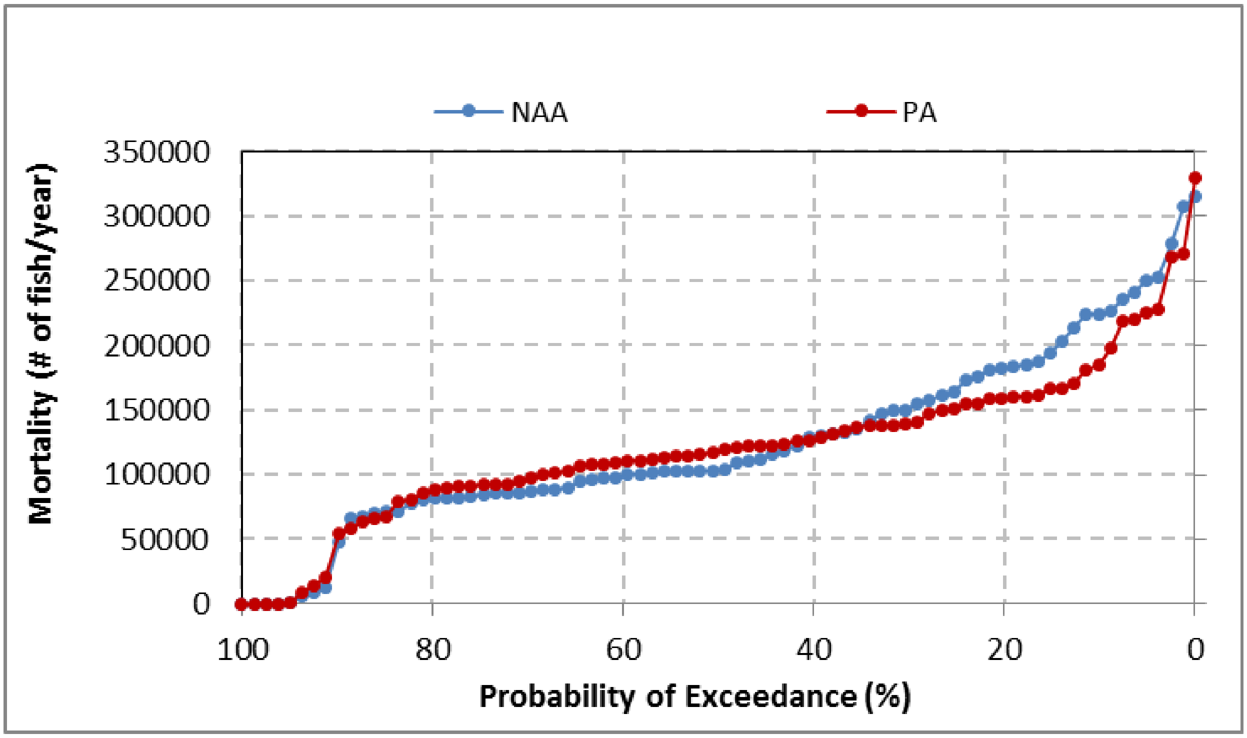

Figure 5.4-108. Exceedance Plot of Annual Flow-Based Mortality (# of Fish/Year) of Winter-Run Chinook Salmon Fry and Juveniles

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[46] "Negligible" is defined as a difference between the NAA and PA of <5%. It can differ from the term "biologically meaningful".

5.4.2.1.3.1.2.2 Water Temperature-Related Effects

Modeled mean monthly water temperatures during the July through November juvenile rearing period for winter-run Chinook salmon in the Sacramento River upstream of the Delta (Table 5.4-25) are presented in Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results*, Table 5.C.7-3, Table 5.C.7-4, Table 5.C.7-5, Table 5.C.7-7, Table 5.C.7-8, Table 5.C.7-10[47]. Overall, the PA would change mean water temperatures very little (predominantly less than 1°F, or approximately 1%) throughout the juvenile rearing reach of Keswick Dam to Knights Landing in all months and water year types in the period. The largest increase in mean monthly water temperatures under the PA relative to NAA would be 1.0°F (1.4%), and would occur at Knights Landing in below normal years during August.

Exceedance plots of monthly mean water temperatures were examined during each month throughout the juvenile rearing period (Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results*, Figure 5.C.7.3-7, Figure 5.C.7.4-7, Figure 5.C.7.5-7, Figure 5.C.7.7-7, Figure 5.C.7.8-7, Figure 5.C.7.10-7[48]). The values for the PA in these exceedance plots generally match those of the NAA. Further examination of below normal water years in August at Knights Landing, where the largest increase in mean monthly water temperature was seen, indicates that water temperatures under the PA would be higher than those under NAA for most of the exceedance range by up to approximately 2.2°F, particularly in the colder end of the range (Figure 5.4-109). As indicated below in the temperature threshold analysis results description, temperatures predicted for Knights Landing during August of below normal water years would be greater than the 64°F 7DADM threshold on 100% of days under both the NAA and PA, although there is low certainty that modeled values are comparable to actual values. Therefore, this suggests that, with low certainty, conditions would already be unsuitable for winter-run Chinook salmon fry and juvenile rearing for reasons that are independent of the PA.

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[47] Water temperature results for Wilkins Slough were used to represent Knights Landing for this analysis

[48] Water temperature results for Wilkins Slough were used to represent Knights Landing for this analysis

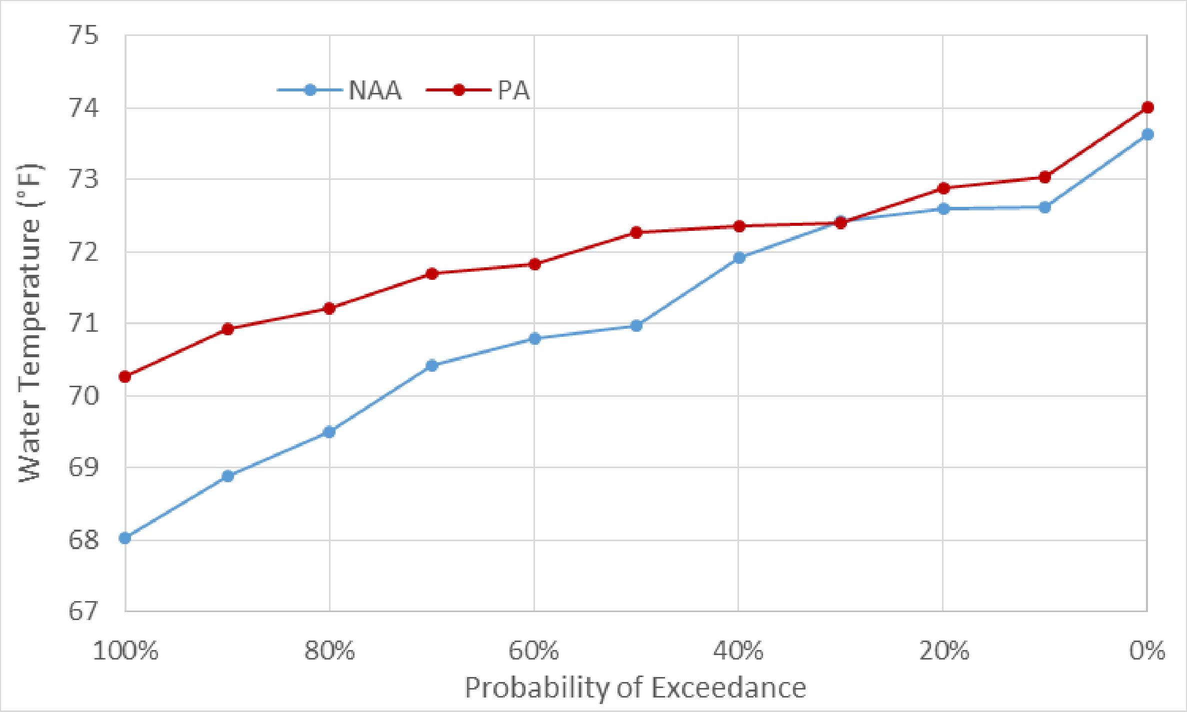

Figure 5.4-109. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the Sacramento River at Wilkins Slough/Knights Landing in August of Below Normal Water Years[49]

For purposes of this analysis, the water temperature thresholds analysis for juvenile rearing and emigration have been combined and the period of July through March was evaluated. The threshold used was from the USEPA's 7DADM value of 61°F for the core juvenile rearing reach from Keswick Dam to Red Bluff and 64°F for the non-core juvenile rearing reach at Knights Landing (Appendix 5.D, Section 5.D.2.1, *Water Temperature Analysis Methods*, Table 5.D-49). The 7DADM values were converted by month to function with daily model outputs (Appendix 5.D, Section 5.D.2.1, *Water Temperature Analysis Methods*, Table 5.D-51).

Results of the water temperature thresholds analysis are presented in Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Tables 5.D-68 through 5.D-73. At Keswick Dam, there would be no months or water year types in which there would be both more than 5% more days under the PA compared to the NAA on which temperatures would exceed the threshold and a more-than-0.5°F difference in the magnitude of average daily exceedance (Appendix 5.D, Section 5.D.2.5 *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-68).

At Clear Creek, there would be no months or water year types in which there would be both 5% more days under the PA compared to the NAA on which temperatures would exceed the 61°F 7DADM threshold and a more-than-0.5°F difference in the magnitude of average daily exceedance (Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-69). However, the percent of days exceeding the threshold under the PA

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[49] Water temperature results for Wilkins Slough were used to represent Knights Landing for this analysis

would be more than 5% lower than under the NAA during September and October of critical water years (6.7% and 11.8%, respectively). Despite this reduction during September of critical water years, the difference in mean daily exceedance would increase by 0.7°F. This indicates that the frequency of days above the threshold would decrease under the PA, but exceedances would be higher on average.

At Balls Ferry, there would be no months or water year types in which there would be 5% more days under the PA compared to the NAA on which temperatures would exceed the 61°F 7DADM threshold and no more-than-0.5°F difference in the magnitude of average daily exceedance (Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-70). Therefore, it was concluded that there would be no biologically meaningful effect. There are also two situations at Balls Ferry during which the percent of days exceeding the threshold under the PA would be more than 5% lower than under the NAA during September and October of critical water years (10% and 14%, respectively). Despite this reduction during September of critical water years, the difference in mean daily exceedance would increase by 0.7°F. This indicates that the frequency of days above the threshold would decrease under the PA, but exceedances would be higher on average.

At Bend Bridge, the percent of days exceeding the 61°F 7DADM threshold under the PA would be more than 5% higher than under the NAA during July (7.8%) of critical years, August (5.9%) and September (15.8%) of below normal years, and September of dry years (8.0%) (Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-71). However, in none of these situations would there concurrently be a more-than-0.5°F difference in the magnitude of average daily exceedance. Therefore, it was concluded that there would be no biologically meaningful effect at Bend Bridge. There are also three situations at Bend Bridge during which the percent of days exceeding the threshold under the PA would be more than 5% lower than under the NAA: August of dry years (8.4%), August of critical years (11.6%), and October of critical years (11%). In August of critical years, despite the reduction in threshold exceedance frequency, there would be a 0.6°F increase in average daily exceedance under the PA relative to the NAA.

At Red Bluff, the percent of days exceeding the 64°F 7DADM threshold for non-core rearing and emigration habitat under the PA would be more than 5% higher than under the NAA during July (5.1%) of critical water years, and during September of below normal (11.5%) and dry (5.8%) water years (Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-72). However, in none of these situations would there also be a more-than-0.5°F difference in the magnitude of average daily exceedance. Therefore, it was concluded that there would be no biologically meaningful effect.

At Knights Landing, the percent of days exceeding the 64°F 7DADM threshold for non-core rearing and emigration habitat under the PA would be more than 5% higher than under the NAA during October of wet water years (6.9%) (Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-73). There would also be a 7.9% reduction in the percent of days exceeding the threshold during October of below normal water years. However, in neither of these situations would there also be a more than 0.5°F difference in the magnitude of average daily exceedance. Therefore, it was concluded that there would be no biologically meaningful effect.

Overall, the thresholds analysis indicates that there would be more exceedances (5% or greater) in certain months and water year types under the PA

The SALMOD model provides predicted water temperature-related fry and juvenile winter-run Chinook salmon mortality, which is a combination of mortality of the fry, pre-smolt, and immature smolt life stages (see Attachment 5.D.2, *SALMOD Model*, for a full description). Results for water temperature-related mortality of these life stages are presented in Table 5.4-38 and the annual exceedance plot for all water year types combined is presented in Figure 5.4-110. These results indicate that differences under the PA in temperature-related mortality relative to the NAA would generally be insignificant. The highest mean annual mortality would occur in critical water years in both the NAA and PA and there would be insignificant differences between scenarios in mortality (759 fish, or 1% lower under the PA). Accordingly, these results indicate that the PA would not increase water temperature-related mortality of fry and juvenile winter-run Chinook salmon relative to the NAA.

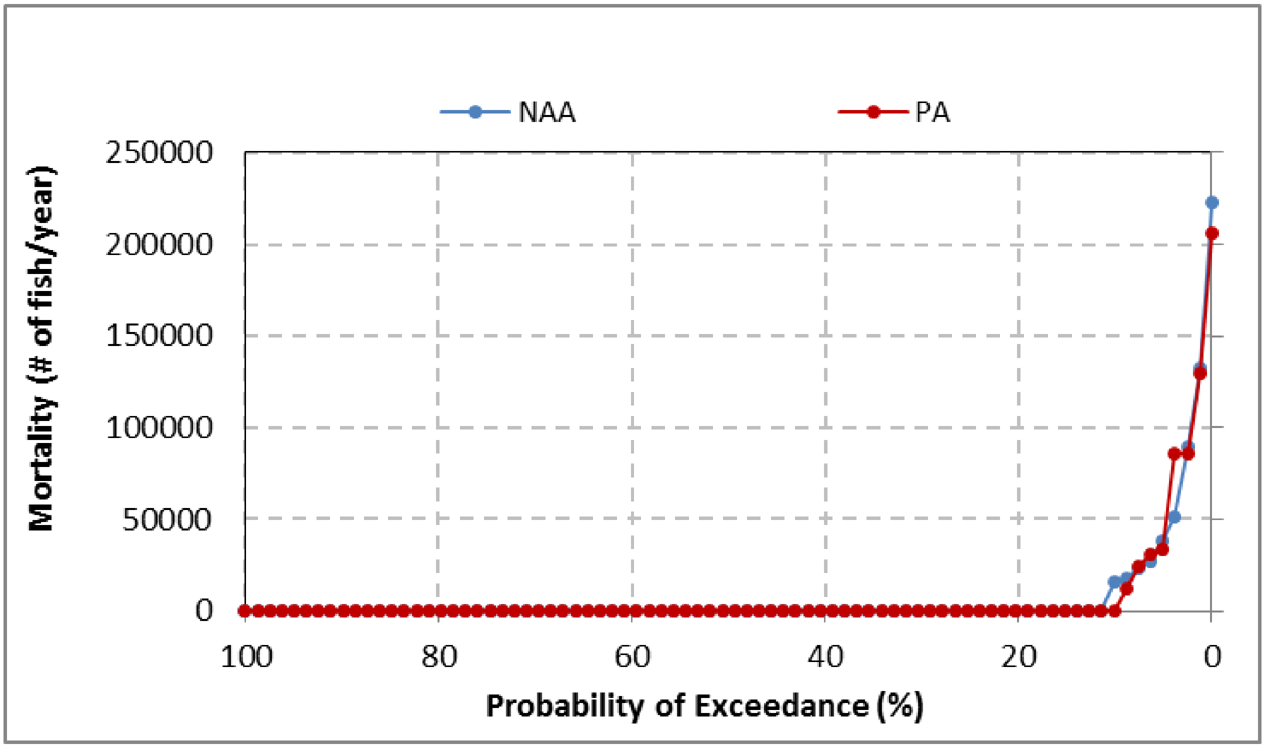

Figure 5.4-110. Exceedance Plot of Annual Water Temperature-Based Mortality (# of Fish/Year) of Winter-Run Chinook Salmon Fry and Juveniles

5.4.2.1.3.1.3 Juvenile Emigration

5.4.2.1.3.1.3.1 Flow-Related Effects

Mean monthly flows were evaluated in the Sacramento River at four locations along the downstream migration corridor of juvenile winter-run Chinook salmon (i.e., Keswick, Red Bluff, Wilkins Slough, and Verona) during the July through March emigration period, with peak emigration at Keswick Dam and Red Bluff during September and October (Table 5.4-25). Changes in flow potentially affect the emigration of juveniles, including the timing and rate of emigration, as well as conditions for feeding, protective cover, resting, temperature, turbidity, and other habitat factors. Crowding and stranding, especially in side-channel habitats, can also be affected (Quinn 2005; Williams 2006; del Rosario et al. 2013). As described in Appendix 5.D, Section 5.D.2.4, *Migration Flows Methods*, quantitative relationships between flow and downstream migration generally are highly variable and poorly understood, but on balance, except under very high flows, benefits of increased flow generally outweigh the costs. Therefore, it is assumed for the purposes of this effects analysis that increased flow would improve conditions for the emigration of juvenile winter-run Chinook salmon. Milner et al. 2012 and del Rosario et al. 2013 found that migration cues for anadromous fish species are often the result of natural pulse flows, or pulse flows caused by natural events, such as an extensive rainfall event, which will not be affected by the PA.

Shasta Reservoir storage volume at the end of May influences flow rates in the Sacramento River during the first three months of the juvenile emigration period; Shasta storage volume at the end of September may influence flow during the rest of the period. Mean Shasta May storage under the PA would be similar (less than 5% difference) to storage under NAA for all water year types. Mean Shasta September storage under the PA would be similar (less than 5% difference) to storage under NAA for all water year types, except for 7% higher mean storage during critical water years under the PA (Appendix 5.A, *CALSIM Methods and Results*, Table 5.A.6-3).

In general, mean flow under the PA at the Keswick, Red Bluff, Wilkins Slough, and Verona locations in the Sacramento River would be similar to (less than 5% difference) or lower than the flow under the NAA during the first five months of the winter-run Chinook salmon juvenile migration period and similar to (less than 5% difference) or higher than under the NAA during the last four months, with some exceptions (Appendix 5.A, *CALSIM Methods and Results*, Table 5.A.6-10, Table 5.A.6-14, Table 5.A.6-35, Table 5.A.6-36). During July, mean flow in critical water years under the PA would be 10% and 13% lower than it would be under the NAA at Wilkins Slough and Verona, but the flows would be similar (less than 5% difference) at Keswick and Red Bluff. During August, mean flow in below normal years would be lower at all four locations (up to 18% lower flow at Wilkins Slough). During August of dry and critical years, at Wilkins Slough and Verona only, flow under the PA would be greater (up to 10% greater). Mean flow during September would be lower for most water year types at all the locations (up to 24% lower in below normal years at Verona). During October, flow under the PA would be 7% to 11% lower in wet years at all the locations but would be up to 17% higher in below normal and dry years. The changes in flow during September and October coincide with the peak of the juvenile emigration period at Keswick and Red Bluff. During November of wet and above normal water years, flow would be 26% lower under the PA than it would be under the NAA at Keswick Dam, 21% lower at Red Bluff, up to 24% lower at Wilkins Slough, and up to 17% lower at Verona, but in critical water years, flow would be greater at all the locations (up to 13% greater at Keswick). During January, mean flow under the PA at Keswick would be 18% greater than it would be under the NAA in critical water year types and 8% greater in wet years. At Red Bluff, the mean January flow in critical years would be 7% greater under the PA; at the other two locations, all differences in January flow would be less than 5%. During February, mean flow would be lower (up to 13% lower at Keswick) under the PA compared with the NAA at all the locations, except Verona. During March, flow under the PA at Keswick would be 9% greater in above normal and below normal years and 8% greater in critical years; there would be no differences greater than 5% at the other locations.

The CALSIM modeling results given here indicate that the PA would reduce flow in some months and water year types, although this does not consider real-time operational management described in Section 3.1.5, *Real-Time Operations Upstream of the Delta,* and Section 3.3.3, *Real-Time Operational Decision-Making Process,* that would be used to avoid and minimize any modeled effects. Further discussion regarding flow-related effects during the June through November period is provided in Section 5.4.2.3, *Summary of Upstream Effects*.

5.4.2.1.3.1.3.2 Water Temperature-Related Effects

Modeled mean monthly water temperatures in the Sacramento River in the reach from Keswick Dam to Knights Landing during the July through March juvenile emigration period for winter-run Chinook salmon, with a peak during September and October (Table 5.4-25) are presented in Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results,* Table 5.C.7-3, Table 5.C.7-4, Table 5.C.7-5, Table 5.C.7-7, Table 5.C.7-8, Table 5.C.7-10[50]. Overall, the PA would change mean water temperatures very little (less than 1°F, or approximately 1%) throughout the Sacramento River upstream of the Delta in all months and water year types in the period. The largest increase in mean monthly water temperatures under the PA relative to NAA would be 1.0°F (1.4%), and would occur at Knights Landing in below normal years during August.

Exceedance plots of monthly mean water temperatures were examined during each month throughout the winter-run Chinook salmon juvenile emigration period (Appendix 5.C, *Upstream Water Temperature Methods and Results,* Section 5.C.7, *Upstream Water Temperature Modeling Results,* Figure 5.C.7.3-7, Figure 5.C.7.4-7, Figure 5.C.7.5-7, Figure 5.C.7.7-7, Figure 5.C.7.8-7, Figure 5.C.7.10-7[51]). The curves for PA generally match those of the NAA, except in below normal water years in August at Knights Landing, during which water temperatures under the PA would be higher than those under NAA for most of the exceedance range by up to approximately 2.2°F, particularly in the colder end of the range (Figure 5.4-108). As indicated above, temperatures predicted for Knights Landing during August of below normal water years would be greater than the 64°F 7DADM threshold on 100% of days under both the NAA and PA, although there is low certainty that modeled values are comparable to actual values. Therefore, this suggests that, with low certainty, conditions would already be unsuitable for winter-run Chinook salmon fry and juvenile rearing for reasons that are independent of the PA.

Please see the discussion of water temperature thresholds for juvenile winter-run Chinook salmon emigration in Section 5.4.2.1.3.1.2, *Fry and Juvenile Rearing*, which concludes that there would be more exceedances (5% or greater) in certain months and water year types under the PA. These exceedances could have lethal or sublethal effects on juvenile emigrants, although this does not consider real-time operational management described in Section 3.1.5, *Real-Time Operations Upstream of the Delta*, and Section 3.3.3, *Real-Time Operational Decision-Making Process*, which would be used to avoid and minimize any modeled effects. The biological interpretation of these results, combined with all upstream results, in the context of real-time operational management is provided in Section 5.4.2.3, *Summary of Upstream Effects,* below.

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[50] Water temperature results for Wilkins Slough were used to represent Knights Landing for this analysis

[51] Water temperature results for Wilkins Slough were used to represent Knights Landing for this analysis

5.4.2.1.3.1.4 Adult Immigration

5.4.2.1.3.1.4.1 Flow-Related Effects

Mean monthly flows were evaluated in the Sacramento River at four locations along the upstream migration corridor of adult winter-run Chinook salmon (i.e., Keswick, Red Bluff, Wilkins Slough and Verona) during the December through August immigration period, with peak migration from February through April (Table 5.4-25). Changes in flow potentially affect conditions for upstream migration of adults, including bioenergetic cost, water quality, crowding, cues for locating natal streams, and passage conditions, but quantitative relationships between flow and such conditions are generally poorly understood (Quinn 2005; Milner et al. 2012). As described in Appendix 5.D, Section 5.D.2.4, *Migration Flows Methods*, on balance, except under very high flows, the benefits of increased flow generally outweigh the costs and, therefore, it is assumed for the purposes of this effects analysis that increased flow would improve conditions for upstream migration of adult winter-run Chinook salmon. It is known that migration cues for anadromous fish species are often the result of natural pulse flows, which will not be affected by the PA (Milner et al. 2012; del Rosario et al. 2013).

Shasta Reservoir storage volume at the end of September may influence flow rates in the Sacramento River during the first part of the winter-run Chinook salmon immigration period; Shasta storage volume at the end of May would influence flows during the last part of the immigration period. Mean Shasta September storage under the PA would be similar (less than 5% difference) to storage under NAA for all water year types, except for 7% higher mean storage during critical water years under the PA. Mean Shasta May storage under the PA would also be similar (less than 5% difference) to storage under NAA for all water year types (Appendix 5.A, *CALSIM Methods and Results,* Table 5.A.6-3).

For most months and water year types of the adult immigration period, mean flow at Keswick, Red Bluff, Wilkins Slough and Verona would be similar (less than 5% difference) between the PA and the NAA or would be greater under the PA. During January, mean flow under the PA at Keswick would be 18% greater than it would be under the NAA in critical water years and 8% greater in wet years. At Red Bluff, the mean January flow in critical years would be 7% greater under the PA; at the other two locations, all differences in January flow would be less than 5% (Appendix 5.A, *CALSIM Methods and Results*, Table 5.A.6-10, Table 5.A.6-14, Table 5.A.6-35, Table 5.A.6-36). During February, mean flow would be lower (up to 13% lower at Keswick) under the PA compared with the NAA at all the locations, except Verona. During March, flow under the PA at Keswick would be 9% greater in above normal and below normal years and 8% greater in critical years; there would be no differences greater than 5% at the other locations. The flow differences during February and March coincide with the peak immigration period. During May, flow under the PA would be greater (up to 8% greater at Wilkins Slough) at all the locations, except Verona. During June, flow under the PA would be greater at all the locations, including all water year types at Verona and all water year types, except wet years at the other locations. The increases for all water year types would be greater at Wilkins Sough and Verona (up to 25% greater in above normal years) than those at Keswick and Red Bluff. During July, mean flow in critical years under the PA would be up to 13% lower at Wilkins Slough and Verona; during August, mean flow in below normal years would be lower at all four locations, including up to 18% lower flow at Wilkins Slough. During August of dry and critical years, flow under the PA would be greater (up to 10% greater) at Wilkins Slough and Verona.

The CALSIM modeling results given here indicate that the PA would reduce flow in only three months and water year types, although this does not consider real-time operational management described in Section 3.1.5, *Real-Time Operations Upstream of the Delta*, and Section 3.3.3, *Real-Time Operational Decision-Making Process,* that would be used to avoid and minimize any modeled effects. Further discussion regarding flow-related effects during the June through November period is provided in Section 5.4.2.3, *Summary of Upstream Effects*.

As described in Appendix 5.D, Section 5.D.2.4, *Migration Flows Methods*, mean monthly flow below about 3,250 cfs is considered to have potentially adverse effects on Chinook salmon, CCV steelhead, and green sturgeon adult immigration conditions in the Sacramento River. The effect of the PA on the frequency of flows below this threshold was evaluated by comparing CALSIM flows between the PA and the NAA at three of the migration corridor locations in the river: Keswick, Red Bluff, and Wilkins Slough. The CALSIM results include no flows below 3,250 cfs for the Sacramento River at any of these locations for any month of the winter-run Chinook salmon adult immigration period.

5.4.2.1.3.1.4.2 Water Temperature-Related Effects

Modeled mean monthly water temperatures in the Sacramento River at Keswick Dam, Bend Bridge, and Red Bluff during the December through August adult immigration period for winter-run Chinook salmon (Table 5.4-25) are presented in Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results,* Table 5.C.7-3, Table 5.C.7-7, Table 5.C.7-8. Overall, the PA would change mean water temperatures very little (less than 1°F, or approximately 1%) at these locations in all months and water year types in the period. The largest increase in mean monthly water temperatures under the PA relative to NAA would be 0.6°F (0.9%), and would occur at Red Bluff in below normal years during August.

Exceedance plots of monthly mean water temperatures were examined during each month throughout the juvenile emigration period (Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results,* Figure 5.C.7.3-7, Figure 5.C.7.7-7, Figure 5.C.7.8-7). The values for the PA in these exceedance plots generally match those of the NAA. For below normal water years in August at Red Bluff, where the largest increases in mean monthly water temperatures were seen, the PA curve is consistently higher than the NAA curve by approximately 0.5°F (Figure 5.4-111). As indicated below in the threshold analysis, temperatures predicted at Red Bluff during August of below normal water years would be lower than the 68°F 7DADM for all days in both the NAA and PA and, therefore, there would be no biologically meaningful effect on winter-run Chinook salmon adult immigrants moving through the Red Bluff area.

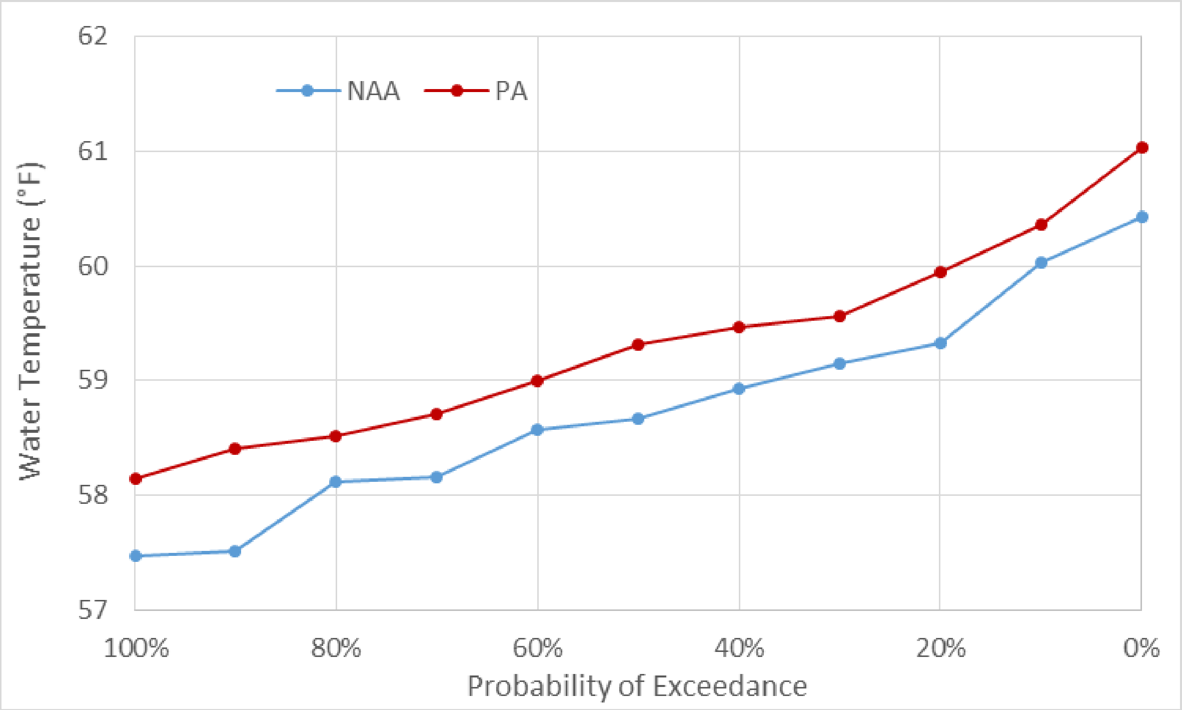

Figure 5.4-111. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the Sacramento River at Red Bluff in August of Below Normal Water Years

The USEPA's 7DADM threshold value of 68°F was used to evaluate water temperature threshold exceedance during the winter-run Chinook salmon adult immigration life stage at Keswick Dam, Bend Bridge, and Red Bluff (Appendix 5.D, Section 5.D.2.1, *Water Temperature Analysis Methods*, Table 5.D-49). The threshold was converted to function with daily model outputs for each month separately (Appendix 5.D, Section 5.D.2.1, *Water Temperature Analysis Methods*, Table 5.D-51).

Results of the water temperature thresholds analysis are presented in Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-74 through Table 5.D-76. At Keswick Dam and Red Bluff, there would be no months or water year types in which there would be 5% more days under the PA compared to the NAA on which temperatures would exceed the threshold, and no more-than-0.5°F difference in the magnitude of average daily exceedance.

At Bend Bridge, there is one instance during which the percent of days exceeding the 68°F DADM under the PA would be more than 5% higher than under the NAA: August in critical years (5.1% higher under the PA) (Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-75). However, there would be an insignificant (less than 0.1°F) difference in average daily exceedance in this instance. Therefore, it was concluded that there would be no biologically meaningful effect on winter-run adult immigration.

Overall, there would be more exceedances (5% or greater) in certain months and water year types under the PA, which could have lethal or sublethal effects on adult immigrants, although this does not consider real-time operational management described in Section 3.1.5, *Real-Time*

Operations Upstream of the Delta, and Section 3.3.3, *Real-Time Operational Decision-Making Process*, that would be used to avoid and minimize any modeled effects. The biological interpretation of these results, combined with all upstream results, in the context of real-time operational management is provided in Section 5.4.2.3, *Summary of Upstream Effects*, below.

5.4.2.1.3.1.5 Adult Holding

5.4.2.1.3.1.5.1 Flow-Related Effects

Mean monthly flow rates and reservoir storage volumes were examined for the PA and NAA in the Sacramento River at the Keswick Dam and Red Bluff locations during the January through August holding period, with peak occurrence during April through June, for winter-run Chinook salmon (Table 5.4-25). Changes in flow likely affect holding habitat for winter-run, with higher flows potentially providing greater depths and improved water quality in pools. Shasta Reservoir storage volume at the end of May influences flow rates below the dam during much of the winter-run holding period. Mean Shasta May storage under the PA would be similar (less than 5% difference) to storage under NAA for all water year types (Appendix 5.A, *CALSIM Methods and Results*, Table 5.A.6-3). During the majority of months and water year types of the winter-run holding period, the PA would result in minor changes (less than 5% difference) in mean flow in the Sacramento River at the Keswick Dam and Red Bluff locations (Appendix 5.A, *CALSIM Methods and Results*, Table 5.A.6-10, Table 5.A.6-35). However, at both locations flows under the PA would be 5% to 7% higher during May of dry years and June of all water year types except wet years. During January of critical years, mean flow under the PA would be up to 18% higher than flow under the NAA; during February of critical years flow under the PA would be up to 13% lower; and during August of below normal years flow would be 10% lower under the PA (Appendix 5.A, *CALSIM Methods and Results*, Table 5.A.6-10, Table 5.A.6-35). The flow increases during May and June occur within the peak winter-run adult holding period (April through June). Because flow would generally be higher (greater than 5% difference) under the PA during the peak holding period, and increases and decreases in flow would, on balance, be similar during the rest of the holding period, the PA is predicted to have a small positive effect on flow conditions for winter-run holding habitat.

5.4.2.1.3.1.5.2 Water Temperature-Related Effects

Modeled mean monthly water temperatures in the Sacramento River at Keswick Dam, Balls Ferry, and Red Bluff during the January through August adult holding period for winter-run Chinook salmon (Table 5.4-25) are presented in Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results*, Table 5.C.7-3, Table 5.C.7-5, Table 5.C.7-8. Overall, the PA would change mean water temperatures very little (less than 1°F, or approximately 1%) at these locations in all months and water year types in the period. The largest increase in mean monthly water temperatures under the PA relative to NAA would be 0.6°F (0.9%), and would occur at Red Bluff in below normal years during August.

Exceedance plots of monthly mean water temperatures were examined during each month throughout the adult holding period (Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results*, Figure 5.C.7.3-7, Figure 5.C.7.5-7, Figure 5.C.7.8-7). The curves for PA generally match those of the NAA. For below normal water years in August at Red Bluff, where the largest increase in mean monthly water temperature was seen, the PA curve is consistently higher than the NAA curve by approximately 0.5°F (Figure 5.4-111).

To evaluate water temperature threshold exceedance during the adult holding life stage at Keswick Dam, Balls Ferry, and Red Bluff, the USEPA's 7DADM threshold value of 61°F was used Appendix 5.D, Section 5.D.2.1, *Water Temperature Analysis Methods*, Table 5.D-49) (U.S. Environmental Protection Agency 2003). The threshold was converted to function with daily model outputs for each month separately (Appendix 5.D, Section 5.D.2.1, *Water Temperature Analysis Methods*, Table 5.D-51).

Results of the water temperature thresholds analysis are presented in Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Tables 5.D-77 through 5.D-79. At Keswick Dam, there would be no months or water year types in which there would be 5% more days under the PA compared to the NAA on which temperatures would exceed the threshold and no more-than-0.5°F difference in the magnitude of average daily exceedance (Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-77).

At Balls Ferry, the percent of days exceeding the 61°F 7DADM threshold for adult holding habitat under the PA would not differ by more than 5% in any month or water year type (Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-78). The average daily exceedance under the PA would increase by 0.7°F in August of all water year types combined. However, combined, these results indicate that there would be no biologically meaningful effect at Balls Ferry.

At Red Bluff, the percent of days exceeding the 61°F 7DADM threshold for adult holding habitat under the PA would be more than 5% higher than under the NAA during July (6.5%) of critical water years and during August of below normal water years (9.4%) (Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-79). There would also be reductions in the percent of days exceeding the threshold in June of critical years (5.8%) and August of dry (6.1%) and critical (6.5%) water years. However, in none of these situations would there also be a more than 0.5°F difference in the magnitude of average daily exceedance. Therefore, it was concluded that there would be no biologically meaningful effect.

Overall, the thresholds analysis indicates that there would be more exceedances (5% or greater) in certain months and water year types under the PA, which could have lethal or sublethal effects on holding adults, although this does not consider real-time operational management described in Section 3.1.5, *Real-Time Operations Upstream of the Delta*, and Section 3.3.3, *Real-Time Operational Decision-Making Process*, that would be used to avoid and minimize any modeled effects. CALSIM modeling also does not consider the current revision process to OCAP RPA Action Suite 1.2 described in Section 3.1.4.5, *Annual/Seasonal Temperature Management Upstream of the Delta*, to improve winter-run Chinook salmon egg-to-fry survival. This process may result in refinements and additions to the existing annual/seasonal temperature management processes, including spring storage targets, revised temperature compliance criteria and a range in summertime Keswick release rates. The biological interpretation of these results, combined with all upstream results, in the context of real-time operational management and RPA revisions is provided in Section 5.4.2.3, *Summary of Upstream Effects*, below.

5.4.2.1.3.1.6 Life Cycle Models

Two winter-run Chinook salmon life cycle models, Interactive Object-Oriented Salmon Simulation (IOS) and Oncorhynchus Bayesian Analysis (OBAN), and SALMOD, a model that behaves like a life cycle model in some ways, are described in this section. Because these models integrate multiple life stages, they are described separately from the life stage-specific results for the winter-run Chinook salmon analysis in the Sacramento River. A full description of each model can be found as follows:

- IOS: Appendix 5.D, Section 5.D.3.1, *IOS*
- OBAN: Appendix 5.D, Section 5.D.3.2, *OBAN*
- SALMOD: Appendix 5.D, Attachment 5.D.2, *SALMOD Model*,

5.4.2.1.3.1.6.1 IOS

Results of the IOS model are presented in Appendix 5.D Section 5.D.3.1, *IOS*. The model predicts that upstream effects of the PA would be insignificant. Median egg survival under the PA (0.991) would be nearly identical to that under the NAA (0.990) with overlapping 95% confidence intervals in all but 12 of the 81 simulated years. In addition, median fry survival under the PA (0.991) would be nearly identical to that under the NAA (0.990), with overlapping 95% confidence intervals in all but 15 of the 81 simulated years. Such small differences in upstream survival would be unlikely to measurably affect escapement. Median escapement is predicted to be lower under the PA relative to the NAA, but this is largely an effect of in-Delta survival resulting from lower flows downstream of the North Delta intake facilities. Median through-Delta survival under the PA was predicted to be 0.354, compared to 0.380 under the NAA, with overlapping confidence intervals in all but one out of 81 simulated years.

It is worth noting that the difference in egg survival and fry survival between the NAA and PA shifts temporally during the 80-year time series (Appendix 5.D, Section 5.D.3.1, *IOS*). In the late 1920s to early 1930s, egg and fry survival under the PA was lower than survival under the NAA. In the late 1980s and early 1990s, egg and fry survival under the PA was higher than survival under the NAA. Despite this pattern, the escapement results primarily result from reduced in-Delta survival under the PA.

5.4.2.1.3.1.6.2 OBAN

Results of the OBAN model are presented in Appendix 5.D, Section 5.D.3.2, *OBAN*. The model predicts temporal variability in escapement, with insignificant differences between the NAA and PA. These patterns were driven predominantly by fluctuations in water temperatures and flows in the spawning reach of the Sacramento River. Therefore, upstream conditions affect escapement, but these upstream conditions are generally similar between NAA and PA such that there is no overall difference in median escapement.

5.4.2.1.3.1.6.3 SALMOD

The SALMOD model is not a full life cycle model, but it does integrate all early life stages of a Chinook salmon race together on an annual basis to provide an *Annual Potential Production* value (Attachment 5.D.2, *SALMOD Model*). This value represents all individuals that survive from the *pre-spawn egg* stage to the end of the year in each year of the 80-year simulation period. Individual years are independent of one another and, therefore, effects through time cannot be evaluated as a time series.

Mean winter-run Chinook salmon annual potential production values from SALMOD and differences between scenarios are presented in Table 5.4-46 and an exceedance plot is provided in Figure 5.4-112. Overall, these results indicate that changes in winter-run Chinook salmon annual potential production under the PA relative to the NAA would be insignificant. This result is consistent among water year types and when all water year types are combined. Despite the small magnitude of the effect of the PA on mean winter-run Chinook salmon annual potential production, it could compound with in-Delta effects to negatively affect the species if there were no benefits implemented to offset them. As a model that integrates early life stages, but not all life stages, SALMOD does not provide a basis to evaluate the subsequent impacts of in-Delta effects on the predicted total annual potential production. However, this modeling does not consider real-time operational management described in Section 3.1.5, *Real-Time Operations Upstream of the Delta*, and Section 3.3.3, *Real-Time Operational Decision-Making Process*, that would be used to avoid and minimize any modeled effects. Further, this modeling also does not consider the current revision process to OCAP RPA Action Suite 1.2 described in Section 3.1.4.5, *Annual/Seasonal Temperature Management Upstream of the Delta*, to improve winter-run Chinook salmon egg-to-fry survival. This process may result in refinements and additions to the existing annual/seasonal temperature management processes, including spring storage targets, revised temperature compliance criteria and a range in summertime Keswick release rates.

Table 5.4-46. Mean Annual Potential Production of Winter-Run Chinook Salmon and Differences between Model Scenarios, SALMOD

Analysis Period	Annual Potential Production (# of Fish/year)
All Water Year Types Combined	
Full Simulation Period[1]	
NAA	1,810,410
PA	1,797,449
Difference	-12,961
Percent Difference[2]	-1
Water Year Types[3]	
Wet (32.5%)	
NAA	1,983,169
PA	1,963,584
Difference	-19,584
Percent Difference	-1
Above Normal (12.5%)	

Analysis Period	Annual Potential Production (# of Fish/year)
NAA	1,639,594
PA	1,633,821
Difference	-5,773
Percent Difference	0
Below Normal (17.5%)	
NAA	2,069,244
PA	2,019,856
Difference	-49,389
Percent Difference	-2
Dry (22.5%)	
NAA	1,801,338
PA	1,775,288
Difference	-26,050
Percent Difference	-1
Critical (15%)	
NAA	1,399,166
PA	1,448,020
Difference	48,854
Percent Difference	3

[1] Based on the 80-year simulation period

[2] Relative difference of the annual average

[3] As defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (State Water Resources Control Board 1995). Water years may not correspond to the biological years in SALMOD.

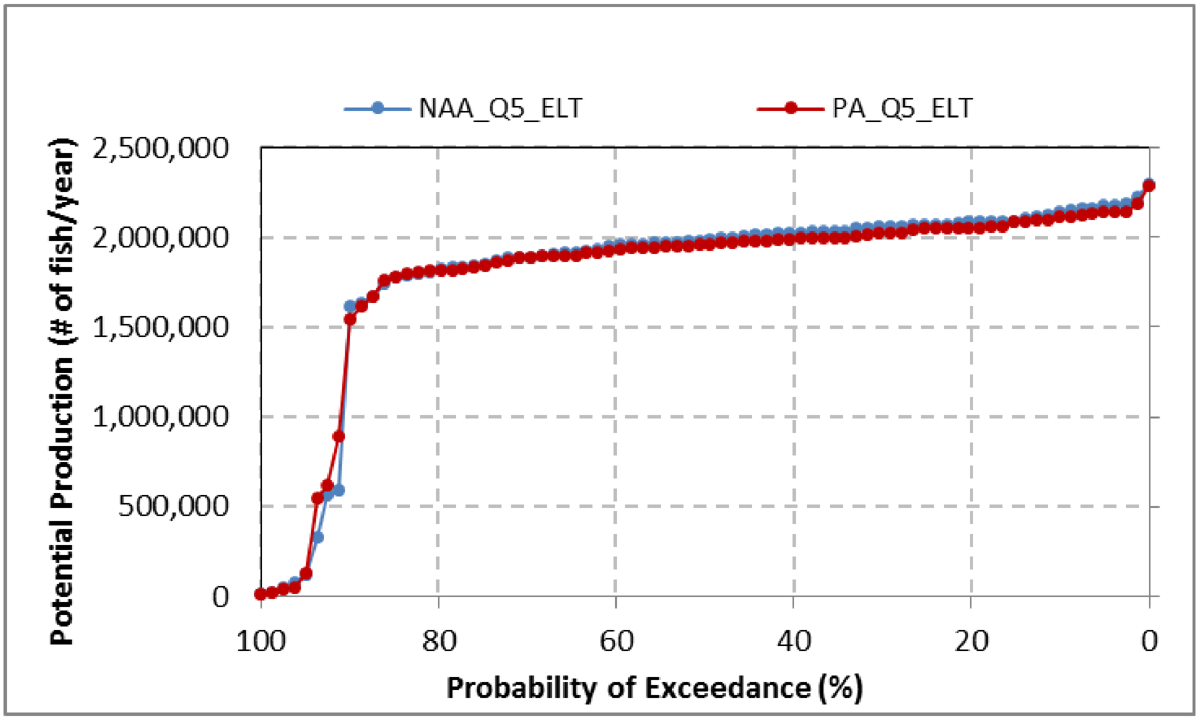

Figure 5.4-112. Exceedance Plot for Annual Potential Production (# of Fish/Year) of Winter-Run Chinook Salmon, SALMOD

The frequency at which annual production was below minimum production thresholds was evaluated as a measure of a worst-case scenario for winter-run Chinook salmon. Thresholds were determined as 5% and 10% of the number of eggs used as inputs into the model (see Attachment 5.D.2, *SALMOD Model*, for details). The initial egg value was 5,913,000 for both NAA and PA and, therefore, the 5% and 10% values were 295,650 fish per year and 591,300 fish per year, respectively. Results are presented in Table 5.4-47. There would be 5 years during which production would be below the 5% (295,650 fish) threshold under both the NAA and PA. There would be 1 year fewer (14% lower) under the PA compared to the NAA during which production would be below the 10% (591,300 fish) threshold. Therefore, the PA would have insignificant effects on the frequency of worst-case scenario years for winter-run Chinook salmon.

Table 5.4-47. Number of Years during which Winter-Run Chinook Salmon Production Would be Lower than Production Thresholds and Differences (Percent Differences) between Model Scenarios, SALMOD

Production Threshold (# of Fish)	NAA (# of Years)	PA (# of Years)	PA vs. NAA (# of Years [%])
295,650 (based on 5% of eggs)	5	5	0 (0%)
591,300 (based on 10% of eggs)	7	6	-1 (-14%)

5.4.2.1.3.2 Spring-run Chinook salmon

5.4.2.1.3.2.1 Spawning, Egg Incubation, and Alevins

5.4.2.1.3.2.1.1 Flow-Related Effects

Mean monthly flow rates and reservoir storage volumes were examined for the PA and NAA during the August through December spawning and incubation period, with peak occurrence during September and October, for spring-run Chinook salmon (Table 5.4-27). Changes in flow can affect the instream area available for spawning and egg incubation, along with the quality of the habitat, and can result in dewatering or scour of the redds. Shasta Reservoir storage volume at the end of September influences flow rates below the dam during much of the spring-run spawning and egg incubation period. Mean Shasta September storage under the PA would be similar (less than 5% difference) to storage under NAA for all water year types, except for 7% higher mean storage during critical water years under the PA (Appendix 5.A, *CALSIM Methods and Results*, Table 5.A.6-3). Mean flow due to the PA at the Keswick Dam and Red Bluff locations in the Sacramento River would be lower than flow under the NAA during November of all except critical water year types, with 26% lower flows under the PA than under the NAA for wet and above normal water year types at Keswick Dam and 21% lower flows at Red Bluff (Appendix 5.A, *CALSIM Methods and Results*, Table 5.A.6-10, Table 5.A.635). During the majority of the remaining months and water year types of the spawning period, changes in mean flow would be minor (less than 5% difference). However, flows under the PA would be 10% lower in August of below normal water years, up to 11% lower in September of above normal and below normal water year types, and up to 11% lower in October of wet years. Flows under the PA in October of below normal year types and November of critical years would be up to 17% greater than flows under the NAA (Appendix 5.A, *CALSIM Methods and Results*, Table 5.A.6-10, Table 5.A.6-35). During the September and October peak spring-run spawning period, flow reductions would be greater than 5% for several water year types. The results given here indicate that the PA would reduce flow in some months and water year types, although this does not consider real-time operational management described in Section 3.1.5, *Real-Time Operations Upstream of the Delta*, and Section 3.3.3, *Real-Time Operational Decision-Making Process*, that would be used to avoid and minimize any modeled effects. Further discussion regarding flow-related effects during the June through November period is provided in Section 5.4.2.3, *Summary of Upstream Effects*.

5.4.2.1.3.2.1.1.1 Spawning WUA

Because, as described in Appendix 5.D, Section 5.D.2.2, *Spawning Flows Methods*, spawning habitat for spring-run Chinook salmon was not estimated directly by USFWS (2003b, 2006) and no spring-run Chinook salmon WUA curves are provided, spring-run Chinook salmon spawning habitat was modeled using the WUA curves provided for fall-run Chinook salmon. The spawning WUA curves for fall-run Chinook salmon were used because the spawning and incubation period of fall-run is similar to that of spring-run, and because this substitution follows previous practice (Appendix 5.D, Section 5.D.2.3, *Rearing Flows Methods)*. However, as noted by USFWS (2003a), the validity of using the fall-run WUA curves to characterize spring-run spawning habitat is uncertain. To evaluate the effects of the PA on spring-run spawning habitat, spring-run spawning WUA was estimated for flows during the August through December spawning period under the NAA and the PA in the same three segments of the Sacramento River that were used for winter-run: Segment 4 (Battle Creek to the confluence with Cow Creek), Segment 5 (Cow Creek to the A.C.I.D. Dam), and Segment 6 (A.C.I.D. Dam to Keswick Dam). According to the CDFW aerial surveys (Table 5.4-28), about 12% of spring-run redds occur within Segment 6, over 60% are found within Segment 5, and over 7% are in Segment 4.

Differences in spring-run spawning WUA under the PA and NAA were examined using exceedance plots of monthly mean WUA for the spring-run spawning period in each of the river segments for each water year type and all water year types combined Figure 5.4-109 through Figures 5.4-126). The exceedance curves for the PA for all water years combined are similar to or slightly higher than those for the NAA for all three river segments (Figure 5.4-113, Figure 5.4-119, and Figure 5.4-125). With the curves broken out by water year type, increases in WUA under the PA are evident for wet and above normal water year types in all three river segments and for below normal years in Segments 6 and 5 (Figure 5.4-114 through Figure 5.4-116, Figure 5.4-120 through Figure 5.4-122, and Figure 5.4-126 through Figure 5.4-127). Reductions in WUA are evident for critical water years in Segments 6 and 5 (Figure 5.4-118 and Figure 5.4-124).

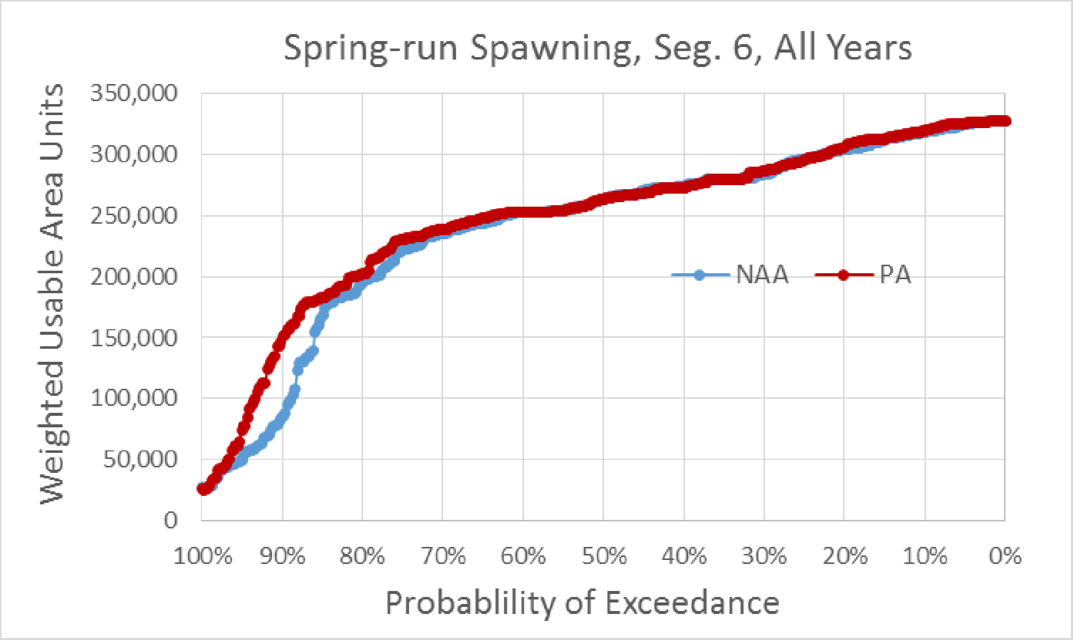

Figure 5.4-113. Exceedance Plot of Spring-Run Chinook Salmon Spawning Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 6, All Water Years

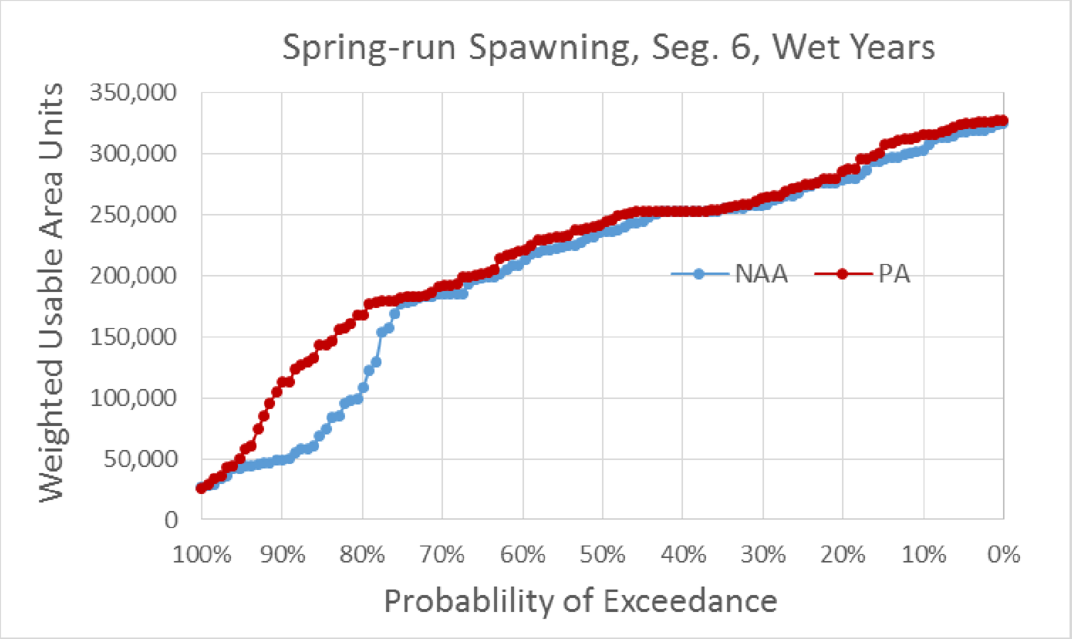

Figure 5.4-114. Exceedance Plot of Spring-Run Chinook Salmon Spawning Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 6, Wet Water Years

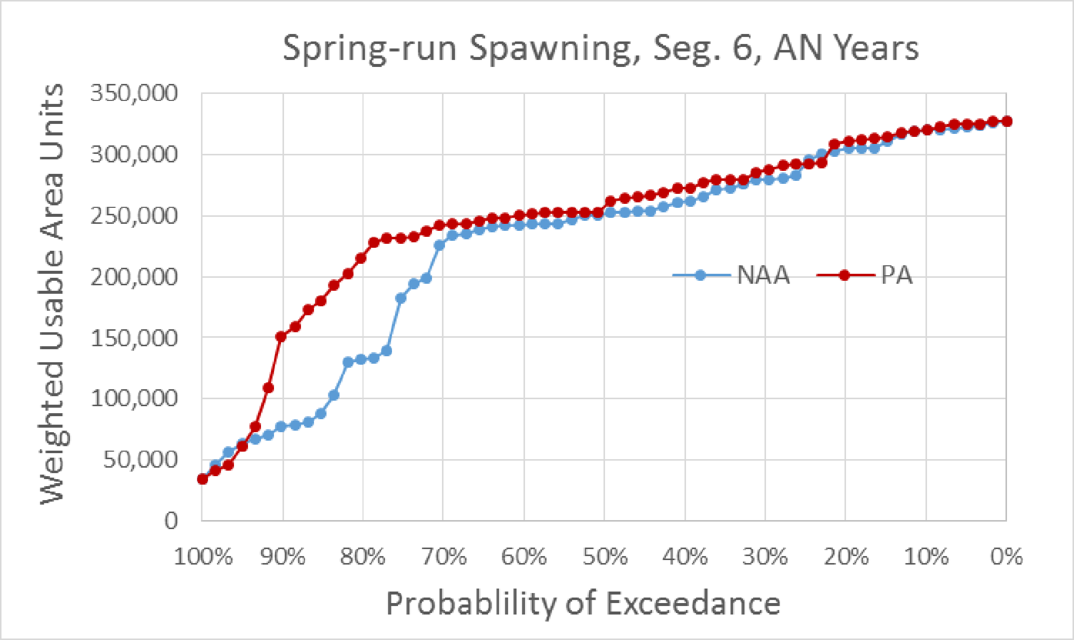

Figure 5.4-115. Exceedance Plot of Spring-Run Chinook Salmon Spawning Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 6, Above Normal Water Years

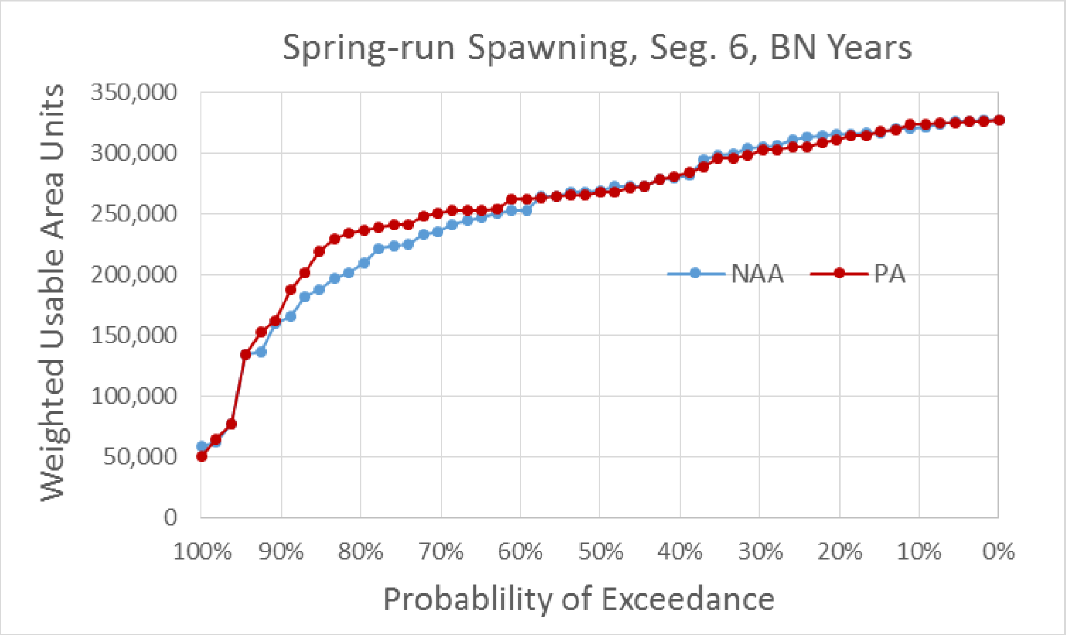

Figure 5.4-116. Exceedance Plot of Spring-Run Chinook Salmon Spawning Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 6, Below Normal Water Years

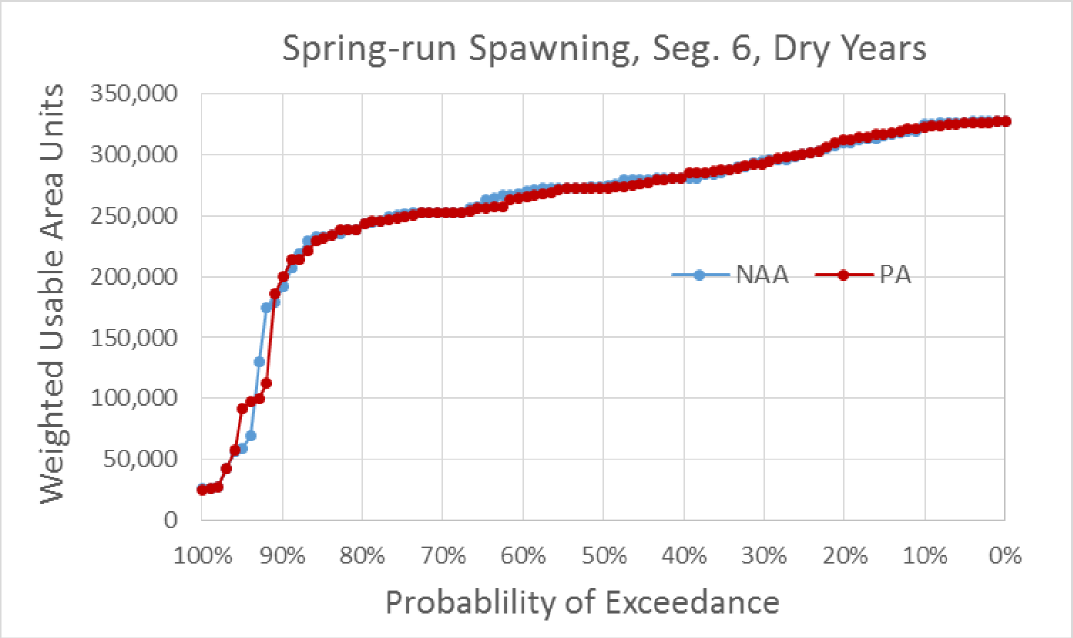

Figure 5.4-117. Exceedance Plot of Spring-Run Chinook Salmon Spawning Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 6, Dry Water Years

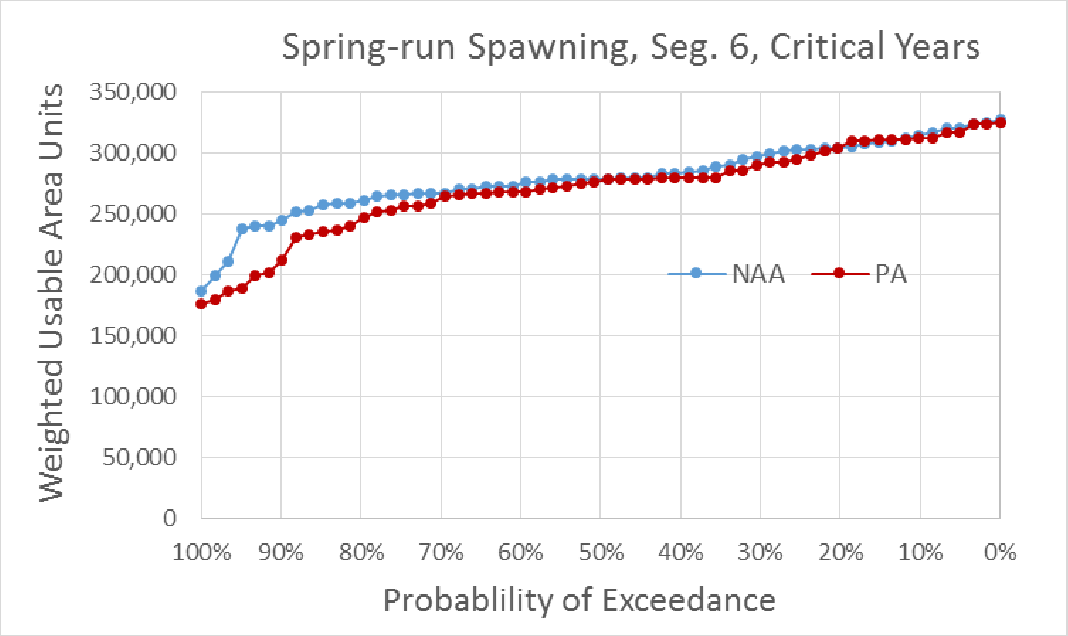

Figure 5.4-118. Exceedance Plot of Spring-Run Chinook Salmon Spawning Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 6, Critical Water Years

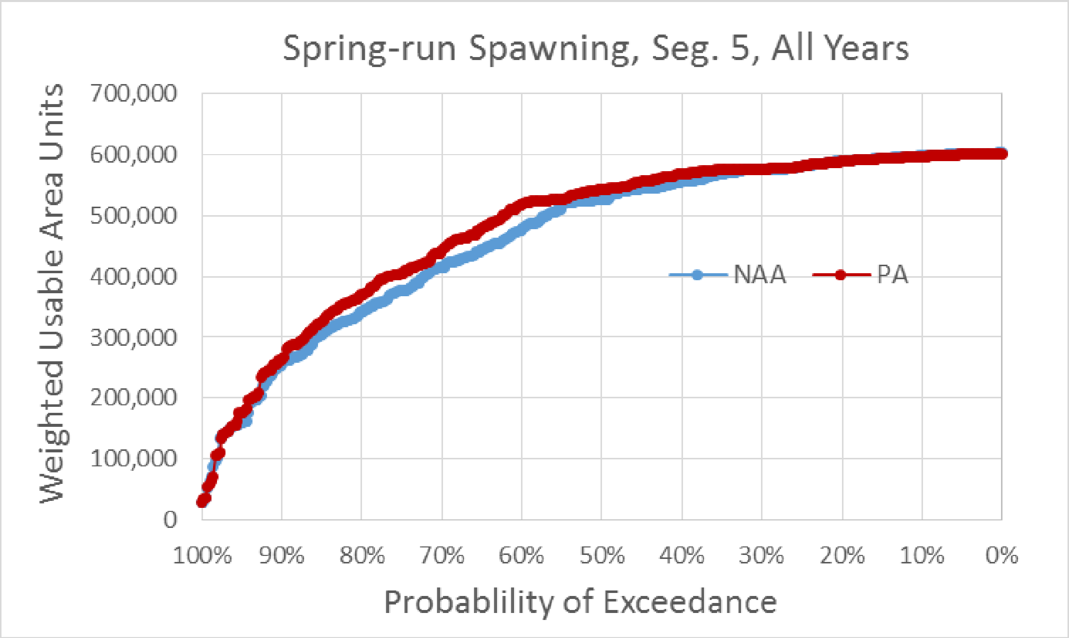

Figure 5.4-119. Exceedance Plot of Spring-Run Chinook Salmon Spawning Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 5, All Water Years

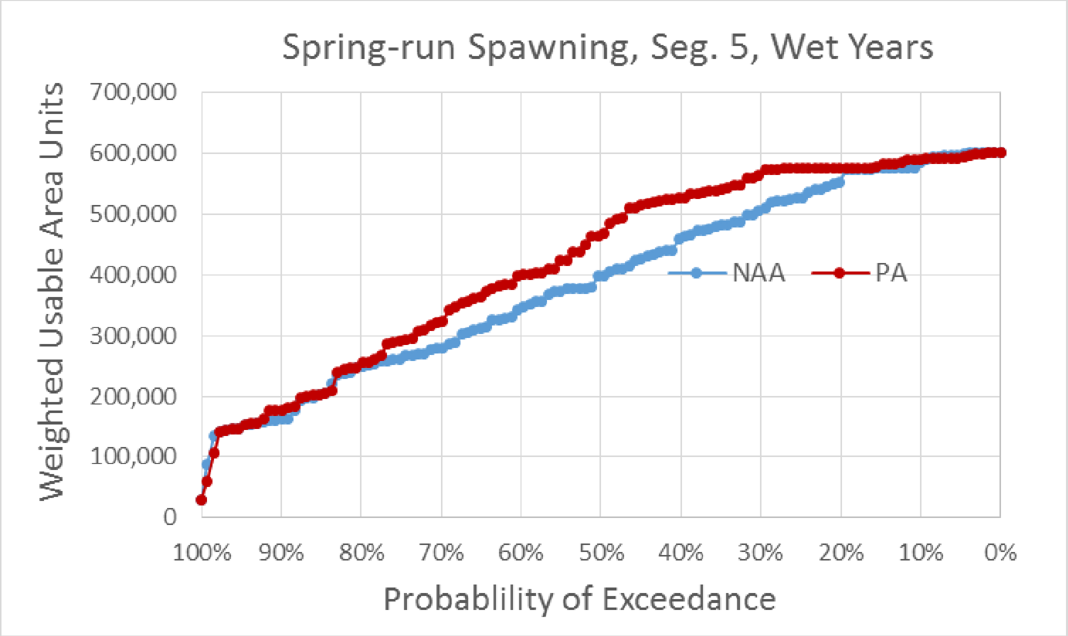

Figure 5.4-120. Exceedance Plot of Spring-Run Chinook Salmon Spawning Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 5, Wet Water Years

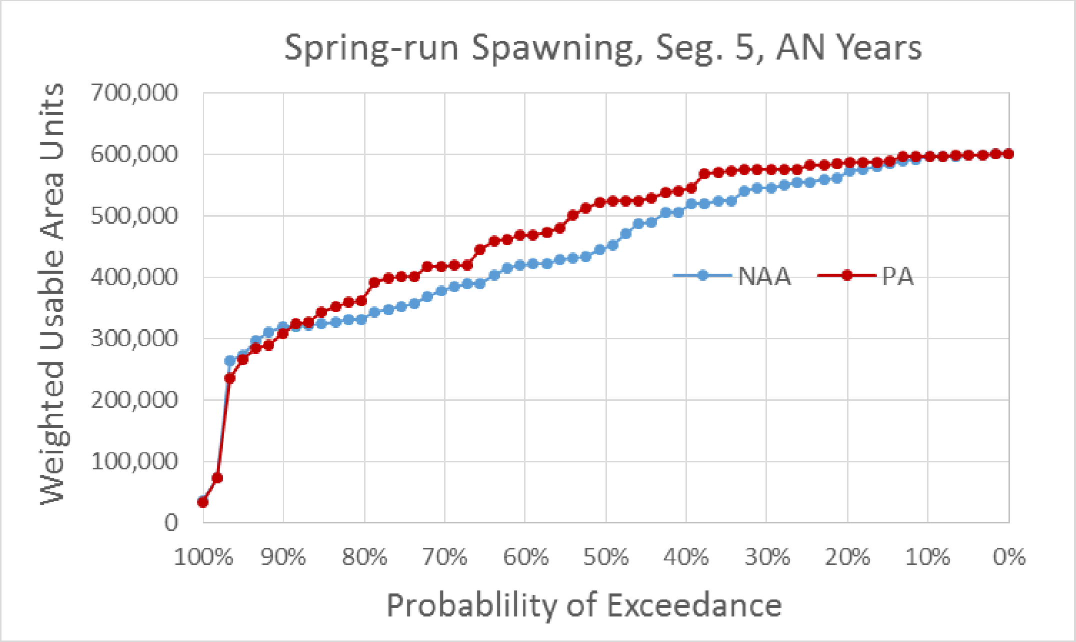

Figure 5.4-121. Exceedance Plot of Spring-Run Chinook Salmon Spawning Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 5, Above Normal Water Years

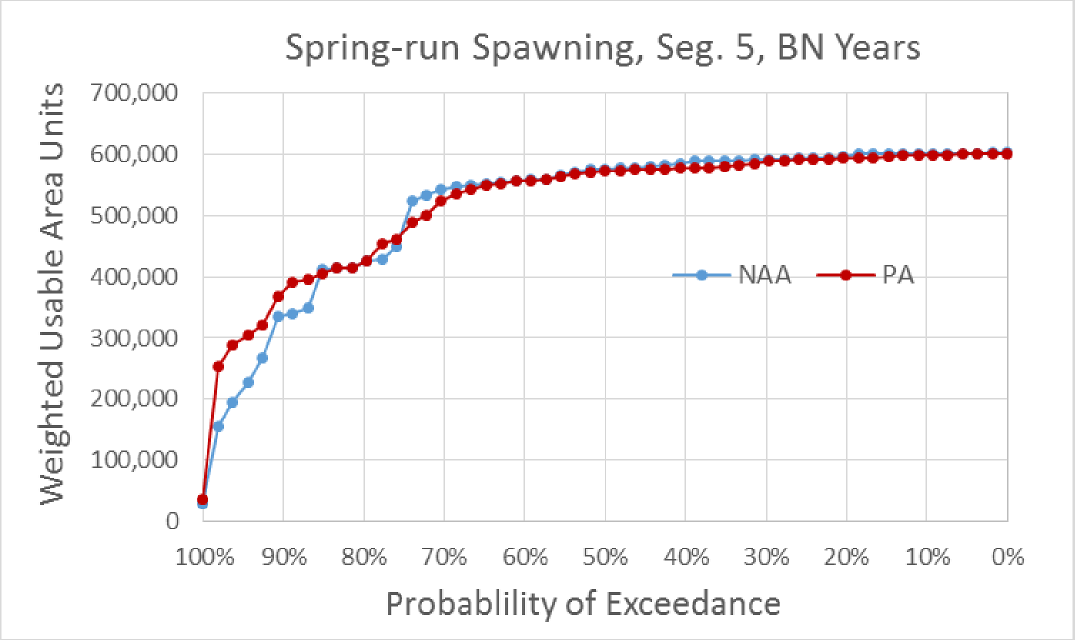

Figure 5.4-122. Exceedance Plot of Spring-Run Chinook Salmon Spawning Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 5, Below Normal Water Years

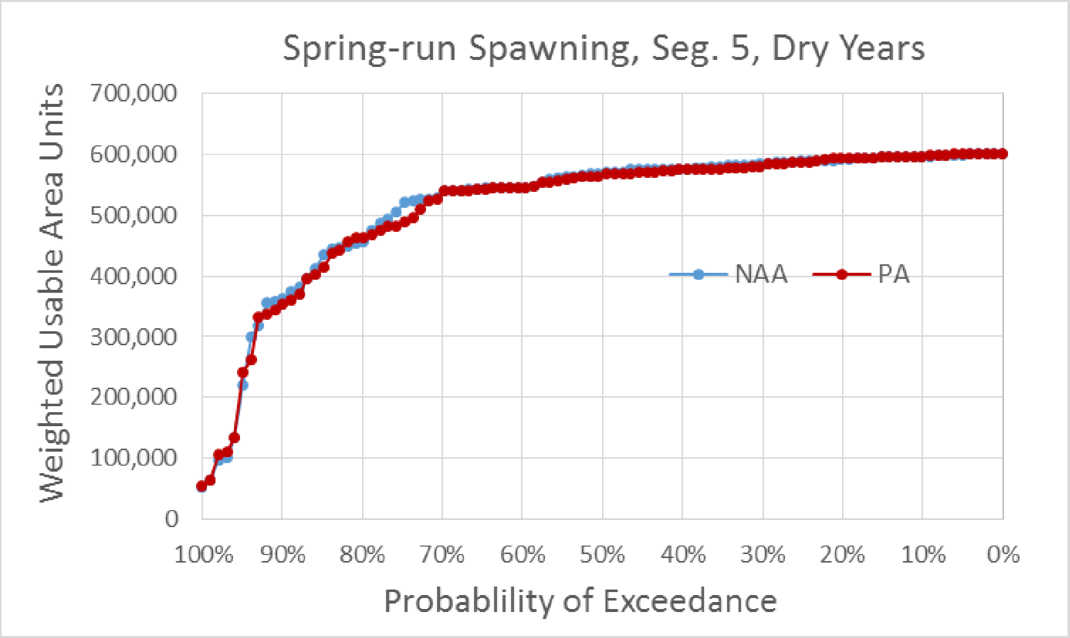

Figure 5.4-123. Exceedance Plot of Spring-Run Chinook Salmon Spawning Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 5, Dry Water Years

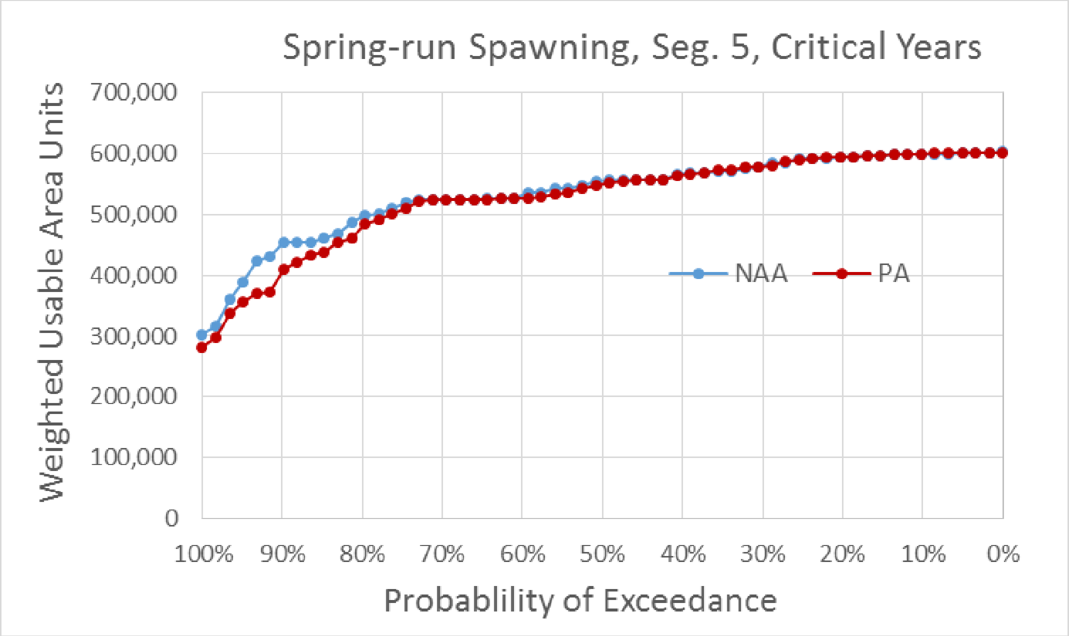

Figure 5.4-124. Exceedance Plot of Spring-Run Chinook Salmon Spawning Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 5, Critical Water Years

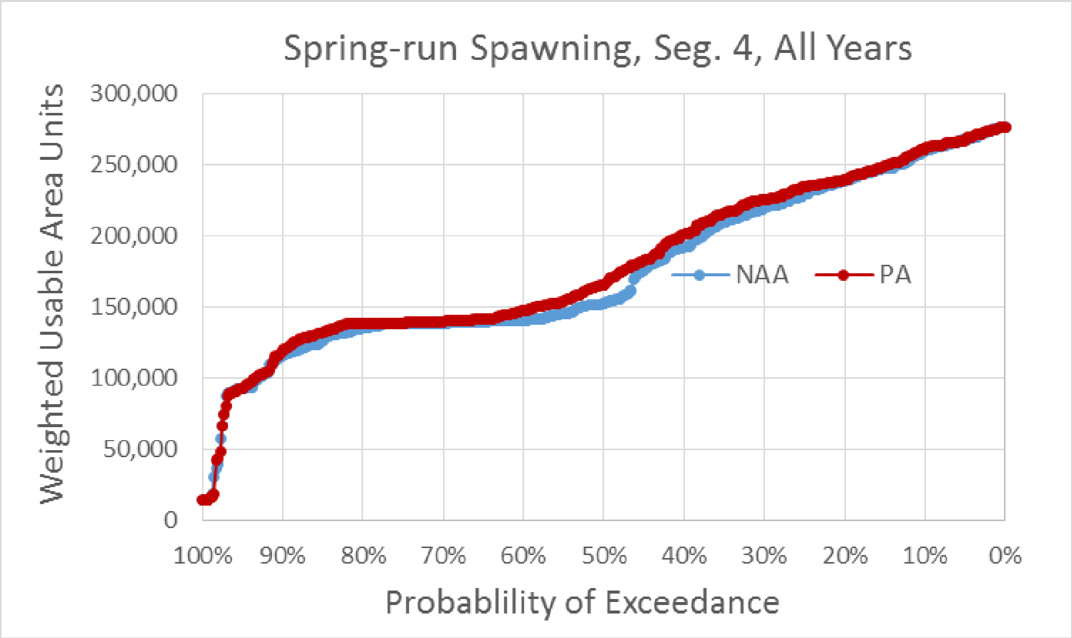

Figure 5.4-125. Exceedance Plot of Spring-Run Chinook Salmon Spawning Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 4, All Water Years

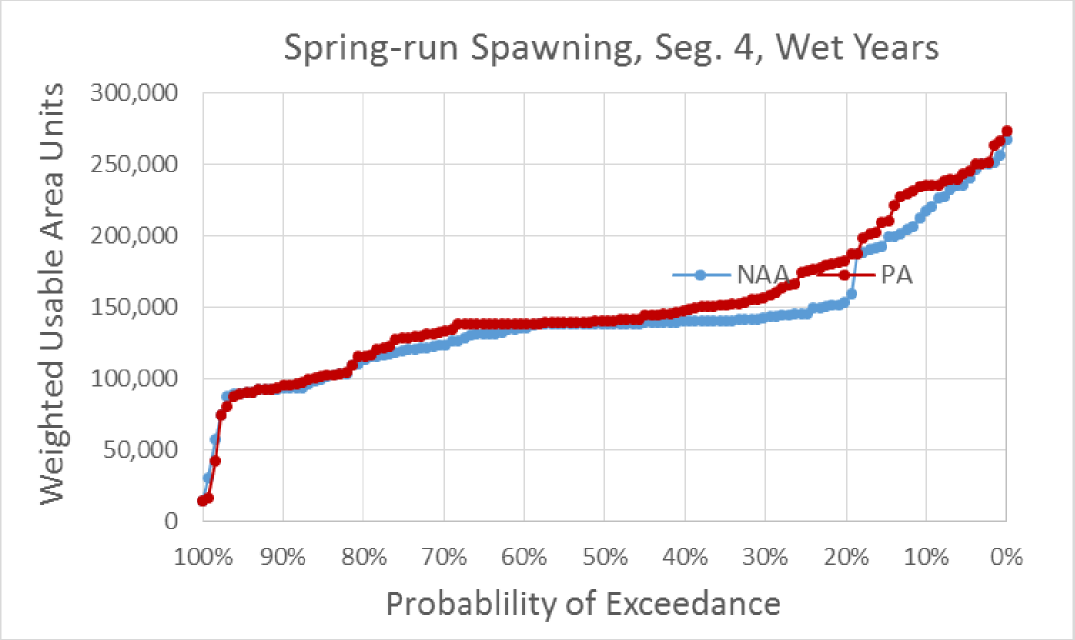

Figure 5.4-126. Exceedance Plot of Spring-Run Chinook Salmon Spawning Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 4, Wet Water Years

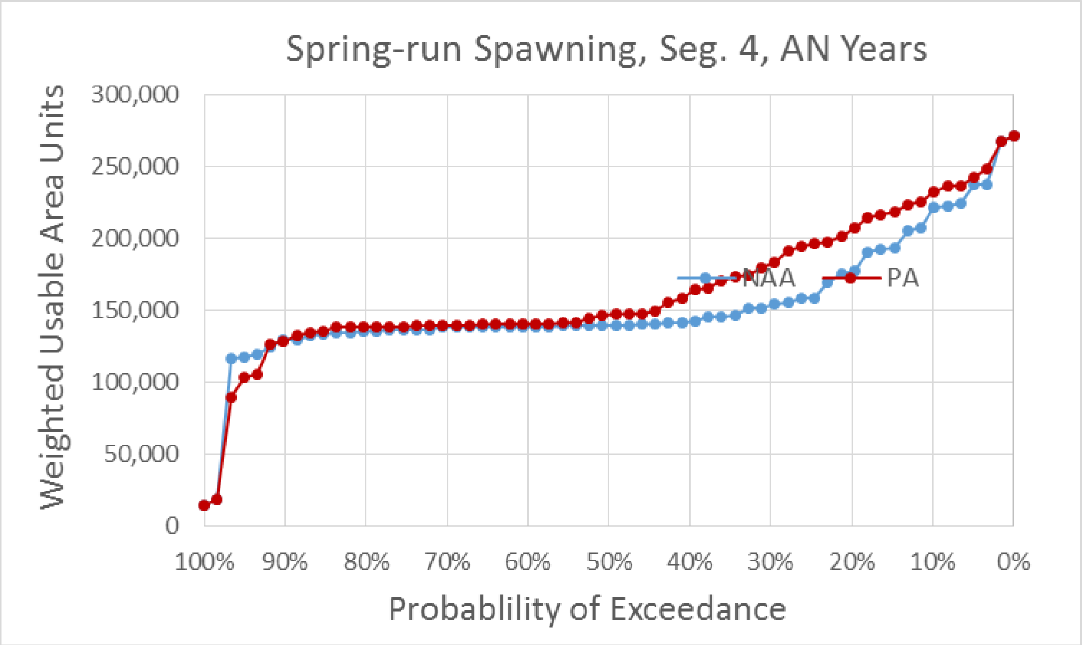

Figure 5.4-127. Exceedance Plot of Spring-Run Chinook Salmon Spawning Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 4, Above Normal Water Years

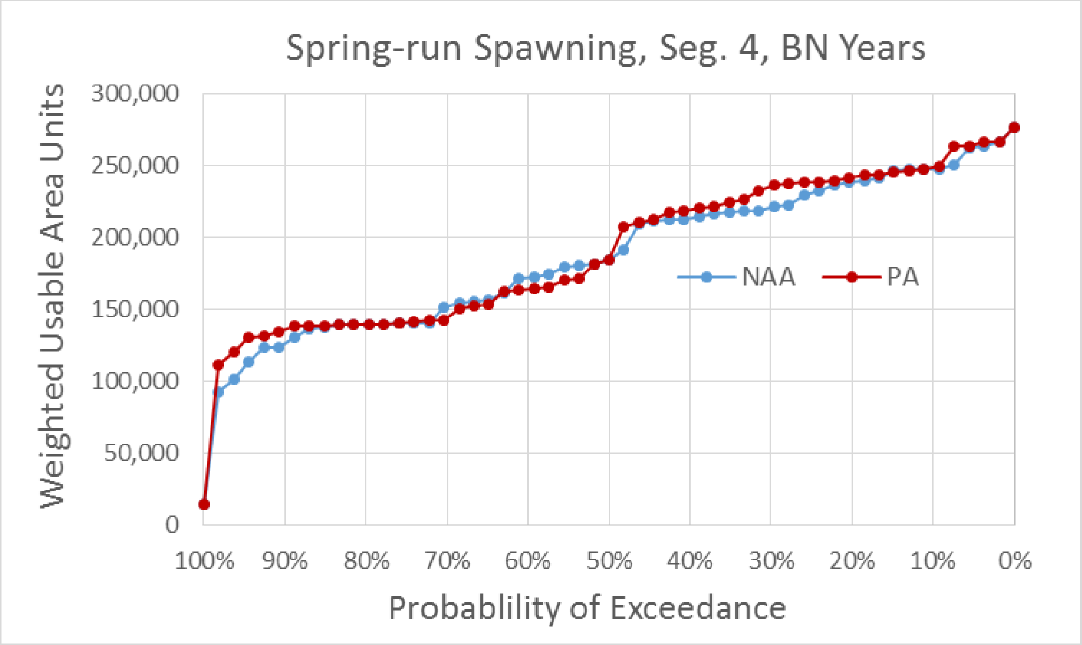

Figure 5.4-128. Exceedance Plot of Spring-Run Chinook Salmon Spawning Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 4, Below Normal Water Years

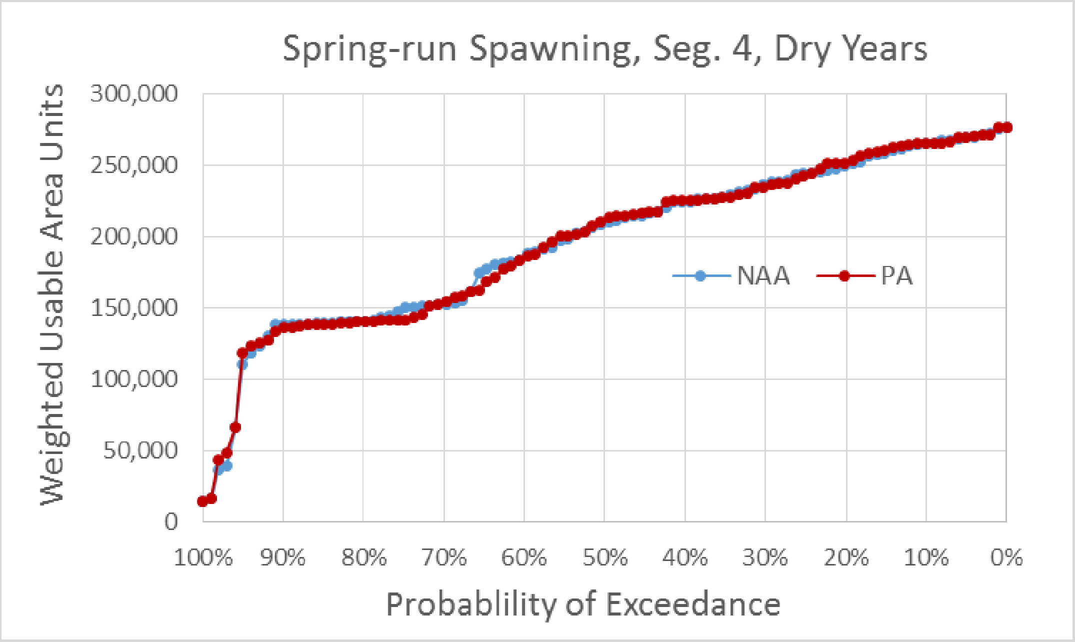

Figure 5.4-129. Exceedance Plot of Spring-Run Chinook Salmon Spawning Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 4, Dry Water Years

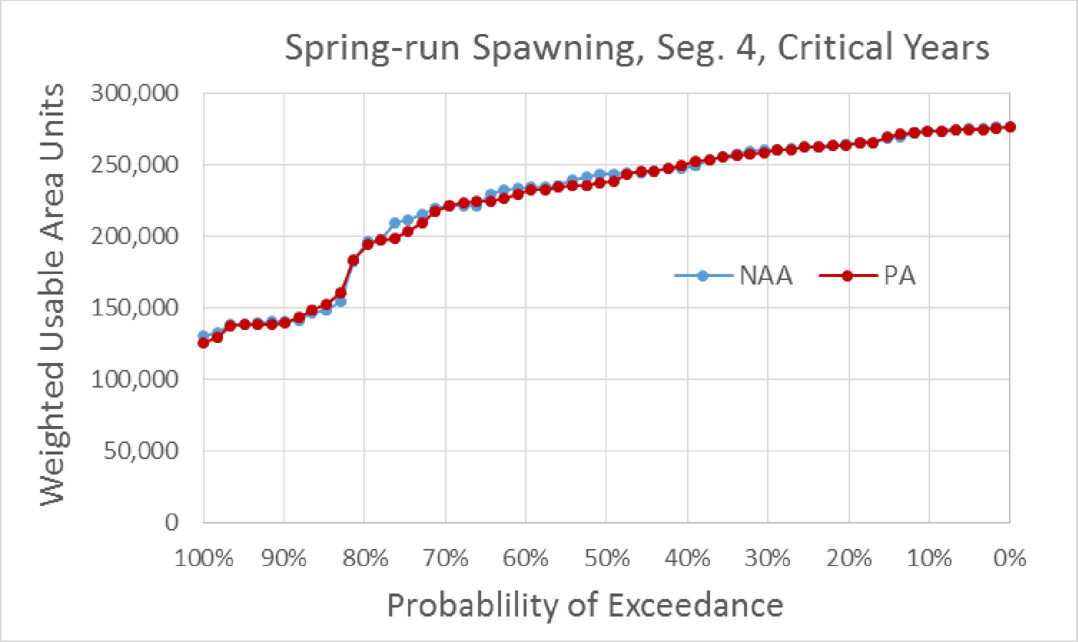

Figure 5.4-130. Exceedance Plot of Spring-Run Chinook Salmon Spawning Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 4, Critical Water Years

Differences in spawning WUA in each river segment under the PAA and NAA were also examined using the grand mean spawning WUA for each month of the spawning period under each water year type and all water year types combined (Table 5.4-48 to Table 5.4-50). Mean WUA would increase under the PA during November of wet and above normal years in all three segments by 18% to 84%. As noted above, mean flows in the Sacramento River are expected to be 21% to 26% lower under the PA during November of wet and above normal years, showing that reduced flow may enhance spawning WUA under some conditions. Mean WUA would be 5% lower under the PA than under the NAA during September of critical year types in Segment 6, and up to 13% lower during October of below normal and dry water year types in Segment 4. September and October are the peak spawning months for spring-run Chinook salmon.

Table 5.4-48. Spring-Run Chinook Salmon Spawning Weighted Usable Area (WUA) and Differences (Percent Differences) in River Segment 6 between Model Scenarios (green indicates PA is at least 5% higher [raw difference] than NAA; red indicates PA is at least 5% lower)

Month	WYT	NAA	PA	PA vs. NAA
August	Wet	251,743	250,121	-1,622 (-0.6%)
	Above Normal	249,843	249,892	50 (0.02%)
	Below Normal	242,565	260,419	17,854 (7%)
	Dry	275,674	268,798	-6,876 (-2%)
	Critical	278,675	272,849	-5,826 (-2%)
	All	259,988	259,347	-641 (-0.2%)
September	Wet	211,699	214,296	2,598 (1%)
	Above Normal	276,118	295,892	19,774 (7%)
	Below Normal	310,740	302,440	-8,300 (-3%)
	Dry	297,451	292,461	-4,990 (-2%)
	Critical	295,609	280,631	-14,979 (-5%)
	All	268,392	267,828	-564 (0%)
October	Wet	299,153	309,714	10,561 (4%)
	Above Normal	314,152	310,779	-3,373 (-1%)
	Below Normal	315,959	316,970	1,010 (0.3%)
	Dry	304,903	313,978	9,075 (3%)
	Critical	285,343	276,228	-9,115 (-3%)
	All	303,031	306,949	3,918 (1.3%)
November	Wet	85,349	144,206	58,856 (69%)
	Above Normal	98,745	181,551	82,805 (84%)
	Below Normal	205,611	218,534	12,923 (6%)
	Dry	226,866	229,131	2,266 (1%)
	Critical	263,119	246,772	-16,348 (-6%)
	All	164,944	195,997	31,052 (19%)

Month	WYT	NAA	PA	PA vs. NAA
December	Wet	189,341	192,905	3,565 (2%)
	Above Normal	186,103	186,289	186 (0.1%)
	Below Normal	198,802	198,407	-395 (-0.2%)
	Dry	192,969	189,522	-3,447 (-2%)
	Critical	274,875	276,177	1,303 (0.5%)
	All	203,713	204,173	460 (0.2%)

Table 5.4-49. Spring-Run Chinook Salmon Spawning Weighted Usable Area (WUA) and Differences (Percent Differences) in River Segment 5 between Model Scenarios (green indicates PA is at least 5% higher [raw difference] than NAA; red indicates PA is at least 5% lower)

Month	WYT	NAA	PA	PA vs. NAA
August	Wet	357,991	352,739	-5,253 (-1%)
	Above Normal	349,522	350,996	1,474 (0.4%)
	Below Normal	331,458	384,187	52,730 (16%)
	Dry	430,234	408,673	-21,561 (-5%)
	Critical	441,885	425,204	-16,681 (-4%)
	All	382,986	380,928	-2,058 (-0.5%)
September	Wet	236,285	242,981	6,696 (3%)
	Above Normal	430,088	490,178	60,089 (14%)
	Below Normal	585,549	589,389	3,840 (0.7%)
	Dry	579,037	577,758	-1,280 (-0.2%)
	Critical	579,158	563,100	-16,058 (-3%)
	All	447,637	457,140	9,502 (2.1%)
October	Wet	498,680	538,887	40,207 (8%)
	Above Normal	552,311	545,589	-6,721 (-1%)
	Below Normal	585,179	557,994	-27,185 (-5%)
	Dry	572,802	575,143	2,341 (0.4%)
	Critical	567,178	551,594	-15,584 (-3%)
	All	546,822	553,309	6,488 (1.2%)
November	Wet	380,656	520,050	139,394 (37%)
	Above Normal	422,460	533,933	111,473 (26%)
	Below Normal	587,346	586,203	-1,143 (-0.2%)
	Dry	564,042	569,862	5,820 (1%)
	Critical	539,474	552,498	13,024 (2%)
	All	483,727	548,197	64,470 (13%)

Month	WYT	NAA	PA	PA vs. NAA
December	Wet	475,398	457,821	-17,577 (-4%)
	Above Normal	493,732	461,657	-32,075 (-6%)
	Below Normal	475,415	470,507	-4,908 (-1%)
	Dry	432,047	432,627	580 (0.1%)
	Critical	535,780	532,304	-3,475 (-0.6%)
	All	476,358	464,926	-11,432 (-2%)

Table 5.4-50. Spring-Run Chinook Salmon Spawning Weighted Usable Area (WUA) and Differences (Percent Differences) in River Segment 4 between Model Scenarios (green indicates PA is at least 5% higher [raw difference] than NAA; red indicates PA is at least 5% lower)

Month	WYT	NAA	PA	PA vs. NAA
August	Wet	134,404	133,896	-508 (-0.4%)
	Above Normal	136,051	136,053	2 (0%)
	Below Normal	127,707	136,842	9,135 (7%)
	Dry	142,402	140,006	-2,396 (-2%)
	Critical	148,854	149,882	1,029 (0.7%)
	All	137,832	138,463	631 (0%)
September	Wet	110,983	111,256	272 (0.2%)
	Above Normal	146,690	152,626	5,936 (4%)
	Below Normal	219,170	240,628	21,457 (10%)
	Dry	242,792	252,590	9,798 (4%)
	Critical	242,618	252,566	9,948 (4%)
	All	182,569	190,321	7,751 (4%)
October	Wet	155,097	167,335	12,237 (8%)
	Above Normal	168,198	169,618	1,420 (0.8%)
	Below Normal	194,636	169,106	-25,530 (-13%)
	Dry	203,681	188,415	-15,266 (-7%)
	Critical	233,616	231,468	-2,148 (-1%)
	All	186,036	182,620	-3,416 (-2%)
November	Wet	131,699	156,053	24,354 (18%)
	Above Normal	131,743	172,295	40,553 (31%)
	Below Normal	198,448	210,003	11,555 (6%)
	Dry	211,308	216,165	4,858 (2%)
	Critical	261,540	245,589	-15,950 (-6%)
	All	179,662	193,893	14,231 (8%)

Month	WYT	NAA	PA	PA vs. NAA
December	Wet	182,846	186,060	3,215 (2%)
	Above Normal	183,340	184,920	1,579 (0.9%)
	Below Normal	193,754	192,608	-1,146 (-0.6%)
	Dry	176,833	179,354	2,521 (1%)
	Critical	248,662	250,069	1,407 (0.6%)
	All	192,666	194,607	1,941 (1%)

5.4.2.1.3.2.1.1.2 Redd scour

The probability of flows occurring under the PA and the NAA that would be high enough to mobilize sediments and scour spring-run Chinook salmon redds was estimated from CALSIM II estimates of mean monthly flows, using a relationship determined from the historical record between actual mean monthly flow and maximum daily flow (Appendix 5.D, Section 5.D.2.2, *Spawning Flows Methods*). The actual monthly and daily flow data used in the analysis are from gage records just below Keswick Dam and at Bend Bridge, and the CALSIM II estimates used to compare probabilities of redd scour for the PA and the NAA are for the Keswick Dam and Red Bluff locations. As discussed in Appendix 5.D, Section 5.D.2.2, *Spawning Flows Methods*, 40,000 cfs is treated as the minimum daily flow at which redd scour occurs in the Sacramento River. The analysis of the Keswick Dam gage data shows that for months with a mean monthly flow of at least 27,300 cfs, the maximum daily flow in that month is always at least 40,000 cfs. The Bend Bridge gage data show that for months with a mean flow of at least 21,800 cfs, the maximum daily flow in that month is always 40,000 cfs. Therefore, redd scour probabilities for the PA and the NAA were evaluated by comparing frequencies of CALSIM II flows greater than 27,300 cfs at Keswick Dam or greater than 21,800 cfs at Red Bluff during the spring-run August through December spawning and incubation period. Further information on the redd scour analysis methods is provided in Appendix 5.D, Section 5.D.2.2, *Spawning Flows Methods*.

Table 5.4-53 shows that fewer than 5% of months in the CALSIM II record during the spawning and incubation period of spring-run Chinook salmon (August through December) would have flows of more than 27,300 cfs at Keswick Dam or more than 21,800 cfs at Red Bluff. This was expected, given that all of the months of the spring-run spawning and incubation period except December rarely experience such high flows. Water years and months with mean monthly flow greater than 27,300 cfs predicted at Keswick Dam for the spring-run spawning and incubation period (under either the PA or the NAA or both) are listed in Table 5.4-46a, and those with mean monthly flow greater than 21,800 cfs predicted at Red Bluff are listed in Table 5.4.46b. Differences between the PA and the NAA in the percentage of scouring flows at either location are insignificant.

Table 5.4-51. Water Years and Months with Mean Flow > 27,300 cfs at Keswick Dam for the PA and/or the NAA during the Spring-run Chinook Salmon Spawning and Incubation Period

Water Year	Month	WYT	Flow (cfs)	
			NAA	PA
1945	December	Below Normal	31,540	29,102
1955	December	Dry	27,318	26,935
1973	November	Above Normal	29,514	29,913
1983	December	Wet	33,201	33,201

Table 5.4-52. Water Years and Months with Mean Flow > 21,800 cfs at Red Bluff for the NAA and/or the NAA during the Spring-run Chinook Salmon Spawning and Incubation Period

Water Year	Month	WYT	Flow (cfs)	
			NAA	PA
1937	December	Dry	30,649	30,029
1940	December	Above Normal	20,610	22,620
1941	December	Wet	21,964	23,292
1945	December	Below Normal	44,541	42,119
1950	December	Dry	24,773	24,789
1951	December	Above Normal	20,624	23,775
1955	December	Dry	43,925	43,545
1958	December	Wet	22,228	22,228
1964	December	Dry	34,329	32,345
1969	December	Wet	26,013	28,454
1973	November	Above Normal	38,394	38,789
1973	December	Above Normal	33,753	33,749
1981	December	Dry	38,173	38,204
1982	December	Wet	23,928	23,927
1983	December	Wet	53,169	53,169
1996	December	Wet	30,177	34,956
2002	December	Dry	22,758	21,248

Note that SALMOD also predicts redd scour risk for spring-run Chinook salmon in the Sacramento River, although it is combined with redd dewatering and the combination is reported as “Incubation” mortality. Please see Table 5.4-50 below for these results.

5.4.2.1.3.2.1.1.3 Redd dewatering

The percentage of spring-run Chinook salmon redds dewatered by reductions in Sacramento River flow was estimated from CALSIM II estimates of monthly mean flows during the 3 months following each of the months that spring-run spawn (Appendix 5.D, Section 5.D.2.2, *Spawning Flows Methods*, Table 5.D-54). This analysis employed functional relationships developed in field studies by USFWS (2006) that predicted percentages of redds dewatered from an array of paired spawning and dewatering flows. As described above for the spawning WUA analyses, redd dewatering for spring-run was modeled using the relationship developed for fall-run Chinook salmon. Because, as noted in Section 5.4.2.1.3.1.1.1.1, *Spawning WUA*, spring-run spawning has peaked, on average, in river Segment 5 based on recent redd surveys, the Segment 5 CALSIM II flows were used to estimate redd dewatering under the PA and NAA. The CALSIM II flows for Segments 4 and 6 are similar to those for Segment 5, so redd dewatering estimates using the Segment 4 and Segment 6 flows differ little from those for Segment 5 (Appendix 5.D, Section 2.6, *Redd Dewatering Results*, *Sacramento River Segments 4 and 6*). Further information on the redd dewatering analysis methods is provided in Appendix 5.D, Section 5.D.2.2, *Spawning Flows Methods*.

Differences in spring-run redd dewatering under the PA and NAA were examined using exceedance plots of mean monthly percent dewatered for the August through October months that spring-run spawn. The exceedance curves for the PA generally show slightly higher redd dewatering percentages than those for the NAA for all water year types combined, and substantially higher dewatering percentages for above normal and below normal water year types in particular (Figure 5.4-131 through Figure 5.4-136). The biggest differences in the dewatering curves are predicted for above normal water years, with about 24% of all months having greater than 20% of redds dewatered under the NAA, but about 43% of all months having greater than 20% of redds dewatered under the PA.

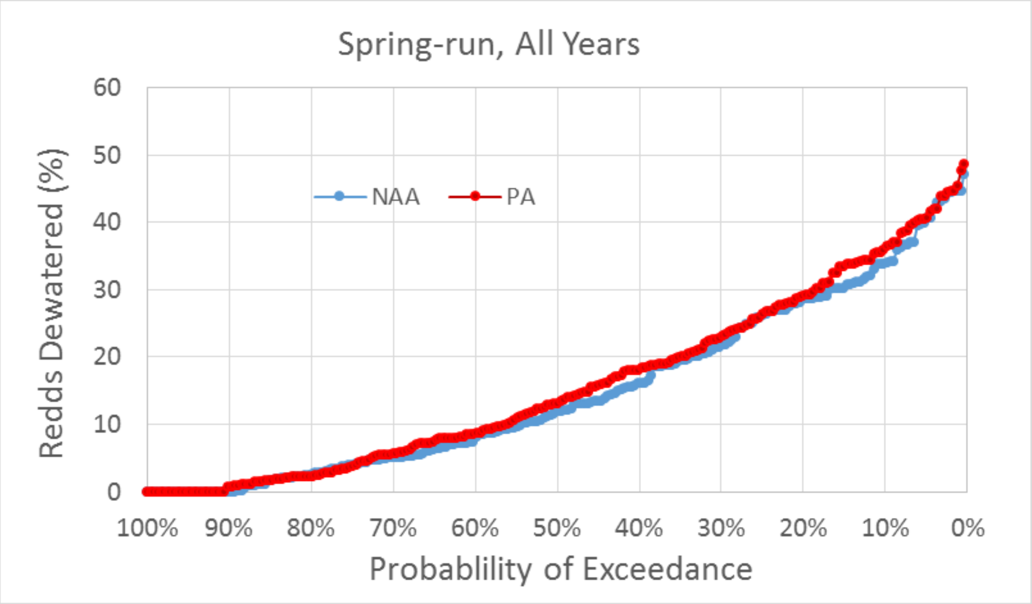

Figure 5.4-131. Exceedance Plot of Spring-Run Chinook Salmon Percent of Redds Dewatered for NAA and PA Model Scenarios, All Water Years

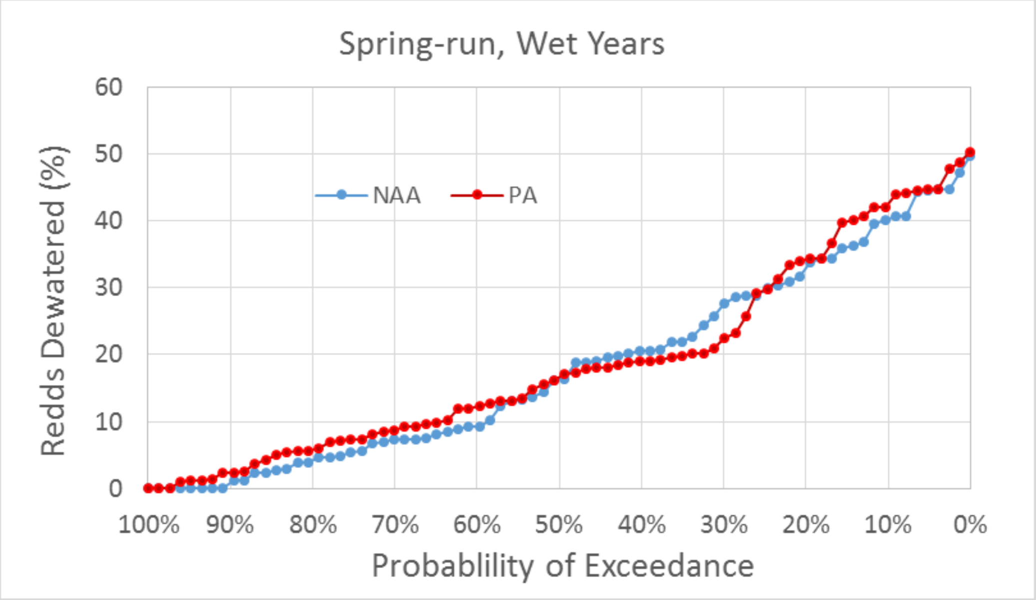

Figure 5.4-132. Exceedance Plot of Spring-Run Chinook Salmon Percent of Redds Dewatered for NAA and PA Model Scenarios, Wet Water Years

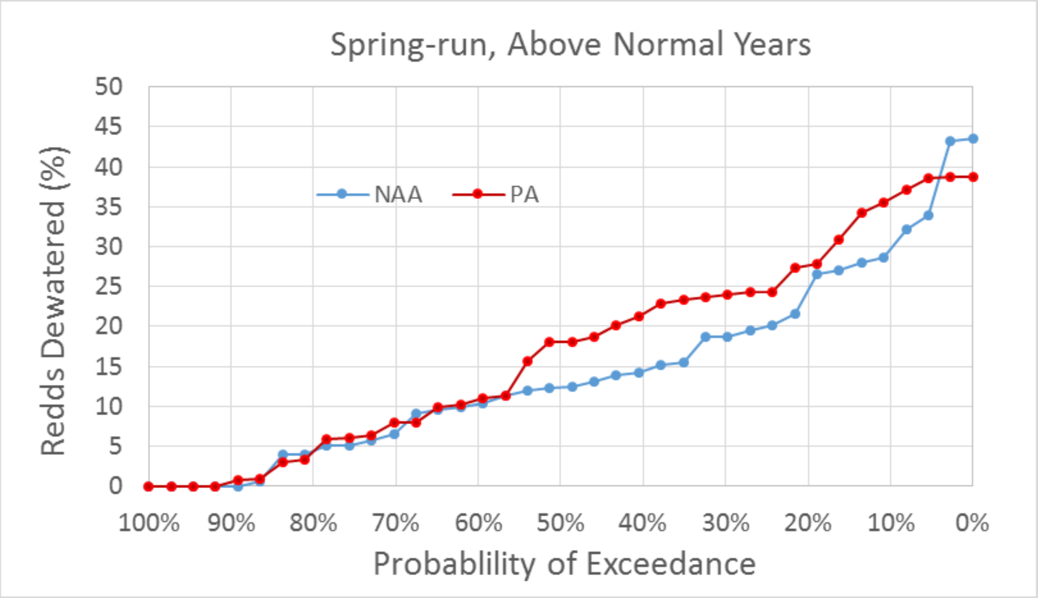

Figure 5.4-133. Exceedance Plot of Spring-Run Chinook Salmon Percent of Redds Dewatered for NAA and PA Model Scenarios, Above Normal Water Years

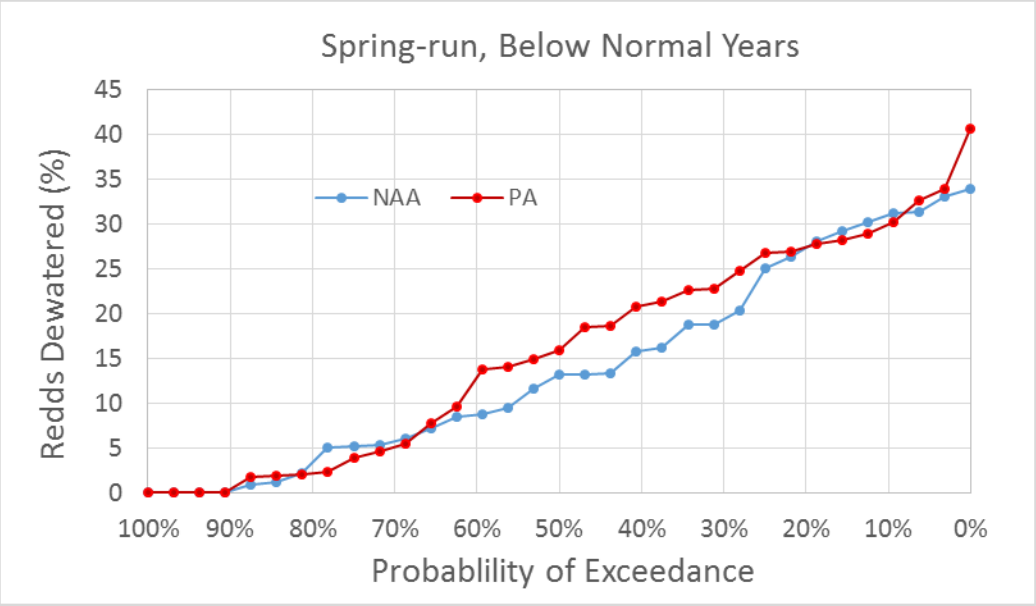

Figure 5.4-134. Exceedance Plot of Spring-Run Chinook Salmon Percent of Redds Dewatered for NAA and PA Model Scenarios, Below Normal Water Years

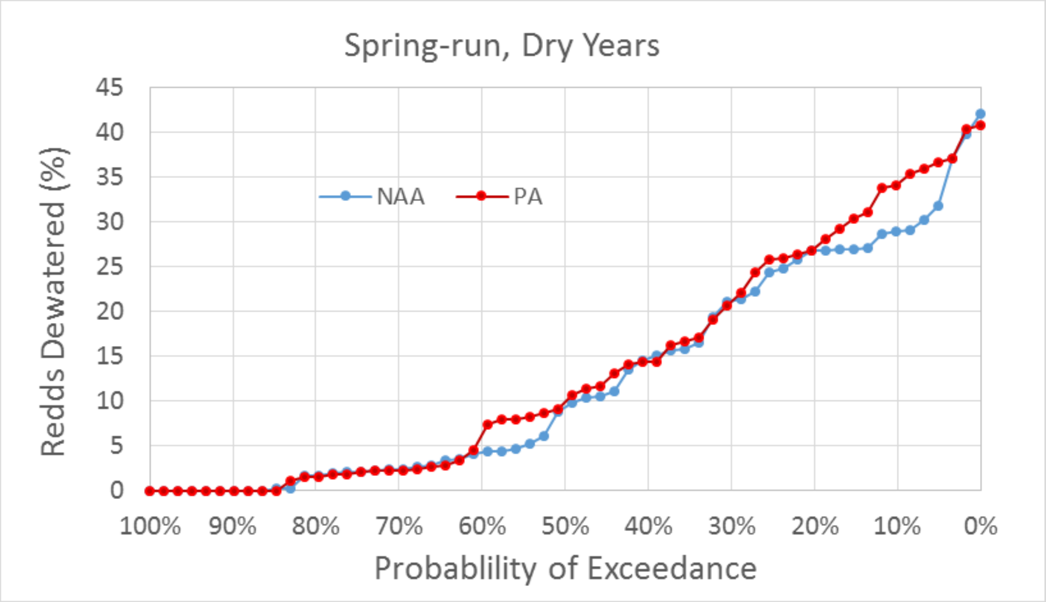

Figure 5.4-135. Exceedance Plot of Spring-Run Chinook Salmon Percent of Redds Dewatered for NAA and PA Model Scenarios, Dry Water Years

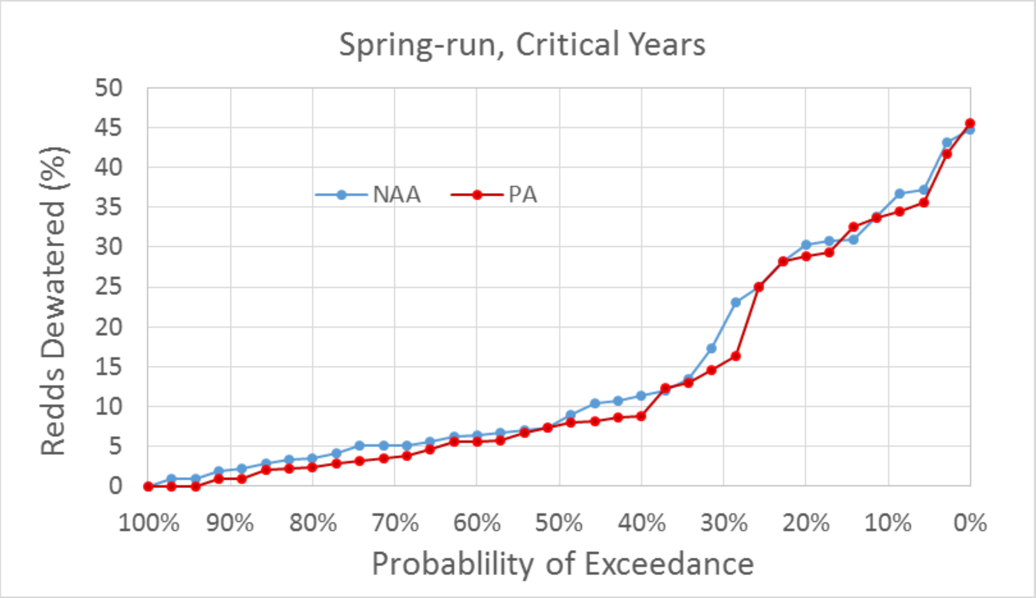

Figure 5.4-136. Exceedance Plot of Spring-Run Chinook Salmon Percent of Redds Dewatered for NAA and PA Model Scenarios, Critical Water Years

Differences in redd dewatering between the PA and NAA were also examined using the grand mean percentages of redds dewatered for each month of spawning under each water type and all water year types combined (Table 5.4-53). During August, the mean percent of redds dewatered would be 5% and 8% greater under the PA than under the NAA in wet and above normal water years, respectively. During October, the mean under the PA would be 5% lower in wet years and 6% higher in below normal years. During September of below normal water years, the mean percent of redds dewatered would be up to 3% lower under the PA than under the NAA. The percent differences between the PA and the NAA in the percent of redds dewatered are generally large, but for many months and water year types this is an artifact of the low percentages of redds dewatered under both scenarios. These results indicate that, in general, a greater percentage of spring-run Chinook salmon redds would be dewatered in August under the PA, but the differences, on balance, would be insignificant between the PA and the NAA during September and October. Further discussion regarding flow-related effects during the June through November period is provided in Section 5.4.2.3, *Summary of Upstream Effects*.

Table 5.4-53. Spring-Run Chinook Salmon Percent of Redds Dewatered (Percent of Total Redds) and Differences (Percent Differences) between Model Scenarios (green indicates PA is at least 5% lower [raw difference] than NAA; red indicates PA is at least 5% higher)

Month	WYT	NAA	PA	PA vs. NAA
August	Wet	10.0	15.0	5 (50%)
	Above Normal	13.0	21.4	8 (64%)
	Below Normal	27.9	29.4	1 (5%)
	Dry	27.1	29.4	2 (9%)
	Critical	30.9	29.7	-1 (-4%)
	All	20.1	23.6	3 (17%)
September	Wet	30.2	31.9	2 (6%)
	Above Normal	17.9	16.5	-1 (-8%)
	Below Normal	5.6	2.7	-3 (-52%)
	Dry	3.1	1.9	-1 (-38%)
	Critical	6.0	4.4	-2 (-26%)
	All	14.8	14.2	-0.6 (-4%)
October	Wet	14.5	9.9	-5 (-32%)
	Above Normal	12.4	13.1	1 (5%)
	Below Normal	9.1	15.4	6 (70%)
	Dry	7.9	9.9	2 (26%)
	Critical	6.7	6.1	-1 (-9%)
	All	10.7	10.6	-0.1 (-1%)

5.4.2.1.3.2.1.1.4 SALMOD flow-related outputs

The SALMOD model provides predicted flow-related mortality of spring-run Chinook salmon spawning, eggs, and alevins in the Sacramento River. The SALMOD results for flow-related mortality are presented in Table 5.4-54, together with results for the other sources of mortality of spring-run Chinook salmon predicted by SALMOD and discussed in other sections of this document. The flow-related mortality of spring-run Chinook salmon spawning, eggs, and alevins is split up as “incubation” (which refers to redd dewatering and scour) and “superimposition” (of redds) mortality (see Attachment 5.D.2, *SALMOD Model*, for full model description). The annual exceedance plot of flow-related mortality of spring-run Chinook salmon spawning, eggs, and alevins is presented in Figure 5.4-137. These results indicate that there would be increases in flow-related mortality of spring-run Chinook salmon spawning, eggs, and alevins from incubation-related factors under the PA relative to the NAA for all water year types except dry years. The largest increases, about 30%, would be for wet, above normal and below normal water year types. No mortality is predicted from redd superimposition for either scenario. It should be noted, however, that SALMOD predicts redd superimposition for each race of salmon without consideration of redd densities of the other races. SALMOD predicts no superimposition for spring-run because numbers of spring-run spawners are low. However, the spring-run spawning period (August to December) considerably overlaps that of fall-run Chinook salmon (September through January) and the spawning reaches also overlap, so the SALMOD prediction of low superimposition of spring-run redds may be unreliable.

Table 5.4-54. Mean Annual Spring-Run Chinook Salmon Mortality[1] (# of Fish/Year) Predicted by SALMOD

	Spawning, Egg Incubation, and Alevins							Fry and Juvenile Rearing									
	Temperature-Related Mortality			Flow-Related Mortality				Temperature-Related Mortality				Flow-Related Mortality					
Analysis Period	Pre-Spawn	Eggs	Subtotal	Incubation	Super-imposition	Subtotal	Life Stage Total	Fry	Pre-smolt	Immature Smolt	Subtotal	Fry	Pre-smolt	Immature Smolt	Subtotal	Life Stage Total	Grand Total
All Water Year Types2																	
NAA	46,032	124,013	170,045	1,905	0	1,905	171,950	1	0	0	1	2,265	0	0	2,265	2,265	174,215
PA	50,462	107,473	157,935	2,118	0	2,118	160,053	0	0	0	0	2,273	0	0	2,273	2,273	162,325
Difference	4,431	-16,540	-12,110	212	0	212	-11,898	-1	0	0	-1	8	0	0	8	7	-11,890
Percent Difference[3]	10	-13	-7	11	0	11	-7	-100	0	0	-100	0	0	0	0	0	-7
Water Year Types4																	
Wet (32.5%)																	
NAA	116	6,530	6,646	1,336	0	1,336	7,983	0	0	0	0	2,614	0	0	2,614	2,614	10,597
PA	117	5,835	5,952	1,748	0	1,748	7,699	0	0	0	0	2,815	0	0	2,815	2,815	10,514
Difference	1	-695	-695	411	0	411	-283	0	0	0	0	200	0	0	200	200	-83
Percent Difference	0	-11	-10	31	0	31	-4	0	0	0	NA5	8	0	0	8	8	-1
Above Normal (12.5%)																	
NAA	78	4,181	4,258	1,162	0	1,162	5,420	0	0	0	0	2,703	0	0	2,703	2,703	8,124
PA	65	3,888	3,953	1,509	0	1,509	5,463	0	0	0	0	2,354	0	0	2,354	2,354	7,816
Difference	-12	-293	-305	347	0	347	42	0	0	0	0	-350	0	0	-350	-350	-307
Percent Difference	-16	-7	-7	30	0	30	1	0	0	0	NA	-13	0	0	-13	-13	-4
Below Normal (17.5%)																	
NAA	154	34,929	35,084	1,300	0	1,300	36,384	0	0	0	0	2,634	0	0	2,634	2,634	39,018
PA	309	41,242	41,551	1,711	0	1,711	43,262	0	0	0	0	2,591	0	0	2,591	2,591	45,853
Difference	155	6,313	6,467	411	0	411	6,878	0	0	0	0	-43	0	0	-43	-43	6,835
Percent Difference	100	18	18	32	0	32	19	0	0	0	NA	-2	0	0	-2	-2	18
Dry (22.5%)																	
NAA	1,093	66,312	67,406	3,652	0	3,652	71,058	0	0	0	0	2,468	0	0	2,468	2,468	73,526
PA	995	64,050	65,045	3,422	0	3,422	68,467	0	0	0	0	2,438	0	0	2,438	2,438	70,905
Difference	-98	-2,263	-2,361	-230	0	-230	-2,591	0	0	0	0	-30	0	0	-30	-30	-2,621
Percent Difference	-9	-3	-4	-6	0	-6	-4	0	0	0	NA	-1	0	0	-1	-1	-4
Critical (15%)																	
NAA	304,677	671,412	976,089	1,670	0	1,670	977,759	3	0	0	3	408	0	0	408	411	978,170
PA	334,238	560,737	894,976	1,835	0	1,835	896,811	0	0	0	0	463	0	0	463	463	897,274
Difference	29,562	-110,675	-81,113	165	0	165	-80,949	-3	0	0	-3	55	0	0	55	52	-80,897
Percent Difference	10	-16	-8	10	0	10	-8	-100	0	0	-100	14	0	0	14	13	-8

[1] Mortality values do not include base mortality

[2] Based on the 80-year simulation period

[3] Relative difference of the Annual average

[4] As defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (State Water Resources Control Board 1995). Water years may not correspond to the biological years in SALMOD.

[5] NA = Unable to calculate because dividing by 0

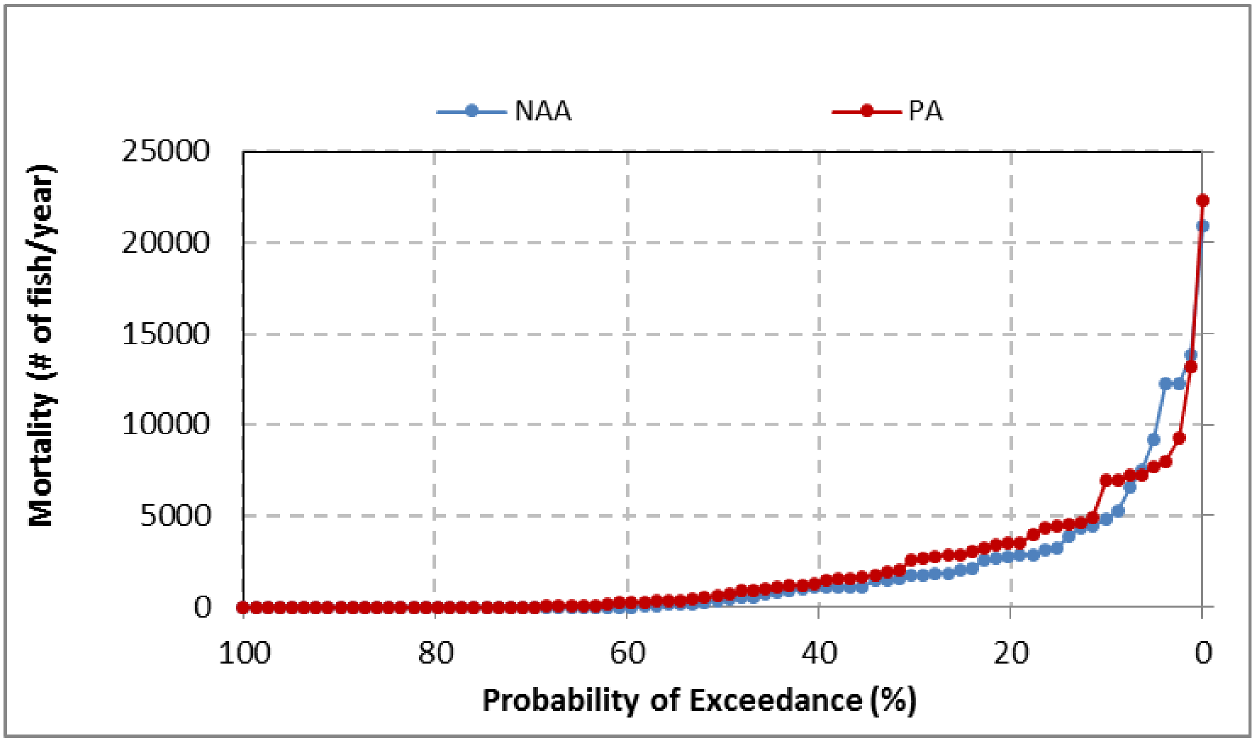

Figure 5.4-137. Exceedance Plot of Annual Flow-Based Mortality (#of Fish/Year) of Spring-Run Chinook Salmon Spawning, Egg Incubation, and Alevins

5.4.2.1.3.2.1.2 Water Temperature-Related Effects

Modeled mean monthly water temperatures during the August through December spawning and incubation period for spring-run Chinook salmon (Table 5.4-27) are presented in Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results*, Table 5.C.7-3, Table 5.C.7-4, Table 5.C.7-5, Table 5.C.7-7, Table 5.C.7-8. Overall, the PA would change mean water temperatures very little (predominantly less than 1°F, or approximately 1%) throughout the spawning reach of Keswick Dam to Red Bluff in all months of the period and water year types. The largest increase in mean monthly water temperatures under the PA relative to NAA would be 0.6°F, or up to 1.1%, and would occur at Red Bluff in above normal years during August, and above- and below normal years during September; and at Bend Bridge in below normal years during September. The increases during September would occur during the period of peak presence of spawners, eggs, and alevins.

Exceedance plots of monthly mean water temperatures were examined during each month throughout the spawning and incubation period (Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results*, Figure 5.C.7.3-7, Figure 5.C.7.4-7, Figure 5.C.7.5-7, Figure 5.C.7.7-7, Figure 5.C.7.8-7). The values for the PA in these exceedance plots generally match those of the NAA. Further examination of above normal water years during August (Figure 5.4-59) and September (
Figure 5.4-60) at Red Bluff, below normal years during September at Red Bluff (Figure 5.4-61), and below-normal years during September at Bend Bridge (Figure 5.4-62), where the largest increases in mean monthly water temperatures were seen, reveals that there is a general trend

towards higher temperatures under the PA but that the difference of 0.6°F in mean monthly temperatures between NAA and PA results in insignificant differences between curves for the NAA and PA in each exceedance plot.

To evaluate water temperature threshold exceedance during the spawning, egg incubation, and alevin life stages between Keswick Dam and Red Bluff, the USEPA's 7DADM threshold value of 55.4°F was used (Appendix 5.D, Section 5.D.2.1, *Water Temperature Analysis Methods*, Table 5.D-49) (U.S. Environmental Protection Agency 2003). The threshold was converted to function with daily model outputs for each month separately (Appendix 5.D, Section 5.D.2.1, *Water Temperature Analysis Methods*, Table 5.D-51).

Results of the water temperature thresholds analysis are presented in Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-80 through Table 5.D-84. At Keswick Dam, there would be no months or water year types in which there would be 5% more days under the PA compared to the NAA on which temperatures would exceed the threshold (Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-80). There would be two instances in which the percent of days exceeding the threshold would be lower under the PA relative to the NAA: November of wet (5.9%) and above normal (13.3%) years. However, in no case would there be a more-than-0.5°F difference in the magnitude of average daily exceedance. Therefore, it was concluded that there would be biologically meaningful effect at Keswick Dam.

At Clear Creek, the percent of days exceeding the 55.4°F 7DADM threshold under the PA would be more than 5% higher than under the NAA during August (7.6%) and September (6.4%) of below normal years, and October (7.3%) and November (5.3%) of dry years (Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-81). There would also be a reduction of 8.9% in the percent of days exceeding the threshold in August of above normal water years. However, in no month or water year type would there be a more-than-0.5°F difference in the magnitude of average daily exceedance. Therefore, it was concluded that there would be no biologically meaningful effect at Clear Creek.

At Balls Ferry, the percent of days exceeding the 55.4°F 7DADM threshold under the PA would be more than 5% higher than under the NAA during August (7.4%) and September (16.7%) of above normal water years (Appendix 5.D,, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-82). There would also be an increase in the percent of days exceeding the threshold in wet (8.5%) and above normal (13.9%) water years for August and September, respectively. However, in no case would there be a more-than-0.5°F difference in the magnitude of average daily exceedance. Therefore, it was concluded that there would be no biologically meaningful effect at Balls Ferry.

At Bend Bridge, the percent of days exceeding the 55.4°F 7DADM threshold under the PA would be more than 5% higher than under the NAA during September of above normal years (8.2%), and the percent of days exceeding the 55.4°F 7DADM threshold under the PA would be more than 5% lower than under the NAA during November of wet (7.1%) and above normal (12.2%) water years (Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-83). However, in none of these situations would there also be a more-than-0.5°F difference in the magnitude of average daily exceedance. There was only one month/water year type combination in which the average daily exceedance would be more than 0.5°F, which was September of below normal water years (0.6°F), but there was no concurrent difference in the percent of days exceeding the threshold. Therefore, it was concluded that there would be no biologically meaningful effect at Bend Bridge.

At Red Bluff, there would be no months or water year types in which there would be both 5% more days under the PA compared to the NAA on which temperatures would exceed the threshold and a more-than-0.5°F difference in the magnitude of average daily exceedance (Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-84). There would be two water year types (wet and above normal) during November in which there would be 10.1% and 11.4% reductions, respectively, in the percent of days exceeding the threshold, but there was no concurrent difference in the magnitude of average daily exceedance. . Therefore, it was concluded that there would be no biologically meaningful effect at Red Bluff.

Overall, the thresholds analysis indicates that there would be more exceedances (5% or greater) in certain months and water year types under the PA, which could have lethal or sublethal effects on spawning, egg incubation, and alevins, although this does not consider real-time operational management described in Section 3.1.5, *Real-Time Operations Upstream of the Delta*, and Section 3.3.3, *Real-Time Operational Decision-Making Process*, that would be used to avoid and minimize any modeled effects. Further, this analysis does not consider the current revision process to OCAP RPA Action Suite 1.2 described in Section 3.1.4.5, *Annual/Seasonal Temperature Management Upstream of the Delta*, to improve winter-run Chinook salmon egg-to-fry survival. This process may result in refinements and additions to the existing annual/seasonal temperature management processes, including spring storage targets, revised temperature compliance criteria and a range in summertime Keswick release rates. Although the process targets winter-run Chinook salmon, these changes are expected to benefit other races of Chinook salmon. The biological interpretation of these results, combined with all upstream results, in the context of real-time operational management is provided in Section 5.4.2.3, *Summary of Upstream Effects*, below.

The Reclamation Egg Mortality Model provides temperature-related estimates of spring-run egg mortality in the Sacramento River (see Appendix 5.D, Attachment 1, *Reclamation Egg Mortality Model*, for full model description). As noted in Appendix 5.D, Section 5.D.2.1. *Water Temperature Analysis Methods*, NMFS believes this model underestimates temperature related mortality and likely is not sensitive enough to capture small differences in scenarios or temperature related mortality experienced by recent winter-run brood years and, as a result, should be viewed with caution until a more accurate model is developed or there is better understanding of temperature effects on juvenile production. Because of this and the fact that the egg life stage has the highest potential effect on the propagation of population size in a life cycle context, a conservative value of a more-than-2% change in percent of total individuals (on a raw scale) was defined as a biologically meaningful effect for Reclamation Egg Mortality Model results (see Appendix 5.D, Section 5.D.2.1.2.3, *Reclamation Egg Mortality Model*, for details). Results of the model are presented in Table 5.4-55 and Figure 5.4-138 through Figure 5.4-143.

The results indicate that there would be no large increases in egg mortality under the PA relative to the NAA. The largest increase in mean egg mortality would be 1.9% (raw difference) in below-normal water years. There would be a biologically meaningful reduction in egg mortality of 6.7% in critical water years, although this difference in means is driven largely by 2 years in which egg mortality would be substantially (35% to 45%) reduced under the PA relative to the NAA (Figure 5.4-142).

Table 5.4-55. Spring-run Chinook Salmon Egg Mortality (Percent of Total Individuals) and Differences (Percent Differences) between Model Scenarios, Reclamation Egg Mortality Model

WYT	NAA	PA	PA vs. NAA
Wet	6.3	6.3	0.1 (1%)
Above Normal	5.0	5.4	0.4 (9%)
Below Normal	13.3	15.2	1.9 (14%)
Dry	19.0	19.1	0.1 (0.4%)
Critical	86.3	79.7	-6.7 (-8%)
All	22.0	21.4	-0.6 (-3%)

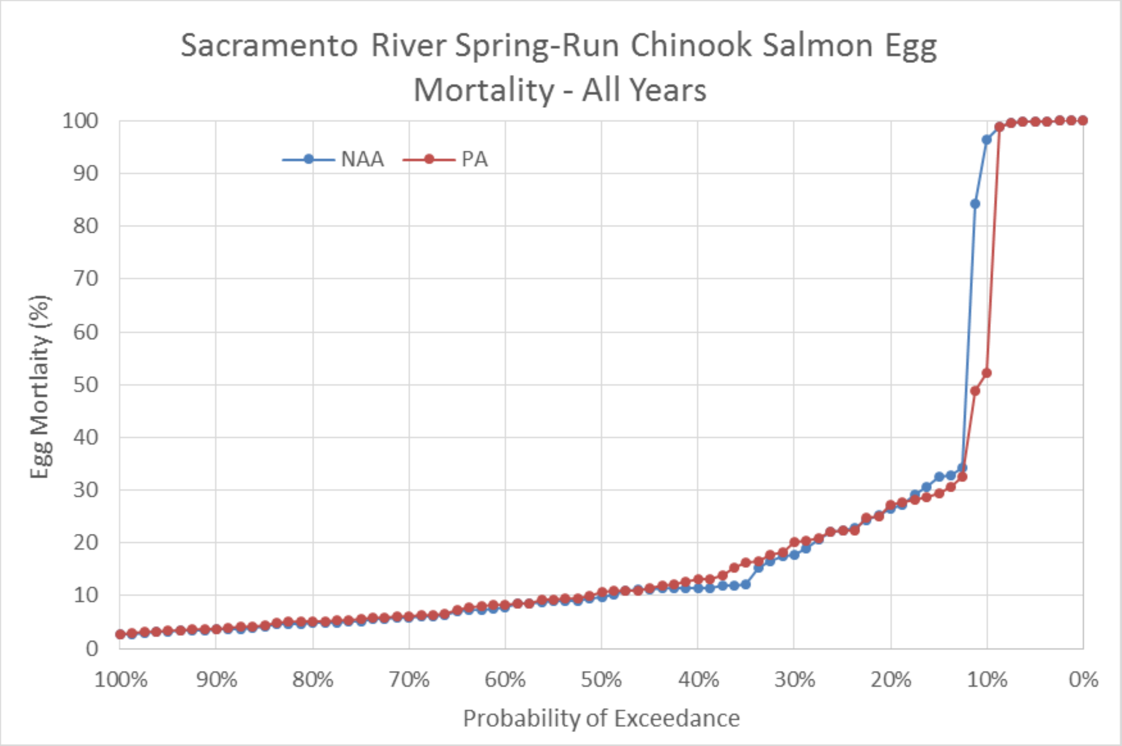

Figure 5.4-138. Exceedance Plot of Spring-Run Chinook Salmon Egg Mortality for NAA and PA Model Scenarios, Reclamation Egg Mortality Model, All Water Years

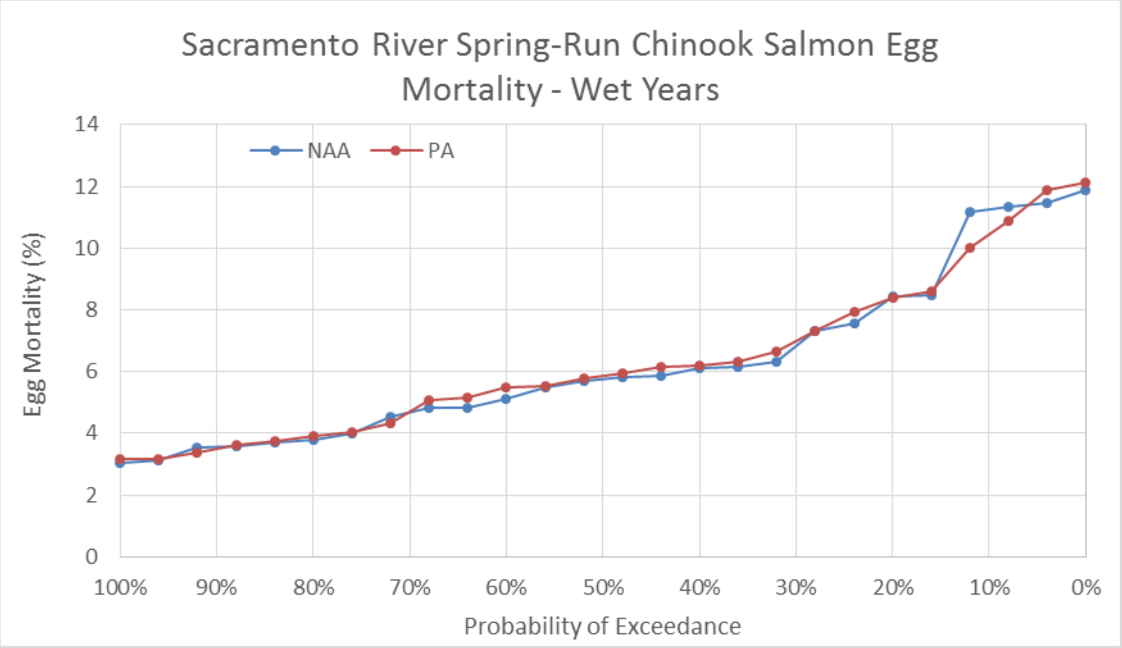

Figure 5.4-139. Exceedance Plot of Spring-Run Chinook Salmon Egg Mortality for NAA and PA Model Scenarios, Reclamation Egg Mortality Model, Wet Water Years

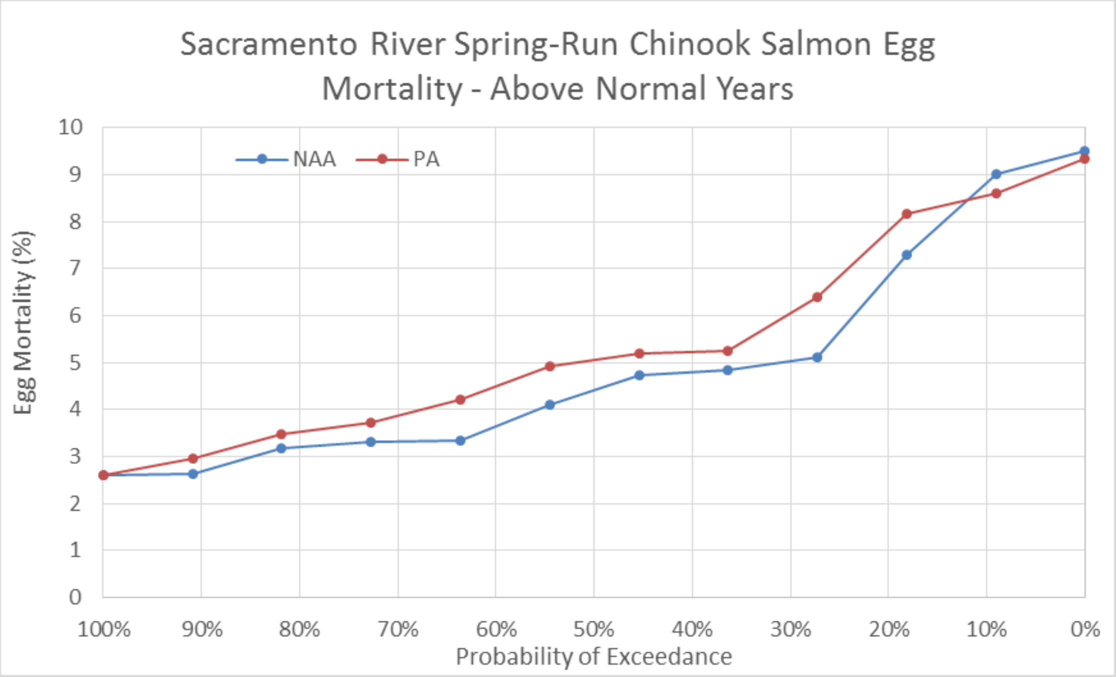

Figure 5.4-140. Exceedance Plot of Spring-Run Chinook Salmon Egg Mortality for NAA and PA Model Scenarios, Reclamation Egg Mortality Model, Above Normal Water Years

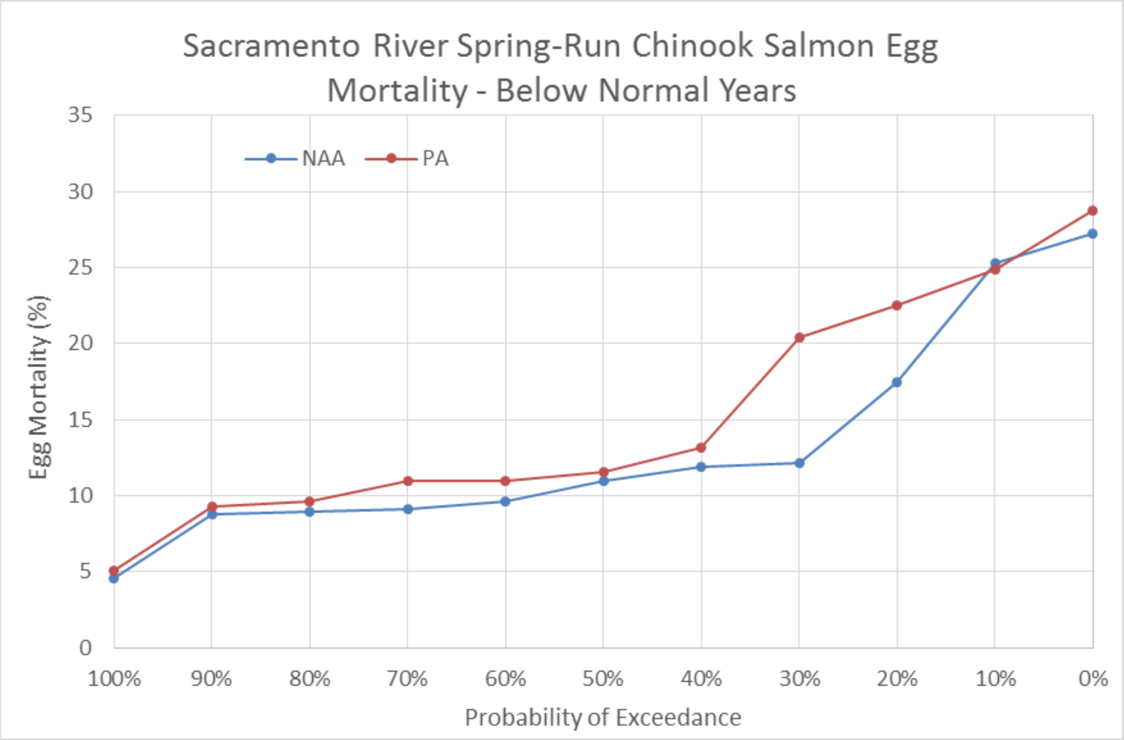

Figure 5.4-141. Exceedance Plot of Spring-Run Chinook Salmon Egg Mortality for NAA and PA Model Scenarios, Reclamation Egg Mortality Model, Below Normal Water Years

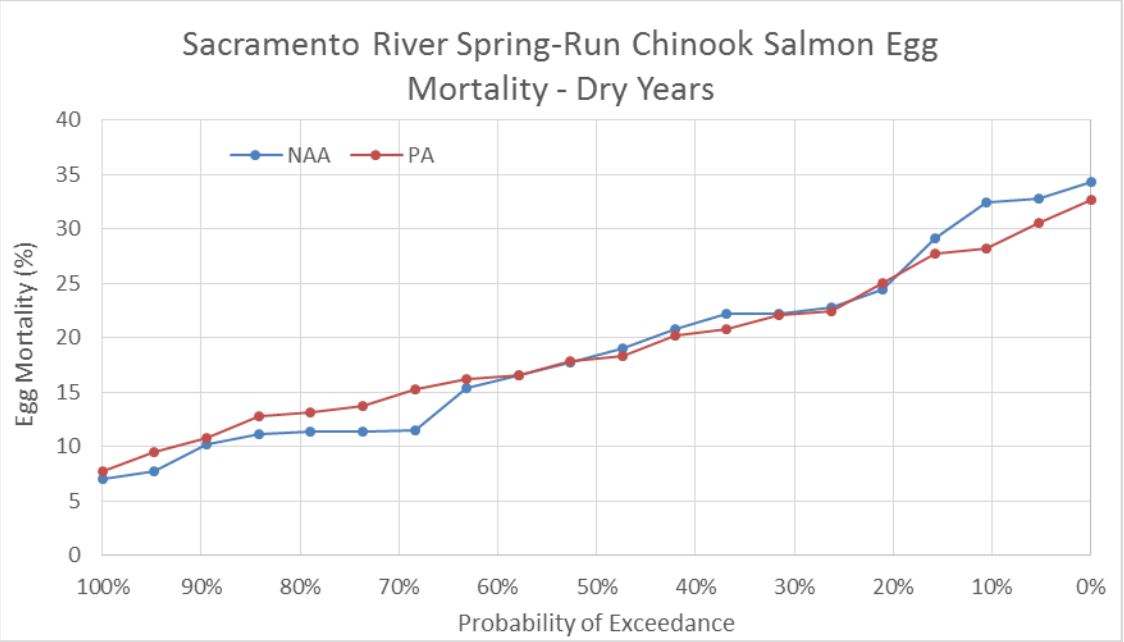

Figure 5.4-142. Exceedance Plot of Spring-Run Chinook Salmon Egg Mortality for NAA and PA Model Scenarios, Reclamation Egg Mortality Model, Dry Water Years

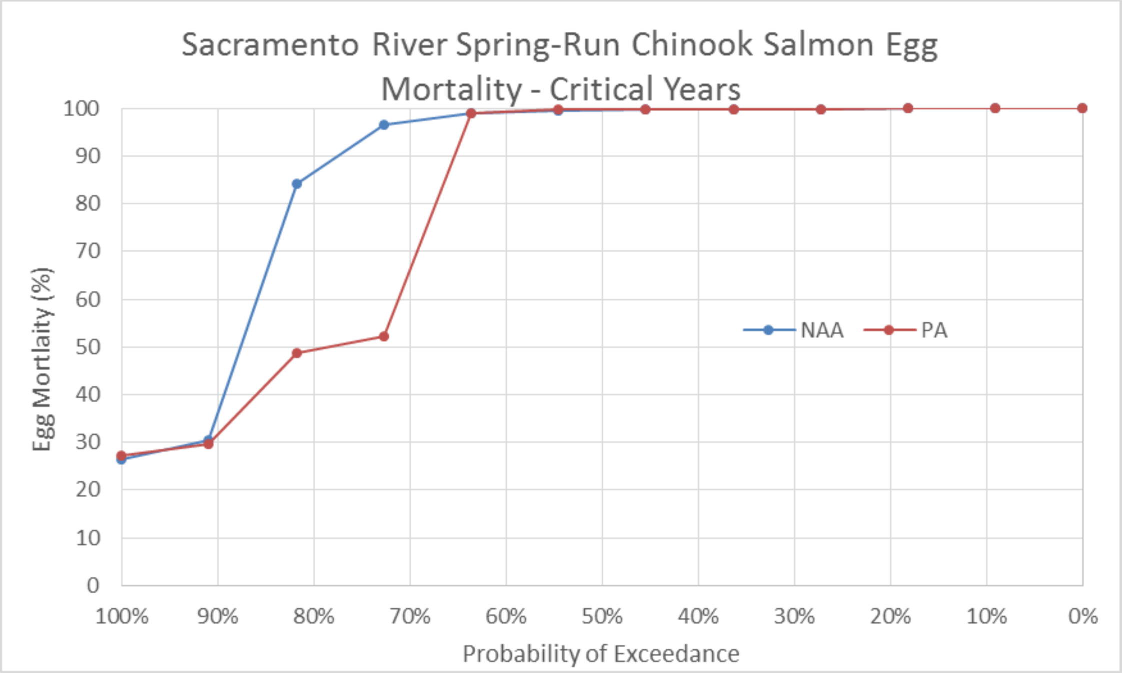

Figure 5.4-143. Exceedance Plot of Spring-Run Chinook Salmon Egg Mortality for NAA and PA Model Scenarios, Reclamation Egg Mortality Model, Critical Water Years

The SALMOD model provides predicted water temperature-related mortality of spring-run Chinook salmon spawning, eggs, and alevins the Sacramento River. This water temperature-related mortality of the combined spring-run Chinook salmon “spawning, eggs, and alevins” life stage is split up as *pre-spawn* (in vivo, or in the mother before spawning) and *egg* (in the gravel) mortality (see Attachment 5.D.2, *SALMOD Model*, for a full description). Results are presented in Table 5.4-54. The annual exceedance plot of temperature-related mortality of spring-run Chinook salmon spawning, eggs, and alevins is presented in Figure 5.4-144. The model indicates that, combining all water year types, water temperature-related mortality of the spawning, egg, and alevin life stage would decrease by 12,110 fish (7%) under the PA relative to the NAA. Within the combined spawning, egg, and alevin life stage, there would be an increase in pre-spawn mortality of 4,431 eggs in the mother (10%) under the PA, but a decrease in egg mortality of 16,540 eggs (13%). Water temperature-related mortality of this combined spawning, egg, and alevin life stage would comprise the large majority (more than 95%) of overall spring-run Chinook salmon mortality and, therefore, can be considered an important source of mortality to early life stages of spring-run Chinook salmon. Individual water year types largely follow the same patterns as for all water year types combined, with few exceptions. Most notably, in below normal years, there would be an overall increase in water temperature-related mortality under the PA in both pre-spawn (100%) and egg (18%) mortality, and an overall increase in water temperature-related mortality under the PA (18%).

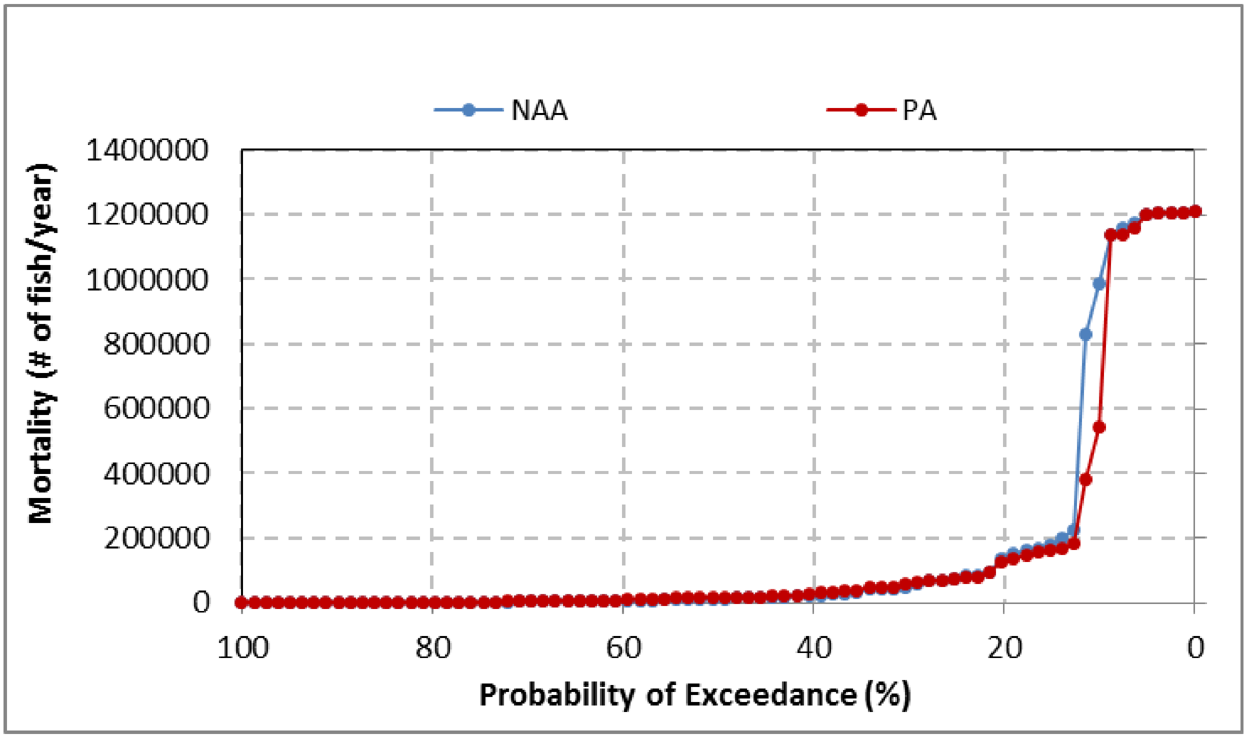

Figure 5.4-144. Exceedance Plot of Annual Water Temperature-Based Mortality (#of Fish/Year) of Spring-Run Chinook Salmon Spawning, Egg Incubation, and Alevins

5.4.2.1.3.2.2 Fry and Juvenile Rearing

5.4.2.1.3.2.2.1 Flow-Related Effects

As discussed above in the winter-run fry and juvenile rearing section and in Appendix 5.D, Section 5.D.2.3, *Rearing Flows Methods*, the stranding of juvenile salmonids is not evaluated in the effects analysis due to limitations of CALSIM modeling. However, current operations of the Sacramento River include ramping rate restrictions, designed to minimize juvenile stranding, that limit the rate at which river flow can be changed. These restrictions would be kept in place for the PA.

Mean monthly flow rates and reservoir storage volumes were examined for the PA and NAA in the Sacramento River at the Keswick to Red Bluff locations during the year-round fry and juvenile rearing period for spring-run Chinook salmon, with peak occurrence during November and December (Table 5.4-25). Changes in flow can affect the instream area available for rearing, along with habitat quality, and can affect stranding of fry and juveniles, especially in side-channel habitats. Shasta Reservoir storage volumes at the end of May and the end of September influence flow rates in the Sacramento River. Mean Shasta May storage under the PA would be similar (less than 5% difference) to storage under NAA for all water year types (Appendix 5.A, *CALSIM Methods and Results*, Table 5.A.6-3). Mean Shasta September storage under the PA would also be similar (less than 5% difference) to storage under NAA for all water year types, except for 7% higher mean storage during critical water years under the PA.

In general, mean flow due to the PA at the Keswick and Red Bluff locations in the Sacramento River flow would be similar to (less than 5% difference) or higher than flow due to the NAA during winter, spring, and summer months and would be similar to or lower than flow due to the NAA during the fall, with exceptions (Appendix 5.A, *CALSIM Methods and Results*, Table 5.A.6-10, Table 5.A.6-35). Flows under the PA during December through August would be similar to (less than 5% difference) or greater than those under the NAA for all months and water year types, except for 13% and 7% lower flow during February of critical water years at Keswick and Red Bluff, respectively, and 10% lower flow during August of below normal years at both locations. Flow increases during the same months would range up to 18% for January of critical years. During June, flows would be greater than 5% higher under the PA than the NAA in all water year types except wet years. Flows under the PA during September through November would be similar to (less than 5% difference) or lower than those under the NAA in all months and water year types, except for flows up to 17% greater during October of below normal and dry years and up to 13% greater during November of critical years. During September, flow would be up to 11% lower under the PA than the NAA for all water year types except wet years. The largest flow reductions would occur in November of wet and above normal year, with reductions of 26% at Keswick and 21% at Red Bluff for both year types. The November reductions coincide with the period of peak occurrence of spring-run fry. The results given here indicate that the PA would reduce flow in some months and water year types, although this does not consider real-time operational management described in Section 3.1.5, *Real-Time Operations Upstream of the Delta*, and Section 3.3.3, *Real-Time Operational Decision-Making Process*, that would be used to avoid and minimize any modeled effects. Further discussion regarding flow-related effects during the June through November period is provided in Section 5.4.2.3, *Summary of Upstream Effects*.

Because, as described in Appendix 5.D, Section 5.D.2.3, *Rearing Flows Methods*, rearing habitat WUA for spring-run Chinook salmon was not estimated directly by USFWS (2005b) but was modeled using the rearing habitat WUA curves obtained for fall-run Chinook salmon in Segments 4, 5 and 6 (U.S. Fish and Wildlife Service 2003a, 2006), the fall-run WUA curves for these three segments were also used in this effects analysis to model spring-run Chinook salmon rearing habitat. The rearing WUA curves for fall-run Chinook salmon were used because the fry rearing period of fall-run is similar to that of spring-run, and because this substitution follows previous practice (Appendix 5.D, Section 5.D.2.3, *Rearing Flows Methods)*. However, as noted by USFWS (2005b), the validity of using the fall-run Chinook salmon rearing WUA curves to characterize spring-run Chinook salmon rearing habitat is uncertain. To estimate changes in rearing WUA that would result from the PA, the fall-run Chinook salmon WUA curves developed for each of the river segments was used with mean monthly CALSIM II flow estimates for the midpoint of each segment under the PA and the NAA during the rearing periods for spring-run fry (November through February) and juveniles (year-round) (Appendix 5.D, Section 5.D.2.3, *Rearing Flows Methods*, Table RFM-1). Fry were defined in this analysis as fish less than 60 mm, and juveniles were those greater than 60 mm. Further information on the rearing WUA analysis methods is provided in Appendix 5.D, Section 5.D.2.3, *Rearing Flows Methods*.

Differences under the PA and NAA in rearing WUA for spring-run fry and juveniles were examined using exceedance plots of mean monthly WUA for the spring-run fry (Figure 5.4-145–Figure 5.4-162) and juvenile (Figure 5.4-163–Figure 5.4-180) rearing periods in each of the river segments for each water year type and all water year types combined. The PA exceedance curves for both fry and juvenile rearing WUA for all water years combined are similar to those for the NAA for all three river segments (Figure 5.4-145, Figure 5.4-151, Figure 5.4-154 Figure 5.4-153, Figure 5.4-163, Figure 5.4-169, and Figure 5.4-175). With the curves broken out by water year type, increases in fry rearing habitat WUA under the PA are evident in Segments 5 and 4 during above normal years (Figure 5.4-153 and Figure 5.4-155), and increases in juvenile rearing WUA under the PA are evident in Segment 4 during wet and above normal years (Figure 5.4-176 and Figure 5.4-177).

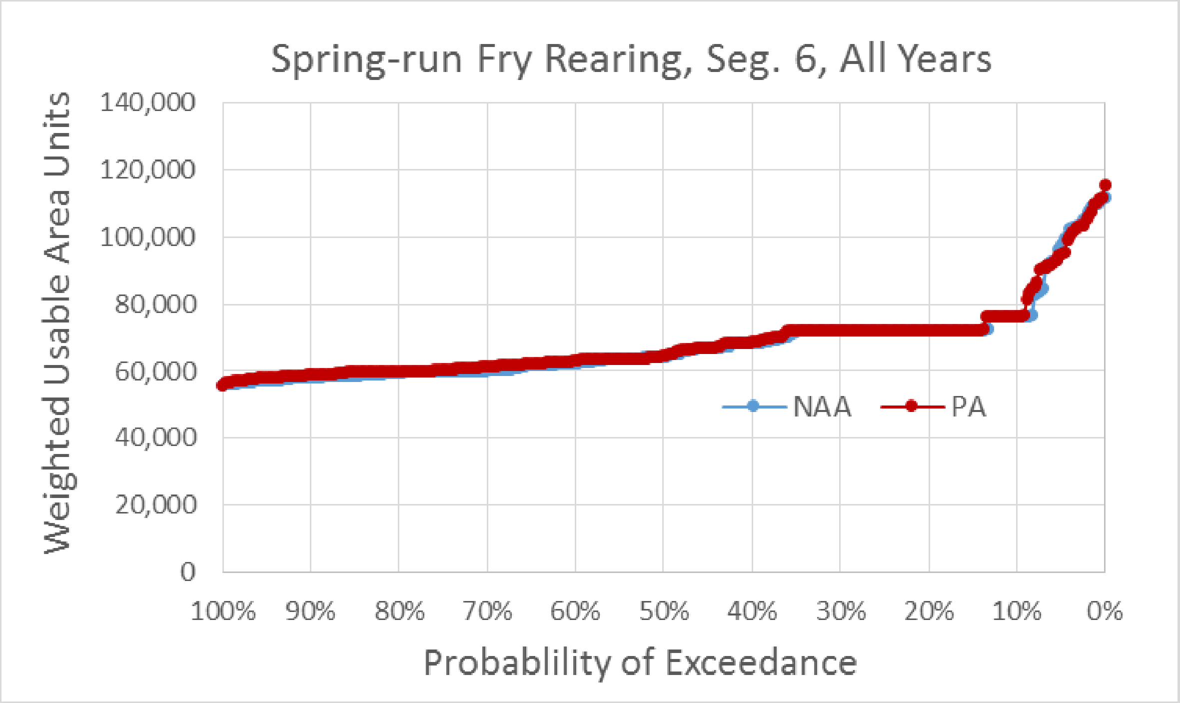

Figure 5.4-145. Exceedance Plot of Spring-Run Chinook Salmon Fry Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 6, All Water Years

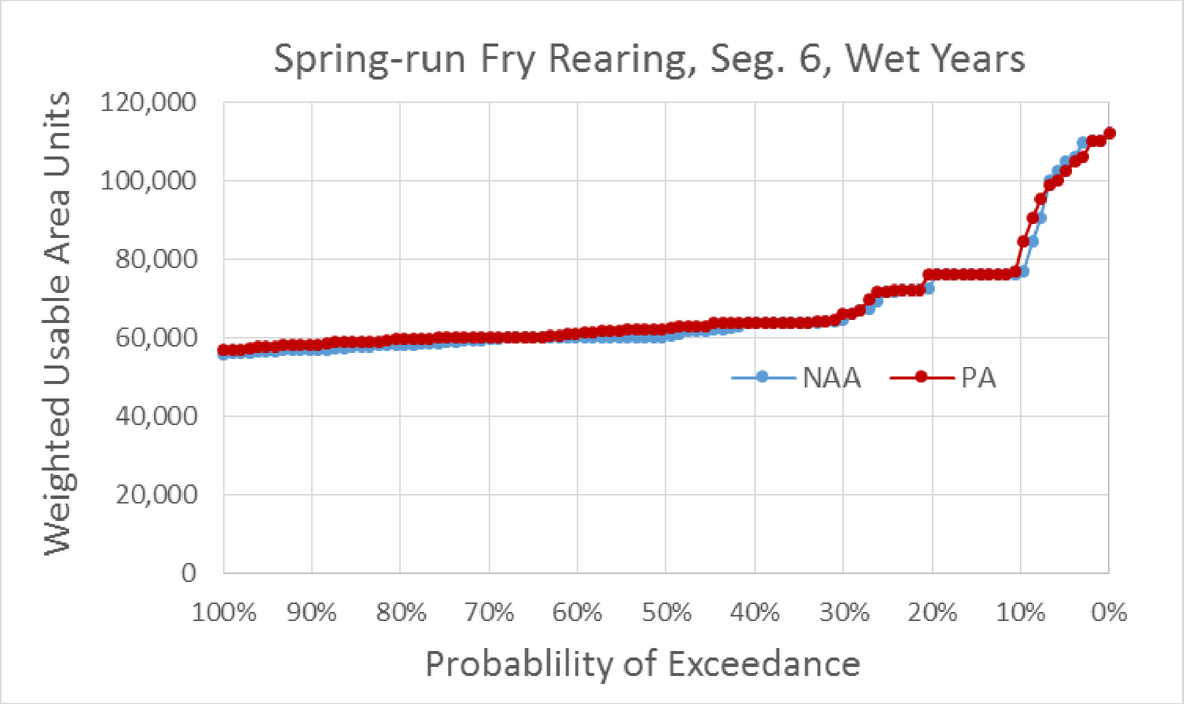

Figure 5.4-146. Exceedance Plot of Spring-Run Chinook Salmon Fry Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 6, Wet Water Years

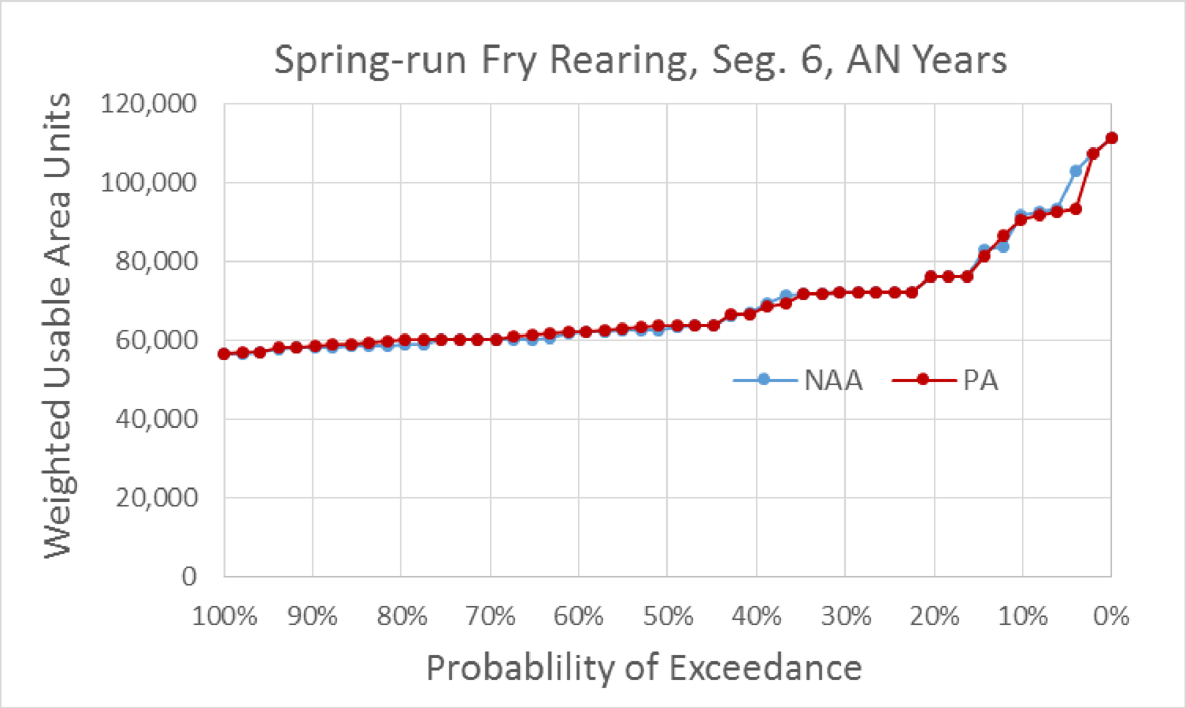

Figure 5.4-147. Exceedance Plot of Spring-Run Chinook Salmon Fry Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 6, Above Normal Water Years

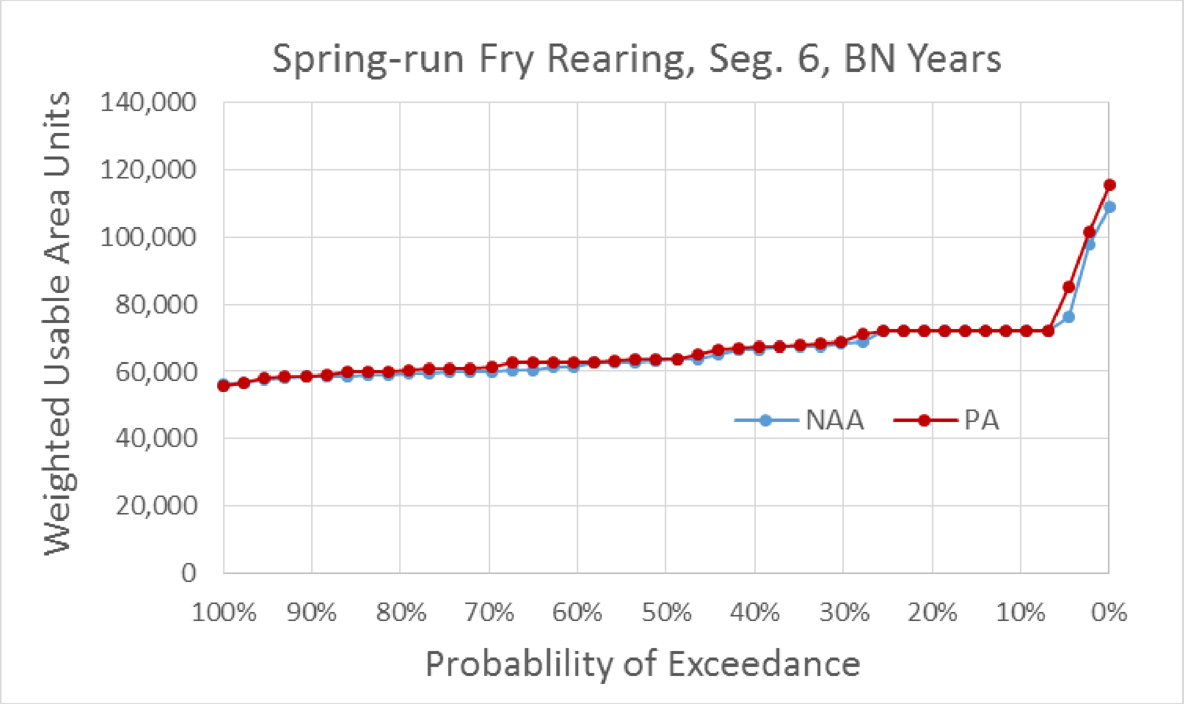

Figure 5.4-148. Exceedance Plot of Spring-Run Chinook Salmon Fry Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 6, Below Normal Water Years

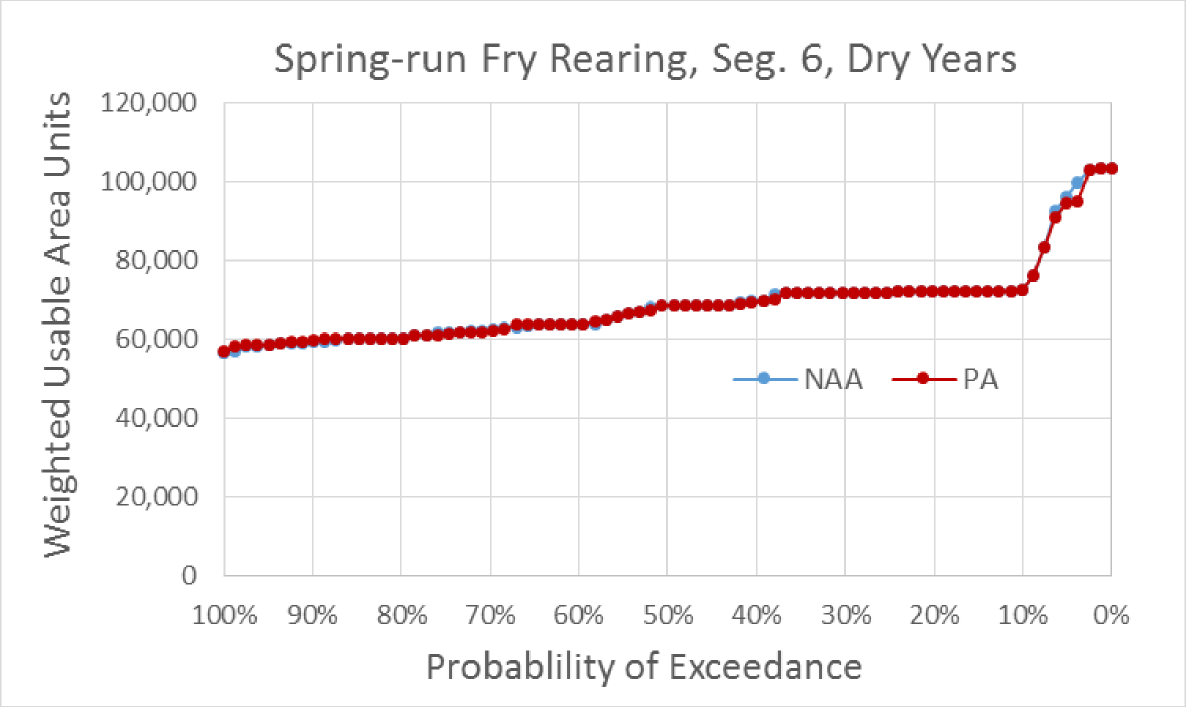

Figure 5.4-149. Exceedance Plot of Spring-Run Chinook Salmon Fry Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 6, Dry Water Years

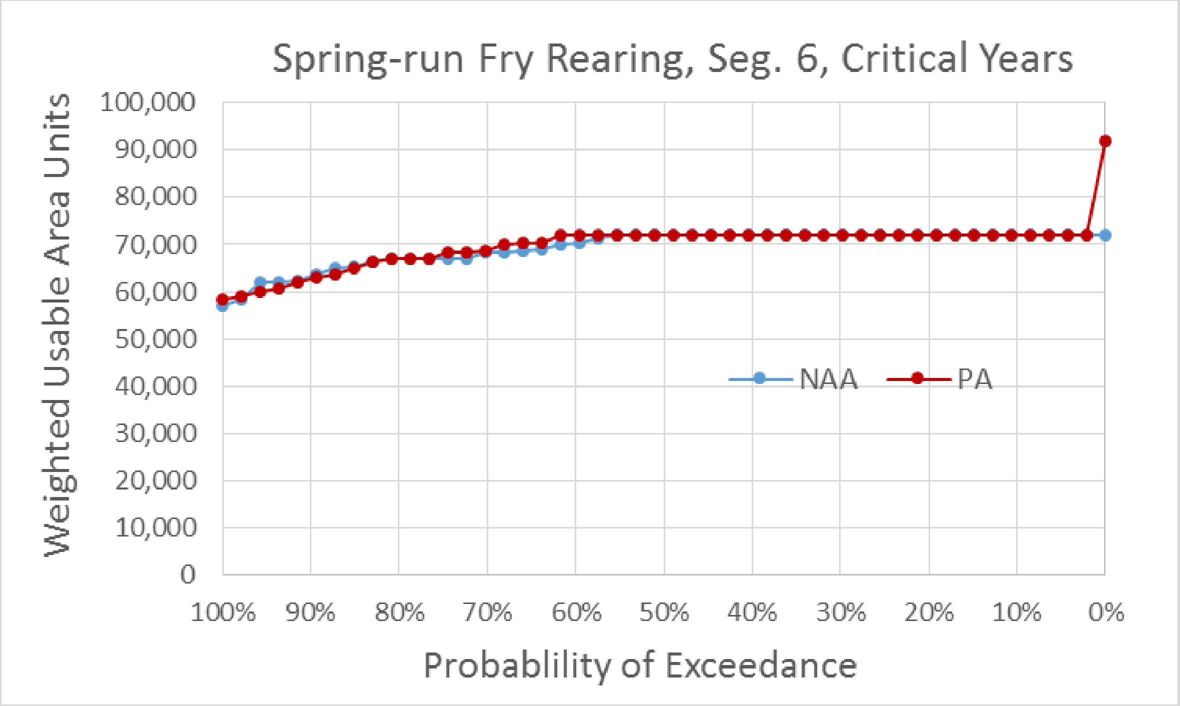

Figure 5.4-150. Exceedance Plot of Spring-Run Chinook Salmon Fry Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 6, Critical Water Years

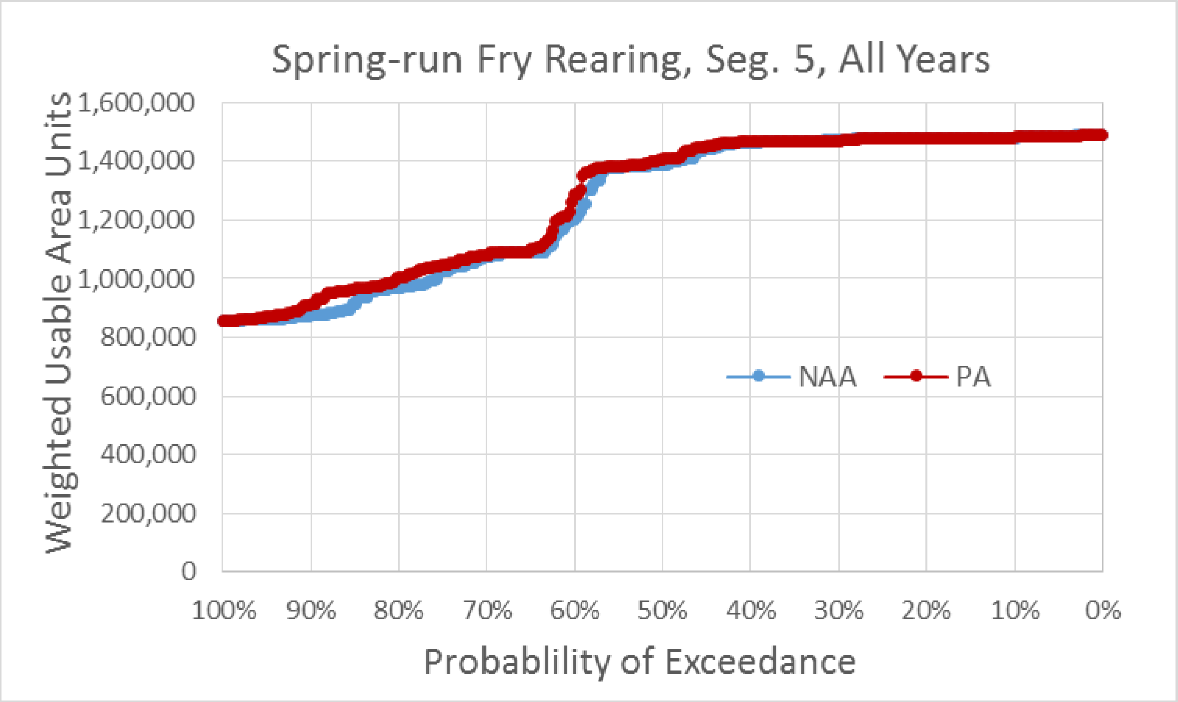

Figure 5.4-151. Exceedance Plot of Spring-Run Chinook Salmon Fry Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 5, All Water Years

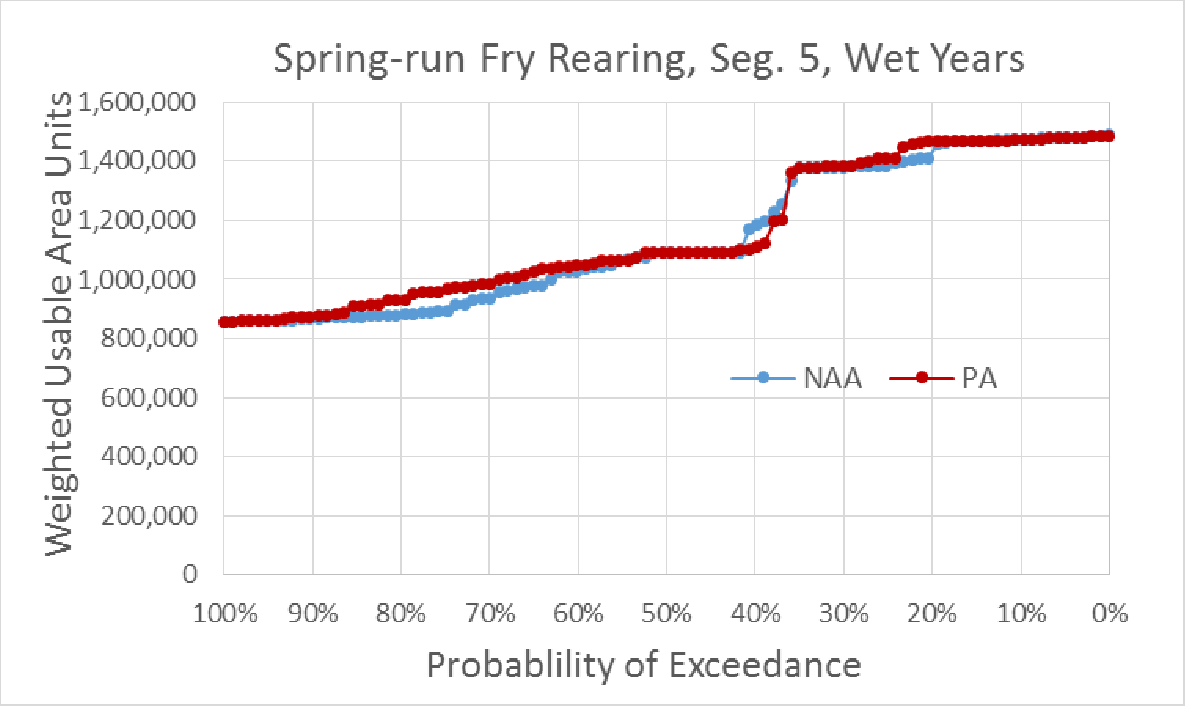

Figure 5.4-152. Exceedance Plot of Spring-Run Chinook Salmon Fry Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 5, Wet Water Years

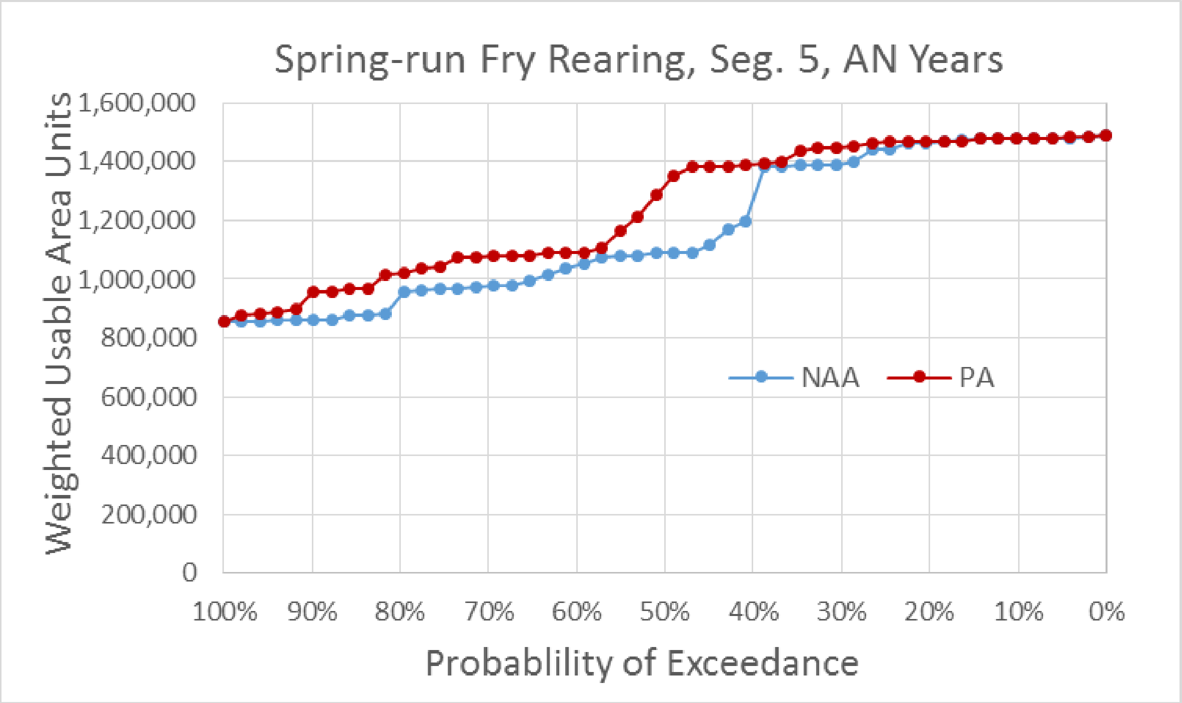

Figure 5.4-153. Exceedance Plot of Spring-Run Chinook Salmon Fry Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 5, Above Normal Water Years

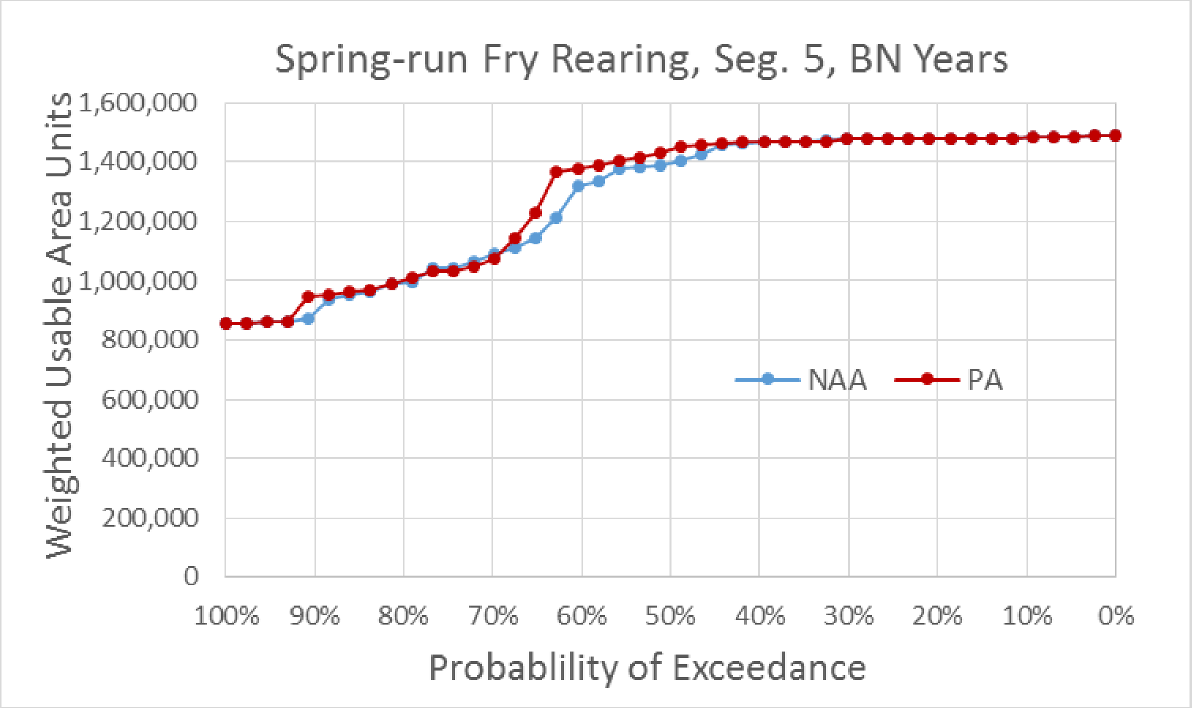

Figure 5.4-154. Exceedance Plot of Spring-Run Chinook Salmon Fry Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 5, Below Normal Water Years

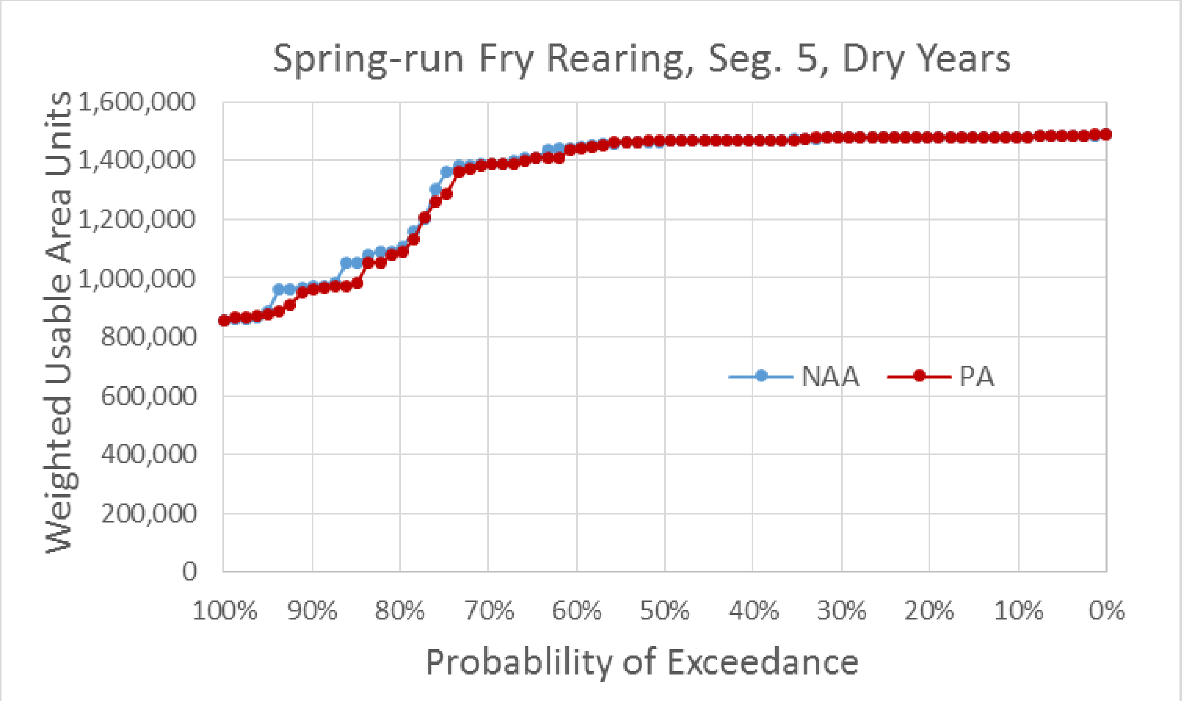

Figure 5.4-155. Exceedance Plot of Spring-Run Chinook Salmon Fry Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 5, Dry Water Years

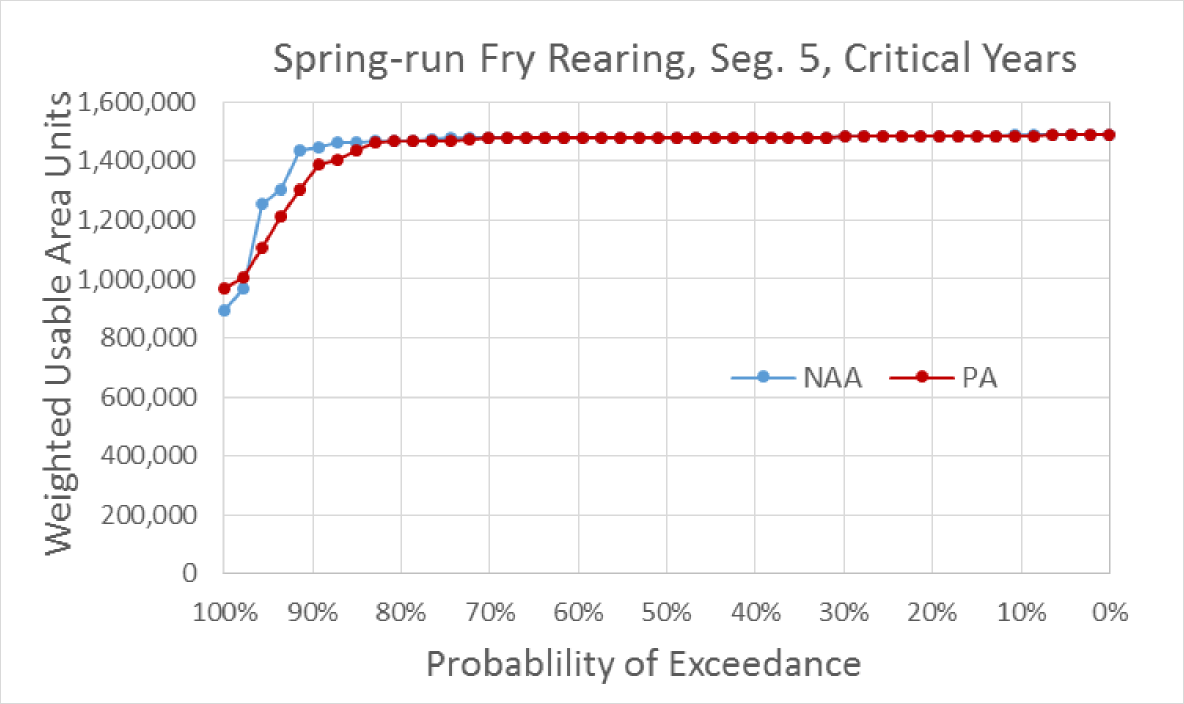

Figure 5.4-156. Exceedance Plot of Spring-Run Chinook Salmon Fry Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 5, Critical Water Years

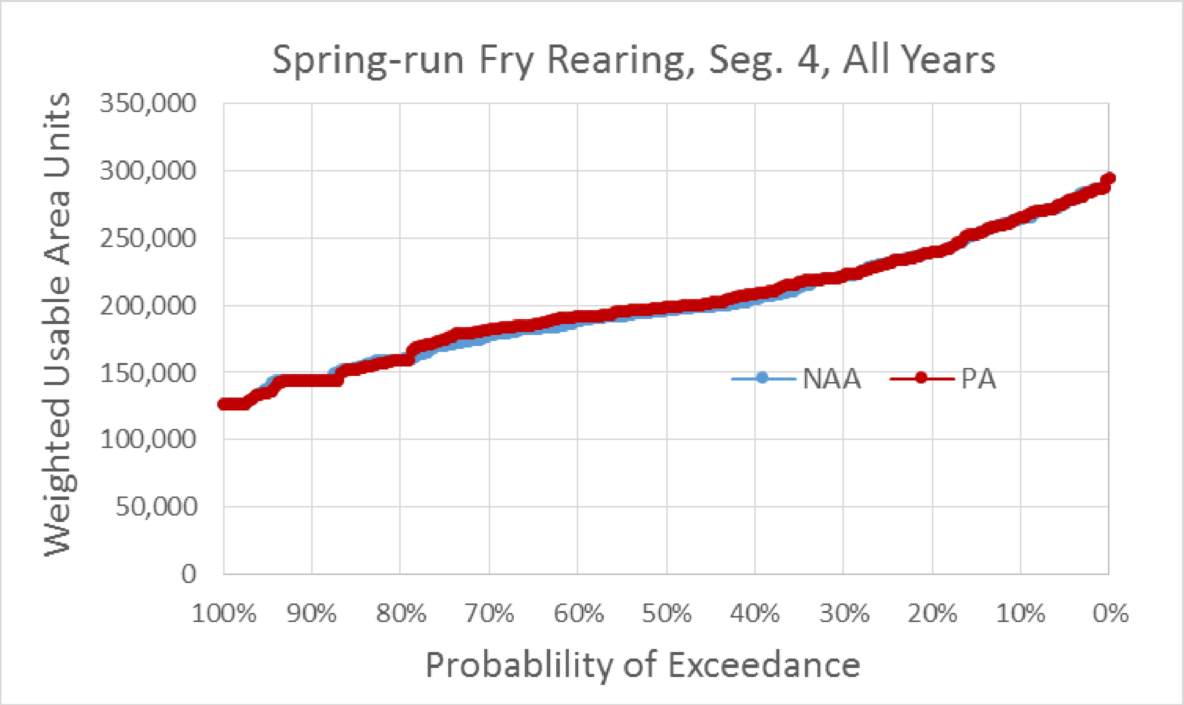

Figure 5.4-157. Exceedance Plot of Spring-Run Chinook Salmon Fry Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 4, All Water Years

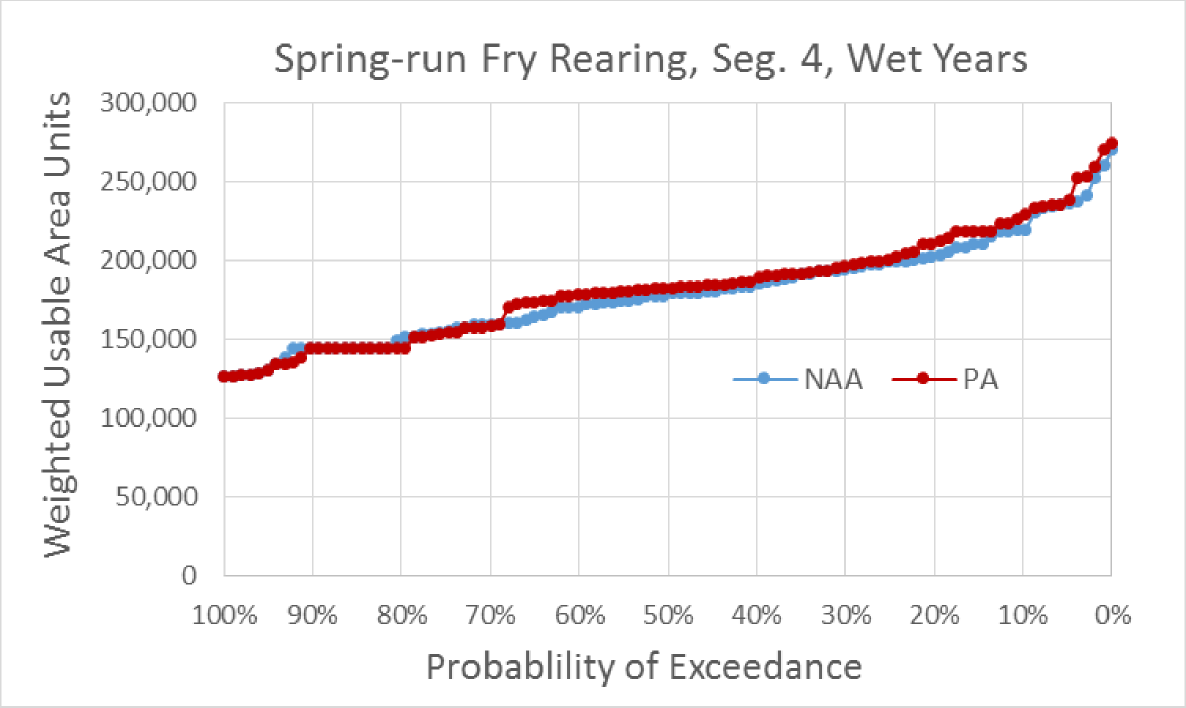

Figure 5.4-158. Exceedance Plot of Spring-Run Chinook Salmon Fry Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 4, Wet Water Years

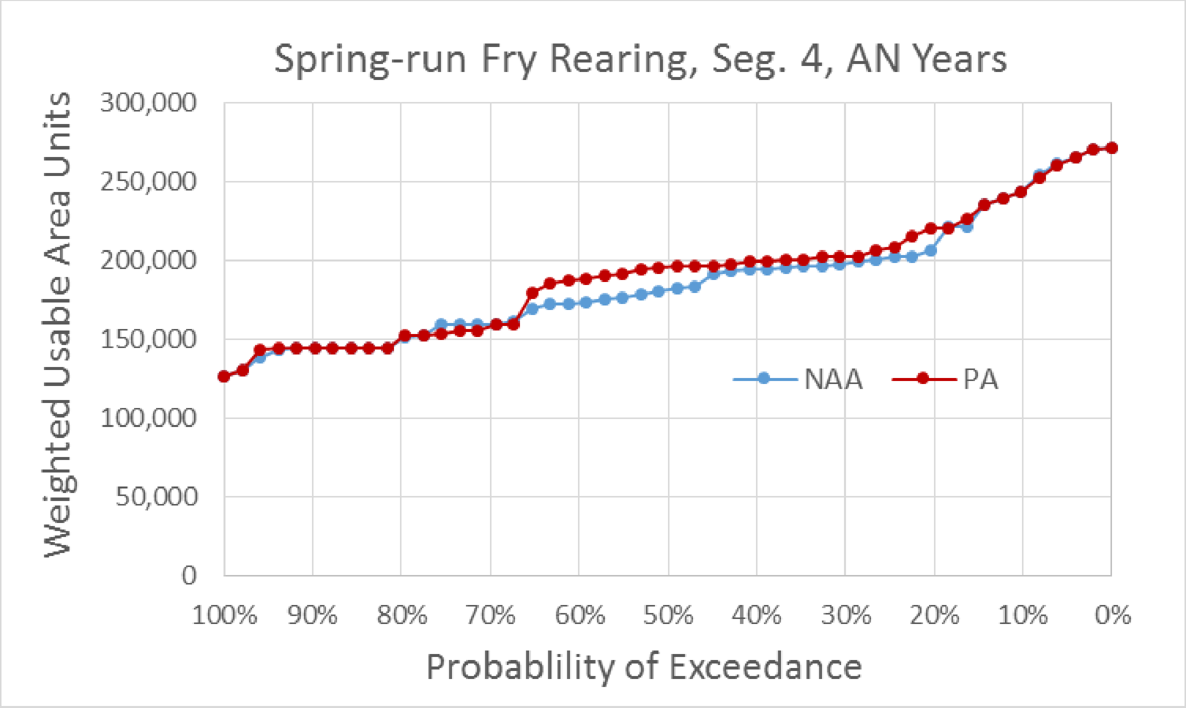

Figure 5.4-159. Exceedance Plot of Spring-Run Chinook Salmon Fry Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 4, Above Normal Water Years

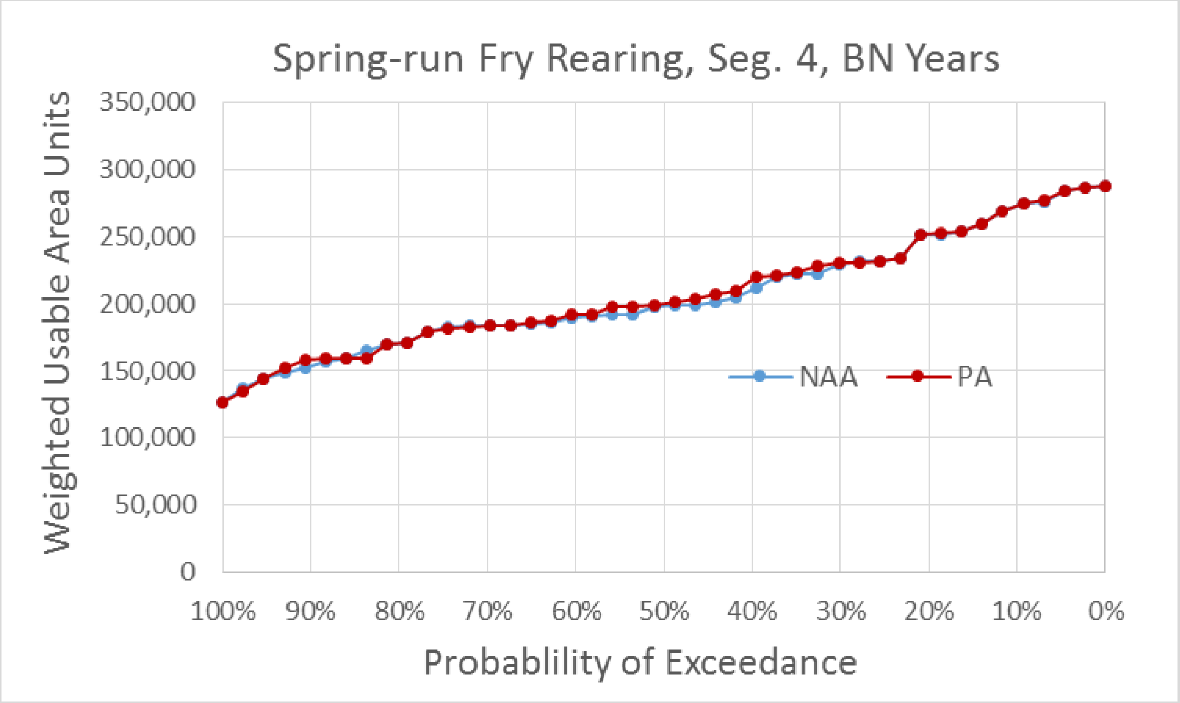

Figure 5.4-160. Exceedance Plot of Spring-Run Chinook Salmon Fry Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 4, Below Normal Water Years

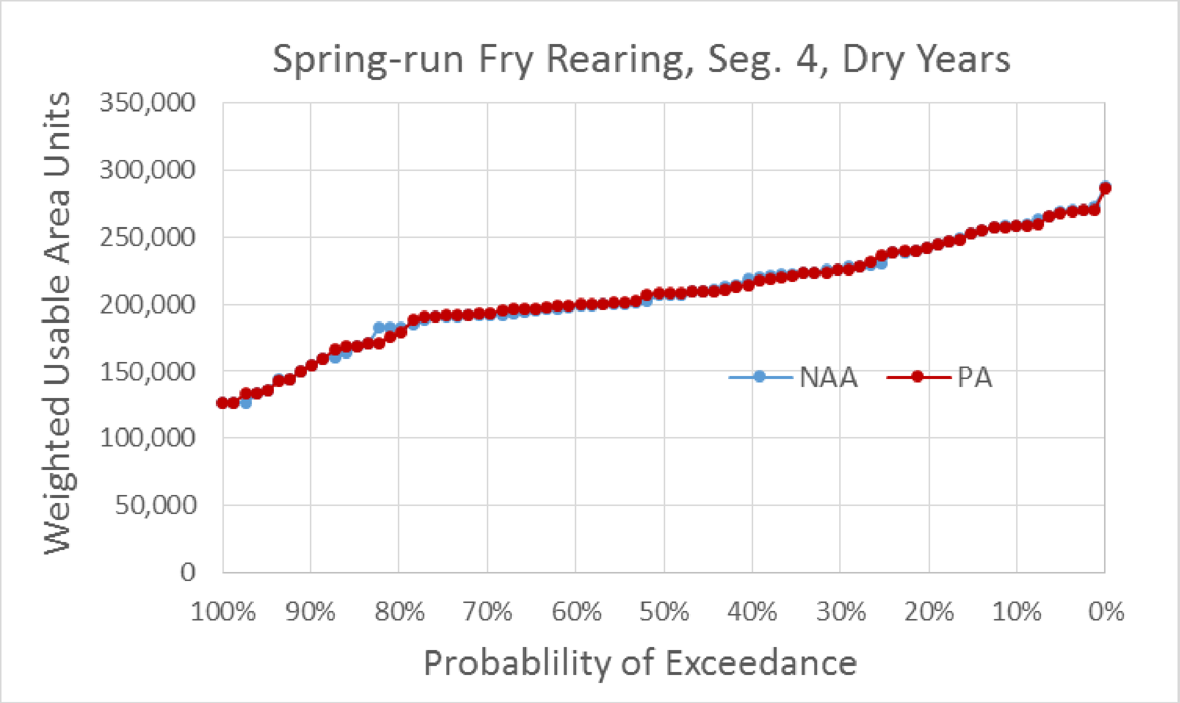

Figure 5.4-161. Exceedance Plot of Spring-Run Chinook Salmon Fry Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 4, Dry Water Years

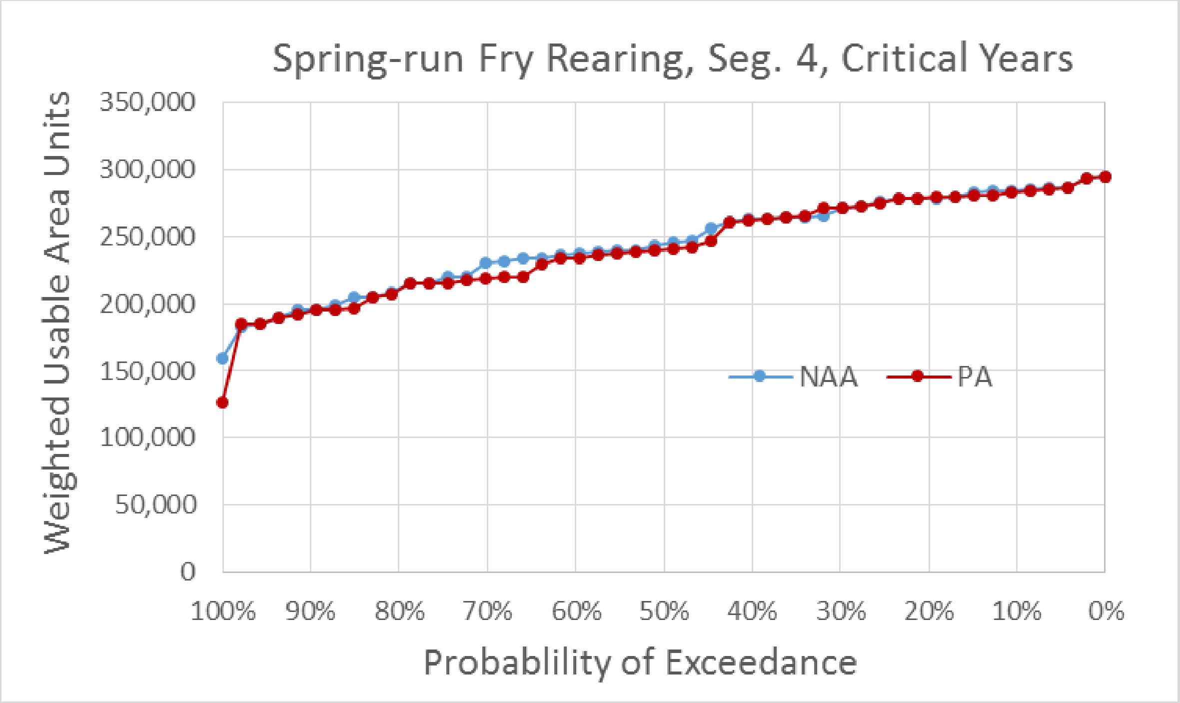

Figure 5.4-162. Exceedance Plot of Spring-Run Chinook Salmon Fry Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 4, Critical Water Years

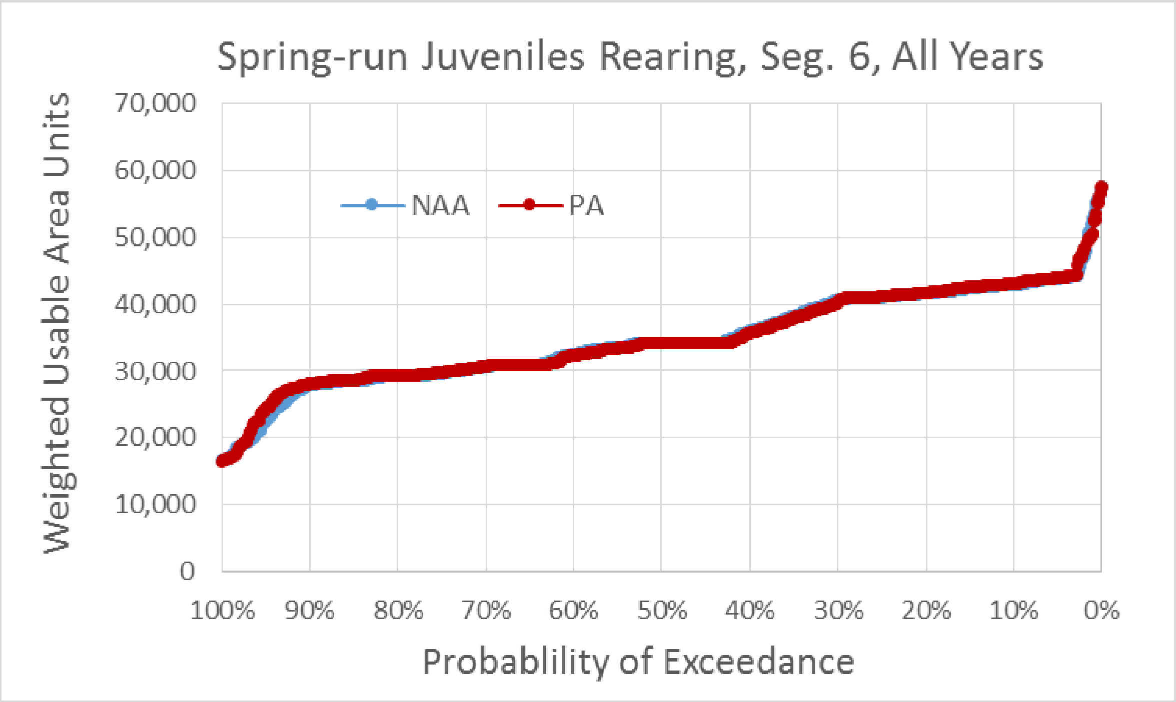

Figure 5.4-163. Exceedance Plot of Spring-Run Chinook Salmon Juvenile Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 6, All Water Years

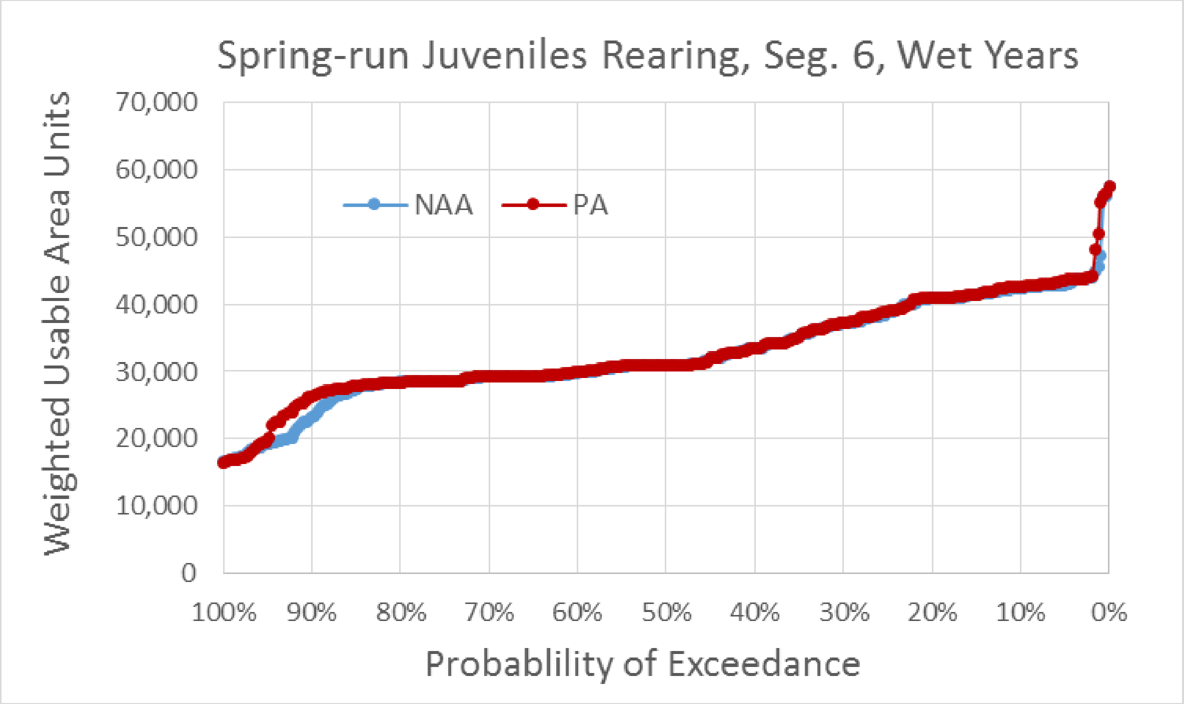

Figure 5.4-164. Exceedance Plot of Spring-Run Chinook Salmon Juvenile Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 6, Wet Water Years

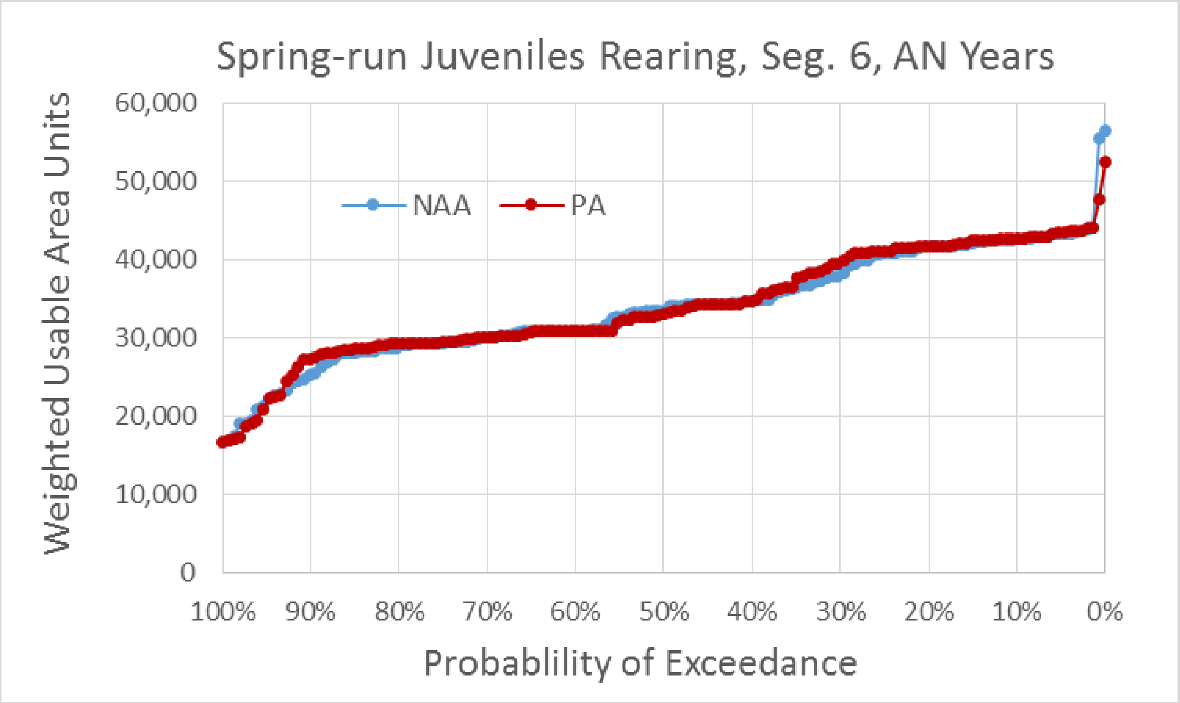

Figure 5.4-165. Exceedance Plot of Spring-Run Chinook Salmon Juvenile Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 6, Above Normal Water Years

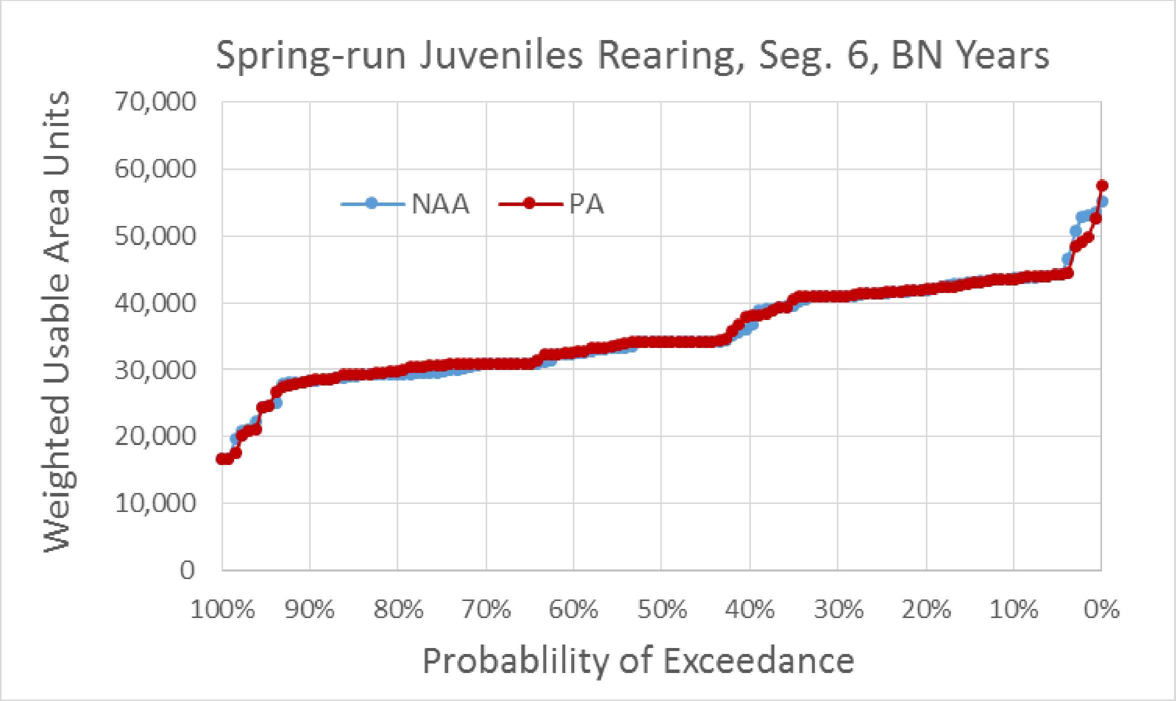

Figure 5.4-166. Exceedance Plot of Spring-Run Chinook Salmon Juvenile Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 6, Below Normal Water Years

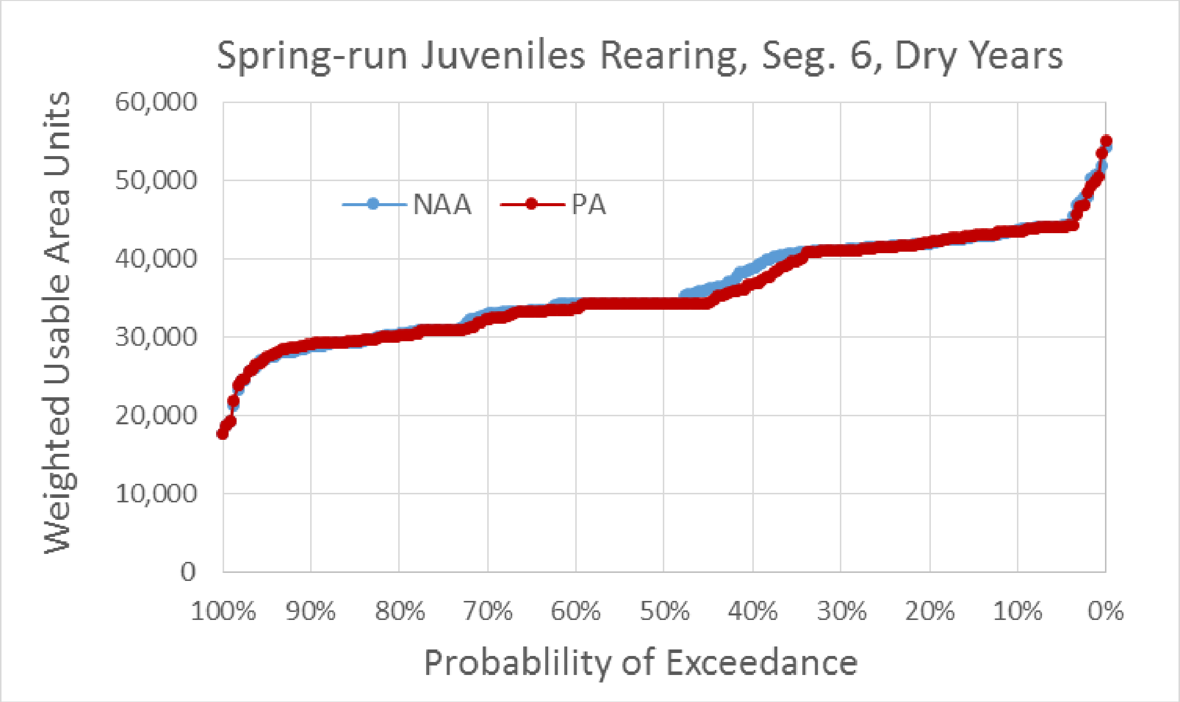

Figure 5.4-167. Exceedance Plot of Spring-Run Chinook Salmon Juvenile Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 6, Dry Water Years

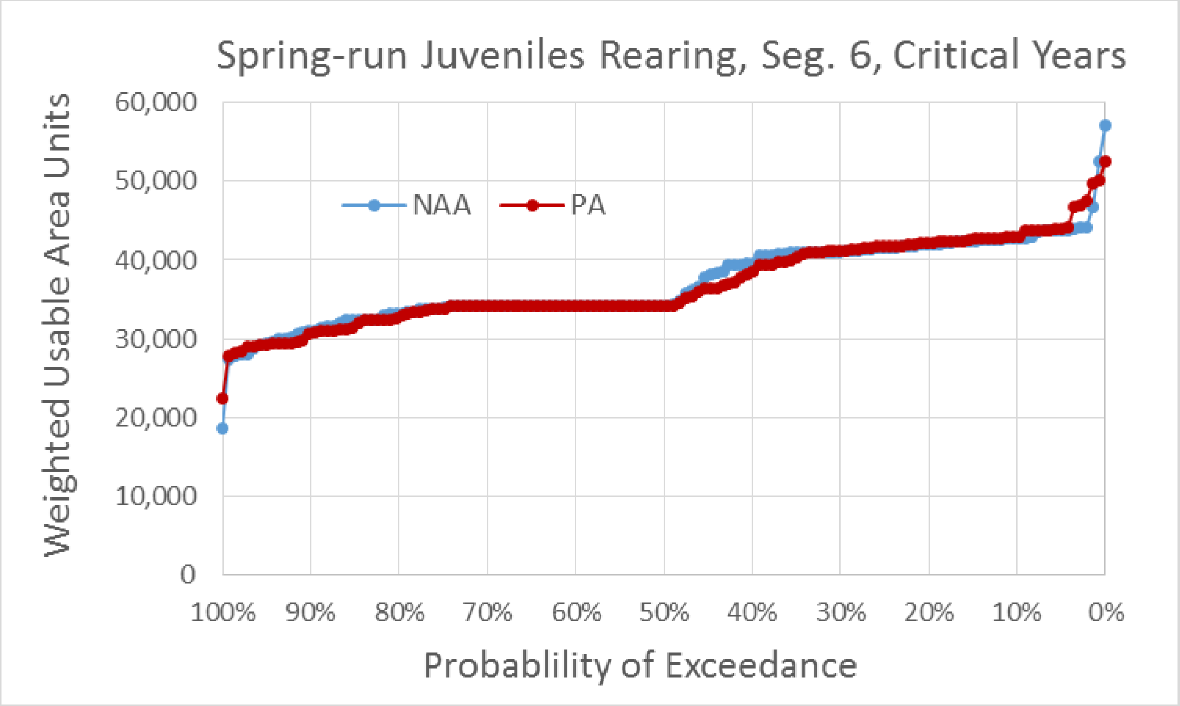

Figure 5.4-168. Exceedance Plot of Spring-Run Chinook Salmon Juvenile Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 6, Critical Water Years

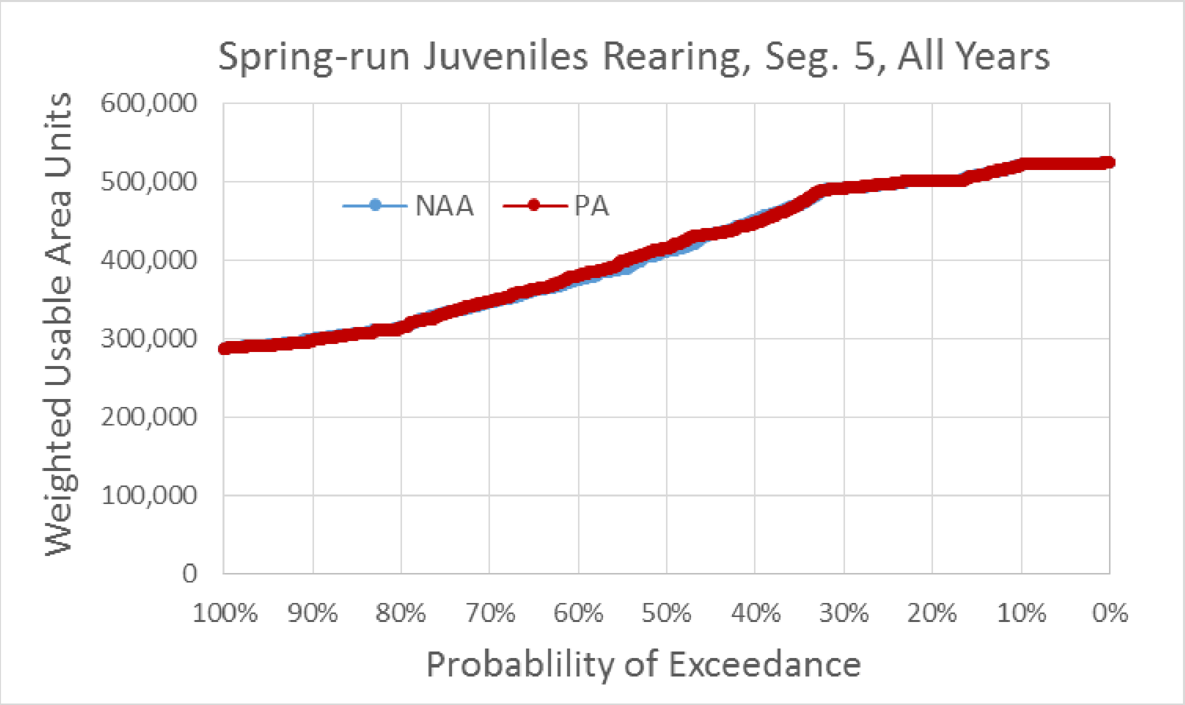

Figure 5.4-169. Exceedance Plot of Spring-Run Chinook Salmon Juvenile Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 5, All Water Years

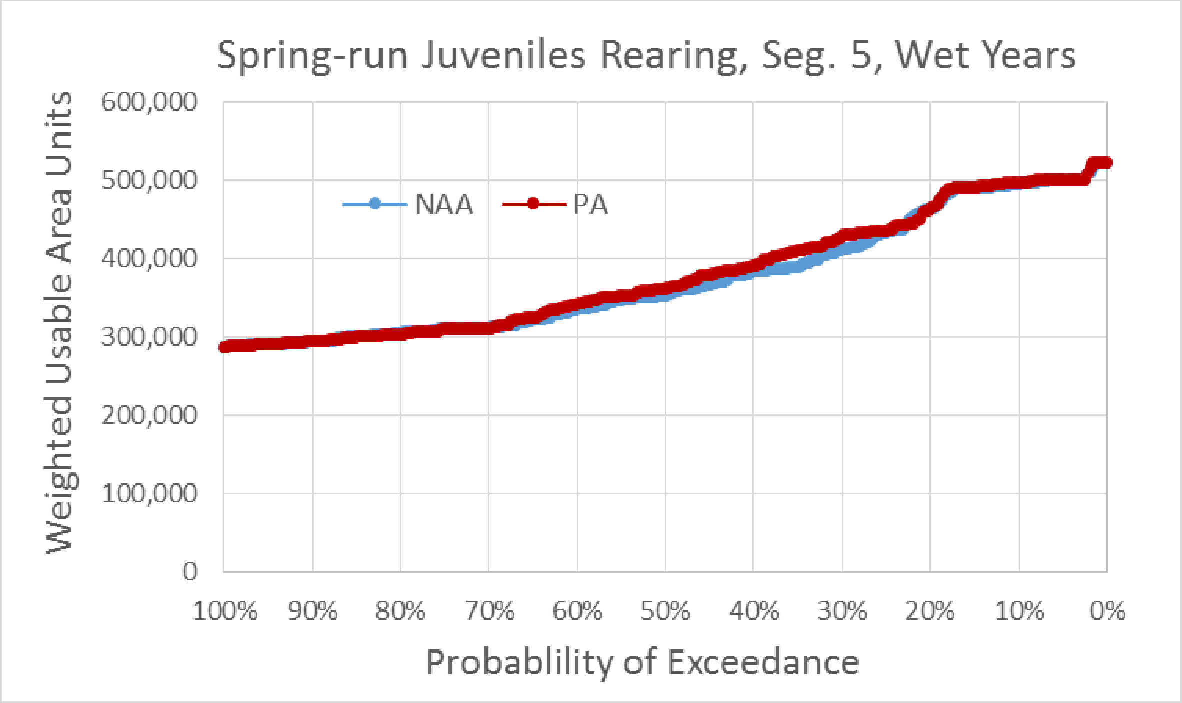

Figure 5.4-170. Exceedance Plot of Spring-Run Chinook Salmon Juvenile Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 5, Wet Water Years

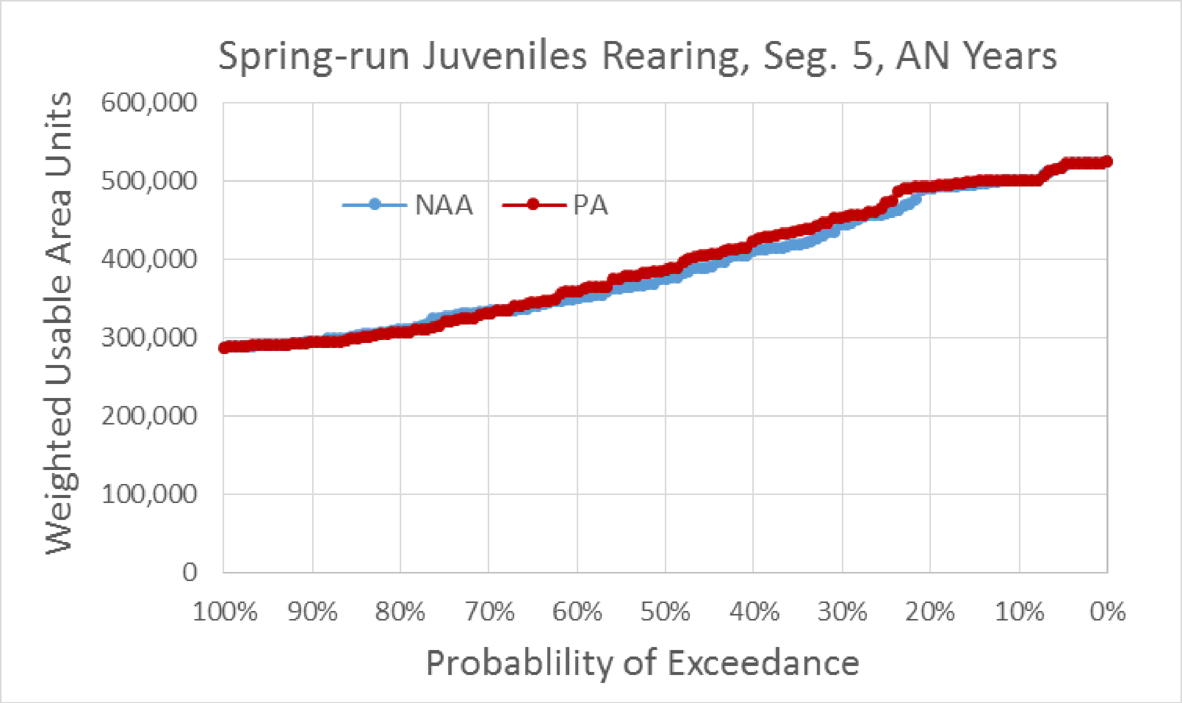

Figure 5.4-171. Exceedance Plot of Spring-Run Chinook Salmon Juvenile Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 5, Above Normal Water Years

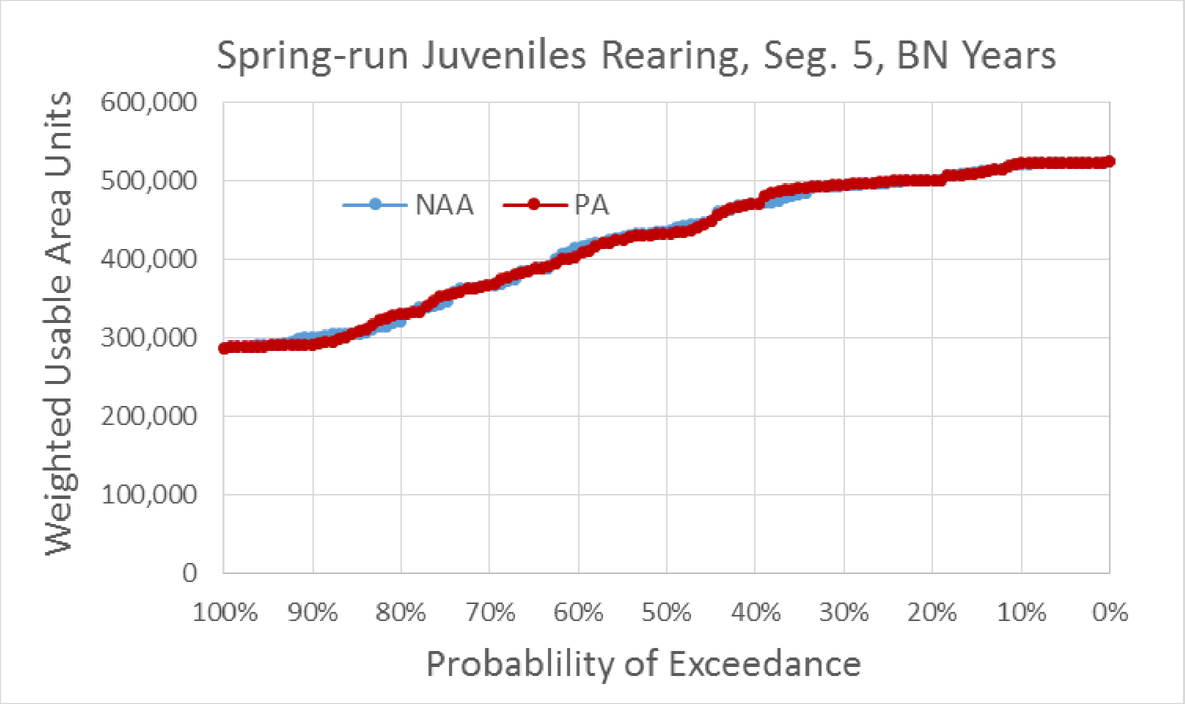

Figure 5.4-172. Exceedance Plot of Spring-Run Chinook Salmon Juvenile Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 5, Below Normal Water Years

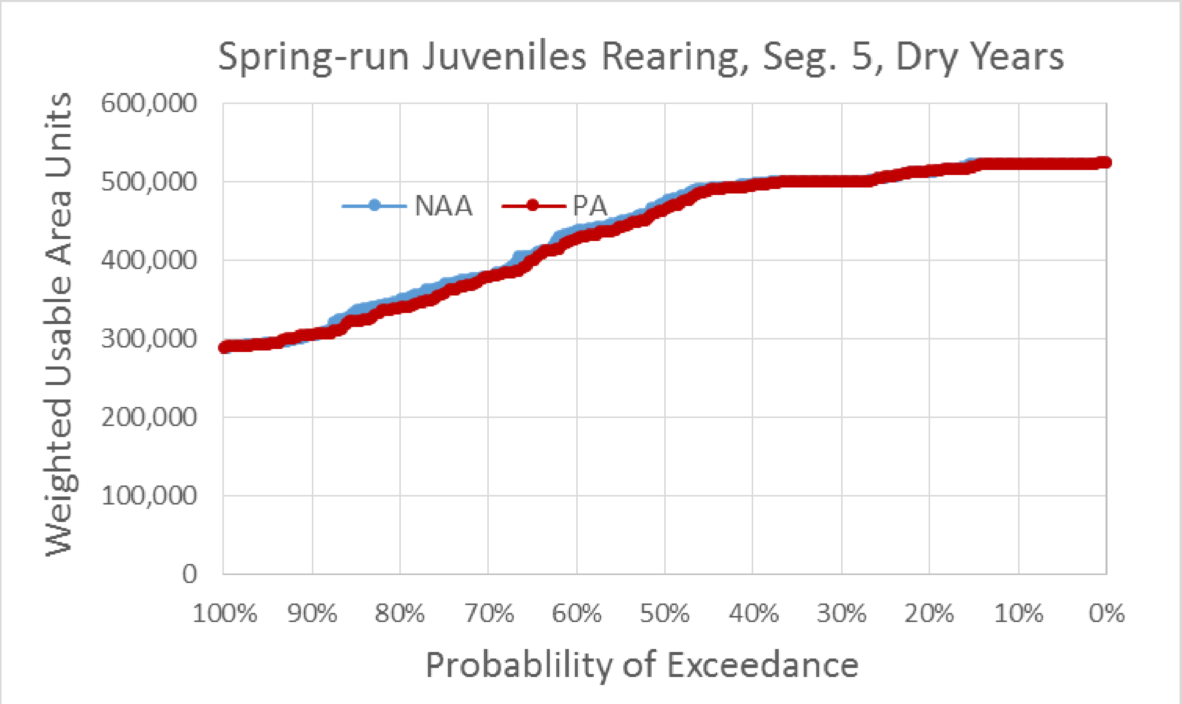

Figure 5.4-173. Exceedance Plot of Spring-Run Chinook Salmon Juvenile Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 5, Dry Water Years

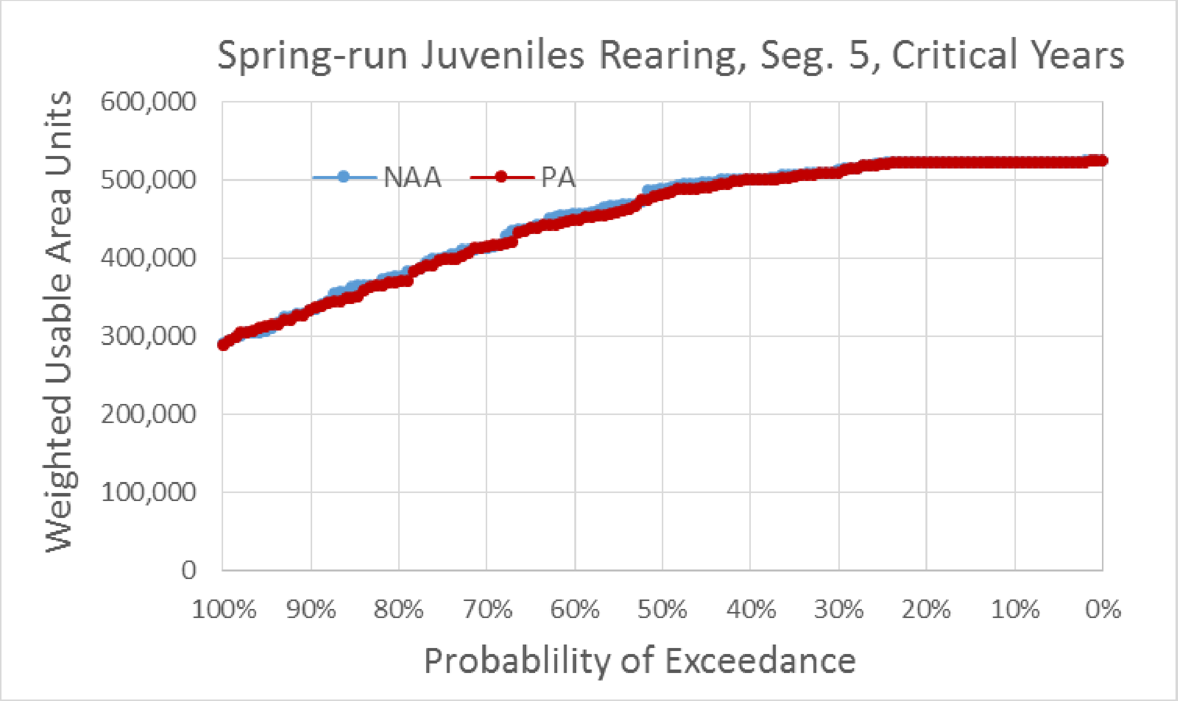

Figure 5.4-174. Exceedance Plot of Spring-Run Chinook Salmon Juvenile Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 5, Critical Water Years

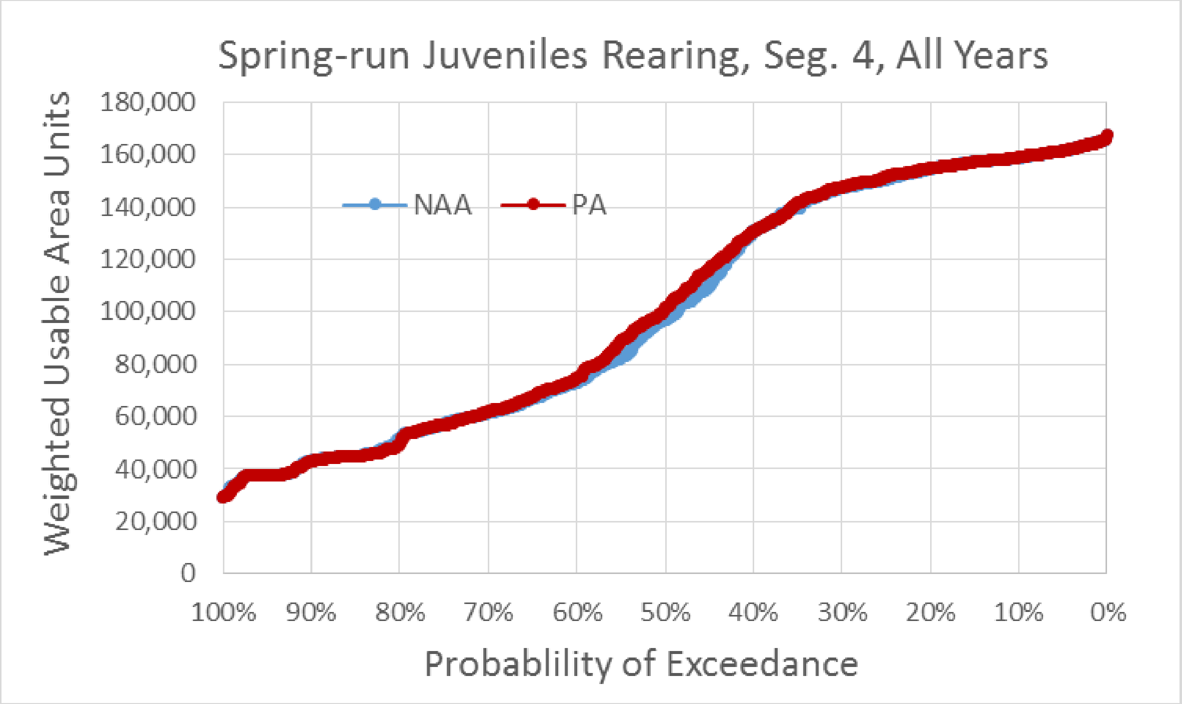

Figure 5.4-175. Exceedance Plot of Spring-Run Chinook Salmon Juvenile Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 4, All Water Years

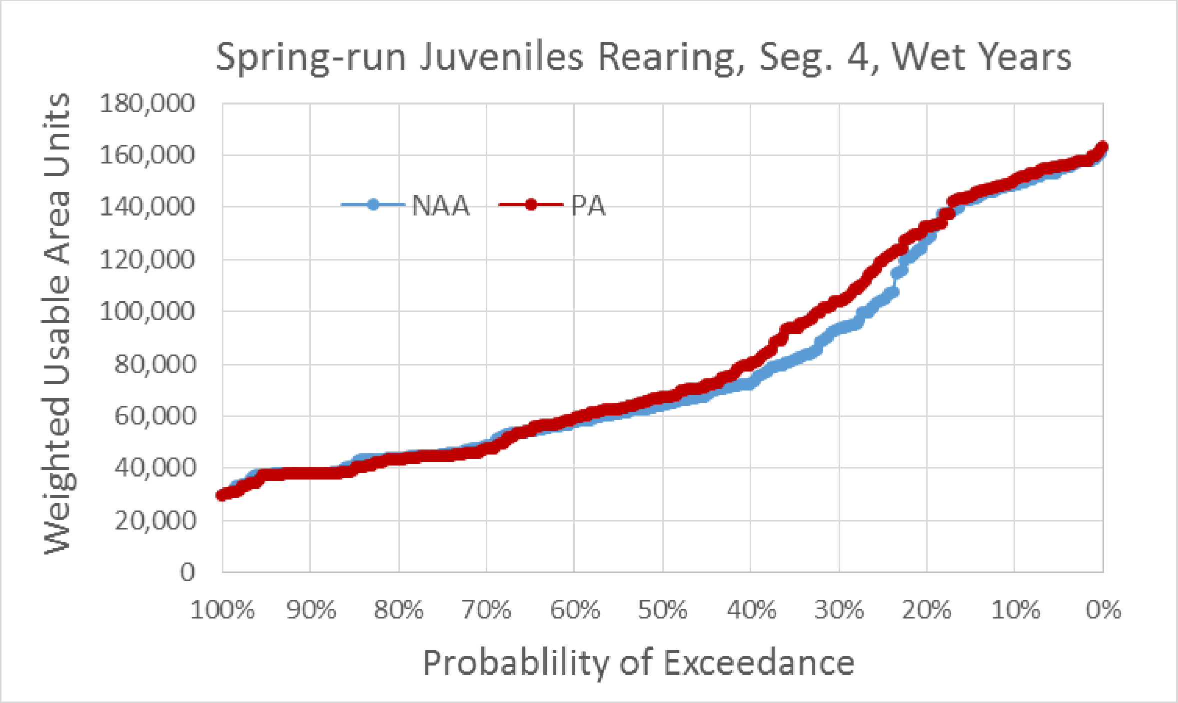

Figure 5.4-176. Exceedance Plot of Spring-Run Chinook Salmon Juvenile Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 4, Wet Water Years

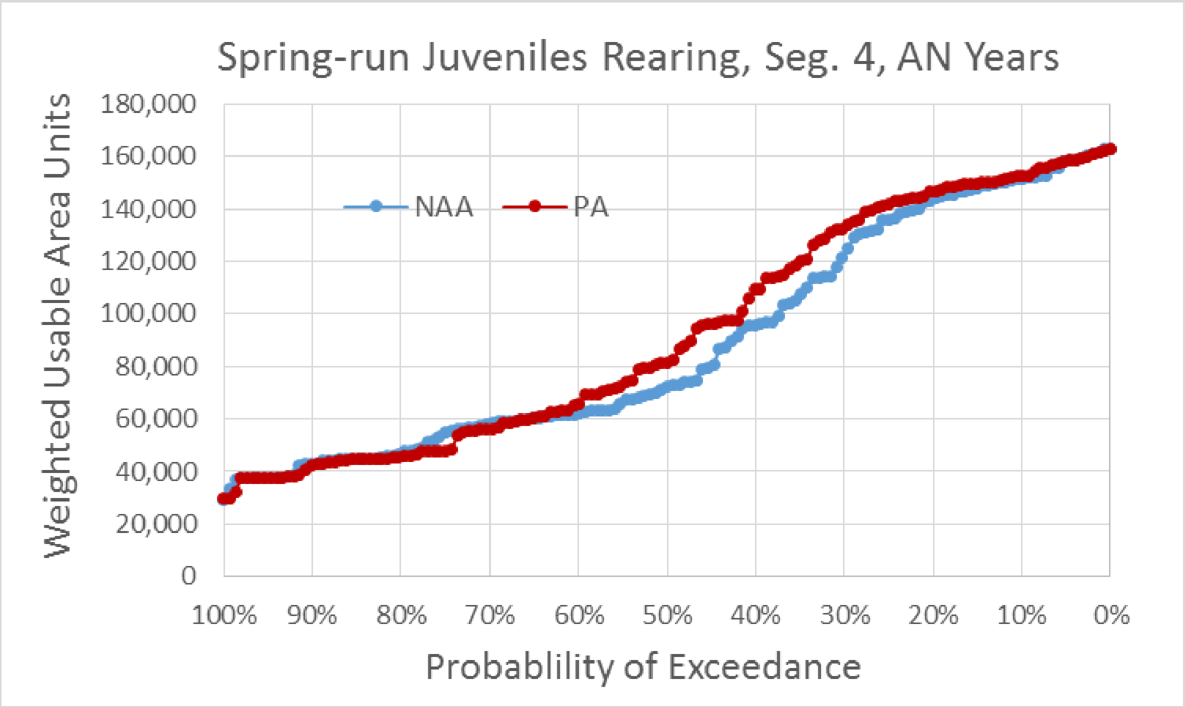

Figure 5.4-177. Exceedance Plot of Spring-Run Chinook Salmon Juvenile Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 4, Above Normal Water Years

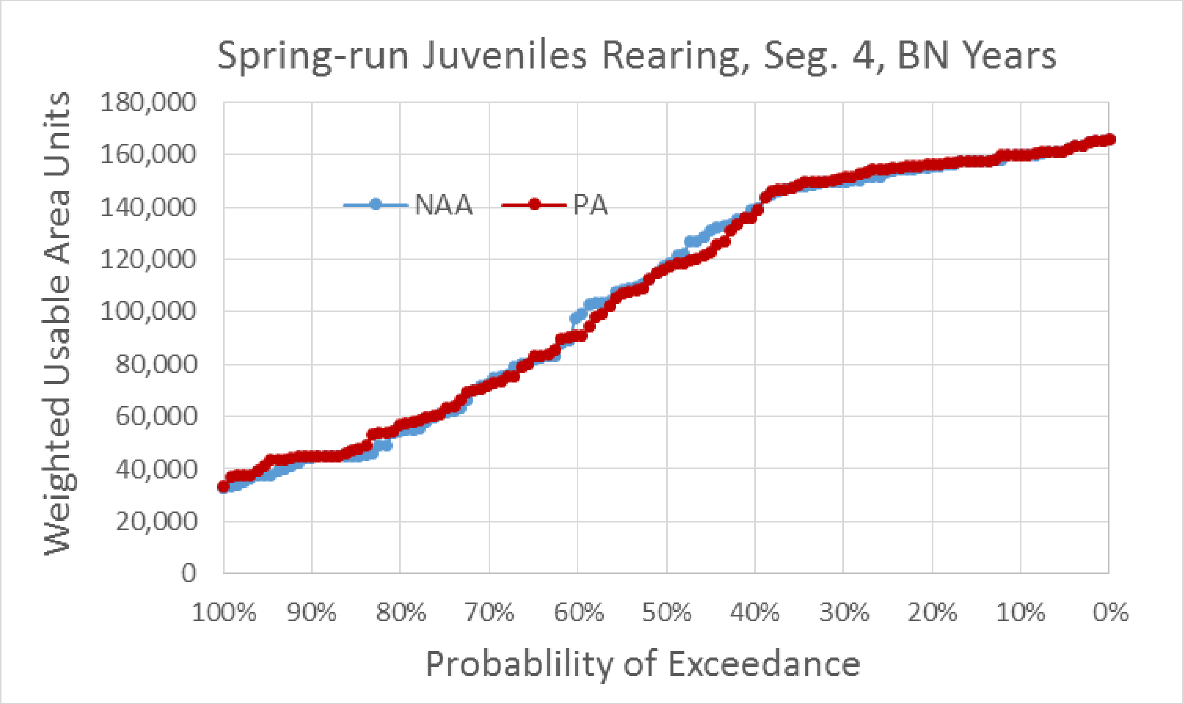

Figure 5.4-178. Exceedance Plot of Spring-Run Chinook Salmon Juvenile Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 4, Below Normal Water Years

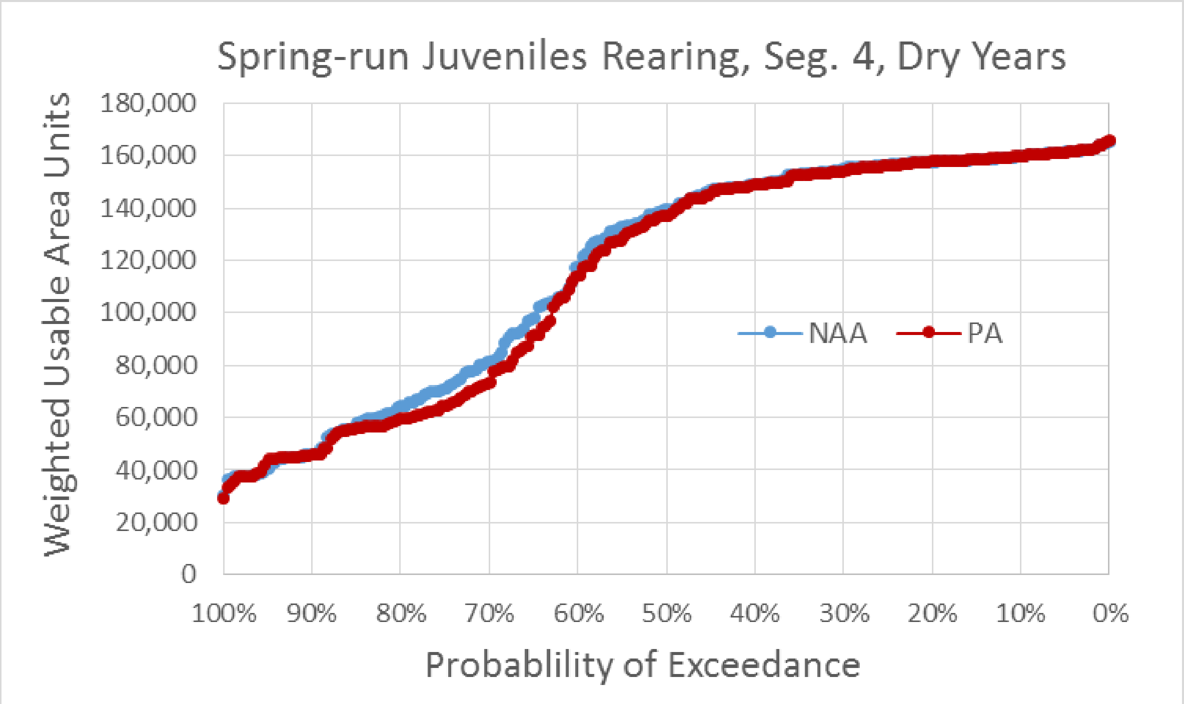

Figure 5.4-179. Exceedance Plot of Spring-Run Chinook Salmon Juvenile Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 4, Dry Water Years

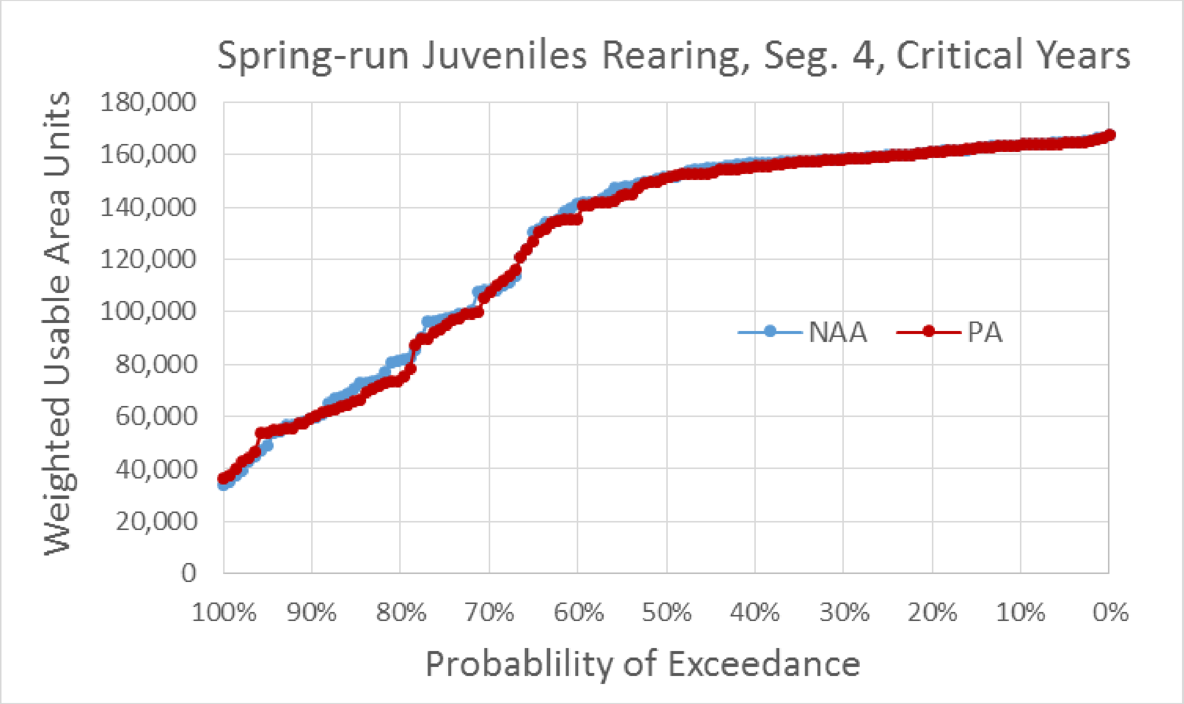

Figure 5.4-180. Exceedance Plot of Spring-Run Chinook Salmon Juvenile Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 4, Critical Water Years

Differences in spring-run Chinook salmon fry and juvenile rearing WUA in each segment under the PAA and NAA were also examined using the grand mean rearing WUA for each month of the fry and juvenile rearing periods under each water year type and all water year types combined (Table 5.4-56 to Table 5.4-57). The means for fry rearing WUA differed by less than 5% for all months and water year types in Segment 6 and for most months and water year types in the other two segments. However, mean fry rearing WUA during November in Segment 5 was 27% higher under the PA than under the NAA in above normal water years and 12% higher in wet years (Table 5.4-57). In Segment 4, mean fry rearing WUA during November was 7% and 9% higher under the PA in wet and above normal years, respectively, but was 6% lower in critical years (Table 5.4-58). The means for juvenile rearing WUA also differed by less than 5% for most months and water year types in Segments 6 and 5 (Table 5.4-59, Table 5.4-60), but differences were greater and more frequent in Segment 4 (Table 5.4-61). In Segments 6 and 5, mean juvenile rearing WUA under the PA was up to 6% lower than that under the NAA during October of below normal years, 6% higher during September of above normal years, and up to 18% higher than that under the NAA during November of wet and above normal years. In Segment 4, mean juvenile rearing habitat WUA under the PA was 8% lower in January of wet years, 6% lower in March of above normal years, 5% lower in May of dry years, 13% and 8% lower in June of dry and critical years, 6% lower in August of dry years, and 14% lower in October of below normal years (Table 5.4-61). Also in Segment 4, mean juvenile WUA under the PA was 5% and 6% higher than that under the NAA in July of dry and critical years, 14% higher during August of below normal years, 19% and 7% higher in September of above normal and below normal years, 16% higher in October of wet years, and 51% and 63% higher in November of wet and above normal years. The WUA modeling indicates that the PA would reduce spring-run Chinook salmon rearing habitat during several months and water year types, especially in Segment 4. Further discussion regarding flow-related effects during the June through November period is provided in Section 5.4.2.3, *Summary of Upstream Effects*.

Table 5.4-56. Spring-Run Chinook Salmon Fry Rearing Weighted Usable Areas (WUA) and Differences (Percent Differences) between Model Scenarios in River Segment 6 (green indicates PA is at least 5% higher [raw difference] than NAA; red indicates PA is at least 5% lower)

Month	Water Year Type	NAA	PA	PA vs. NAA
November	Wet	58,557	60,764	2,207 (4%)
	Above Normal	61,618	62,370	752 (1%)
	Below Normal	60,551	61,282	731 (1%)
	Dry	62,562	62,588	26 (0.04%)
	Critical	66,986	64,682	-2,303 (-3%)
	All	61,519	62,103	584 (0.9%)
December	Wet	65,548	66,992	1,444 (2%)
	Above Normal	66,635	66,829	194 (0.3%)
	Below Normal	65,809	66,446	637 (1%)
	Dry	72,907	72,256	-651 (-0.9%)
	Critical	70,121	70,661	540 (0.8%)
	All	68,239	68,737	498 (0.7%)
January	Wet	68,569	68,470	-100 (-0.1%)
	Above Normal	68,778	68,771	-6 (-0.01%)
	Below Normal	69,865	70,433	568 (0.8%)
	Dry	70,819	70,945	126 (0.2%)
	Critical	70,170	72,298	2,128 (3%)
	All	69,559	69,945	386 (0.6%)
February	Wet	74,671	74,615	-56 (-0.1%)
	Above Normal	78,836	77,904	-932 (-1%)
	Below Normal	68,593	70,799	2,205 (3%)
	Dry	69,051	69,175	124 (0.2%)
	Critical	70,032	71,994	1,963 (3%)
	All	72,466	72,914	448 (0.6%)

Table 5.4-57. Spring-Run Chinook Salmon Fry Rearing Weighted Usable Areas (WUA) and Differences (Percent Differences) between Model Scenarios in River Segment 5 (green indicates PA is at least 5% higher [raw difference] than NAA; red indicates PA is at least 5% lower)

Month	Water Year Type	NAA	PA	PA vs. NAA
November	Wet	926,011	1,041,104	115,093 (12%)
	Above Normal	933,140	1,181,900	248,760 (27%)
	Below Normal	1,253,988	1,314,002	60,014 (5%)
	Dry	1,352,099	1,359,639	7,540 (0.6%)
	Critical	1,459,455	1,393,442	-66,013 (-5%)

Month	Water Year Type	NAA	PA	PA vs. NAA
	All	1,155,843	1,229,872	74,029 (6%)
December	Wet	1,279,311	1,299,436	20,126 (2%)
	Above Normal	1,235,383	1,272,981	37,598 (3%)
	Below Normal	1,285,634	1,284,178	-1,457 (-0.1%)
	Dry	1,302,331	1,284,844	-17,487 (-1%)
	Critical	1,478,631	1,478,842	211 (0.01%)
	All	1,308,875	1,316,421	7,546 (0.6%)
January	Wet	1,243,402	1,184,743	-58,659 (-5%)
	Above Normal	1,315,155	1,315,630	475 (0.04%)
	Below Normal	1,270,988	1,269,935	-1,053 (-0.1%)
	Dry	1,284,618	1,275,452	-9,167 (-0.7%)
	Critical	1,432,288	1,399,043	-33,245 (-2%)
	All	1,296,173	1,270,407	-25,766 (-2%)
February	Wet	1,129,301	1,109,445	-19,856 (-2%)
	Above Normal	1,180,418	1,181,957	1,539 (0.1%)
	Below Normal	1,283,450	1,283,647	197 (0.02%)
	Dry	1,454,111	1,441,233	-12,879 (-0.9%)
	Critical	1,418,711	1,480,899	62,188 (4%)
	All	1,279,658	1,279,592	-66 (0%)

Table 5.4-58. Spring-Run Chinook Salmon Fry Rearing Weighted Usable Areas (WUA) and Differences (Percent Differences) between Model Scenarios in River Segment 4 (green indicates PA is at least 5% higher [raw difference] than NAA; red indicates PA is at least 5% lower)

Month	Water Year Type	NAA	PA	PA vs. NAA
November	Wet	170,587	183,246	12,659 (7%)
	Above Normal	174,232	189,361	15,129 (9%)
	Below Normal	199,855	204,797	4,942 (2%)
	Dry	208,079	209,412	1,334 (0.6%)
	Critical	258,353	242,021	-16,332 (-6%)
	All	197,361	202,247	4,885 (2%)
December	Wet	197,730	203,064	5,334 (3%)
	Above Normal	198,735	200,701	1,967 (1%)
	Below Normal	212,080	211,503	-576 (-0.3%)
	Dry	200,937	202,090	1,153 (0.6%)
	Critical	241,605	243,986	2,380 (1%)
	All	207,119	209,682	2,563 (1%)
January	Wet	188,718	184,053	-4,666 (-2%)
	Above Normal	205,594	205,565	-28 (-0.01%)
	Below Normal	204,395	204,175	-220 (-0.1%)
	Dry	198,053	196,521	-1,532 (-0.8%)

Month	Water Year Type	NAA	PA	PA vs. NAA
	Critical	230,927	219,761	-11,166 (-5%)
	All	201,950	198,429	-3,521 (-2%)
February	Wet	162,338	161,481	-857 (-0.5%)
	Above Normal	167,556	168,140	584 (0.3%)
	Below Normal	209,012	210,031	1,020 (0.5%)
	Dry	224,619	224,143	-476 (-0.2%)
	Critical	245,154	259,482	14,328 (6%)
	All	196,736	198,675	1,939 (1%)

Table 5.4-59. Spring-Run Chinook Salmon Juvenile Rearing Weighted Usable Areas (WUA) and Differences (Percent Differences) between Model Scenarios in River Segment 6 (green indicates PA is at least 5% higher [raw difference] than NAA; red indicates PA is at least 5% lower)

Month	Water Year Type	NAA	PA	PA vs. NAA
January	Wet	28,944	27,904	-1,041 (-4%)
	Above Normal	29,751	29,740	-11 (-0.04%)
	Below Normal	29,628	29,571	-57 (-0.2%)
	Dry	29,921	29,966	45 (0.1%)
	Critical	32,677	32,493	-184 (-0.6%)
	All	29,948	29,593	-355 (-1%)
February	Wet	28,792	28,607	-186 (-0.6%)
	Above Normal	28,233	28,133	-100 (-0.4%)
	Below Normal	29,268	29,101	-166 (-0.6%)
	Dry	33,062	33,018	-44 (-0.1%)
	Critical	33,245	34,224	978 (3%)
	All	30,460	30,496	35 (0.1%)
March	Wet	25,414	25,390	-24 (-0.1%)
	Above Normal	27,393	26,663	-731 (-3%)
	Below Normal	31,873	31,373	-500 (-2%)
	Dry	32,863	32,806	-58 (-0.2%)
	Critical	33,622	32,647	-975 (-3%)
	All	29,612	29,265	-347 (-1%)
April	Wet	39,471	39,526	55 (0.1%)
	Above Normal	41,850	41,523	-327 (-0.8%)
	Below Normal	42,342	43,080	738 (2%)
	Dry	42,862	43,323	461 (1%)
	Critical	42,321	42,262	-59 (-0.1%)
	All	41,478	41,646	168 (0.4%)
May	Wet	40,927	40,990	63 (0.2%)
	Above Normal	41,545	41,674	129 (0.3%)
	Below Normal	43,144	42,896	-248 (-0.6%)

Month	Water Year Type	NAA	PA	PA vs. NAA
	Dry	43,171	41,734	-1,437 (-3%)
	Critical	42,326	42,435	108 (0.3%)
	All	42,074	41,747	-328 (-0.8%)
June	Wet	37,291	36,889	-402 (-1%)
	Above Normal	34,123	32,682	-1,441 (-4%)
	Below Normal	34,136	34,230	94 (0.3%)
	Dry	35,461	33,581	-1,880 (-5%)
	Critical	37,656	36,318	-1,338 (-4%)
	All	35,973	34,975	-998 (-3%)
July	Wet	30,648	30,478	-169 (-0.6%)
	Above Normal	30,536	30,212	-324 (-1%)
	Below Normal	30,240	30,586	346 (1%)
	Dry	30,969	31,366	397 (1%)
	Critical	32,998	34,171	1,173 (4%)
	All	30,998	31,207	210 (0.7%)
August	Wet	36,130	35,871	-258 (-0.7%)
	Above Normal	35,711	35,907	196 (0.5%)
	Below Normal	35,227	37,372	2,144 (6%)
	Dry	39,218	38,279	-939 (-2%)
	Critical	39,446	38,559	-887 (-2%)
	All	37,181	37,059	-122 (-0.3%)
September	Wet	31,672	31,609	-63 (-0.2%)
	Above Normal	39,161	41,403	2,242 (6%)
	Below Normal	42,904	43,765	861 (2%)
	Dry	43,006	42,872	-134 (-0.3%)
	Critical	41,419	43,050	1,631 (4%)
	All	38,557	39,214	657 (2%)
October	Wet	41,662	43,027	1,365 (3%)
	Above Normal	43,615	42,822	-792 (-2%)
	Below Normal	45,982	43,621	-2,361 (-5%)
	Dry	42,941	43,409	468 (1.1%)
	Critical	43,397	42,174	-1,223 (-3%)
	All	43,111	43,045	-66 (-0.2%)
November	Wet	23,266	27,516	4,249 (18%)
	Above Normal	25,892	29,210	3,318 (13%)
	Below Normal	29,302	29,654	352 (1%)
	Dry	29,992	30,160	168 (0.6%)
	Critical	32,175	31,239	-936 (-3%)
	All	27,456	29,262	1,806 (7%)
December	Wet	28,523	29,190	668 (2%)

Month	Water Year Type	NAA	PA	PA vs. NAA
	Above Normal	29,402	28,844	-558 (-2%)
	Below Normal	29,969	29,906	-62 (-0.2%)
	Dry	30,546	30,190	-356 (-1%)
	Critical	33,603	33,786	183 (0.5%)
	All	30,101	30,164	62 (0.2%)

Table 5.4-60. Spring-Run Chinook Salmon Juvenile Rearing Weighted Usable Areas (WUA) and Differences (Percent Differences) between Model Scenarios in River Segment 5 (green indicates PA is at least 5% higher [raw difference] than NAA; red indicates PA is at least 5% lower)

Month	Water Year Type	NAA	PA	PA vs. NAA
January	Wet	432,112	413,583	-18,529 (-4%)
	Above Normal	445,682	445,658	-24 (-0.01%)
	Below Normal	443,727	443,611	-115 (-0.03%)
	Dry	445,606	444,111	-1,495 (-0.3%)
	Critical	502,981	493,596	-9,384 (-2%)
	All	449,484	441,851	-7,632 (-2%)
February	Wet	373,821	368,986	-4,834 (-1%)
	Above Normal	378,117	377,920	-197 (-0.1%)
	Below Normal	450,190	445,515	-4,674 (-1%)
	Dry	513,604	510,977	-2,627 (-0.5%)
	Critical	508,642	522,494	13,852 (3%)
	All	438,570	437,765	-805 (-0.2%)
March	Wet	366,405	366,379	-26 (-0.01%)
	Above Normal	424,177	410,918	-13,258 (-3%)
	Below Normal	497,733	487,596	-10,137 (-2%)
	Dry	506,508	505,929	-579 (-0.1%)
	Critical	519,295	512,383	-6,912 (-1%)
	All	449,727	445,104	-4,623 (-1%)
April	Wet	420,914	420,134	-780 (-0.2%)
	Above Normal	443,907	443,595	-311 (-0.1%)
	Below Normal	456,425	459,248	2,823 (0.6%)
	Dry	478,483	474,249	-4,234 (-0.9%)
	Critical	436,575	433,844	-2,731 (-0.6%)
	All	445,656	444,306	-1,350 (-0.3%)
May	Wet	394,060	394,839	779 (0.2%)
	Above Normal	413,996	413,087	-909 (-0.2%)
	Below Normal	413,934	415,744	1,810 (0.4%)
	Dry	427,754	416,004	-11,750 (-3%)
	Critical	432,727	429,645	-3,082 (-0.7%)
	All	413,763	410,792	-2,971 (-0.7%)

Month	Water Year Type	NAA	PA	PA vs. NAA
June	Wet	353,610	350,912	-2,698 (-0.8%)
	Above Normal	333,162	323,726	-9,436 (-3%)
	Below Normal	335,110	328,009	-7,101 (-2%)
	Dry	339,645	326,841	-12,804 (-4%)
	Critical	359,134	348,083	-11,051 (-3%)
	All	345,289	337,245	-8,044 (-2%)
July	Wet	304,401	303,147	-1,255 (-0.4%)
	Above Normal	292,543	293,527	983 (0.3%)
	Below Normal	295,515	295,330	-186 (-0.1%)
	Dry	309,237	309,588	351 (0.1%)
	Critical	326,040	332,004	5,964 (2%)
	All	305,675	306,367	692 (0.2%)
August	Wet	346,188	344,506	-1,682 (-0.5%)
	Above Normal	343,345	343,179	-166 (-0.05%)
	Below Normal	338,449	353,968	15,519 (5%)
	Dry	371,310	363,110	-8,200 (-2%)
	Critical	379,657	375,652	-4,006 (-1%)
	All	355,724	354,660	-1,064 (-0.3%)
September	Wet	311,968	313,612	1,644 (0.5%)
	Above Normal	373,342	394,735	21,392 (6%)
	Below Normal	470,407	489,201	18,793 (4%)
	Dry	486,797	495,488	8,691 (2%)
	Critical	485,334	489,551	4,217 (0.9%)
	All	410,964	420,135	9,171 (2%)
October	Wet	402,160	422,695	20,535 (5%)
	Above Normal	428,233	426,672	-1,562 (-0.4%)
	Below Normal	456,276	429,635	-26,640 (-6%)
	Dry	460,804	448,849	-11955 (-3%)
	Critical	478,293	467,689	-10603 (-2%)
	All	439,131	437,350	-1780 (-0.4%)
November	Wet	359,835	417,002	57167 (16%)
	Above Normal	375,328	443,072	67744 (18%)
	Below Normal	467,852	477,774	9922 (2%)
	Dry	481,554	484,303	2749 (0.6%)
	Critical	505,551	493,755	-11796 (-2%)
	All	428,441	457,106	28665 (7%)

Month	Water Year Type	NAA	PA	PA vs. NAA
December	Wet	444,484	446,185	1701 (0.4%)
	Above Normal	446,543	443,261	-3282 (-0.7%)
	Below Normal	453,829	450,779	-3051 (-0.7%)
	Dry	444,837	442,933	-1904 (-0.4%)
	Critical	517,248	518,823	1575 (0.3%)
	All	456,925	456,334	-591 (-0.1%)

Table 5.4-61. Spring-Run Chinook Salmon Juvenile Rearing Weighted Usable Areas (WUA) and Differences (Percent Differences) between Model Scenarios in River Segment 4 (green indicates PA is at least 5% higher [raw difference] than NAA; red indicates PA is at least 5% lower)

Month	Water Year Type	NAA	PA	PA vs. NAA
January	Wet	105,561	96,786	-8774 (-8%)
	Above Normal	120,006	120,026	19 (0.02%)
	Below Normal	111,312	111,317	5 (0.004%)
	Dry	113,748	113,146	-602 (-0.5%)
	Critical	142,557	137,324	-5233 (-4%)
	All	116,033	112,342	-3691 (-3%)
February	Wet	72,975	70,412	-2563 (-4%)
	Above Normal	82,159	82,191	32 (0.04%)
	Below Normal	115,508	114,052	-1456 (-1%)
	Dry	150,024	148,480	-1,544 (-1%)
	Critical	154,053	160,903	6,850 (4%)
	All	110,794	110,417	-377 (-0.3%)
March	Wet	74,330	74,044	-287 (-0.4%)
	Above Normal	101,342	95,175	-6,167 (-6%)
	Below Normal	146,884	139,687	-7,197 (-5%)
	Dry	145,837	145,714	-123 (-0.1%)
	Critical	160,506	157,978	-2,528 (-1.6%)
	All	118,397	115,963	-2,434 (-2%)
April	Wet	100,706	100,259	-447 (-0.4%)
	Above Normal	114,559	114,471	-87 (-0.1%)
	Below Normal	125,936	128,216	2,281 (2%)
	Dry	141,034	137,514	-3,520 (-2%)
	Critical	123,099	121,151	-1,948 (-2%)
	All	119,400	118,406	-993 (-0.8%)
May	Wet	84,773	85,296	522 (0.6%)
	Above Normal	103,129	102,211	-918 (-0.9%)
	Below Normal	102,810	103,712	901 (0.9%)
	Dry	113,644	107,550	-6,093 (-5%)
	Critical	120,533	117,678	-2,855 (-2%)

Month	Water Year Type	NAA	PA	PA vs. NAA
	All	102,378	100,615	-1,763 (-2%)
June	Wet	64,501	63,511	-990 (-2%)
	Above Normal	55,834	54,584	-1,250 (-2%)
	Below Normal	55,813	58,223	2,411 (4%)
	Dry	61,880	53,985	-7,895 (-13%)
	Critical	72,830	66,683	-6,147 (-8%)
	All	62,541	59,527	-3,014 (-5%)
July	Wet	47,124	45,954	-1,170 (-2%)
	Above Normal	44,779	43,791	-988 (-2%)
	Below Normal	43,578	44,027	449 (1%)
	Dry	48,479	50,945	2,466 (5%)
	Critical	55,578	60,078	4,500 (8%)
	All	47,844	48,637	793 (2%)
August	Wet	64,888	64,007	-881 (-1%)
	Above Normal	65,342	64,175	-1,167 (-2%)
	Below Normal	61,595	70,346	8,750 (14%)
	Dry	81,374	76,801	-4,573 (-6%)
	Critical	86,051	84,560	-1,491 (-2%)
	All	71,636	71,012	-624 (-0.9%)
September	Wet	52,473	51,421	-1,052 (-2%)
	Above Normal	80,500	95,548	15,049 (19%)
	Below Normal	146,125	155,660	9,534 (7%)
	Dry	154,899	158,005	3,105 (2%)
	Critical	156,031	158,501	2,470 (2%)
	All	109,616	114,066	4,450 (4%)
October	Wet	95,915	111,740	15,824 (16%)
	Above Normal	115,276	113,689	-1,586 (-1%)
	Below Normal	134,904	116,236	-18,667 (-14%)
	Dry	137,405	131,516	-5,889 (-4%)
	Critical	152,604	151,355	-1,249 (-0.8%)
	All	122,721	123,391	670 (0.5%)
November	Wet	68,272	103,228	34,956 (51%)
	Above Normal	75,596	122,916	47,320 (63%)
	Below Normal	137,638	143,452	5,814 (4%)
	Dry	140,893	142,968	2,075 (1%)
	Critical	160,501	156,188	-4,313 (-3%)
	All	110,372	129,266	18,894 (17%)
December	Wet	120,552	119,449	-1,103 (-0.9%)
	Above Normal	117,007	114,999	-2,008 (-2%)
	Below Normal	120,260	119,003	-1,257 (-1%)

Month	Water Year Type	NAA	PA	PA vs. NAA
	Dry	118,140	117,090	-1,050 (-0.9%)
	Critical	157,336	157,833	496 (0.3%)
	All	124,841	123,833	-1,008 (-0.8%)

5.4.2.1.3.2.2.1.1 SALMOD flow-related outputs

The SALMOD model provides predicted flow-related fry and juvenile spring-run Chinook salmon mortality, which is presented as mortality of the fry, pre-smolt, and immature smolt life stages (see Attachment 5.D.2, *SALMOD Model*, for a full description). Results for flow-related mortality of these life stages are presented in Table 5.4-54 and the annual exceedance plot for all water year types combined is presented in Figure 5.4-181. These results show no mortality for the pre-smolt and immature smolt life stages and low mortality (in terms of numbers of fish) for the fry. Flow-related mortality of spring-run Chinook salmon fry would increase moderately under the PA relative to the NAA in wet years (8% or 200 fish) and critical years (14% or 55 fish) and would decrease moderately in above normal years (13% or 350 fish). The flow-related mortality of fry for all water year types combined would be almost the same (difference = 0.4%) between the NAA and PA. Accordingly, the model predicts that there would be no biologically meaningful[52] effect of the PA on flow-related mortality of spring-run Chinook salmon fry and juveniles.

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[52] For purposes of flow-related effects, a "biologically meaningful" effect is defined as an effect that would alter one or more biological processes to the extent that it affects the fish population.

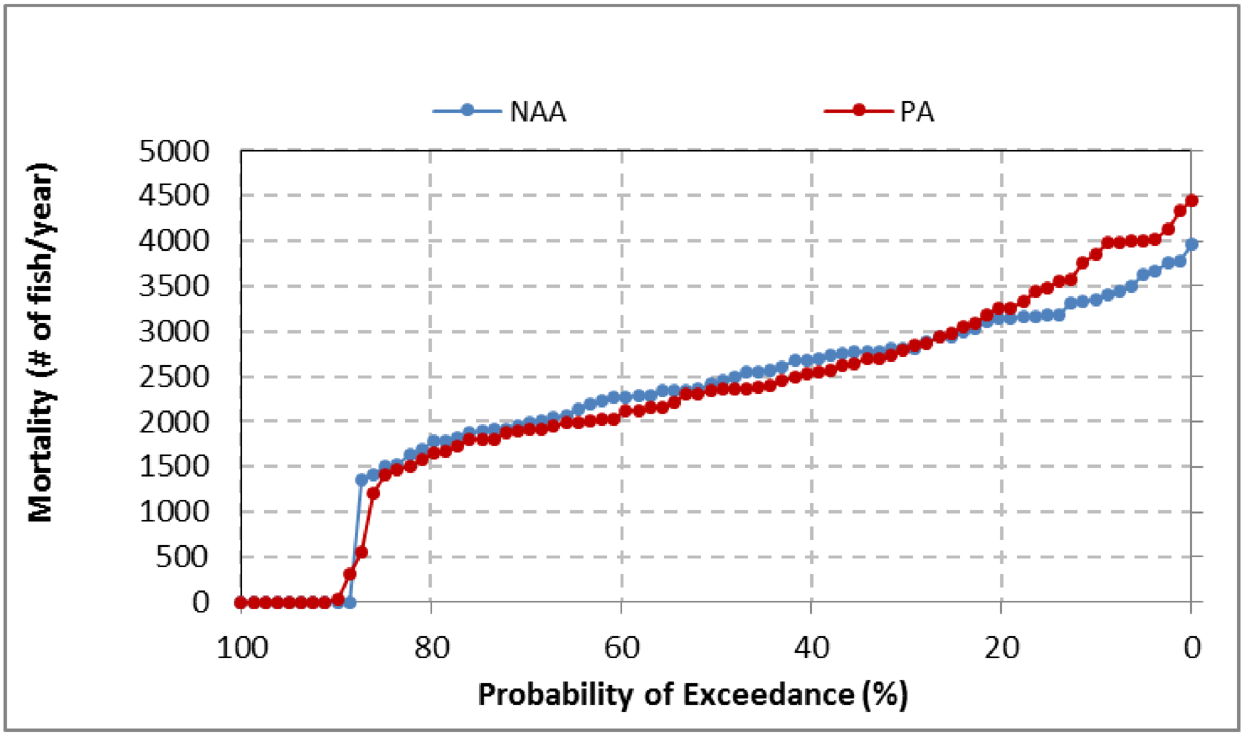

Figure 5.4-181. Exceedance Plot of Annual Flow-Based Mortality (# of Fish/Year) of Spring-Run Chinook Salmon Fry and Juveniles, SALMOD

5.4.2.1.3.2.2.2 Water Temperature-Related Effects

Modeled mean monthly water temperatures during the year-round fry and juvenile rearing period for spring-run Chinook salmon in the Sacramento River upstream of the Delta (Table 5.4-27) are presented in Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results*, Table 5.C.7-3, Table 5.C.7-4, Table 5.C.7-5, Table 5.C.7-7, Table 5.C.7-8, Table 5.C.7-10[53]. Overall, the PA would change mean water temperatures very little (predominantly less than 1°F, or approximately 1%) throughout the juvenile rearing reach of Keswick Dam to Knights Landing in all months and water year types in the period. The largest increase in mean monthly water temperatures under the PA relative to NAA would be 1.0°F (1.4%), and would occur at Knights Landing in below normal years during August.

Exceedance plots of monthly mean water temperatures were examined during each month throughout the juvenile rearing period (Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results*, Figure 5.C.7.3-7, Figure 5.C.7.4-7, Figure 5.C.7.5-7, Figure 5.C.7.7-7, Figure 5.C.7.8-7, Figure 5.C.7.10-7[54]). The values for the PA in these exceedance plots generally match those of the NAA. Further examination of below normal water years in August at Knights Landing, where the largest increase in mean monthly water temperature was seen, indicates that water temperatures under

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[53] Water temperature results for Wilkins Slough were used to represent Knights Landing for this analysis

[54] Water temperature results for Wilkins Slough were used to represent Knights Landing for this analysis

the PA would be higher than those under NAA for most of the exceedance range by up to approximately 2.2°F, particularly in the colder end of the range (Figure 5.4-108). As indicated below in the threshold analysis, temperatures predicted for Knights Landing during August of below normal water years would be greater than the 64°F 7DADM threshold on 100% of days under both the NAA and PA, although there is low certainty that modeled values are comparable to actual values. Therefore, this suggests that, with low certainty, conditions would already be unsuitable for spring-run Chinook salmon fry and juvenile rearing for reasons that are independent of the PA.

For purposes of this analysis, the water temperature thresholds analysis for juvenile rearing and emigration were combined and the year-round period was evaluated. For juvenile rearing and emigration, the thresholds used were from the USEPA's 7DADM value of 61°F for core juvenile rearing reach from Keswick Dam to Red Bluff and 64°F for the non-core juvenile rearing reach at Knights Landing (Appendix 5.D, Section 5.D.2.1, *Water Temperature Analysis Methods*, Table 5.D-49). The 7DADM values were converted to function with daily model outputs for each month separately (Appendix 5.D, Section 5.D.2.1, *Water Temperature Analysis Methods*, Table 5.D-51).

Results of the water temperature thresholds analysis are presented in Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Tables 5.D-85 through 5.D-90. At Keswick Dam, there would be no months or water year types in which there would be 5% more days under the PA compared to the NAA on which temperatures would exceed the threshold (Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-85). There would be two instances in which average daily exceedance would be 0.5°F: September of critical years and September for all water year types combined (reflecting that the only differences in threshold exceedance among water year types during September would occur during critical years). However, there would be no concurrent increase in the percent of days exceeding the threshold in these instances. This indicates that the frequency of days above the threshold be would similar under the PA, but exceedances would be higher on average.

At Clear Creek, there would be no months or water year types in which there would be both 5% more days under the PA compared to the NAA on which temperatures would exceed the threshold, and a more-than-0.5°F difference in the magnitude of average daily exceedance (Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-86). However, the percent of days exceeding the threshold under the PA would be more than 5% lower than under the NAA during September and October of critical water years (6.7% and 11.8%, respectively). Despite this reduction during September of critical water years, the difference in mean daily exceedance would increase by 0.7°F. This indicates that the frequency of days above the threshold would decrease under the PA, but exceedances per day would be higher on average.

At Balls Ferry, there would be no months or water year types in which there would be 5% more days under the PA compared to the NAA on which temperatures would exceed the 61°F 7DADM threshold, and no more-than-0.5°F difference in the magnitude of average daily exceedance (Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-87). Therefore, it was concluded that there would be no biologically meaningful effect. There are two situations at Balls Ferry during which the percent of days exceeding the threshold under the PA would be more than 5% lower than under the NAA during September and October of critical water years (10% and 14%, respectively). Despite this reduction during September of critical water years, the difference in mean daily exceedance would increase by 0.7°F. This indicates that the frequency of days above the threshold would decrease under the PA, but exceedances per day would be higher on average.

At Bend Bridge, the percent of days exceeding the 61°F 7DADM threshold under the PA would be more than 5% higher than under the NAA during July of critical water years (7.8%), August (5.9%) and September of below normal (15.8%) years, and September of dry (8.0%) water years (Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-88). There would also be a reduction of 8.4% and 11.6% in the percent of days exceeding the threshold in August of dry and critical water years, respectively, and of 11% in October of critical water years. There would not be an increase in average daily exceedance except in August of critical water years. This indicates that the frequency of days above the threshold would decrease under the PA, but exceedances per day would be higher on average.

At Red Bluff, the percent of days exceeding the 61°F 7DADM threshold under the PA would be more than 5% higher than under the NAA during July of critical water years (6.5%), August of below normal years (9.4%), and September of above normal (7.7%), below normal (10.3%), and dry (5.5%) water years (Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-89). However, in no month or water year type would there be a more-than-0.5°F difference in the magnitude of average daily exceedance. Therefore, it was concluded that there would be no biologically meaningful effect at Red Bluff.

At Knights Landing, the percent of days exceeding the 64°F 7DADM threshold for non-core rearing and emigration habitat under the PA would be more than 5% higher than under the NAA during October of wet water years (6.9%) (Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-90). There would also be a 7.9% reduction in the percent of days exceeding the threshold during October of below normal water years. However, in neither of these situations would there also be a more-than-0.5°F difference in the magnitude of average daily exceedance. Therefore, it was concluded that there would be no biologically meaningful effect. There would be >0.5F increases in the magnitude of average daily exceedance in 3 cases: September of above normal water years (0.8°F), and August (1.0°F) and September (0.8°F) of below normal water years. Temperatures predicted for Knights Landing during August of below normal water years would be greater than the 64°F 7DADM threshold on 100% of days under both the NAA and PA, although there is low certainty that modeled values are comparable to actual values. Therefore, this suggests that, with low certainty, conditions would already be unsuitable for spring-run Chinook salmon fry and juvenile rearing for reasons that are independent of the PA.

Overall, the thresholds analysis indicates that there would be more exceedances (5% or greater) in certain months and water year types under the PA, which could have lethal or sublethal effects on spring-run Chinook salmon fry and juvenile rearing, although this does not consider real-time operational management described in Section 3.1.5, *Real-Time Operations Upstream of the Delta*, and Section 3.3.3, *Real-Time Operational Decision-Making Process*, that would be used to avoid and minimize any modeled effects. This analysis also does not consider the current revision process to OCAP RPA Action Suite 1.2 described in Section 3.1.4.5, *Annual/Seasonal Temperature Management Upstream of the Delta*, to improve winter-run Chinook salmon egg-to-fry survival. This process may result in refinements and additions to the existing annual/seasonal temperature management processes, including spring storage targets, revised temperature compliance criteria and a range in summertime Keswick release rates. Although the process targets winter-run Chinook salmon, these changes are expected to benefit other races of Chinook salmon. The biological interpretation of these results, combined with all upstream results, in the context of real-time operational management is provided in Section 5.4.2.3, *Summary of Upstream Effects*, below.

The SALMOD model provides predicted water temperature-related fry and juvenile spring-run Chinook salmon mortality, which is a combination of mortality of the fry, pre-smolt, and immature smolt life stages (see Attachment 5.D.2, *SALMOD Model*, for a full description). Results for water temperature-related mortality of these life stages are presented in Table 5.4-55 and the annual exceedance plot is presented in Figure 5.4-182. These results indicate that there would be very little water temperature-related mortality to these life stages. Therefore, there would be no biologically meaningful effect of the PA.

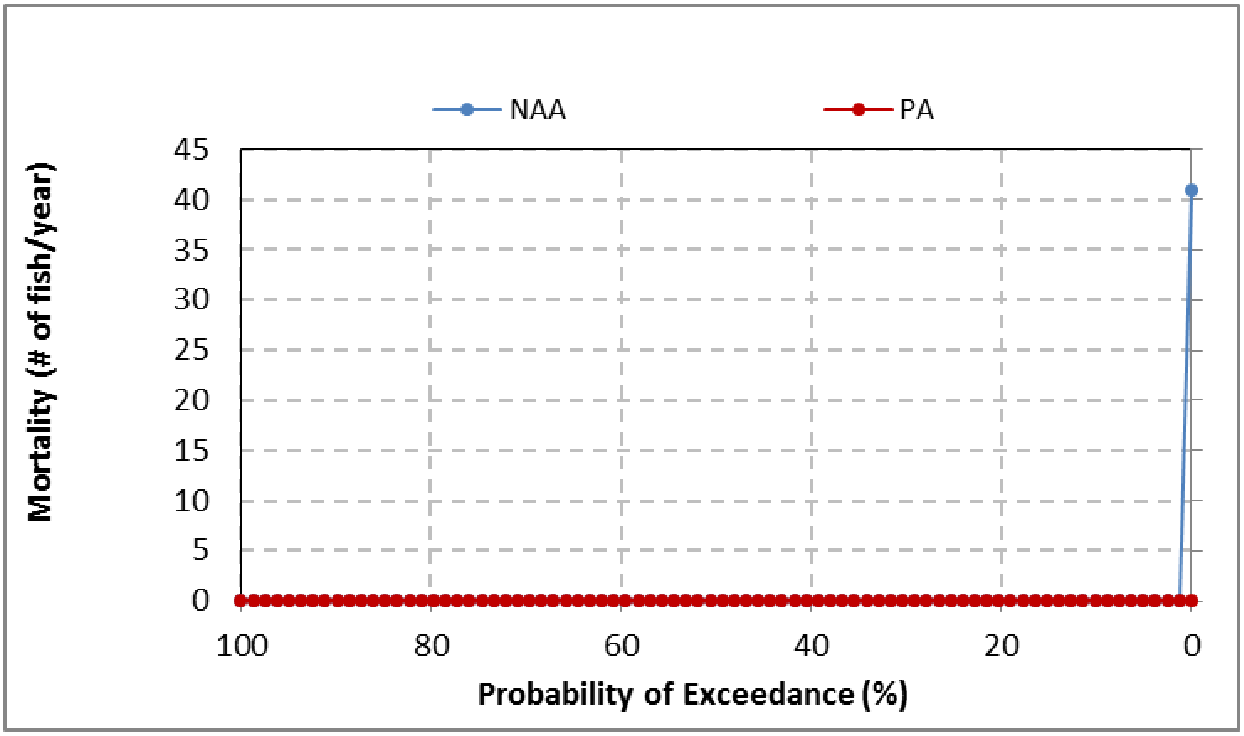

Figure 5.4-182. Exceedance Plot of Annual Water Temperature-Based Mortality (# of Fish/Year) of Spring-Run Chinook Salmon Fry and Juveniles, SALMOD

5.4.2.1.3.2.3 Juvenile Emigration

5.4.2.1.3.2.3.1 Flow-Related Effects

Mean monthly flows were evaluated in the Sacramento River at four locations along the downstream migration corridor of juvenile spring-run Chinook salmon (i.e., Keswick, Red Bluff, Wilkins Slough and Verona) during the October through May emigration period, with peak migration from October through December and in April (Table 5.4-27). Changes in flow potentially affect emigration of juveniles, including the timing and rate of emigration, as well as conditions for feeding, protective cover, resting, temperature, turbidity, and other habitat factors. Crowding and stranding, especially in side-channel habitats, can also be affected (Quinn 2005; Williams 2006; del Rosario et al. 2013). As described in Appendix 5.D, Section 5.D.2.4, *Migration Flows Methods*, quantitative relationships between flow and downstream migration generally are highly variable and poorly understood, but on balance, except under very high flows, benefits of increased flow generally outweigh the costs. Therefore, it is assumed for the purposes of this effects analysis that increased flow would improve conditions for the emigration of juvenile spring-run Chinook salmon. Milner et al. (2012) and del Rosario et al. (2013) have found that migration cues for anadromous fish species are often the result of natural pulse flows, or pulse flows caused by natural events, such as an extensive rainfall event, which will not be affected by the PA.

Shasta Reservoir storage volume at the end of September influences flows in the Sacramento River during much of the juvenile emigration period. Mean Shasta September storage under the PA would be similar (less than 5% difference) to storage under NAA for all water year types, except for 7% higher mean storage during critical water years under the PA (Appendix 5.A, *CALSIM Methods and Results*, Table 5.A.6-3).

In general, mean flow under the PA would be similar to (less than 5% difference) or greater than flow under the NAA during most months and water year types of the spring-run juvenile emigration period (Appendix 5.A, *CALSIM Methods and Results,* Table 5.A.6-10, Table 5.A.6-14, Table 5.A.6-35, Table 5.A.6-36). During November of wet and above normal water years, however, flow under the PA would be 26% lower than it would be under the NAA at Keswick Dam, 21% lower at Red Bluff, up to 24% lower at Wilkins Slough, and up to 17% lower at Verona. In November of critical water years, flow would be greater at all the locations (up to 13% greater in Keswick). Flow would also be lower in October of wet years (7% to 9% lower, depending on location) and 6% to 13% lower in February of critical years, except at Verona. The largest increases in flow under the PA would occur during October of below normal and dry years, with increases in ranging from 6% in dry years at Red Bluff to 17% in below normal years at Keswick. The large flow differences during October and November coincide with the peak of the juvenile emigration period. During January, mean flow under the PA at Keswick would be 18% greater than it would be under the NAA in critical water year types and 8% greater in wet years. At Red Bluff, the mean January flow in critical years would be 7% greater under the PA; at the other two locations, all differences in January flow would be less than 5%. During February, in addition to the flow reductions described above, flow would be 8% greater in below normal years but only at Keswick. During March, flow under the PA at Keswick would be 9% greater in above normal and below normal years and 8% greater in critical years, but there would be no differences greater than 5% at the other locations. During May, flow would be 5% to 8% greater in dry years, except at Verona.

The CALSIM modeling results given here indicate that the PA would reduce flow in some months and water year types, although this does not consider real-time operational management described in Section 3.1.5, *Real-Time Operations Upstream of the Delta*, and Section 3.3.3, *Real-Time Operational Decision-Making Process*, that would be used to avoid and minimize any modeled effects. Further discussion regarding flow-related effects during the June through November period are provided in Section 5.4.2.3, *Summary of Upstream Effects*.

5.4.2.1.3.2.3.2 Water Temperature-Related Effects

Modeled mean monthly water temperatures in the Sacramento River in the reach from Keswick Dam to Knights Landing during the October through May juvenile emigration period for spring-run Chinook salmon (Table 5.4-27) are presented in Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results,* Table 5.C.7-3, Table 5.C.7-4, Table 5.C.7-5, Table 5.C.7-7, Table 5.C.7-8, Table 5.C.7-10[55]. Overall, the PA would change mean water temperatures very little (predominantly less than 1°F, or approximately 1%) throughout the Sacramento River upstream of the Delta in all months and water year types in the period. The largest increase in mean monthly water temperatures under the PA relative to NAA would be 1.0°F (1.4%), and would occur at Knights Landing in below normal years during August.

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[55] Water temperature results for Wilkins Slough were used to represent Knights Landing for this analysis

Exceedance plots of monthly mean water temperatures were examined during each month throughout the spring-run Chinook salmon juvenile emigration period (Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results,* Figure 5.C.7.3-7, Figure 5.C.7.4-7, Figure 5.C.7.5-7, Figure 5.C.7.7-7, Figure 5.C.7.8-7, Figure 5.C.7.10-7[56]). Values in the exceedance plots for PA generally match those of the NAA, except in below normal water years in August at Knights Landing, for which water temperatures under the PA would be higher than those under NAA for most of the range by up to approximately 2.2°F, particularly at the colder end of the range (Figure 5.4-108). As indicated above, temperatures predicted for Knights Landing during August of below normal water years would be greater than the 64°F 7DADM threshold on 100% of days under both the NAA and PA although there is low certainty that modeled values are comparable to actual values. Therefore, this suggests that, with low certainty, conditions would already be unsuitable for spring-run Chinook salmon juvenile emigration for reasons that are independent of the PA.

Please see the discussion of water temperature thresholds for juvenile spring-run Chinook salmon emigration in Section 5.4.2.1.3.1.2, *Fry and Juvenile Rearing,* which concludes that that there would be no water temperature-related effects of the PA on spring-run Chinook salmon juvenile rearing and emigration

5.4.2.1.3.2.4 Adult Immigration

5.4.2.1.3.2.4.1 Flow-Related Effects

Mean monthly flows were evaluated in the Sacramento River at four locations along the upstream migration corridor of adult spring-run Chinook salmon (i.e., Keswick, Red Bluff, Wilkins Slough and Verona) during the March through September immigration period, with peak migration during May and June (Table 5.4-27). Changes in flow potentially affect conditions for upstream migration of adults, including bioenergetic cost, water quality, crowding, cues for locating natal streams, and passage conditions, but the quantitative relationship between flow and upstream migration is poorly understood (Quinn 2005; Milner et al. 2012). As described in Appendix 5.D, Section 5.D.2.4, *Migration Flows Methods,* on balance, except under very high flows, the benefits of increased flow generally outweigh the costs and, therefore, it is assumed for the purposes of this effects analysis that increased flow would improve conditions for upstream migration of adult spring-run Chinook salmon. Milner et al. (2012) and del Rosario et al. (2013) have found that migration cues for anadromous fish species are often the result of natural pulse flows, or pulse flows caused by natural events, such as an extensive rainfall event, which will not be affected by the PA.

Shasta Reservoir storage volume at the end of May influences flows in the Sacramento River during the second half of the immigration period. Mean Shasta May storage under the PA would be similar (less than 5% difference) to storage under NAA for all water year types (Appendix 5.A, *CALSIM Methods and Results,* Table 5.A.6-3).

In general, mean flows under the PA at the four river locations during the 4 months of the adult immigration period for spring-run Chinook salmon would be similar to (less than 5% difference)

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[56] Water temperature results for Wilkins Slough were used to represent Knights Landing for this analysis

or greater than those under the NAA, whereas mean flows during the last 3 months would be similar (less than 5% difference) between the PA and the NAA or would be lower under the PA (Appendix 5.A, *CALSIM Methods and Results*, Table 5.A.6-10, Table 5.A.6-14, Table 5.A.6-35, Table 5.A.6-36). During March, mean flow under the PA at Keswick would be 9% greater in above normal and below normal years and 8% greater in critical years, but there would be no differences greater than 5% at the other locations. During May, flow under the PA would be greater (up to 8% greater at Wilkins Slough) at all the locations, except Verona. During June, flow under the PA would be greater at all the locations, including all water year types at Verona and all water year types, except wet years at the other locations. The increases for all water year types would be greater at Wilkins Sough and Verona (up to 25% greater in above normal years) than those at Keswick and Red Bluff. The flow differences during May and June, all of which are positive for the PA, would occur during the peak immigration period. During July of critical water years, mean flow under the PA would be up to 13% lower at Wilkins Slough and Verona. During August, mean flow in below normal years would be lower at all four locations (up to 18% lower flow at Wilkins Slough). During August of dry and critical years, flow under the PA would be greater (up to 10% greater) at Wilkins Slough and Verona. Mean flow during September would be lower for most water year types at all the locations (up to 24% lower in below normal years at Verona).

The CALSIM modeling results given here indicate that the PA would reduce flow in some months and water year types, although this does not consider real-time operational management described in Section 3.1.5, *Real-Time Operations Upstream of the Delta*, and Section 3.3.3, *Real-Time Operational Decision-Making Process*, that would be used to avoid and minimize any modeled effects. Further discussion regarding flow-related effects during the June through November period are provided in Section 5.4.2.3, *Summary of Upstream Effects*. As described in Appendix 5.D, Section 5.D.2.4, *Migration Flows Methods*, mean monthly flow below about 3,250 cfs is considered to have potentially adverse effects on Chinook salmon, CCV steelhead, and green sturgeon adult immigration conditions in the Sacramento River. The effect of the PA on the frequency of flows below this threshold was evaluated by comparing CALSIM flows between the PA and the NAA at three of the migration corridor locations in the river: Keswick, Red Bluff, and Wilkins Slough. Of the 574 months within the spring-run Chinook salmon migration period, only one has a mean flow less than 3,250 cfs under both the PA and the NAA at Keswick and Wilkins Slough, and none has a mean flow less than 3,250 cfs at Red Bluff. The one month with mean flow less than 3,250 cfs for both scenarios and locations was September of 1934, a critically dry water year.

5.4.2.1.3.2.4.2 Water Temperature-Related Effects

Modeled mean monthly water temperatures in the Sacramento River at Keswick Dam, Bend Bridge, and Red Bluff during the March through September adult immigration period for spring-run Chinook salmon (Table 5.4-27) are presented in Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results*, Table 5.C.7-3, Table 5.C.7-7, Table 5.C.7-8. Overall, the PA would change mean water temperatures very little (less than 1°F, or approximately 1%) at these locations in all months and water year types in the period. The largest increase in mean monthly water temperatures under the PA relative to NAA would be 0.6°F (0.9% to 1.1%), and would occur at Red Bluff in below normal years during August and in above- and below normal water years during September.

Exceedance plots of monthly mean water temperatures were examined during each month throughout the adult immigration period (Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results,* Figure 5.C.7.3-7, Figure 5.C.7.7-7, Figure 5.C.7.8-7). The curves for the PA generally match those of the NAA. For below normal water years in August at Red Bluff, where the largest increase in mean monthly water temperature was seen, the PA curve is consistently higher than the NAA curve by approximately 0.5°F (Figure 5.4-111). During September of above normal and below normal water years, water temperatures are more variable between the two scenarios, but those under the PA are higher in nearly all years (Figure 5.4-60, Figure 5.4-61).

To evaluate water temperature threshold exceedance during the adult immigration life stage at Keswick Dam, Bend Bridge, and Red Bluff, the USEPA's 7DADM threshold value of 68°F was used (Appendix 5.D, Section 5.D.2.1, *Water Temperature Analysis Methods*, Table 5.D.2-49). The threshold was converted to function with daily model outputs for each month separately (Appendix 5.D, Section 5.D.2.1, *Water Temperature Analysis Methods*, Table 5.D.2-51).

Results of the water temperature thresholds analysis are presented in Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Tables 5.D-91 through 5.D-93. At Keswick Dam and Red Bluff, there would be no months or water year types in which there would be both 5% more days under the PA compared to the NAA on which temperatures would exceed the threshold, and a more-than-0.5°F difference in the magnitude of average daily exceedance (Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-91 and Table 5.D-93).

At Bend Bridge, there are two instances during which the percent of days exceeding the 68°F DADM under the PA would be more than 5% higher than under the NAA: August of critical water years (5.1% higher under the PA) and September of critical water years (5.3% higher) (Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-92). However, there would be an insignificant (less than 0.1°F) difference in average daily exceedance in these instances. Therefore, it was concluded that there would be no biologically meaningful effect on spring-run adult immigration.

Overall, the thresholds analysis indicates that there would be more exceedances (5% or greater) in certain months and water year types under the PA, which could have lethal or sublethal effects on winter-run Chinook salmon adult immigration, although this does not consider real-time operational management described in Section 3.1.5, *Real-Time Operations Upstream of the Delta*, and Section 3.3.3, *Real-Time Operational Decision-Making Process*, that would be used to avoid and minimize any modeled effects. The biological interpretation of these results, combined with all upstream results, in the context of real-time operational management is provided in Section 5.4.2.3, *Summary of Upstream Effects*, below.

5.4.2.1.3.2.5 Adult Holding

5.4.2.1.3.2.5.1 Flow-Related Effects

Mean monthly flow rates and reservoir storage volumes were examined for the PA and NAA in the Sacramento River at the Keswick Dam and Red Bluff locations during the April through September holding period, with peak occurrence during May through August, for spring-run

Chinook salmon (Table 5.4-27). Changes in flow likely affect holding habitat for spring-run Chinook salmon, with higher flows potentially providing greater depths and improved water quality in pools. Shasta Reservoir storage volume at the end of May influences flow rates below the dam during much of the spring-run holding period. Mean Shasta May storage under the PA would be similar (less than 5% difference) to storage under NAA for all water year types (Appendix 5.A, *CALSIM Methods and Results*, Table 5.A.6-3). During the majority of months and water year types of the spring-run holding period, the PA would result in minor (less than 5% difference) changes in mean flow in the Sacramento River at the Keswick Dam and Red Bluff locations (Appendix 5.A, *CALSIM Methods and Results*, Table 5.A.6-10, Table 5.A.6-35). However, at both locations, flows under the PA would be 5% to 7% higher during May of dry years and June of all water year types except wet years. Mean flow during August of below normal years would be 10% lower under the PA than under the NAA and mean flows during September would range from 5% to 11% lower under the PA for all water year types except wet years. The flow increases during May and June and the decrease during August occur within the peak spring-run holding period (May through August).

5.4.2.1.3.2.5.2 Water Temperature-Related Effects

Modeled mean monthly water temperatures in the Sacramento River at Keswick Dam, Balls Ferry, and Red Bluff during the April through September adult holding period for spring-run Chinook salmon (Table 5.4-27) are presented in Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results*. Table 5.C.7-3, Table 5.C.7-5, Table 5.C.7-8. Overall, the PA would change mean water temperatures very little (less than 1°F, or approximately 1%) at these locations in all months and water year types in the period. The largest increase in mean monthly water temperatures under the PA relative to NAA would be 0.6°F, or up to 1.1%, and would occur at Red Bluff in above normal years during August and above- and below normal years during September. This 0.6°F increase during August would occur during the last month of the peak adult holding period (May through August).

Exceedance plots of monthly mean water temperatures were examined during each month throughout the adult holding period (Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results*, Figure 5.C.7.3-7, Figure 5.C.7.5-7, Figure 5.C.7.8-7). The curves for PA generally match those of the NAA. For below normal water years in August at Red Bluff, where the largest increase in mean monthly water temperature was seen, the PA curve is consistently higher than the NAA curve by approximately 0.5°F (Figure 5.4-111).

To evaluate water temperature threshold exceedance during the spring-run Chinook salmon adult holding life stage at Keswick Dam, Balls Ferry, and Red Bluff, the USEPA’s 7DADM threshold value of 61°F was used (Appendix 5.D, Section 5.D.2.1, *Water Temperature Analysis Methods*, Table 5.D-49) (U.S. Environmental Protection Agency 2003). The threshold was converted to function with daily model outputs for each month separately (Appendix 5.D, Section 5.D.2.1, *Water Temperature Analysis Methods*, Table 5.D-51).

Results of the water temperature thresholds analysis are presented in Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Tables 5.D-94 through 5.D-96. At Keswick Dam and Balls Ferry, there would be no months or water year types in which there would be both 5% more days under the PA compared to the NAA on which temperatures would exceed the threshold, and a more-than-0.5°F difference in the magnitude of average daily exceedance (Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-94 and Table 5.D-95). Also at Balls Ferry, there would be a 10% reduction under the PA in the percent of days above the threshold in September of critical water years and a concurrent increase in average daily exceedance above the threshold of 0.7°F.

At Red Bluff, the percent of days exceeding the 61°F 7DADM threshold for adult holding habitat under the PA would be more than 5% higher than under the NAA during July (6.5%) of critical water years, August of below normal water years (9.4%), and September of above normal (7.7%), below normal (10.3%) and critical (5.5%) water years (Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-96). There would also be reductions in the percent of days exceeding the threshold in June of critical years (5.8%) and August of dry (6.1%) and critical (6.5%) water years. However, in none of these situations would there also be a more-than-0.5°F difference in the magnitude of average daily exceedance. Therefore, it was concluded that there would be no biologically meaningful effect.

Overall, the thresholds analysis indicates that there would be more exceedances (5% or greater) in certain months and water year types under the PA, which could have lethal or sublethal effects on holding adults, although this does not consider real-time operational management described in Section 3.1.5, *Real-Time Operations Upstream of the Delta*, and Section 3.3.3, *Real-Time Operational Decision-Making Process*, that would be used to avoid and minimize any modeled effects. In addition, this analysis does not consider the current revision process to OCAP RPA Action Suite 1.2 described in Section 3.1.4.5, *Annual/Seasonal Temperature Management Upstream of the Delta*, to improve winter-run Chinook salmon egg-to-fry survival. This process may result in refinements and additions to the existing annual/seasonal temperature management processes, including spring storage targets, revised temperature compliance criteria and a range in summertime Keswick release rates. Although the process targets winter-run Chinook salmon, these changes are expected to benefit other races of Chinook salmon. The biological interpretation of these results, combined with all upstream results, in the context of real-time operational management is provided in Section 5.4.2.3, *Summary of Upstream Effects*, below.

5.4.2.1.3.2.6 SALMOD

The SALMOD model integrates all early life stages of spring-run Chinook salmon race on an annual basis and provides an *Annual Potential Production* value (Attachment 5.D.2, *SALMOD Model*). This value represents all individuals that survive from the pre-spawn egg stage to the end of the year in each year of the 80-year simulation period. Individual years are independent of one another and, therefore, effects through time cannot be evaluated as a time series.

Mean spring-run Chinook salmon annual potential production values and differences between scenarios are presented in Table 5.4-62 and an exceedance plot is provided in Figure 5.4-183. Overall, these results indicate that changes in spring-run Chinook salmon annual potential production under the PA relative to the NAA would be insignificant. This result is consistent among water year types and when all water year types are combined, except in critical years, in which there would be a 20,164 fish (8%) increase in annual potential production under the PA, indicating a beneficial effect of the PA to spring-run Chinook salmon annual potential production.. However, as a model that integrates early life stages, but not all life stages, SALMOD does not provide a basis to evaluate the subsequent impacts of in-Delta effects on the predicted annual potential production.

Table 5.4-62. Mean Annual Potential Production of Spring-Run Chinook Salmon and Differences between Model Scenarios, SALMOD

Analysis Period	Annual Potential Production (# of Fish/year)
All Water Year Types Combined	
Full Simulation Period[1]	
NAA	401,814
PA	407,082
Difference	5,269
Percent Difference[2]	1
Water Year Types[3]	
Wet (32.5%)	
NAA	442,361
PA	457,069
Difference	14,708
Percent Difference	3
Above Normal (12.5%)	
NAA	376,362
PA	379,324
Difference	2,963
Percent Difference	1
Below Normal (17.5%)	
NAA	464,026
PA	463,493
Difference	-533
Percent Difference	0
Dry (22.5%)	
NAA	412,383
PA	401,490
Difference	-10,894
Percent Difference	-3
Critical (15%)	
NAA	268,146
PA	288,311
Difference	20,164
Percent Difference	8

[1] Based on the 80-year simulation period

[2] Relative difference of the annual average

[3] As defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (State Water Resources Control Board 1995). Water years may not correspond to the biological years in SALMOD.

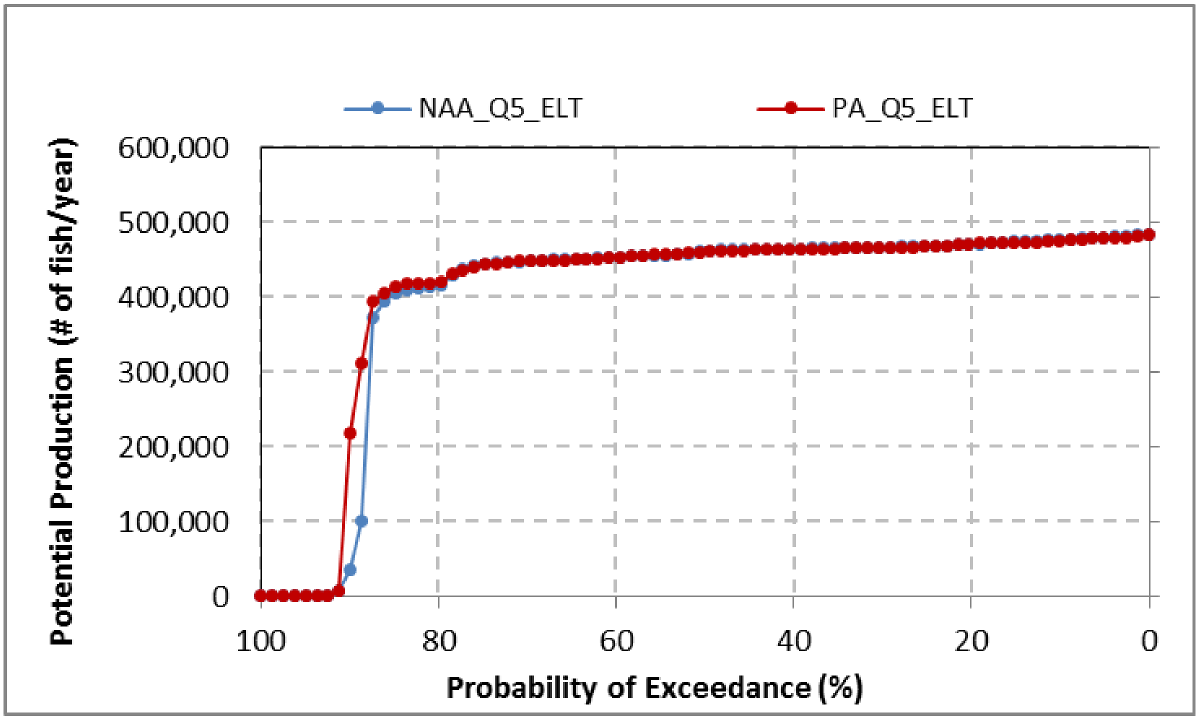

Figure 5.4-183. Exceedance Plot for Annual Potential Production (# of Fish/Year) of Spring-Run Chinook Salmon, SALMOD

The frequency at which annual production was below minimum production thresholds was evaluated as a measure of a worst-case scenario for spring-run Chinook salmon. Thresholds were determined as 5% and 10% of the number of eggs used as inputs into the model (see Attachment 5.D.2, *SALMOD* for details). The initial egg value was 1,210,000 for both NAA and PA and, therefore, the 5% and 10% values were 60,500 fish per year and 121,000 fish per year, respectively. Results are presented in Table 5.4-63. There would be 1 year fewer (11% lower) under the PA compared to the NAA during which production would be below the 5% (60,000 fish) threshold. There would be 2 fewer years (20% lower) under the PA compared to the NAA during which production would be below the 10% (591,300 fish) threshold. Therefore, the PA would have no biologically meaningful negative effects on the frequency of worst-case scenario years for spring-run Chinook salmon.

Table 5.4-63. Number of Years during which Winter-Run Chinook Salmon Production Would be Lower than Production Thresholds and Differences (Percent Differences) between Model Scenarios, SALMOD

Production Threshold (# of Fish)	NAA (# of Years)	PA (# of Years)	PA vs. NAA (# of Years [%])
60,500 (based on 5% of eggs)	9	8	-1 (-11%)
121,000 (based on 10% of eggs)	10	8	-2 (-20%)

5.4.2.1.3.3 California Central Valley Steelhead

5.4.2.1.3.3.1 Spawning, Egg Incubation, and Alevins

5.4.2.1.3.3.1.1 Flow-Related Effects

Mean monthly flow rates and reservoir storage volumes were examined for the PA and NAA during the November through April spawning and incubation period for Central Valley (CV) Steelhead (Table 5.4-29). Changes in flow can affect the instream area available for spawning and egg incubation, along with the quality of the habitat, and can result in dewatering or scour of the redds. Shasta Reservoir storage volume at the end of September influences flow rates below the dam during some of the steelhead spawning and egg incubation period in some years. Mean Shasta September storage under the PA would be similar (less than 5% difference) to storage under NAA for all water year types, except for 7% higher mean storage during critical water years under the PA (Appendix 5.A, *CALSIM Methods and Results*, Table 5.A.6-3). Under the PA, mean flow at the Keswick Dam and Red Bluff locations in the Sacramento River would be lower than flow under the NAA during November of all except critical water year types, with 26% lower flows under the PA than under the NAA for wet and above normal water year types at Keswick Dam and 21% lower flows at Red Bluff (Appendix 5.A, *CALSIM Methods and Results*, Table 5.A.6-10, Table 5.A.6-35). During most of the remaining months and water year types of the spawning period, changes in mean flow would be minor (less than 5% difference). However, flows under the PA at Keswick Dam would be 13% higher during November of critical water years, up to 18% higher during January of critical years, and 13% lower in February of critical years than flows under the NAA. Differences at Red Bluff would generally be similar but smaller. The results given here indicate that the PA would reduce flow in some months and water year types, although this does not consider real-time operational management described in Section 3.1.5, *Real-Time Operations Upstream of the Delta*, and Section 3.3.3, *Real-Time Operational Decision-Making Process*, that would be used to avoid and minimize any modeled effects. Further discussion regarding flow-related effects during the June through November period is provided in Section 5.4.2.3, *Summary of Upstream Effects*.

5.4.2.1.3.3.1.1.1 Spawning WUA

Spawning WUA for Central Valley steelhead in the Sacramento River was determined by USFWS (2003a, 2006) in the same manner that it was determined for winter-run Chinook salmon, except that habitat suitability criteria (HSC) previously determined for Central Valley steelhead in the American River (U.S. Fish and Wildlife Service 2003b) were used in developing the Sacramento River steelhead WUA curves (Appendix 5.D, Section 5.D.2.2, *Spawning Flows Methods*). HSC data were not collected by USFWS for steelhead in the Sacramento River because very few steelhead redds were observed and because the steelhead redds could not be distinguished from those of resident rainbow trout. The validity of this substitution could not be tested and is uncertain (U.S. Fish and Wildlife Service 2003a). To evaluate the effects of the PA on steelhead spawning habitat, steelhead spawning WUA was estimated for flows during the November through April spawning period under the NAA and the PA in the same three segments of the Sacramento River that were used for winter-run and spring-run Chinook salmon: Segment 4 (Battle Creek to the confluence with Cow Creek), Segment 5 (Cow Creek to the A.C.I.D. Dam), and Segment 6 (A.C.I.D. Dam to Keswick Dam). Further information on WUA analysis methods is provided in Appendix 5.D, Section 5.D.2.2, *Spawning Flows Methods*. Differences in steelhead spawning WUA under the PA and NAA were examined using exceedance plots of monthly mean WUA for the steelhead spawning period in each of the river segments for each water year type and all water year types combined (Figure 5.4-180 – Figure 5.4-197). The exceedance curves with all water years combined (Figure 5.4-184, Figure 5.4-190, and Figure 5.4-196) and those broken out by water year type (Figure 5.4-181 through Figure 5.4-189, Figure 5.4-191 through Figure 5.4-195, and Figure 5.4-197 through Figure 5.4-201) are largely similar between the PA and the NAA for all three river segments.

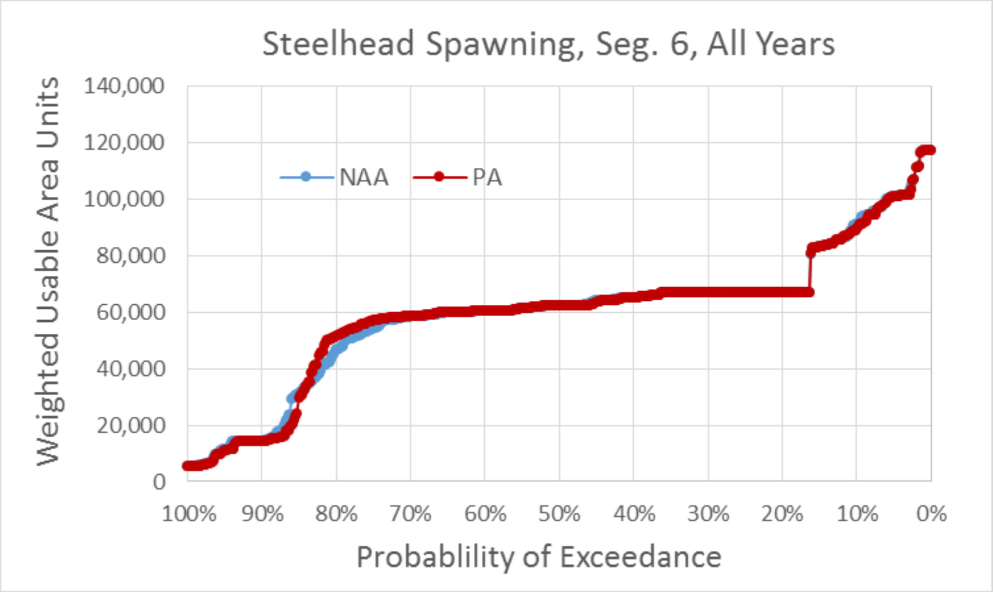

Figure 5.4-184. Exceedance Plot of Central Valley Steelhead Spawning Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 6, All Water Years

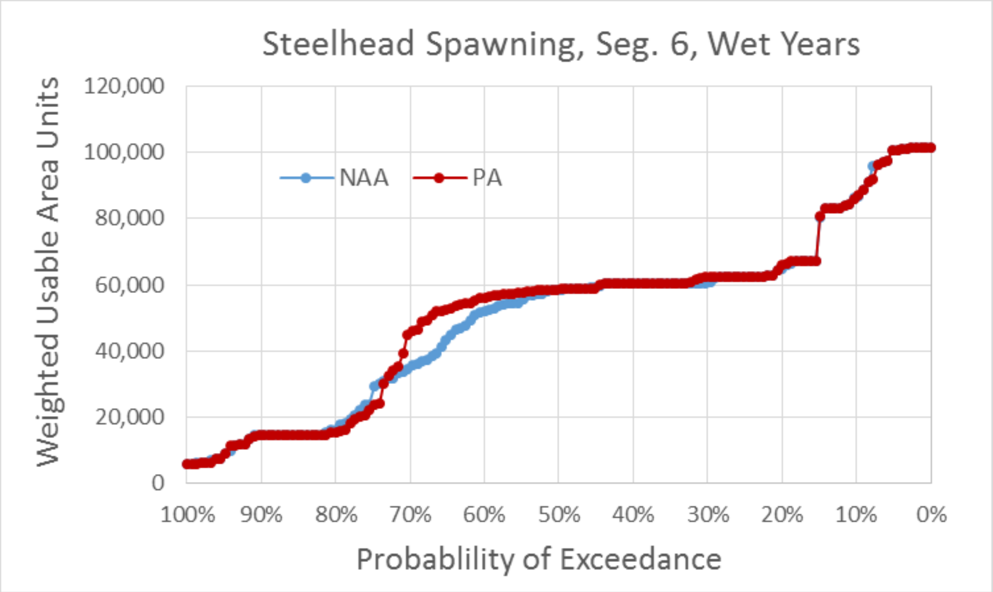

Figure 5.4-185. Exceedance Plot of Central Valley Steelhead Spawning Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 6, Wet Water Years

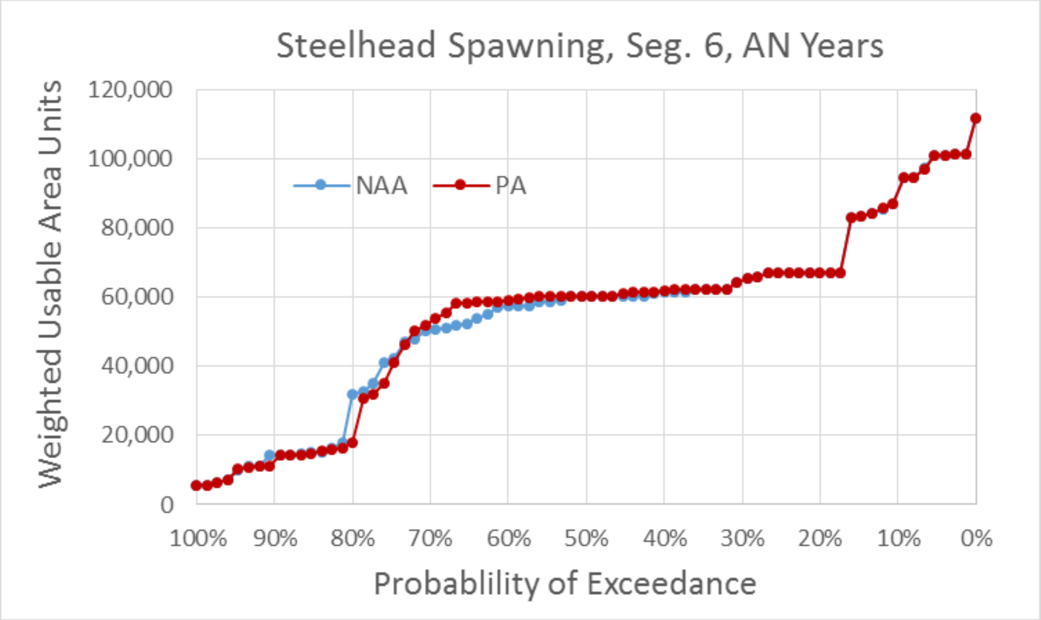

Figure 5.4-186. Exceedance Plot of Central Valley Steelhead Spawning Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 6, Above Normal Water Years

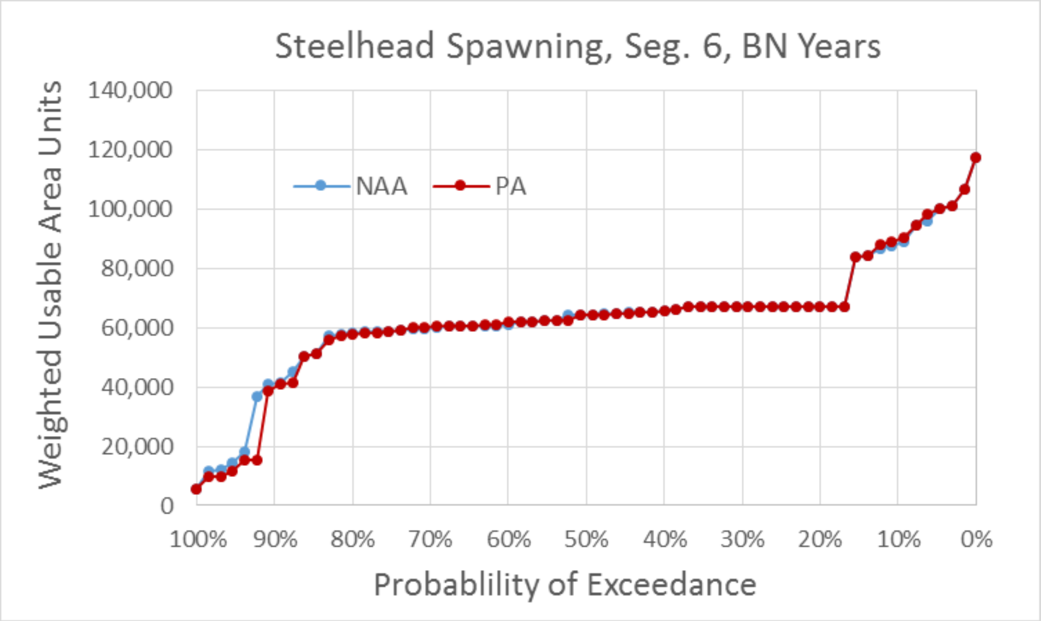

Figure 5.4-187. Exceedance Plot of Central Valley Steelhead Spawning Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 6, Below Normal Water Years

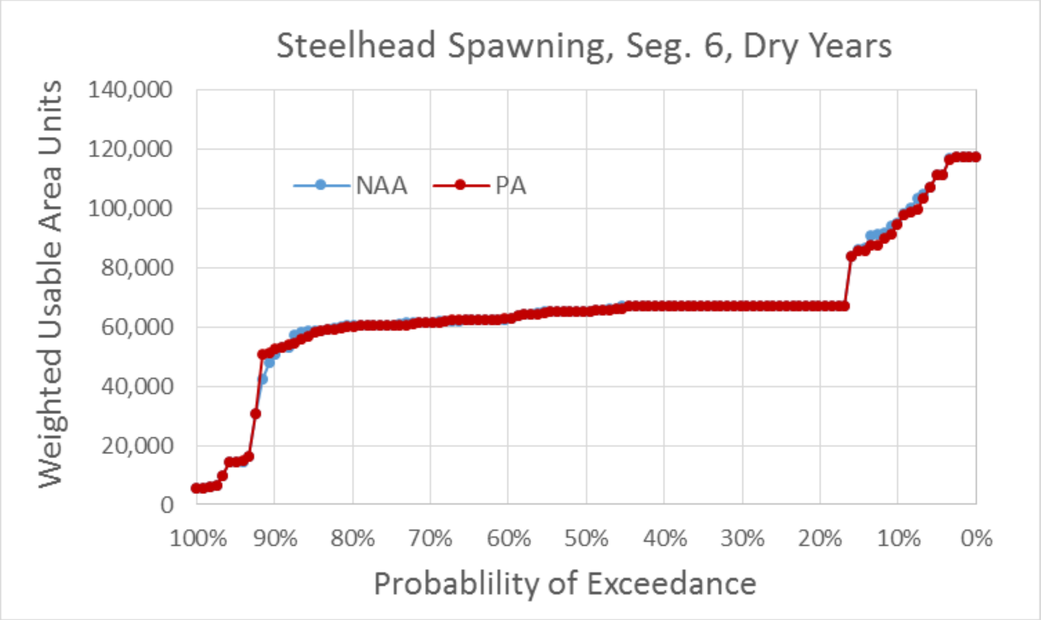

Figure 5.4-188. Exceedance Plot of Central Valley Steelhead Spawning Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 6, Dry Water Years

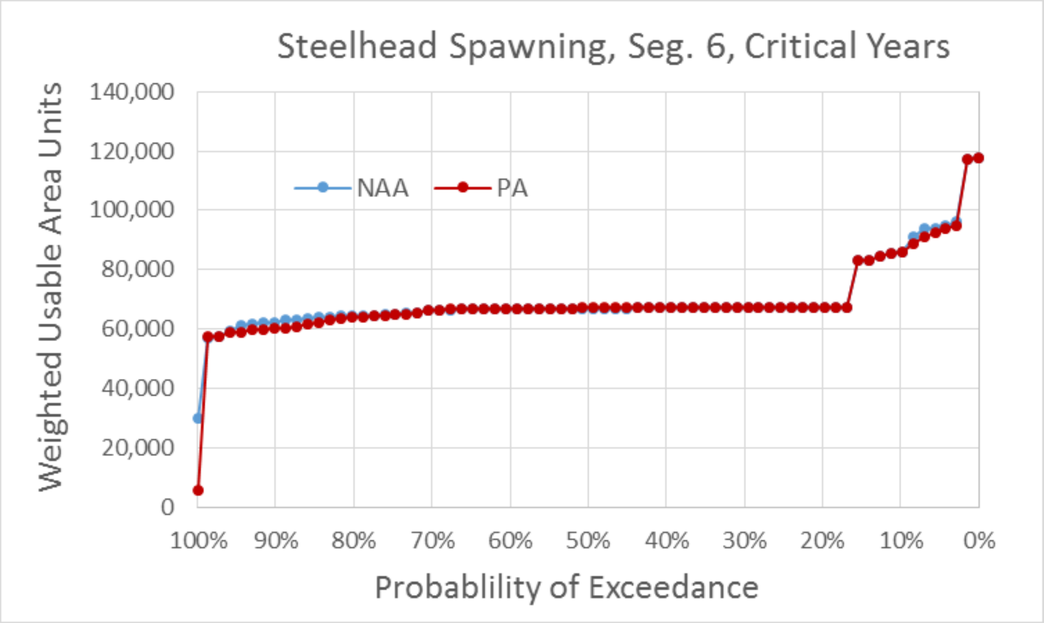

Figure 5.4-189. Exceedance Plot of Central Valley Steelhead Spawning Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 6, Critical Water Years

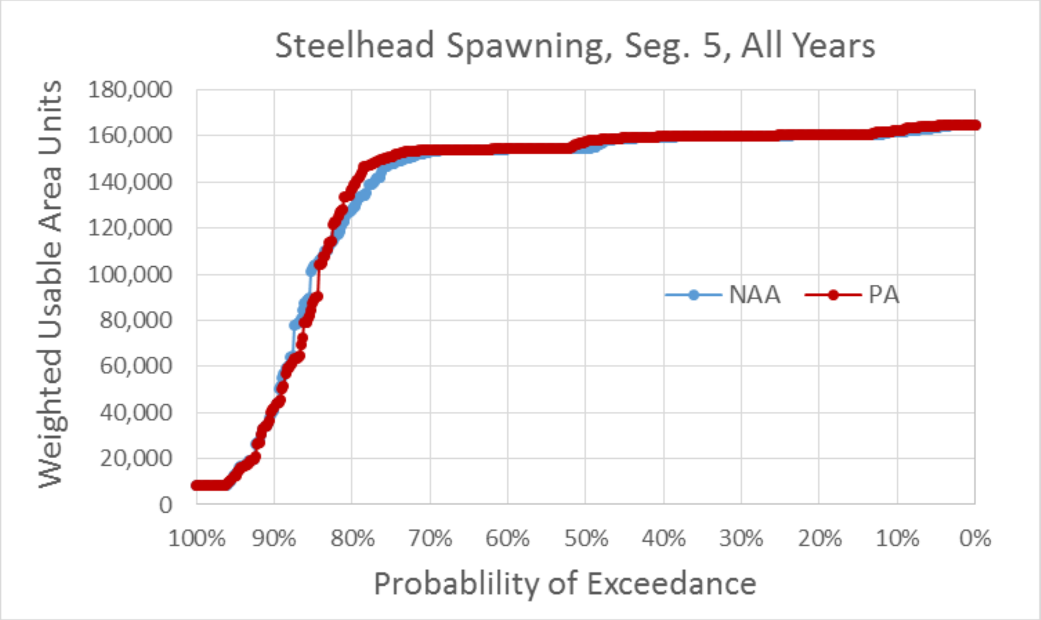

Figure 5.4-190. Exceedance Plot of Central Valley Steelhead Spawning Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 5, All Water Years

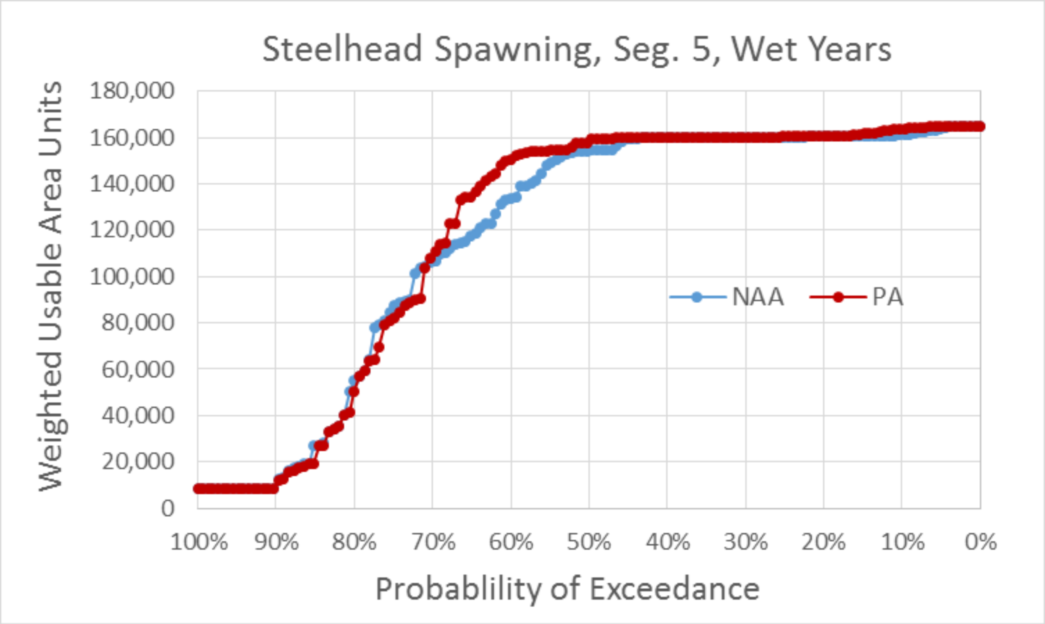

Figure 5.4-191. Exceedance Plot of Central Valley Steelhead Spawning Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 5, Wet Water Years

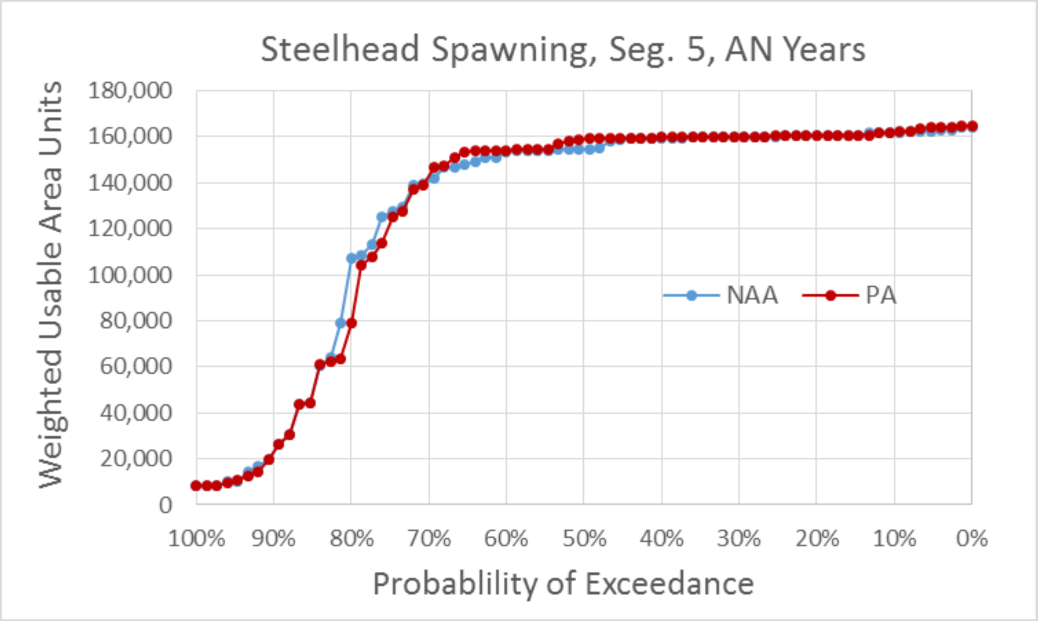

Figure 5.4-192. Exceedance Plot of Central Valley Steelhead Spawning Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 5, Above Normal Water Years

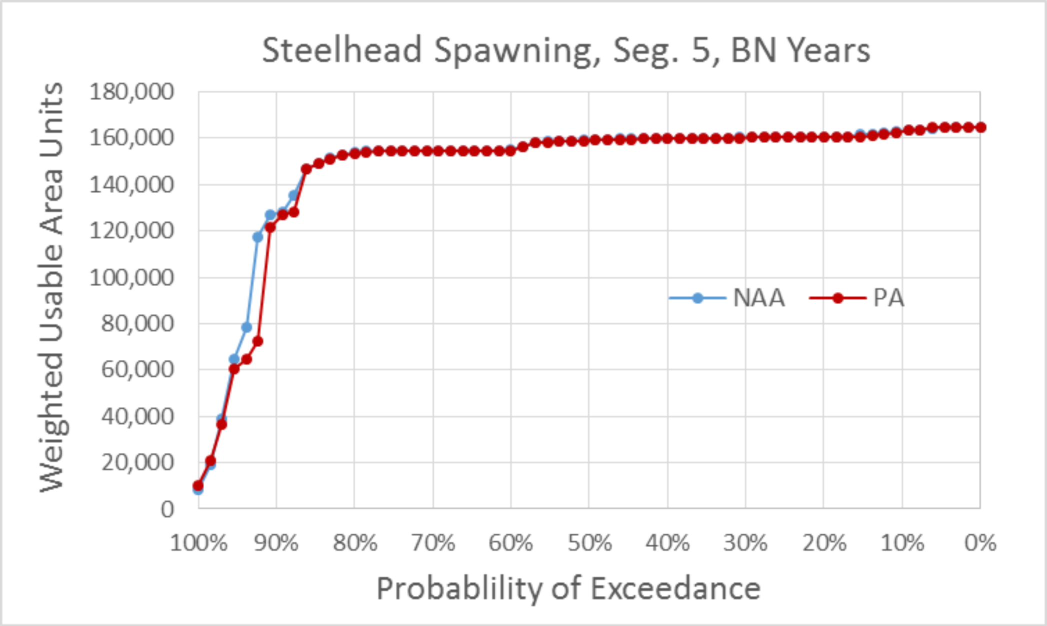

Figure 5.4-193. Exceedance Plot of Central Valley Steelhead Spawning Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 5, Below Normal Water Years

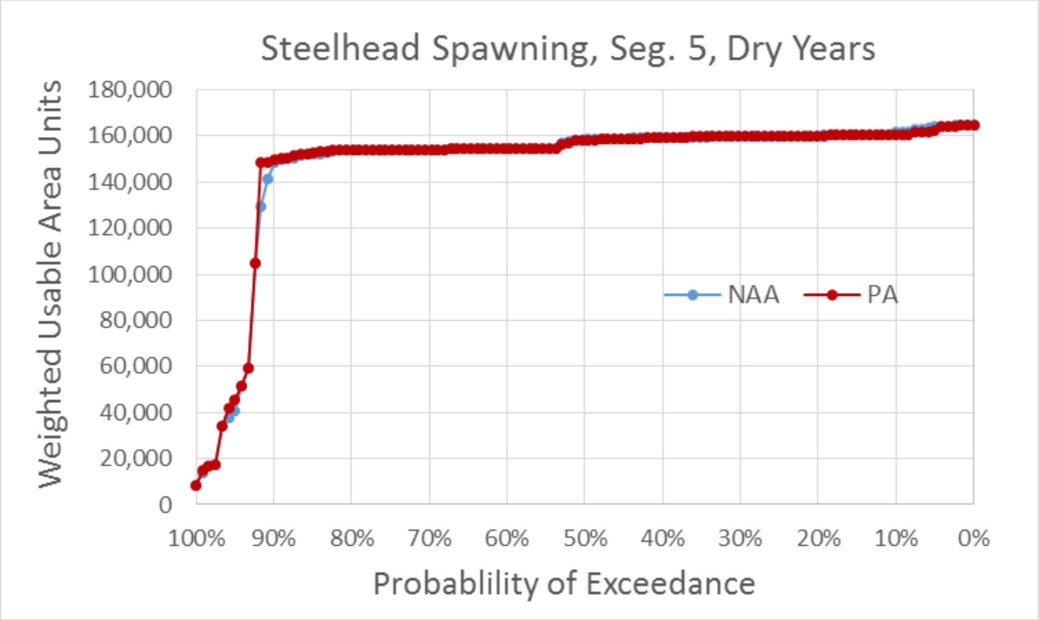

Figure 5.4-194. Exceedance Plot of Central Valley Steelhead Spawning Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 5, Dry Water Years

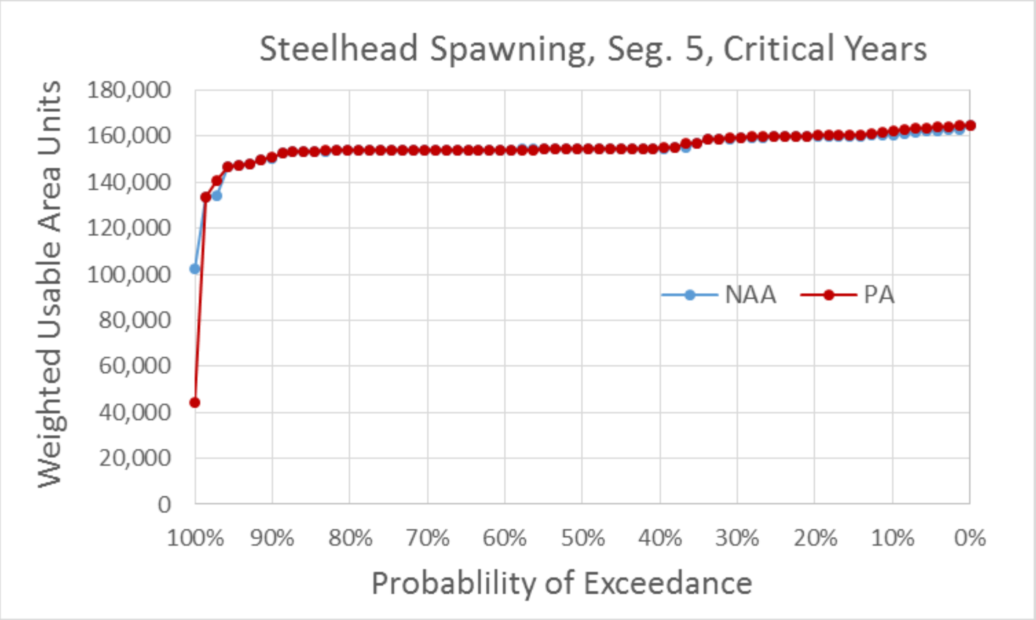

Figure 5.4-195. Exceedance Plot of Central Valley Steelhead Spawning Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 5, Critical Water Years

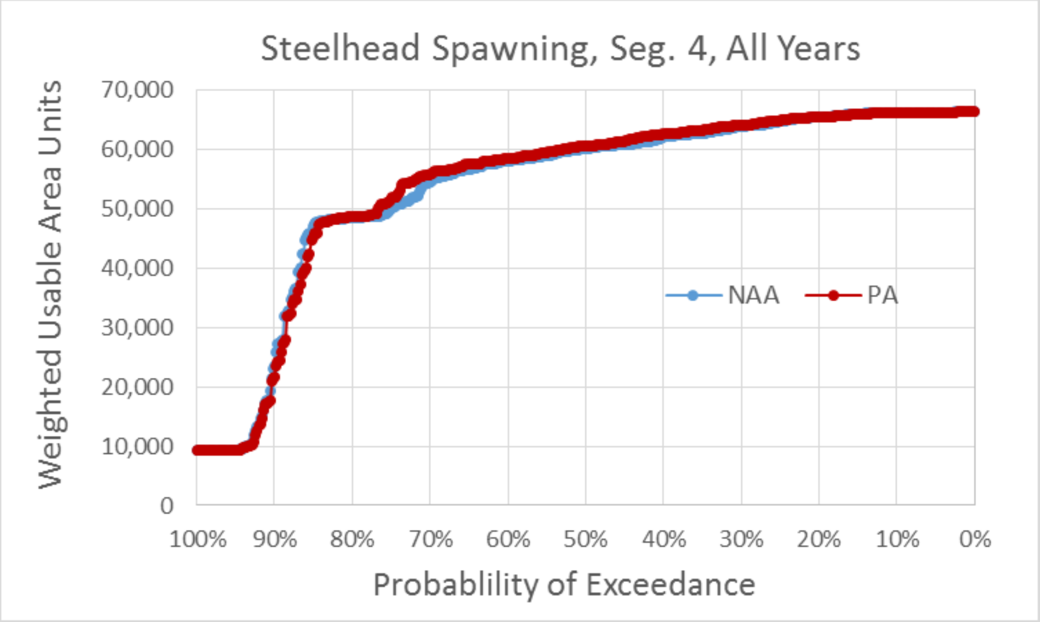

Figure 5.4-196. Exceedance Plot of Central Valley Steelhead Spawning Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 4, All Water Years

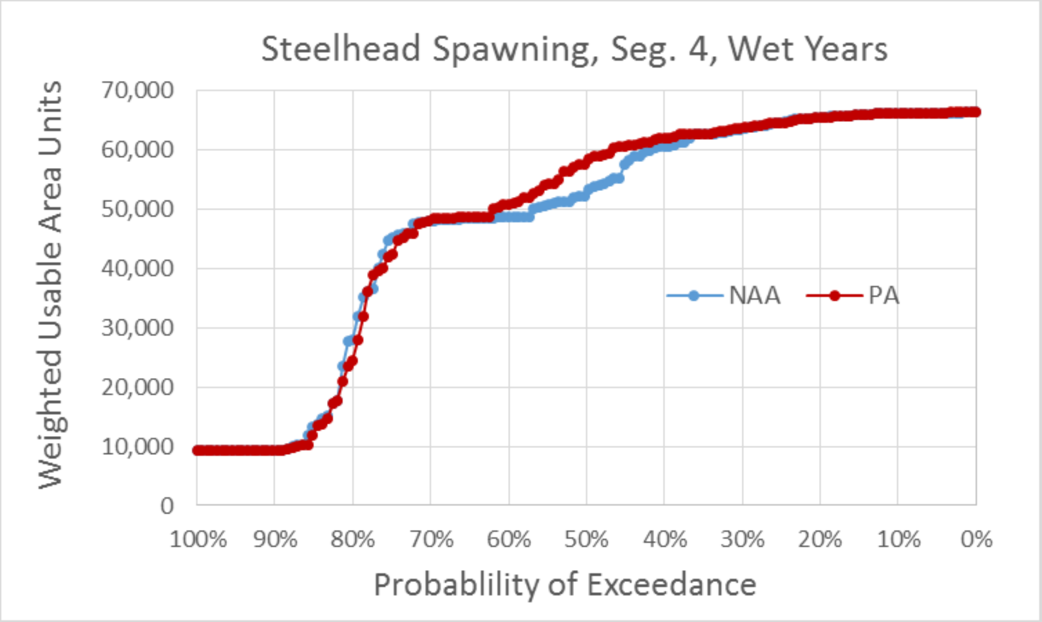

Figure 5.4-197. Exceedance Plot of Central Valley Steelhead Spawning Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 4, Wet Water Years

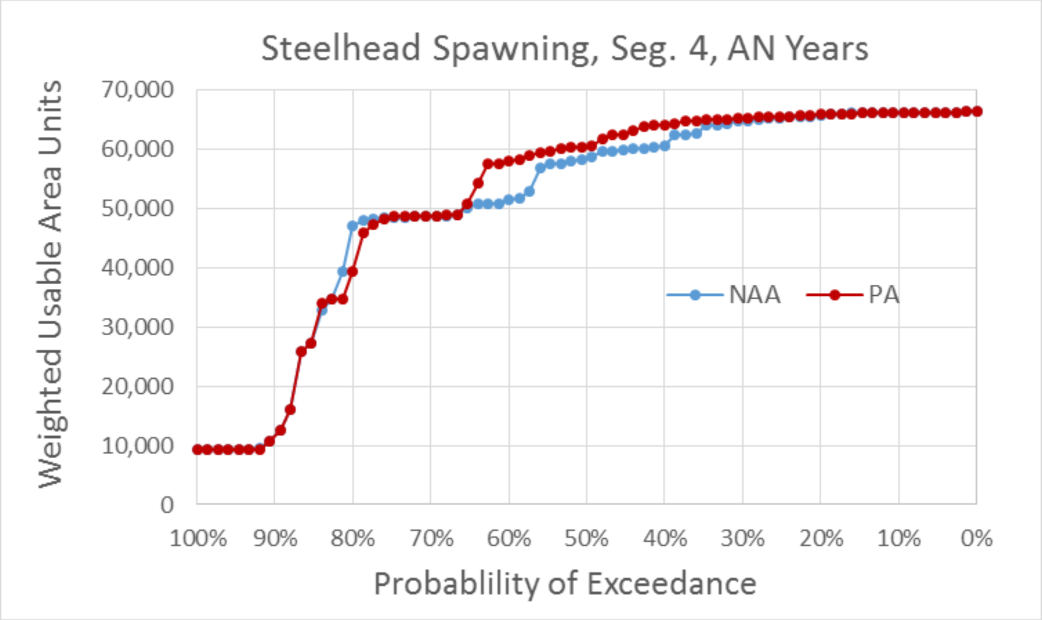

Figure 5.4-198. Exceedance Plot of Central Valley Steelhead Spawning Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 4, Above Normal Water Years

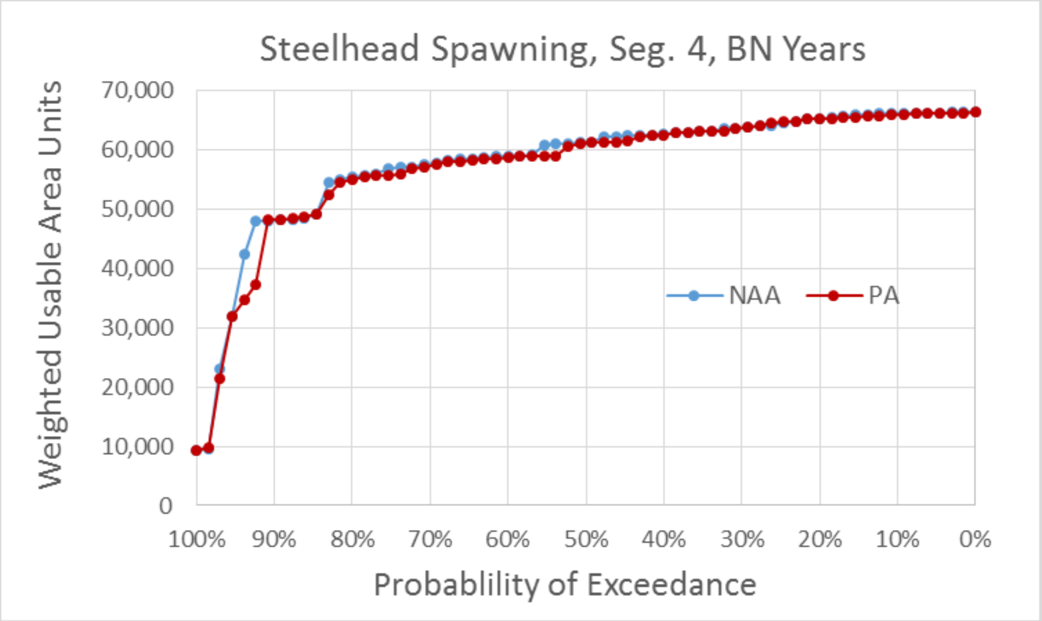

Figure 5.4-199. Exceedance Plot of Central Valley Steelhead Spawning Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 4, Below Normal Water Years

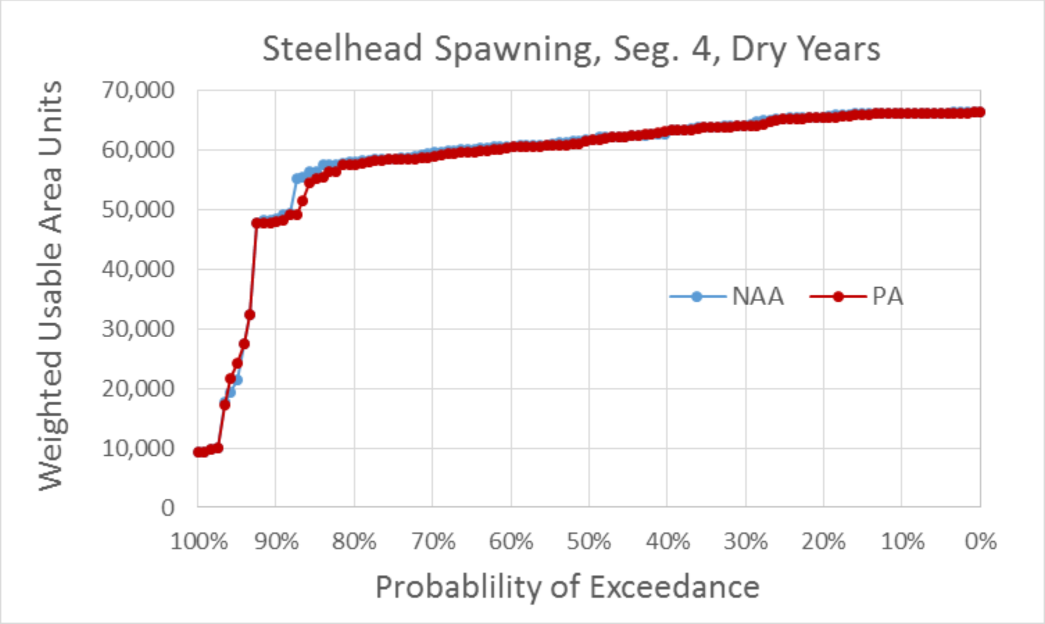

Figure 5.4-200. Exceedance Plot of Central Valley Steelhead Spawning Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 4, Dry Water Years

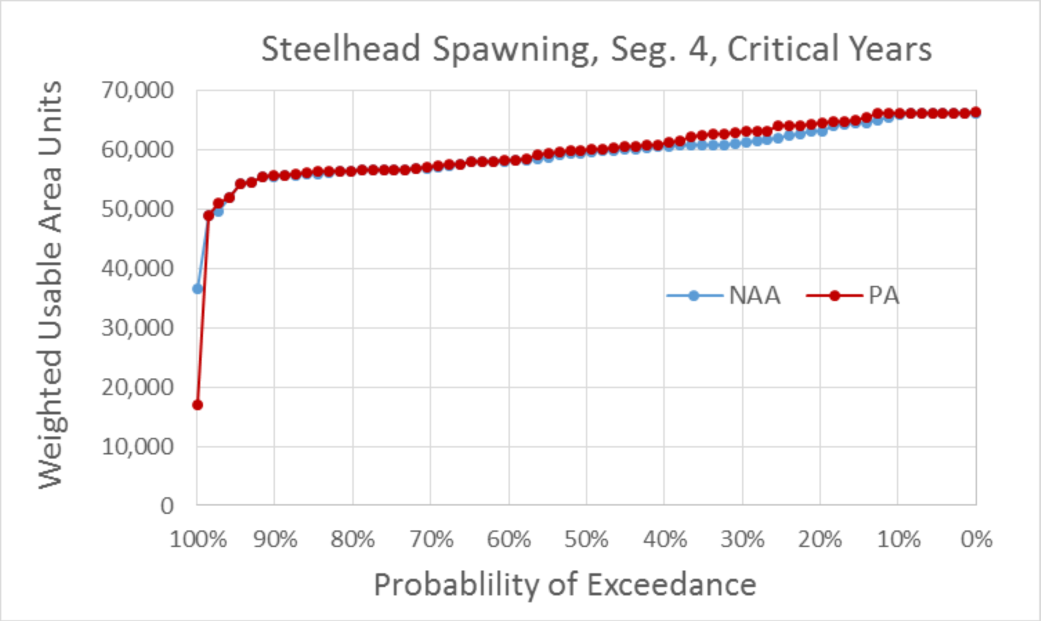

Figure 5.4-201. Exceedance Plot of Central Valley Steelhead Spawning Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 4, Critical Water Years

Differences in the mean spawning WUA in each river segment for the months of the spawning period under each water year type and all water year types combined also indicate that spawning WUA would be little affected by the PA, except for moderate increases in mean WUA during November of wet and above normal water year types (Table 5.4-64 through Table 5.4-66). As noted for spring-run Chinook salmon, mean flows in the Sacramento River are expected to be up to 26% lower under the PA during November of wet and above normal years.

Table 5.4-64. Central Valley Steelhead Spawning Weighted Usable Area (WUA) and Differences (Percent Differences) in River Segment 6 between Model Scenarios (green indicates PA is at least 5% higher [raw difference] than NAA; red indicates PA is at least 5% lower)

Month	WYT	NAA	PA	PA vs. NAA
November	Wet	44,934	55,001	10,066 (22%)
	Above Normal	48,791	55,559	6,769 (14%)
	Below Normal	59,665	60,346	681 (1%)
	Dry	60,619	61,097	478 (0.8%)
	Critical	63,815	62,426	-1,389 (-2.2%)
	All	54,176	58,415	4,239 (8%)
December	Wet	90,427	90,302	-125 (-0.1%)
	Above Normal	94,408	94,374	-35 (-0.04%)
	Below Normal	95,154	95,754	600 (0.6%)
	Dry	102,175	101,105	-1,069 (-1%)
	Critical	93,937	93,146	-791 (-0.8%)
	All	95,071	94,730	-341 (-0.4%)
January	Wet	47,991	44,845	-3,146 (-7%)
	Above Normal	50,103	50,084	-19 (-0.04%)
	Below Normal	52,093	51,860	-233 (-0.4%)
	Dry	50,880	50,762	-119 (-0.2%)
	Critical	63,630	60,825	-2,806 (-4%)
	All	51,870	50,398	-1,471 (-3%)
February	Wet	34,241	33,861	-380 (-1%)
	Above Normal	30,811	30,982	172 (0.6%)
	Below Normal	52,430	49,679	-2,752 (-5%)
	Dry	65,457	65,318	-139 (-0.2%)
	Critical	65,625	67,129	1,504 (2%)
	All	48,344	48,067	-276 (-0.6%)
March	Wet	33,522	33,502	-20 (-0.06%)
	Above Normal	49,551	46,630	-2,921 (-6%)
	Below Normal	63,098	62,275	-823 (-1%)
	Dry	64,981	64,880	-101 (-0.2%)
	Critical	66,249	64,918	-1,331 (-2%)
	All	52,493	51,694	-799 (-2%)

Month	WYT	NAA	PA	PA vs. NAA
April	Wet	90,427	90,302	-125 (-0.1%)
	Above Normal	94,408	94,374	-35 (-0.04%)
	Below Normal	95,154	95,754	600 (0.6%)
	Dry	102,175	101,105	-1,069 (-1%)
	Critical	93,937	93,146	-791 (-0.8%)
	All	95,071	94,730	-341 (-0.4%)

Table 5.4-65. Central Valley Steelhead Spawning Weighted Usable Area (WUA) and Differences (Percent Differences) in River Segment 5 between Model Scenarios (green indicates PA is at least 5% higher [raw difference] than NAA; red indicates PA is at least 5% lower)

Month	WYT	NAA	PA	PA vs. NAA
November	Wet	134,237	155,266	21,029 (16%)
	Above Normal	138,183	149,145	10,962 (8%)
	Below Normal	161,674	161,250	-424 (-0.3%)
	Dry	158,686	159,625	939 (0.6%)
	Critical	155,106	156,314	1,208 (0.8%)
	All	147,676	156,404	8,727 (6%)
December	Wet	136,651	136,947	296 (0.2%)
	Above Normal	155,557	155,489	-69 (-0.04%)
	Below Normal	160,300	160,244	-56 (-0.04%)
	Dry	158,725	158,764	39 (0%)
	Critical	156,285	157,203	918 (0.6%)
	All	151,078	151,297	219 (0%)
January	Wet	124,886	119,593	-5,293 (-4%)
	Above Normal	123,962	123,959	-4 (0%)
	Below Normal	133,040	133,226	186 (0.1%)
	Dry	128,093	127,825	-268 (-0.2%)
	Critical	150,023	145,948	-4,075 (-3%)
	All	130,294	127,979	-2,316 (-2%)
February	Wet	82,820	82,314	-506 (-0.6%)
	Above Normal	78,150	78,049	-101 (-0.1%)
	Below Normal	135,596	129,547	-6,049 (-4%)
	Dry	156,252	156,270	18 (0.01%)
	Critical	155,460	154,255	-1,205 (-0.8%)
	All	117,700	116,540	-1,160 (-1%)
March	Wet	95,020	94,955	-65 (-0.07%)
	Above Normal	135,184	129,848	-5,336 (-4%)
	Below Normal	153,621	153,491	-130 (-0.08%)
	Dry	155,629	155,434	-194 (-0.1%)
	Critical	154,823	155,886	1,064 (0.7%)

Month	WYT	NAA	PA	PA vs. NAA
	All	132,783	132,007	-776 (-0.6%)
April	Wet	136,651	136,947	296 (0.2%)
	Above Normal	155,557	155,489	-69 (-0.04%)
	Below Normal	160,300	160,244	-56 (-0.04%)
	Dry	158,725	158,764	39 (0%)
	Critical	156,285	157,203	918 (0.6%)
	All	151,078	151,297	219 (0%)

Table 5.4-66. Central Valley Steelhead Spawning Weighted Usable Area (WUA) and Differences (Percent Differences) in River Segment 4 between Model Scenarios (green indicates PA is at least 5% higher [raw difference] than NAA; red indicates PA is at least 5% lower)

Month	WYT	NAA	PA	PA vs. NAA
November	Wet	52,447	60,623	8,176 (16%)
	Above Normal	50,951	59,956	9,005 (18%)
	Below Normal	64,550	64,154	-397 (-0.6%)
	Dry	62,752	62,372	-380 (-0.6%)
	Critical	57,853	59,809	1,956 (3%)
	All	57,214	61,315	4,101 (7%)
December	Wet	55,269	55,379	110 (0.2%)
	Above Normal	60,368	60,356	-12 (-0.02%)
	Below Normal	62,831	63,159	328 (0.5%)
	Dry	62,828	62,480	-348 (-0.6%)
	Critical	60,694	60,845	151 (0.2%)
	All	59,730	59,744	14 (0.02%)
January	Wet	49,096	46,930	-2,166 (-4%)
	Above Normal	50,530	50,530	0 (0%)
	Below Normal	51,290	51,312	22 (0.04%)
	Dry	51,204	51,213	9 (0.02%)
	Critical	58,708	57,821	-887 (-2%)
	All	51,538	50,727	-812 (-2%)
February	Wet	34,859	34,368	-491 (-1%)
	Above Normal	35,645	35,721	76 (0.2%)
	Below Normal	54,283	51,867	-2,416 (-4%)
	Dry	61,860	61,407	-453 (-0.7%)
	Critical	59,546	58,465	-1,082 (-2%)
	All	47,788	47,051	-736 (-2%)
March	Wet	41,811	41,715	-96 (-0.2%)
	Above Normal	54,345	51,949	-2,396 (-4%)
	Below Normal	60,258	59,189	-1,069 (-2%)
	Dry	61,160	61,074	-86 (-0.1%)

Month	WYT	NAA	PA	PA vs. NAA
	Critical	58,799	60,354	1,555 (3%)
	All	53,478	53,131	-347 (-0.6%)
April	Wet	55,269	55,379	110 (0.2%)
	Above Normal	60,368	60,356	-12 (-0.02%)
	Below Normal	62,831	63,159	328 (0.5%)
	Dry	62,828	62,480	-348 (-0.6%)
	Critical	60,694	60,845	151 (0.2%)
	All	59,730	59,744	14 (0.02%)

5.4.2.1.3.3.1.1.2 Redd Scour

The probability of flows occurring under the PA and the NAA that would be high enough to mobilize sediments and scour Central Valley steelhead redds was estimated from CALSIM II estimates of mean monthly flows, using a relationship determined from the historical record between actual mean monthly flow and maximum daily flow (Appendix 5.D, Section 5.D.2.2, *Spawning Flows Methods*). The actual monthly and daily flow data used in the analysis are from gage records just below Keswick Dam and at Bend Bridge, and the CALSIM II estimates used to compare probabilities of redd scour for the PA and the NAA are for the Keswick Dam and Red Bluff locations. As discussed in Appendix 5.D, Section 5.D.2.2, *Spawning Flows Methods*, 40,000 cfs is treated as the minimum daily flow at which redd scour occurs in the Sacramento River. The analysis of the Keswick Dam gage data shows that for months with a mean monthly flow of at least 27,300 cfs, the maximum daily flow in that month is always at least 40,000 cfs. The Bend Bridge gage data show that for months with a mean flow of at least 21,800 cfs, the maximum daily flow in that month is always 40,000 cfs. Therefore, redd scour probabilities for the PA and the NAA were evaluated by comparing frequencies of CALSIM II flows greater than 27,300 cfs at Keswick Dam or greater than 21,800 cfs at Red Bluff during the steelhead November through April spawning and incubation period. Further information on the redd scour analysis methods is provided in Appendix 5.D, Section 5.D.2.2, *Spawning Flows Methods*.

Table 5.4-32 shows that about 5% of months at Keswick Dam and about 15% of months at Red Bluff would have flows above the redd scouring thresholds during the November through April spawning and incubation period of Central Valley steelhead. The relatively high percentage of scouring flows in the steelhead spawning and incubation period is expected, given that the period encompasses the wettest months of the year. There would be little difference between the PA and the NAA in the percentage of scouring flows at Keswick Dam. The percentage under the PA at Red Bluff would be about 7% greater than under the NAA on a relative scale, but the difference is 1% on a raw scale. Water years and months with mean monthly flow greater than 27,300 cfs predicted at Keswick Dam for the Central Valley spawning and incubation period (under either the PA or the NAA or both) are listed in Table 5.4-67, and those with mean monthly flow greater than 21,800 cfs predicted at Red Bluff are listed in Table 5.4-68.

Table 5.4-67. Water Years and Months with Mean Flow > 27,300 cfs at Keswick Dam for the PA and/or the NAA during the Central Valley Steelhead Spawning and Incubation Period

Water Year	Month	WYT	Flow (cfs)	
			NAA	PA
1927	February	Above Normal	29,347	28,705
1938	February	Wet	37,196	37,196
1938	March	Wet	35,340	35,340
1940	February	Above Normal	25,084	27,865
1942	February	Wet	30,876	30,876
1945	December	Below Normal	31,540	29,102
1952	January	Wet	31,940	31,940
1955	December	Dry	27,318	26,935
1956	January	Wet	34,001	34,001
1958	February	Wet	60,491	60,491
1963	April	Wet	30,893	30,893
1969	January	Wet	58,978	58,978
1973	January	Above Normal	39,202	39,202
1973	November	Above Normal	29,514	29,913
1974	March	Wet	34,994	34,994
1975	March	Wet	27,693	28,273
1980	February	Above Normal	32,212	32,212
1983	February	Wet	41,920	41,920
1983	March	Wet	50,123	50,123
1983	December	Wet	33,201	33,201
1986	February	Wet	43,792	45,287
1995	March	Wet	47,351	47,351
1996	January	Wet	36,776	36,776
1996	February	Wet	36,796	37,081
1998	February	Wet	51,790	51,790
1999	February	Wet	27,798	27,798
2000	February	Above Normal	30,989	36,419

Table 5.4-68. Water Years and Months with Mean Flow > 21,800 cfs at Red Bluff for the NAA and/or the NAA during the Central Valley Steelhead Spawning and Incubation Period

Water Year	Month	WYT	Flow (cfs)	
			NAA	PA
1925	February	Dry	24,070	24,071
1927	February	Above Normal	49,417	48,776
1928	March	Above Normal	19,932	23,602
1937	December	Dry	30,649	30,029
1938	February	Wet	56,909	56,909
1938	March	Wet	55,120	55,119
1940	January	Above Normal	43,491	43,477
1940	February	Above Normal	38,879	41,661
1940	March	Above Normal	33,599	33,586
1940	December	Above Normal	20,610	22,620
1941	January	Wet	28,155	28,141
1941	February	Wet	43,074	43,074
1941	March	Wet	26,178	26,178
1941	April	Wet	24,464	24,464
1941	December	Wet	21,964	23,292
1942	February	Wet	47,744	47,741
1945	December	Below Normal	44,541	42,119
1950	December	Dry	24,773	24,789
1951	January	Above Normal	22,521	22,497
1951	February	Above Normal	26,705	26,702
1951	December	Above Normal	20,624	23,775
1952	January	Wet	48,541	48,511
1952	February	Wet	31,265	31,264
1953	January	Wet	15,670	22,115
1954	February	Above Normal	26,779	26,734
1955	January	Dry	55,945	55,949
1955	December	Dry	43,925	43,545
1956	February	Wet	34,257	34,258
1957	January	Above Normal	24,267	24,280
1958	February	Wet	95,921	95,922
1958	March	Wet	31,825	31,825
1958	April	Wet	22,228	22,228
1959	February	Below Normal	21,419	23,042
1962	February	Below Normal	28,659	29,188
1963	April	Wet	42,184	42,182
1964	January	Dry	36,532	36,546
1964	December	Dry	34,329	32,345

Water Year	Month	WYT	Flow (cfs)	
			NAA	PA
1968	January	Below Normal	42,219	41,417
1968	February	Below Normal	21,477	24,587
1969	January	Wet	88,102	88,084
1969	February	Wet	43,254	43,259
1969	December	Wet	26,013	28,454
1970	January	Wet	25,837	25,840
1971	March	Wet	23,009	23,007
1972	January	Below Normal	26,964	26,965
1973	January	Above Normal	58,571	58,570
1973	February	Above Normal	31,982	31,983
1973	November	Above Normal	38,394	38,789
1973	December	Above Normal	33,753	33,749
1974	March	Wet	46,485	46,485
1975	March	Wet	41,124	41,672
1978	February	Above Normal	25,264	25,041
1978	March	Above Normal	26,406	26,407
1979	January	Dry	27,900	29,149
1980	February	Above Normal	46,641	46,636
1981	December	Dry	38,173	38,204
1982	January	Wet	31,549	31,548
1982	February	Wet	33,563	33,566
1982	March	Wet	21,927	21,929
1982	April	Wet	33,884	33,885
1982	December	Wet	23,928	23,927
1983	February	Wet	63,449	63,448
1983	March	Wet	81,583	81,583
1983	December	Wet	53,169	53,169
1986	February	Wet	65,637	67,131
1986	March	Wet	33,295	33,286
1994	January	Critical	38,785	44,227
1995	March	Wet	71,080	71,088
1996	January	Wet	53,792	53,761
1996	February	Wet	47,831	48,105
1996	December	Wet	30,177	34,956
1997	January	Wet	29,572	32,414
1998	February	Wet	85,109	85,090
1998	March	Wet	29,700	29,701
1999	February	Wet	37,943	37,942
2000	February	Above Normal	46,308	51,728

Water Year	Month	WYT	Flow (cfs)	
			NAA	PA
2002	January	Dry	28,842	28,849
2002	December	Dry	22,758	21,248

5.4.2.1.3.3.1.1.3 Redd Dewatering

The percentage of steelhead redds dewatered by reductions in Sacramento River flow was estimated from CALSIM II estimates of monthly mean flows during the 3 months following each of the months that steelhead spawn (Section 5.D.2.2, *Spawning Flows Methods*, Table SFM-1). This analysis employed functional relationships developed in field studies by USFWS (2006) that predicted percentages of redds dewatered from an array of paired spawning and dewatering flows. Segment 5 CALSIM II flows were used for the effects analysis to estimate redd dewatering under the PA and NAA. Because the CALSIM II flows for Segments 4 and 6 are similar to those for Segment 5, redd dewatering estimates using the Segment 4 and Segment 6 flows differ little from those for Segment 5 (Appendix 5.D, Section 5.D.2.6, *Redd Dewatering Results, Sacramento River Segments 4 and 6*). Further information on the redd dewatering analysis methods is provided in Appendix 5.D, Section 5.D.2.2, *Spawning Flows Methods*.

Differences in steelhead redd dewatering under the PA and NAA were examined using exceedance plots of mean monthly percent of redds dewatered for the months that steelhead spawn (November through February) (Figure 5.4-202 through Figure 5.4-207). The exceedance curves for wet and above normal water years indicate that frequencies of dewatering in the middle of the range of redd dewatering percentages would be lower under the PA than under the NAA, but that the frequencies would be similar under the two scenarios for the high and low portions of the range. For the other water year types, the frequencies would be similar throughout the range of percentages.

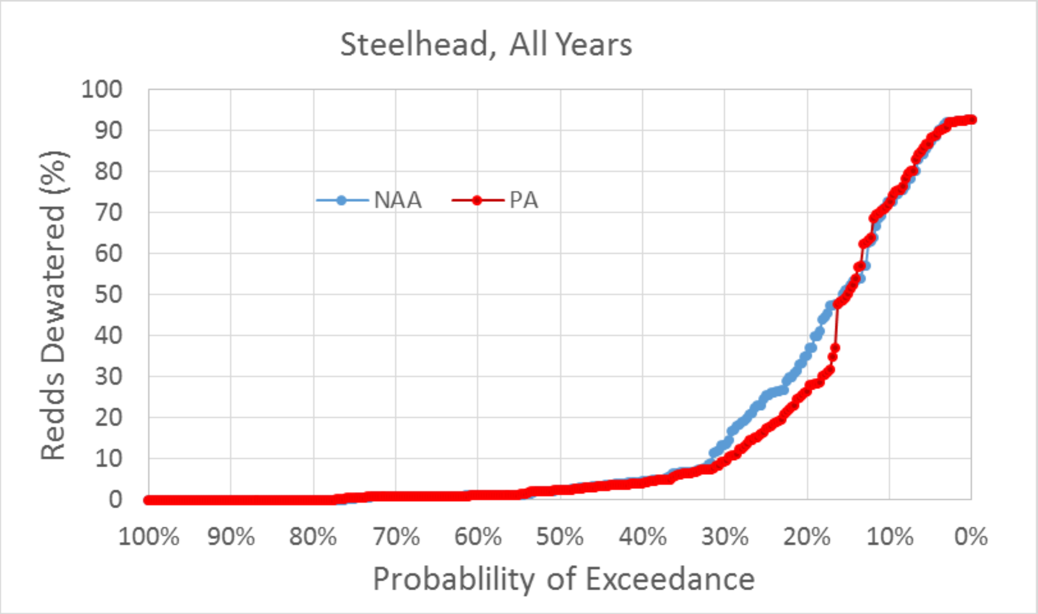

Figure 5.4-202. Exceedance Plot of Central Valley Steelhead Percent of Redds Dewatered for NAA and PA Model Scenarios, All Water Years

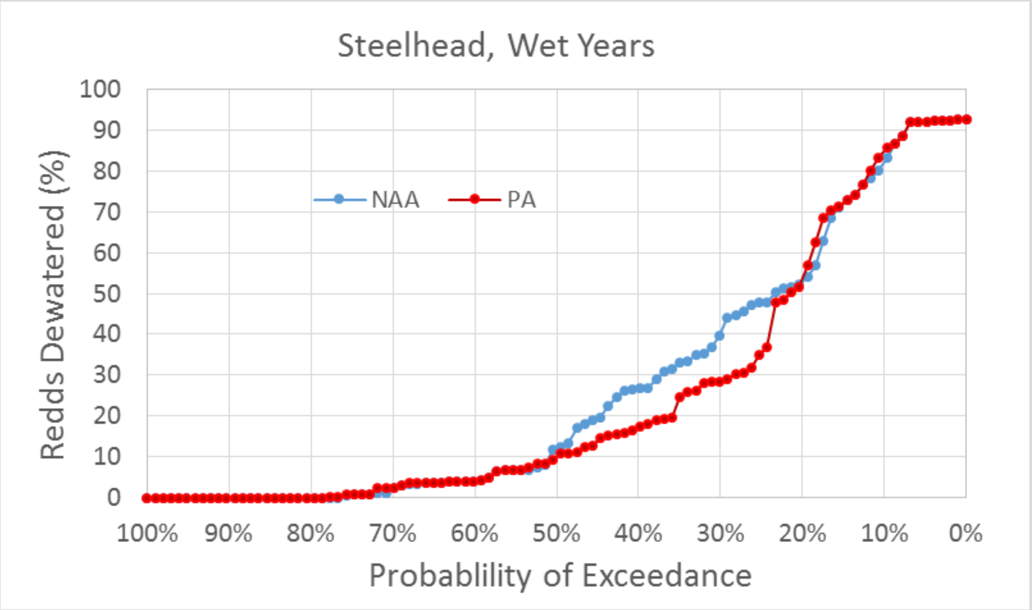

Figure 5.4-203. Exceedance Plot of Central Valley Steelhead Percent of Redds Dewatered for NAA and PA Model Scenarios, Wet Water Years

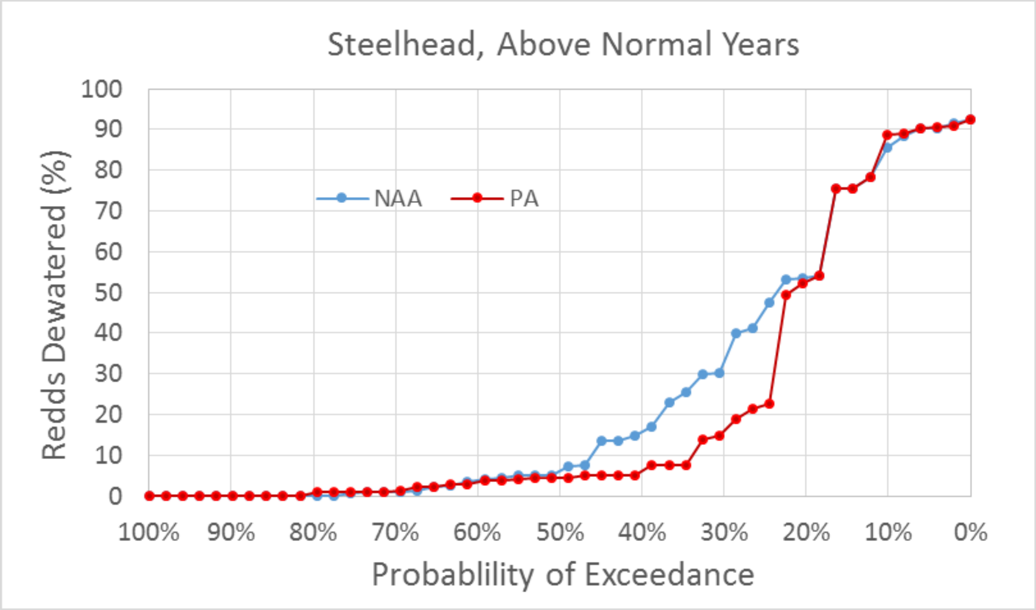

Figure 5.4-204. Exceedance Plot of Central Valley Steelhead Percent of Redds Dewatered for NAA and PA Model Scenarios, Above Normal Water Years

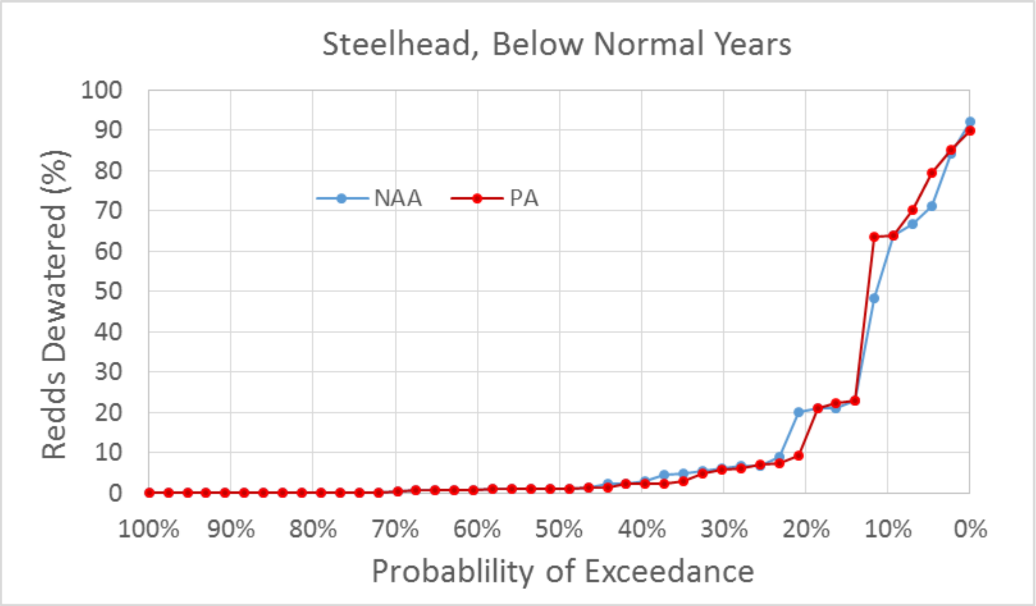

Figure 5.4-205. Exceedance Plot of Central Valley Steelhead Percent of Redds Dewatered for NAA and PA Model Scenarios, Below Normal Water Years

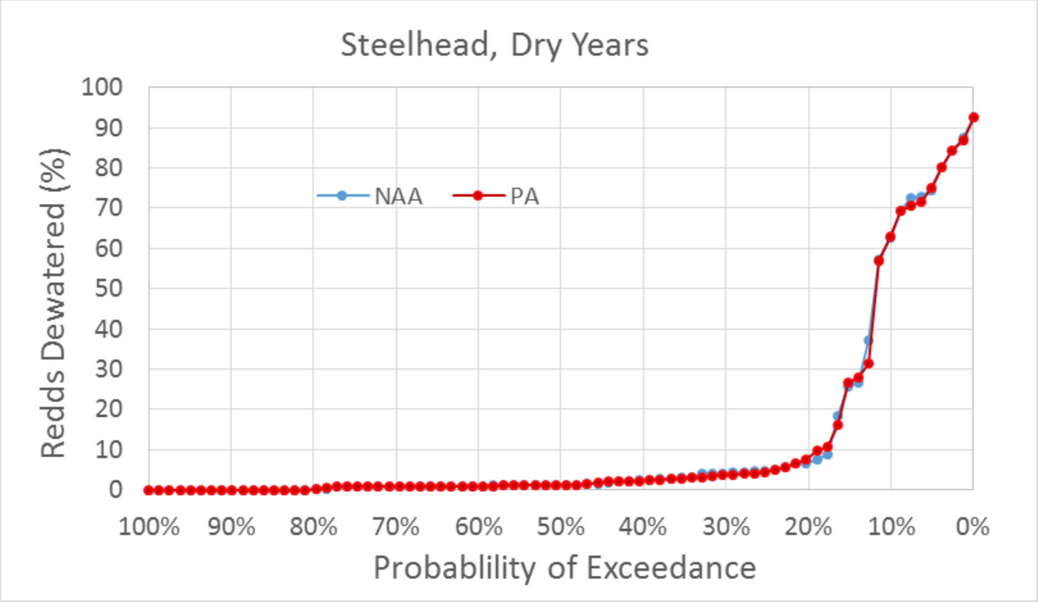

Figure 5.4-206. Exceedance Plot of Central Valley Steelhead Percent of Redds Dewatered for NAA and PA Model Scenarios, Dry Water Years

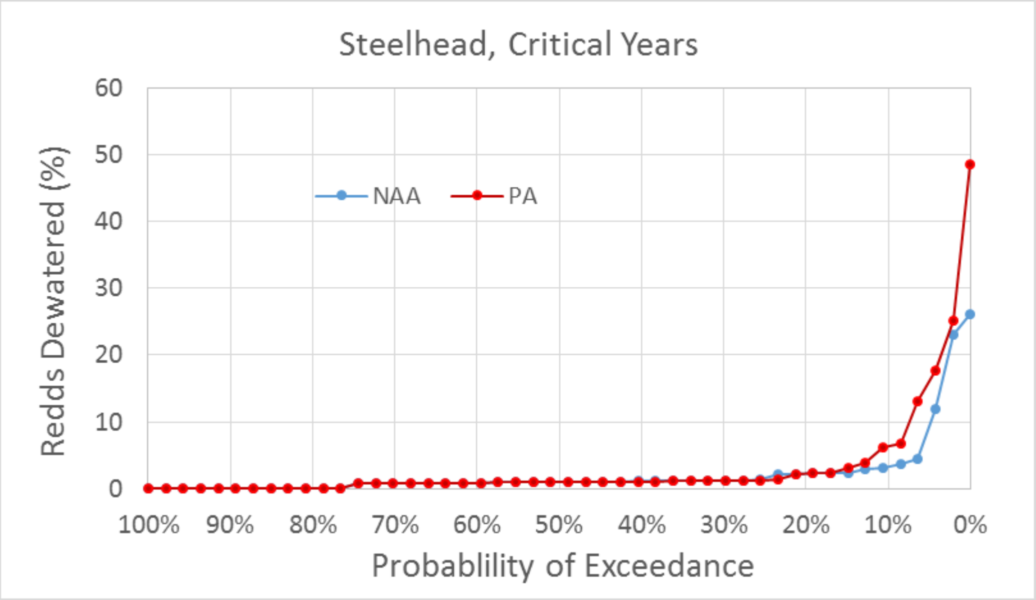

Figure 5.4-207. Exceedance Plot of Central Valley Steelhead Percent of Redds Dewatered for NAA and PA Model Scenarios, Critical Water Years

Differences in the mean percentage of redds dewatered in each river segment for each month of spawning under each water year type and all water year types combined also indicate that the PA would insignificantly affect steelhead redd dewatering, except for reductions in the mean percent of redds dewatered during November of wet and above normal water year types (Table 5.4-69). The percent differences between the PA and the NAA in the percent of redds dewatered range up to a 158% increase under the PA for January of critical water years, but this increase and many of the large relative changes in percent of redds dewatered are artifacts of the low percentages of redds dewatered under both scenarios that were used in computing the percent changes.

Table 5.4-69. Central Valley Steelhead Percent of Redds Dewatered (Percent of Total Redds) and Differences (Percent Differences) between Model Scenarios (green indicates PA is at least 5% lower [raw difference] than NAA; red indicates PA is at least 5% higher)

Month	WYT	NAA	PA	PA vs. NAA
November	Wet	29.4	15.6	-13.8 (-47%)
	Above Normal	29.1	15.5	-13.55 (-47%)
	Below Normal	6.6	5.0	-1.6 (-24%)
	Dry	4.5	3.4	-1.1 (-24%)
	Critical	1.9	4.7	2.8 (153%)
	All	16.0	9.5	-6.5 (-41%)
December	Wet	14.0	14.7	0.7 (5%)
	Above Normal	10.2	8.9	-1.3 (-13%)
	Below Normal	11.8	11.7	-0.1 (-1%)
	Dry	22.2	22.3	0.1 (1%)
	Critical	1.1	1.0	-0.1 (-11%)
	All	13.3	13.3	0 (0%)
January	Wet	22.6	26.0	3.5 (15%)
	Above Normal	14.2	14.3	0.1 (1%)
	Below Normal	14.7	14.2	-0.6 (-4%)
	Dry	21.5	21.9	0.4 (2%)
	Critical	2.6	6.7	4.1 (158%)
	All	17.0	18.8	1.8 (10%)
February	Wet	43.5	44.2	0.8 (1.8%)
	Above Normal	47.7	47.9	0.1 (0%)
	Below Normal	18.8	21.8	3 (16%)
	Dry	1.0	1.1	0.1 (12%)
	Critical	3.6	0.6	-3.1 (-84.1%)
	All	24.6	24.9	0.2 (1%)

5.4.2.1.3.3.1.2 Water Temperature-Related Effects

Modeled mean monthly water temperatures during the November through April spawning and egg/alevins incubation period for steelhead in the Sacramento River reach of Keswick Dam to Red Bluff (Table 5.4-29) are presented in Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results*, Table 5.C.7-3, Table 5.C.7-4, Table 5.C.7-5, Table 5.C.7-7, Table 5.C.7-8. Overall, the PA would change mean water temperatures very little (predominantly less than 1°F, or approximately 1%) throughout the reach in all months and water year types of the period. The largest increase in mean monthly water temperatures under the PA relative to NAA would be 0.2°F, or 0.4%, and would occur at Bend Bridge and Red Bluff in critical water years during February. Despite the increase, water temperatures would remain less than 52°F in both locations under both scenarios during this time, which is well below a temperature range of concern (Appendix 5.D, Section 5.D.2.1, *Water Temperature Analysis Methods*, Table 5.D-49).

Exceedance plots of monthly mean water temperatures were examined during each month throughout the spawning and incubation period (Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results*, Figure 5.C.7.3-7, Figure 5.C.7.4-7, Figure 5.C.7.5-7, Figure 5.C.7.7-7, Figure 5.C.7.8-7). The values for the PA in these exceedance plots generally match those of the NAA. For critical years during February at Bend Bridge and Red Bluff, where the largest increase in mean monthly water temperature was seen, curves would be nearly identical between the NAA and PAA, except for 2 years in which the PA would be approximately 1°F higher (Figure 5.4-208, Figure 5.4-209). However, water temperatures would not differ in the large majority of years at both locations. These results suggest that the differences in water temperature between NAA and PA in February of critical water years would be insignificant at both locations.

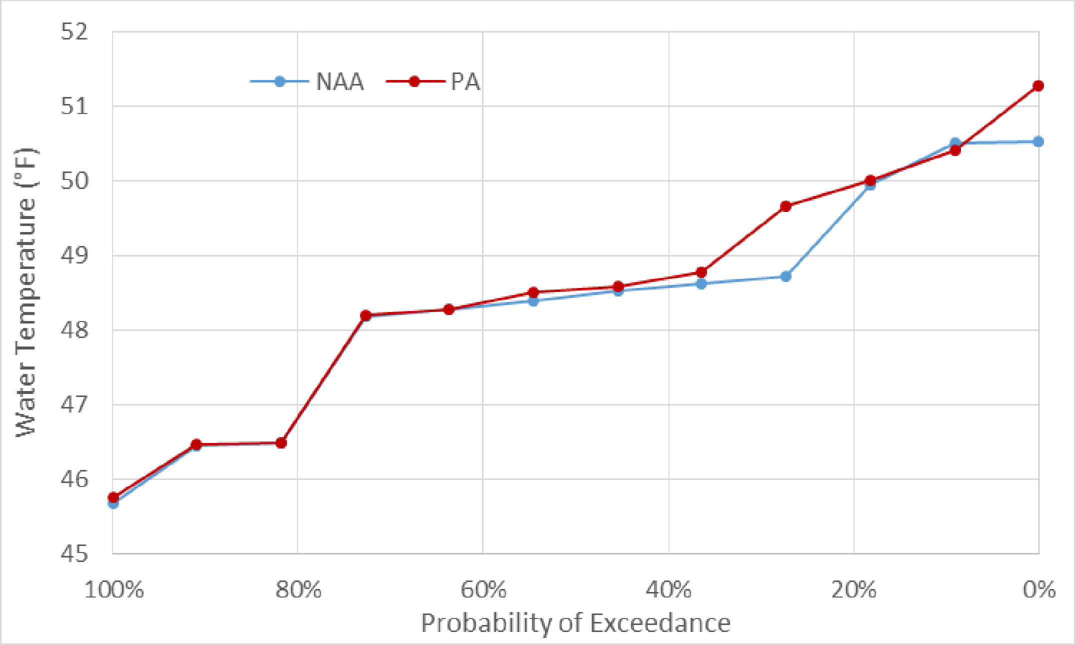

Figure 5.4-208. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the Sacramento River at Bend Bridge in February of Critical Water Years

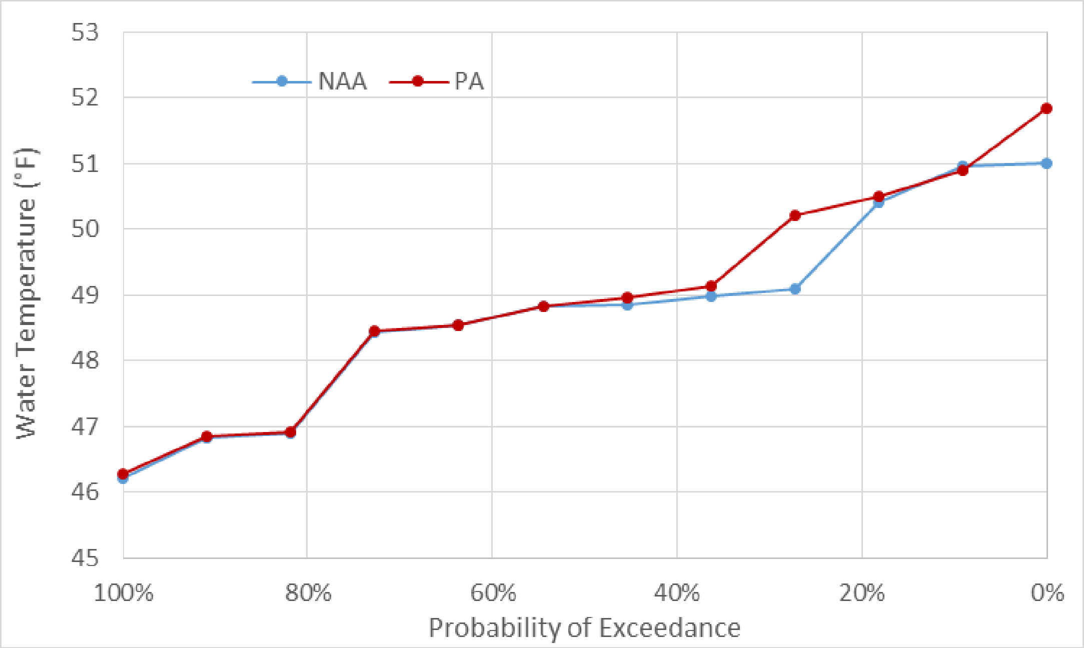

Figure 5.4-209. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the Sacramento River at Red Bluff in February of Critical Water Years

The exceedance of temperature thresholds in the Sacramento River presented in Appendix 5.D, Section 5.D.2.1, *Water Temperature Analysis Methods*, Table 5.D-49 by modeled daily water temperatures was evaluated based on thresholds identified from the literature. For steelhead spawning and egg/alevin incubation, the thresholds used were 53°F (McCullough et al. 2001) and 56°F (McEwan and Jackson 1996) (Appendix 5.D, Section 5.D.2.1, *Water Temperature Analysis Methods*, Table 5.D-51).

Results of the water temperature thresholds analysis are presented in Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-97 through Table 5.D-106. At Keswick Dam, for both temperature thresholds, there would be no months or water year types in which there would be 5% more days under the PA compared to the NAA on which temperatures would exceed the threshold (Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-97, Table 5.D-98). There would be one instance in which the percent of days exceeding the 53°F threshold would be lower under the PA relative to the NAA: November of above normal years (8.3% reduction). There would be two instances in which the percent of days exceeding the 56°F threshold would be lower under the PA relative to the NAA: November of above normal (6.7% reduction) and below normal (5.8% reduction) years. However, in no case would there be a more-than-0.5°F difference in the magnitude of average daily exceedance. Therefore, it was concluded that there would be no biologically meaningful effect at Keswick Dam.

At Clear Creek, for both temperature thresholds, there would be no months or water year types in which there would be both 5% more days under the PA compared to the NAA on which temperatures would exceed the threshold and a more-than-0.5°F difference in the magnitude of average daily exceedance (Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature*

Threshold Analysis Results, Table 5.D-99, Table 5.D-100). There would be 1 month and water year type, November of above normal water years, during which the percent exceedance would be lower under the PA relative to the NAA by 6.9% and 5.8% for the 53°F and 56°F thresholds, respectively. However, there would be no concurrent increase in magnitude of average daily exceedance that is more than 0.5°F for either instance. Therefore, it was concluded that there would be no biologically meaningful effect at Clear Creek.

At Balls Ferry, for both temperature thresholds, there would be no months or water year types in which there would be both 5% more days under the PA compared to the NAA on which temperatures would exceed the threshold and a more-than-0.5°F difference in the magnitude of average daily exceedance (Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-101, Table 5.D-102). There would be 1 water year type during November for each threshold during which the percent exceedance would be lower under the PA relative to the NAA by (53°F threshold: above normal water years, 11.7% lower under PA; 56°F threshold: below normal water years, 5.2% lower under PA). In addition, there would be no increase in magnitude of average daily exceedance that is more than 0.5°F for either instance. Therefore, it was concluded that there would be no biologically meaningful effect at Balls Ferry.

At Bend Bridge, for both temperature thresholds, there would be no months or water year types in which there would be both 5% more days under the PA compared to the NAA on which temperatures would exceed the threshold and a more-than-0.5°F difference in the magnitude of average daily exceedance (Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-103, Table 5.D-104). For the 53°F threshold, there would be two instances, November of wet (8.8% reduction) and above normal (16.1% reduction) water years, in which there would be a reduction in the percent exceedance above the threshold under the PA relative to the NAA. However, there would be no concurrent increase in magnitude of average daily exceedance that is more than 0.5°F for either instance. Therefore, it was concluded that there would be no biologically meaningful effect at Bend Bridge.

At Red Bluff, for both temperature thresholds, there would be no months or water year types in which there would be both 5% more days under the PA compared to the NAA on which temperatures would exceed the threshold, and a more-than-0.5°F difference in the magnitude of average daily exceedance (Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-105, Table 5.D-106). For the 53°F threshold, there would be three instances, November of wet (8.3% reduction) and above normal (15.6% reduction) water years and March of below normal water years (6.7% reduction), in which there would be a reduction in the percent exceedance above the threshold under the PA relative to the NAA. However, there would be no concurrent increase in magnitude of average daily exceedance that is more than 0.5°F for any of these three instances. Therefore, it was concluded that there would be no biologically meaningful effect at Red Bluff.

Overall, the thresholds analysis indicates that there would be more exceedances (5% or greater) in certain months and water year types under the PA which could have lethal or sublethal effects on spawning, egg incubation, and alevins, although this does not consider real-time operational management described in Section 3.1.5, *Real-Time Operations Upstream of the Delta*, and Section 3.3.3, *Real-Time Operational Decision-Making Process*, that would be used to avoid and minimize any modeled effects. Further, these results do not consider the current revision process to OCAP RPA Action Suite 1.2 described in Section 3.1.4.5, *Annual/Seasonal Temperature Management Upstream of the Delta*, to improve winter-run Chinook salmon egg-to-fry survival. This process may result in refinements and additions to the existing annual/seasonal temperature management processes, including spring storage targets, revised temperature compliance criteria and a range in summertime Keswick release rates, some of which may benefit steelhead spawning, egg incubation, and alevins. The biological interpretation of these results, combined with all upstream results, in the context of real-time operational management is provided in Section 5.4.2.3, *Summary of Upstream Effects*, below.

5.4.2.1.3.3.2 Kelt Emigration

5.4.2.1.3.3.2.1 Flow-Related Effects

Mean monthly flows were evaluated in the Sacramento River at Keswick, Red Bluff, Wilkins Slough, and Verona during the February through May emigration period for Central Valley steelhead kelts (Table 5.4-29). Changes in flow potentially affect conditions for emigrating kelts, including bioenergetic cost, water quality, crowding, and passage conditions, but the quantitative relationship between flow and downstream migration is poorly understood. As described in Appendix 5.D, Section 5.D.2.4, *Migration Flows Methods,* on balance, except under very high flows, the benefits of increased flow generally outweigh the costs and, therefore, it is assumed for the purposes of this effects analysis that increased flow would improve conditions for emigration of steelhead kelts. Milner et al. 2012 and del Rosario et al. 2013 have found that migration cues for anadromous fish species are often the result of natural pulse flows, or pulse flows caused by natural events, such as an extensive rainfall event, which will not be affected by the PA.

Shasta Reservoir storage volume at the end of September may influence flows in the Sacramento River during the kelt emigration period in some years. Mean Shasta September storage under the PA would be similar (less than 5% difference) to storage under NAA for all water year types, except for 7% higher mean storage during critical water years under the PA (Appendix 5.A, *CALSIM Methods and Results*, Table 5.A.6-3).

In general, mean flow under the PA would be similar to (less than 5% difference) or greater than flow under the NAA at the four Sacramento River locations during most months and water year types of the kelt emigration period (Appendix 5.A, *CALSIM Methods and Results*, Table 5.A.6-10, Table 5.A.6-14, Table 5.A.6-35, Table 5.A.6-36). However, flow would be lower under the PA during February of critical years (up to 13% lower at Keswick) at all the locations, except Verona. During February of below normal years, flow under the PA would be 8% greater at Keswick. During March, flow under the PA at Keswick would be 9% greater in above normal and below normal years and 8% greater in critical years, but there would be no differences greater than 5% at the other locations. During May, flow would be 5% to 8% greater in dry years, except at Verona.

The CALSIM modeling results given here indicate that the PA would result in increases and decreases in flow during the kelt migration period , but that, on balance, the differences would be insignificant.

5.4.2.1.3.3.2.2 Water Temperature-Related Effects

Modeled mean monthly water temperatures during the February through May kelt emigration period for steelhead in the Sacramento River upstream of the Delta (Table 5.4-29) are presented in Appendix 5.C, *Upstream Water Temperature Methods and Results,* Section 5.C.7, *Upstream Water Temperature Modeling Results*, Table 5.C.7-3, Table 5.C.7-7, Table 5.C.7-8, Table 5.C.7-10[57]. Overall, the PA would change mean water temperatures very little (predominantly less than 1°F, or approximately 1%) throughout the kelt emigration reach of Keswick Dam to Knights Landing in all months and water year types in the period. The largest increase in mean monthly water temperatures under the PA relative to NAA would be 1.0°F (1.4%), and would occur at Knights Landing in below normal water years during August.

Exceedance plots of monthly mean water temperatures were examined during each month throughout the kelt emigration period (Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results,* Figure 5.C.7.3-7, Figure 5.C.7.7-7, Figure 5.C.7.8-7, Figure 5.C.7.10-7[58]). The curves for PA generally match those of the NAA. At Knights Landing in below normal water years during August, where the largest increase in mean monthly water temperature was seen, the difference between PA and NAA would be larger at the lower end of the temperatures range by nearly 2°F in 2 of the 11 years (Figure 5.4-108).

There have been no known studies evaluating specific temperature effects on emigrating kelts. Therefore, adult immigration thresholds of 68°F 7DADM and 70°F were used for kelt emigration thresholds, with an assumption that kelts emigrating downstream would be affected by water temperatures similarly to adults immigrating upstream (Appendix 5.D, Section 5.D.2.1, *Water Temperature Analysis Methods*, Table 5.D-49). The 68°F 7DADM threshold was taken from USEPA (2003) and the 70°F threshold represents the average of the studies cited in Richter and Kolmes (2005) for the upper end of the suboptimal temperature range. The 7DADM threshold was converted to function with daily model outputs for each month separately (Appendix 5.D, Section 5.D.2.1, *Water Temperature Analysis Methods,* Table 5.D-51).

Results of the water temperature thresholds analysis are presented in Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-107 through Table 5.D-112. At all three locations, Keswick Dam, Bend Bridge, and Red Bluff, there would be no months or water year types with both a more-than-5% increase in the percent of total days exceeding the threshold under the PA relative to the NAA and a more-than-0.5°F difference in the magnitude of average daily exceedance. Therefore, it was concluded that there would be no biologically meaningful water temperature-related effects on CCV steelhead kelt emigration.

5.4.2.1.3.3.3 Juvenile Rearing

5.4.2.1.3.3.3.1 Flow-Related Effects

As discussed above in the winter-run fry and juvenile rearing section and in Appendix 5.D, Section 5.D.2.3, *Rearing Flows Methods,* the stranding of juvenile salmonids is not evaluated in

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[57] Water temperature results for Wilkins Slough were used to represent Knights Landing for this analysis

[58] Water temperature results for Wilkins Slough were used to represent Knights Landing for this analysis

the effects analysis due to limitations of CALSIM modeling. However, current operations of the Sacramento River include ramping rate restrictions, designed to minimize juvenile stranding, that limit the rate at which river flow can be changed. These restrictions would be kept in place for the PA.

Mean monthly flow rates and reservoir storage volumes were examined for the PA and NAA in the Sacramento River at the Keswick to Red Bluff locations during the Central Valley steelhead year-round fry and juvenile rearing period (Table 5.4-29). Changes in flow can affect the instream area available for rearing, along with habitat quality, and stranding of fry and juveniles, especially in side-channel habitats. Shasta Reservoir storage volume at the end of May and the end of September influences flow rates in the Sacramento River. Mean Shasta May storage under the PA would be similar to (less than 5% difference) storage under NAA for all water year types (Appendix 5.A, *CALSIM Methods and Results*, Table 5.A.6-3). Mean Shasta September storage under the PA would also be similar to (less than 5% difference) storage under NAA for all water year types, except for 7% higher mean storage during critical water years under the PA.

Mean flow under the PA at the Keswick and Red Bluff locations in the Sacramento River flow would generally be similar to (less than 5% difference) or higher than flow under the NAA during winter, spring and summer months and would be similar to or lower than flow under the NAA during the fall, with exceptions (Appendix 5.A, *CALSIM Methods and Results*, Table 5.A.6-10, Table 5.A.6-35). Flows under the PA during December through August would be similar to (less than 5% difference) or greater than those under the NAA for all months and water year types, except for 13% and 7% lower flow during February of critical water years at Keswick and Red Bluff, respectively, and 10% lower flow during August of below normal years at both locations. Flow increases during the same months would range up to 18% for January of critical years. During June, flows would be more than 5% higher under the PA than the NAA in all water year types, except wet years. Flows under the PA during September through November would be similar to (less than 5% difference) or lower than those under the NAA in all months and water year types, except for flows up to 17% greater during October of below normal and dry years and up to 13% greater during November of critical years. During September, flow would be up to 11% lower under the PA than the NAA for all water year types except wet years. The largest flow reductions would occur in November of wet and above normal year, with reductions of 26% at Keswick and 21% at Red Bluff for both year types. The results given here indicate that the PA would reduce flow in some months and water year types, although this does not consider real-time operational management described in Section 3.1.5, *Real-Time Operations Upstream of the Delta*, and Section 3.3.3, *Real-Time Operational Decision-Making Process*, that would be used to avoid and minimize any modeled effects Further discussion regarding flow-related effects during the June through November period is provided in Section 5.4.2.3, *Summary of Upstream Effects*.

As described in Appendix 5.D, Section 5.D.2.3, *Rearing Flows Methods*, rearing habitat WUA for Central Valley steelhead was not estimated directly by USFWS (2005b), but was modeled using the rearing WUA curves obtained for late fall-run Chinook salmon, in the same three Sacramento River segments that were used for the winter-run Chinook salmon rearing habitat WUA studies (USFWS 2005b). The rearing WUA curves for late fall-run Chinook salmon were used because the fry rearing period of late fall-run Chinook salmon is similar to that of Central Valley steelhead, and because this substitution follows previous practice (Appendix 5.D, Section

5.D.2.3, *Rearing Flows Methods)*. However, the validity of using the late fall-run Chinook salmon WUA curves to characterize Central Valley steelhead rearing habitat is uncertain. To estimate changes in rearing WUA that would result from the PA, the late fall-run Chinook salmon WUA curves developed for each of the river segments was used with mean monthly CALSIM II flow estimates for the midpoint of each segment under the PA and the NAA during the rearing periods for CCV steelhead fry (February through May) and juveniles (year-round) (Appendix 5.D, Section 5.D.2.3, *Rearing Flows Methods,* Table RFM-1). Fry were defined as fish less than 60 mm and juveniles were those greater than 60 mm. Further information on the WUA analysis methods is provided in Appendix 5.D, Section 5.D.2.3, *Rearing Flows Methods*.

Differences under the PA and NAA in rearing WUA for CCV steelhead fry and juveniles were examined using exceedance plots of mean monthly WUA for the CCV steelhead fry (Figure 5.4-210–Figure 5.4-227) and juvenile (Figure 5.4-228-Figure 5.4-245) rearing periods in each of the river segments for each water year type and all water year types combined. The PA exceedance curves for both fry and juvenile rearing WUA for all water years combined are similar to those for the NAA for all three river segments (Figure 5.4-210, Figure 5.4-216, Figure 5.4-222, Figure 5.4-228, Figure 5.4-234, and Figure 5.4-240). With the curves broken out by water year type, reductions in fry rearing habitat WUA under the PA compared to the NAA are evident in Segment 6 during dry and critical water years (Figure 5.4-214 and Figure 5.4-215) and in Segment 5 during dry years (Figure 5.4-220), while increases in juvenile rearing WUA under the PA are evident in Segment 4 during wet and above normal years (Figure 5.4-241 and Figure 5.4-242). The WUA modeling indicates that the PA would reduce CCV steelhead salmon rearing habitat during several months and water year types. Further discussion regarding flow-related effects during the June through November period is provided in Section 5.4.2.3, *Summary of Upstream Effects*.

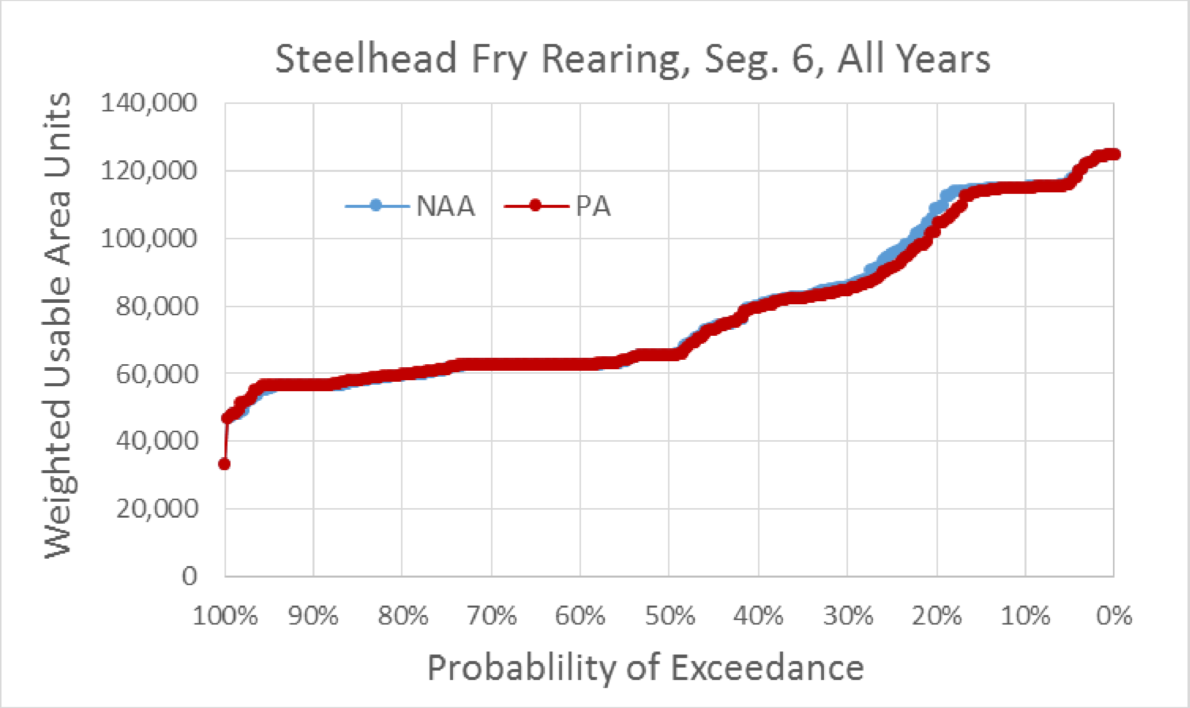

Figure 5.4-210. Exceedance Plot of CCV Steelhead Fry Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 6, All Water Years

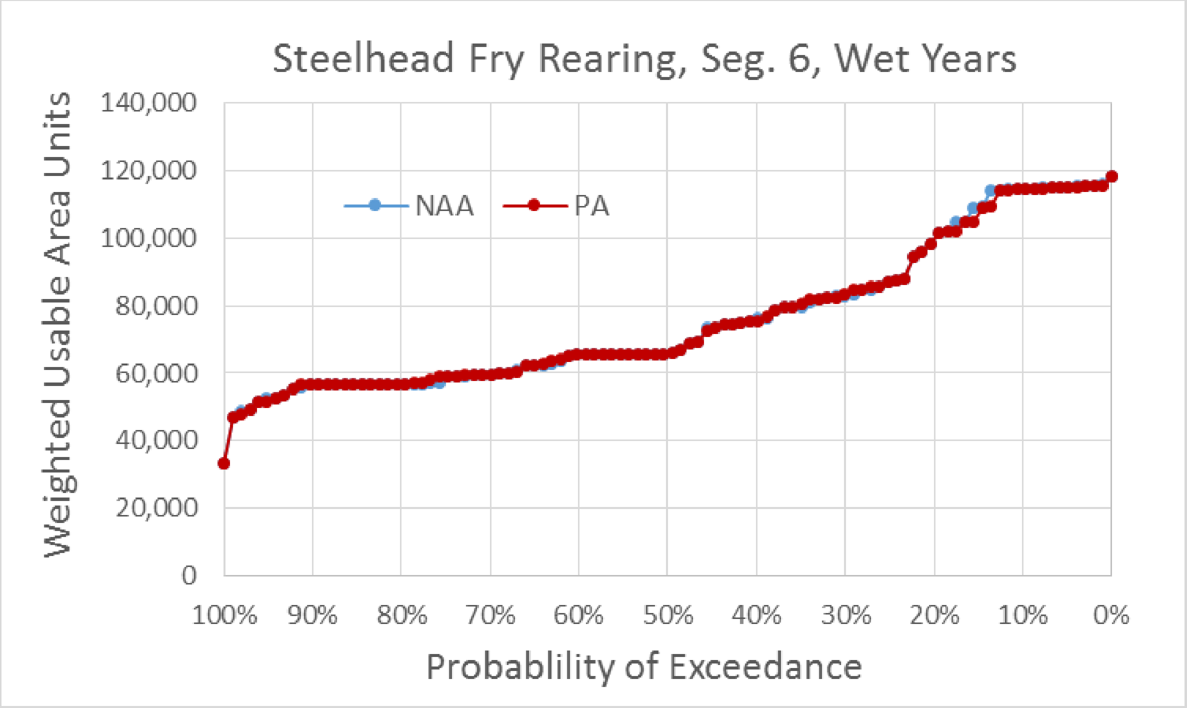

Figure 5.4-211. Exceedance Plot of CCV Steelhead Fry Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 6, Wet Water Years

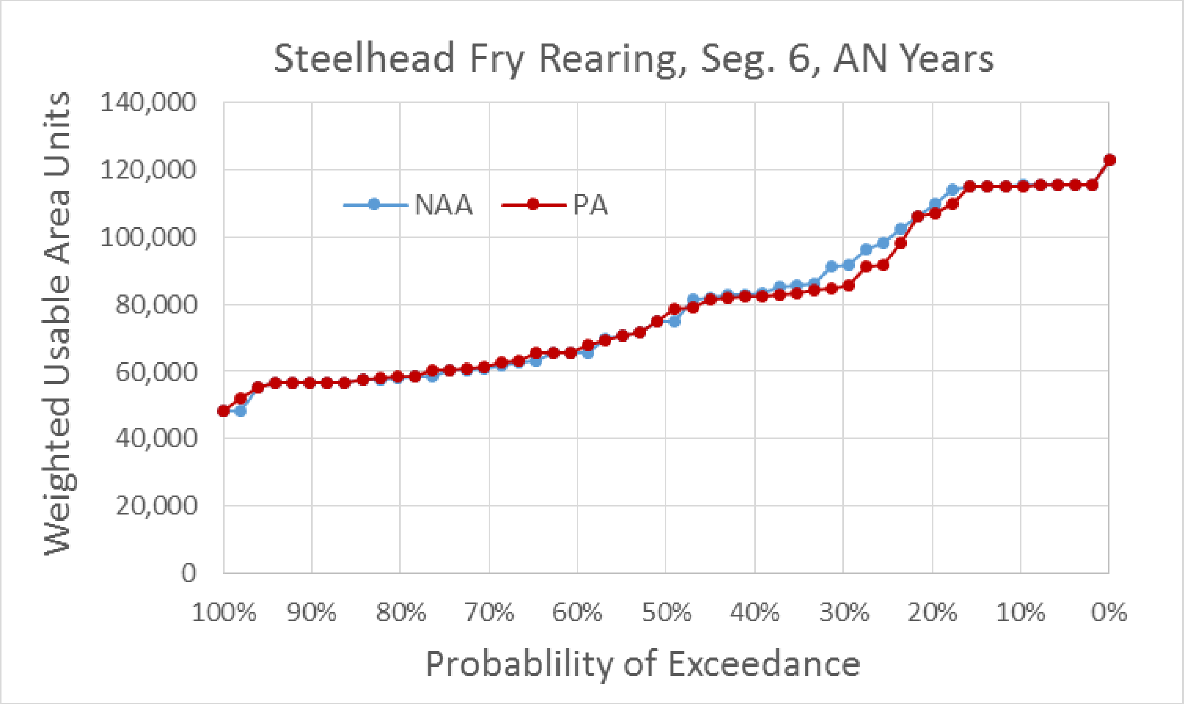

Figure 5.4-212. Exceedance Plot of CCV Steelhead Fry Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 6, Above Normal Water Years

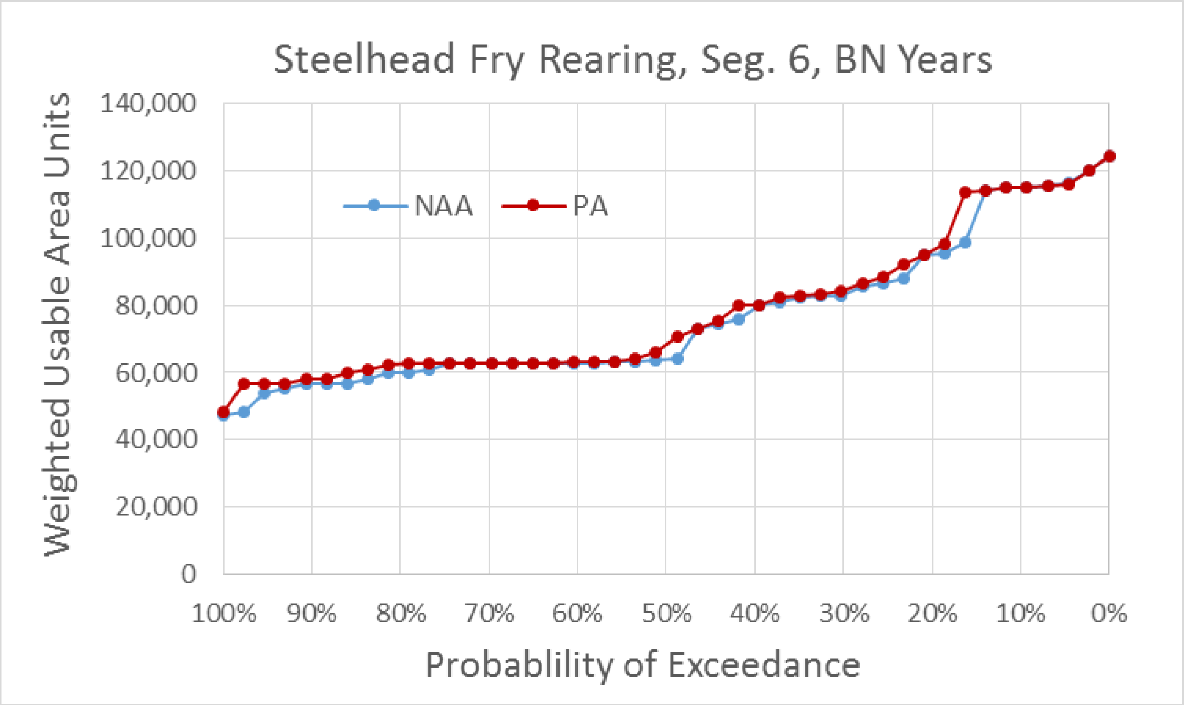

Figure 5.4-213. Exceedance Plot of CCV Steelhead Fry Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 6, Below Normal Water Years

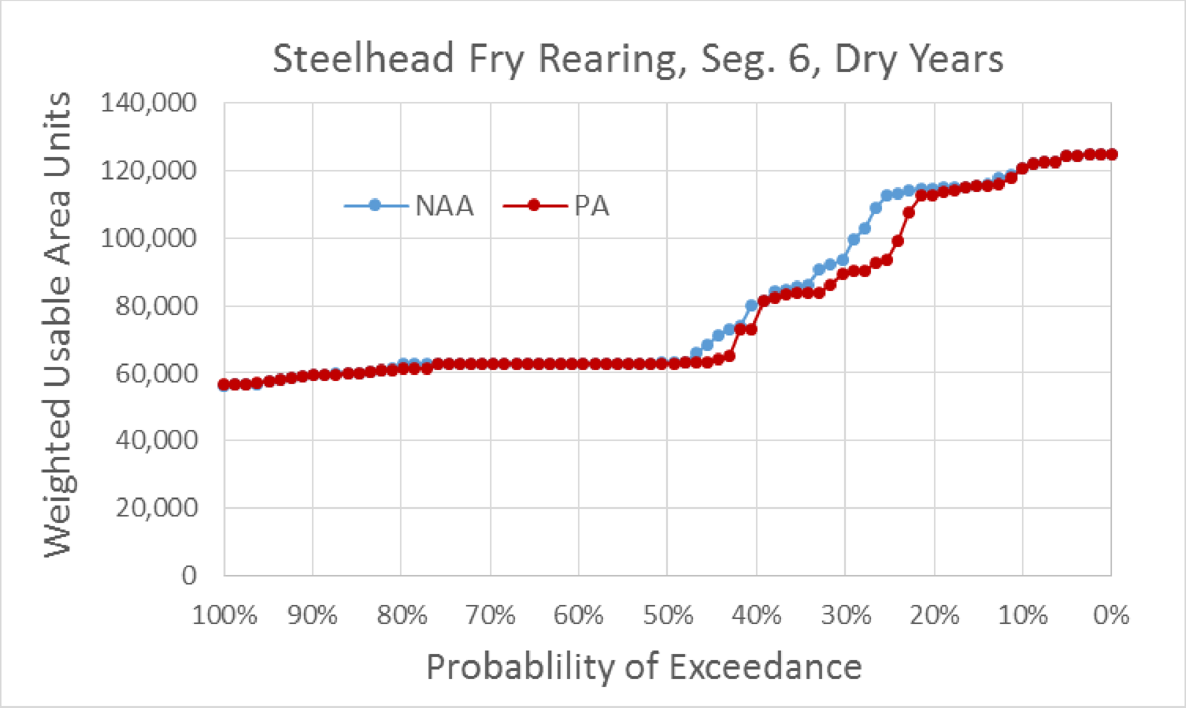

Figure 5.4-214. Exceedance Plot of CCV Steelhead Fry Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 6, Dry Water Years

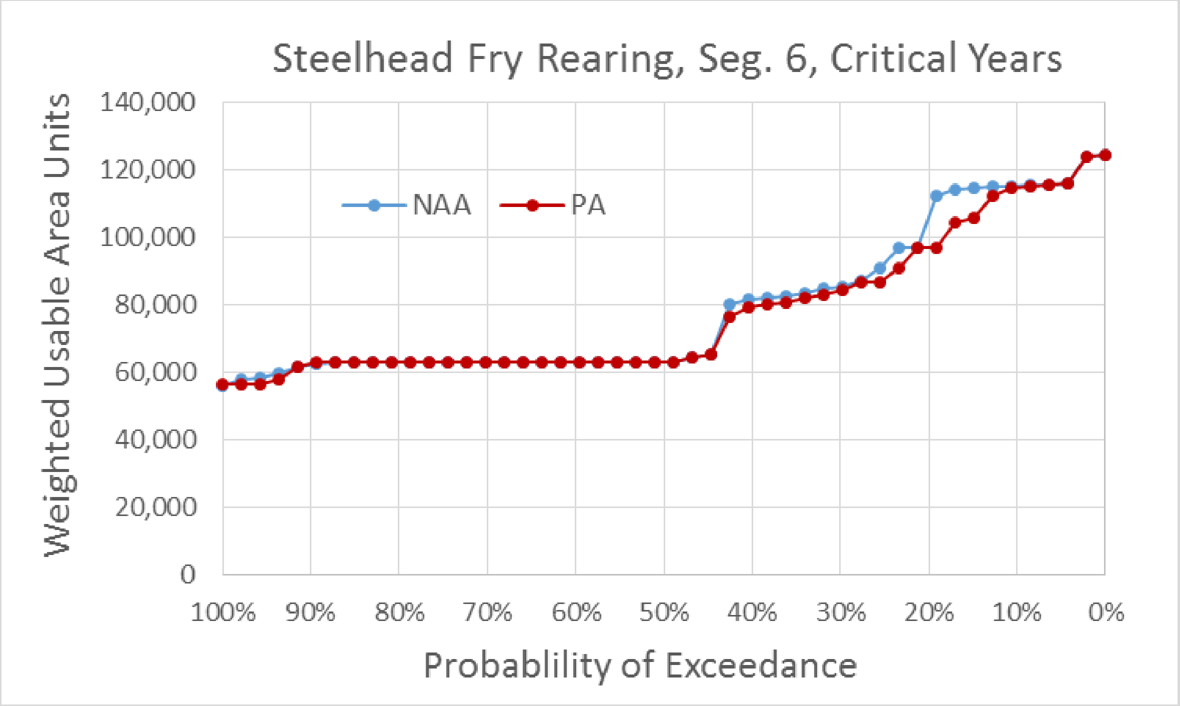

Figure 5.4-215. Exceedance Plot of CCV Steelhead Fry Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 6, Critical Water Years

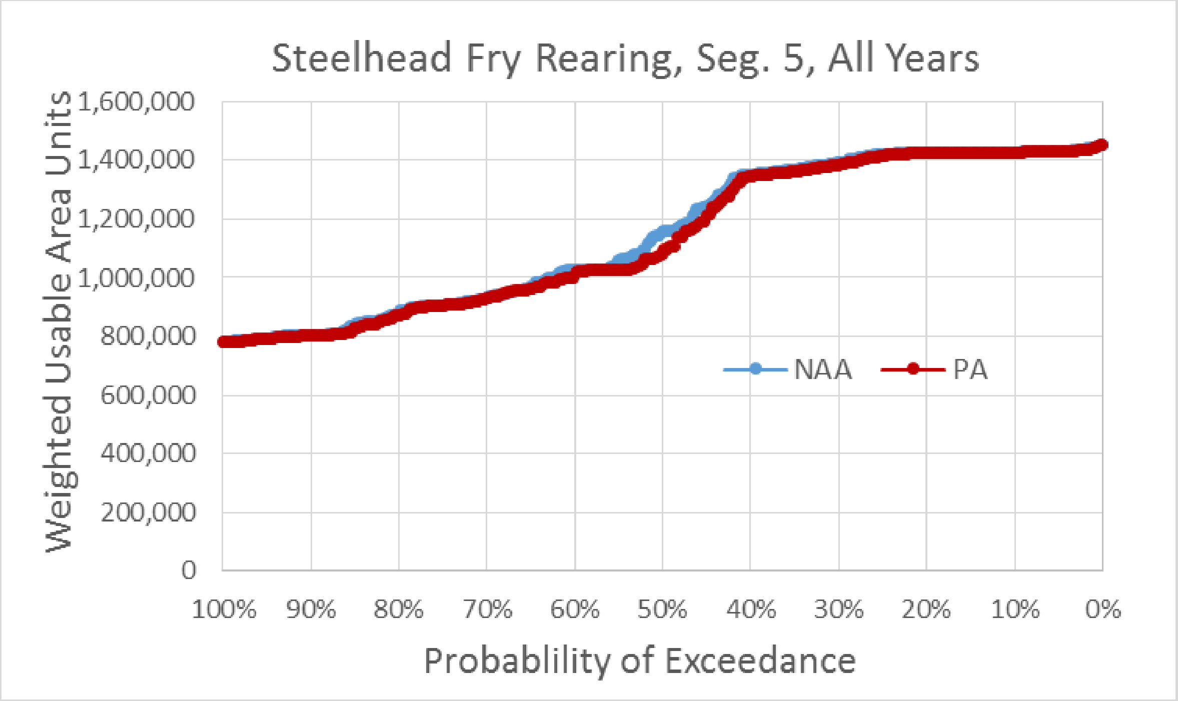

Figure 5.4-216. Exceedance Plot of CCV Steelhead Fry Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 5, All Water Years

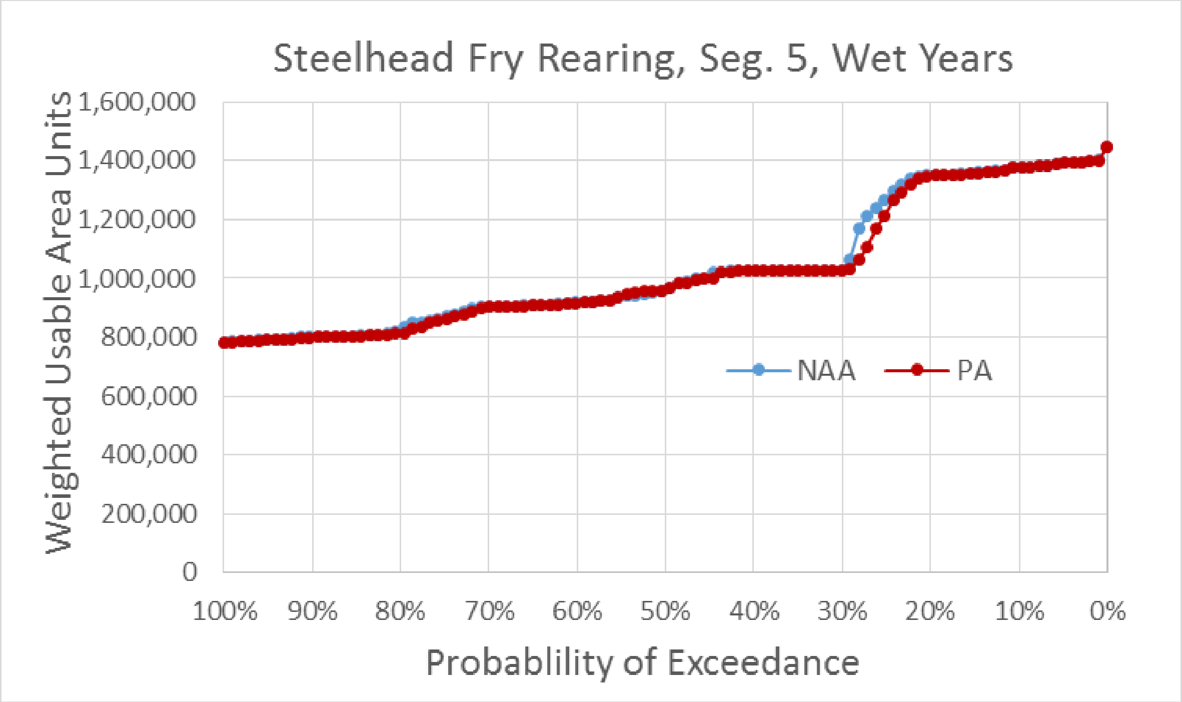

Figure 5.4-217. Exceedance Plot of CCV Steelhead Fry Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 5, Wet Water Years

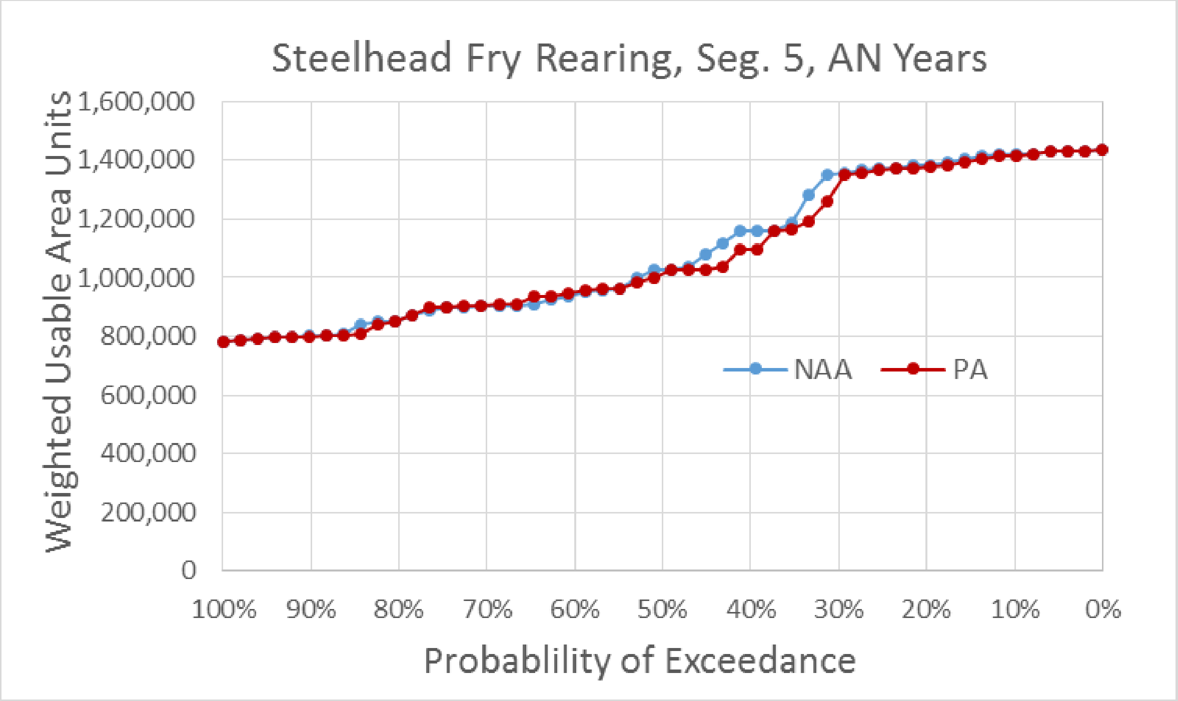

Figure 5.4-218. Exceedance Plot of CCV Steelhead Fry Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 5, Above Normal Water Years

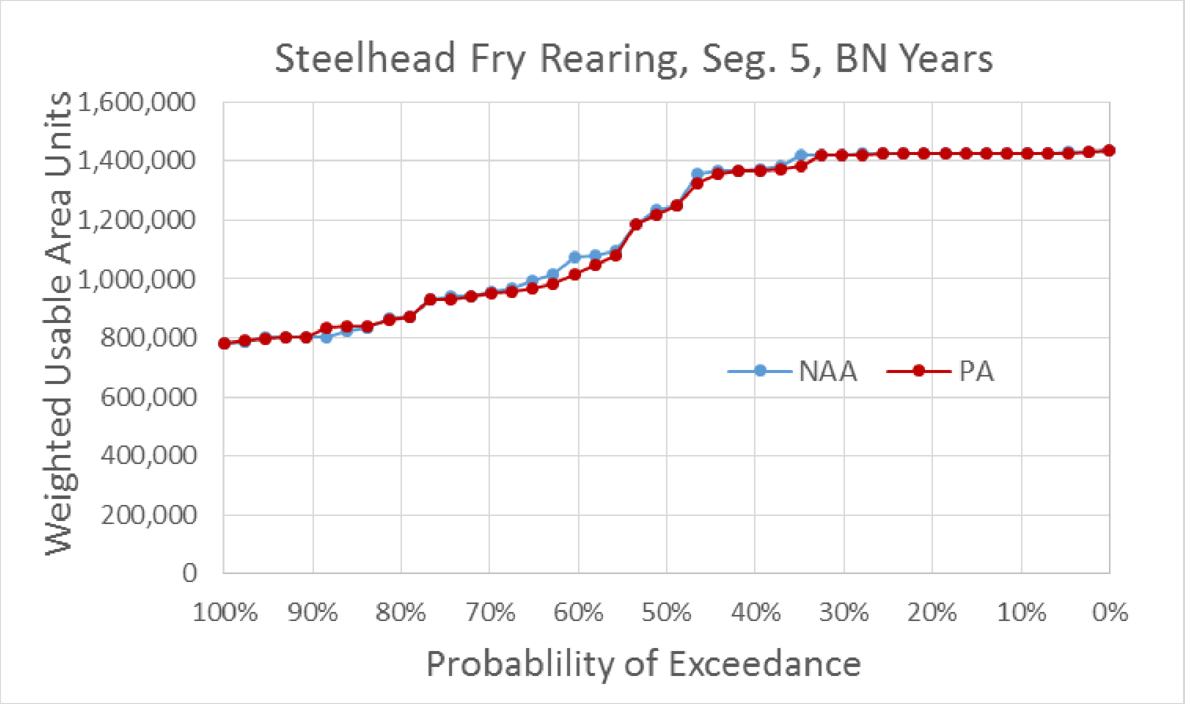

Figure 5.4-219. Exceedance Plot of CCV Steelhead Fry Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 5, Below Normal Water Years

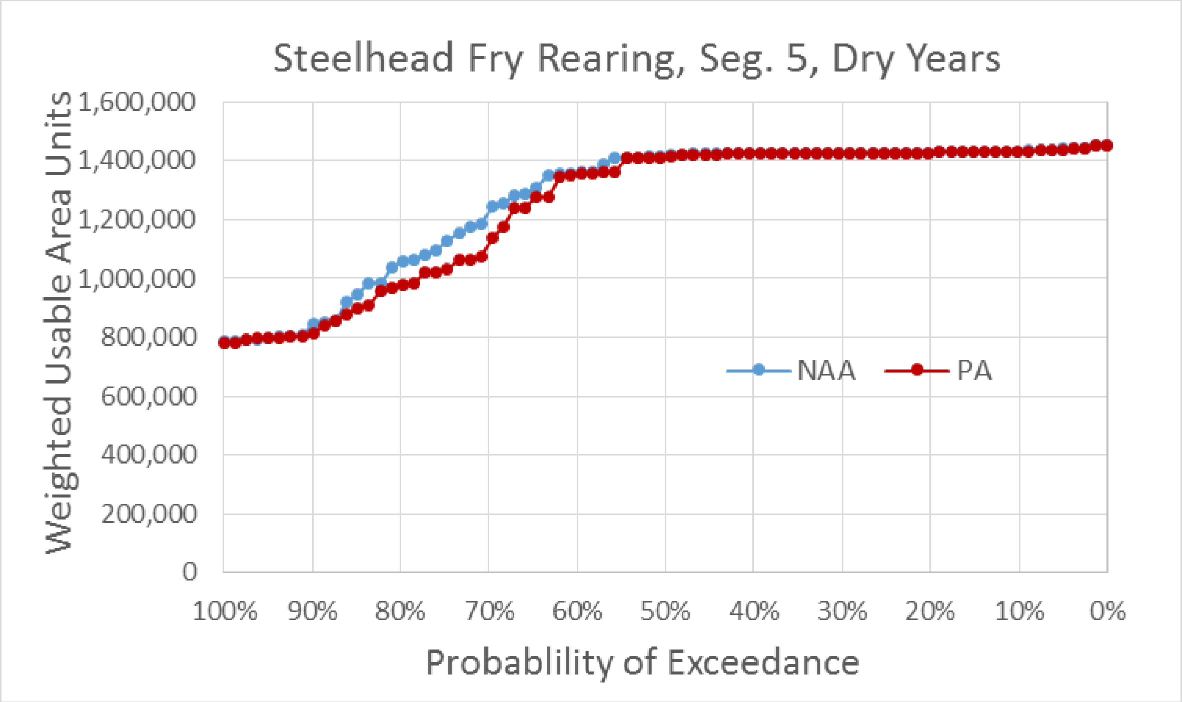

Figure 5.4-220. Exceedance Plot of CCV Steelhead Fry Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 5, Dry Water Years

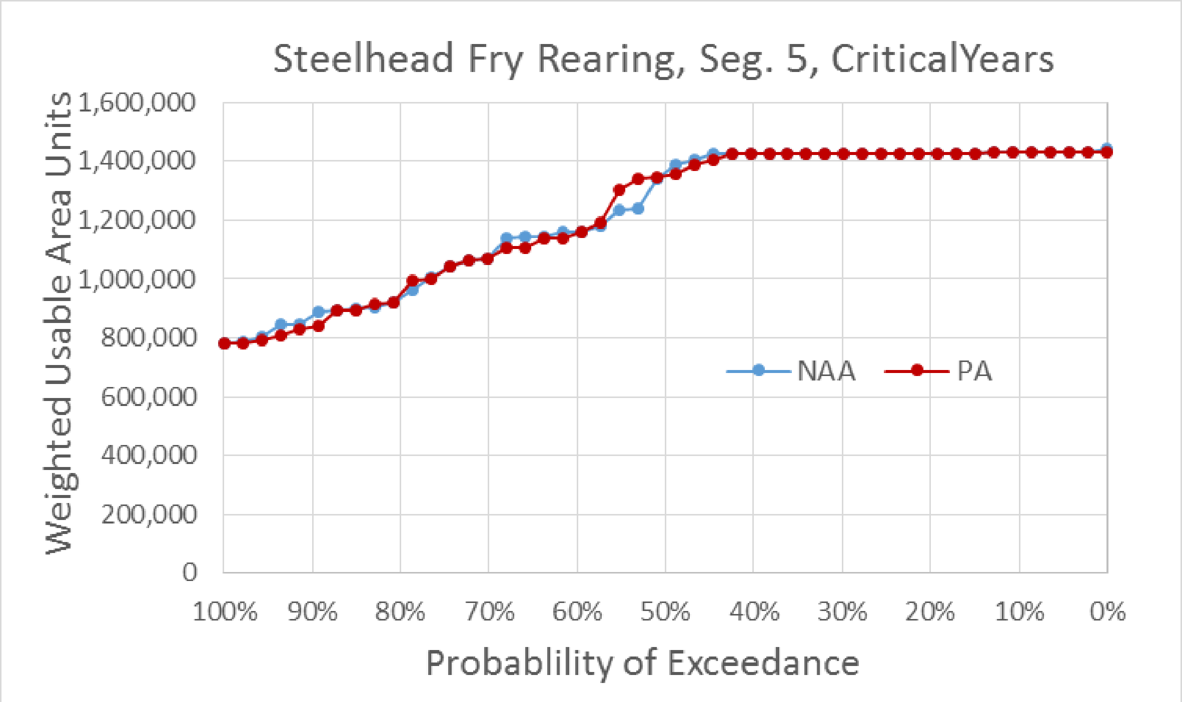

Figure 5.4-221. Exceedance Plot of CCV Steelhead Fry Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 5, Critical Water Years

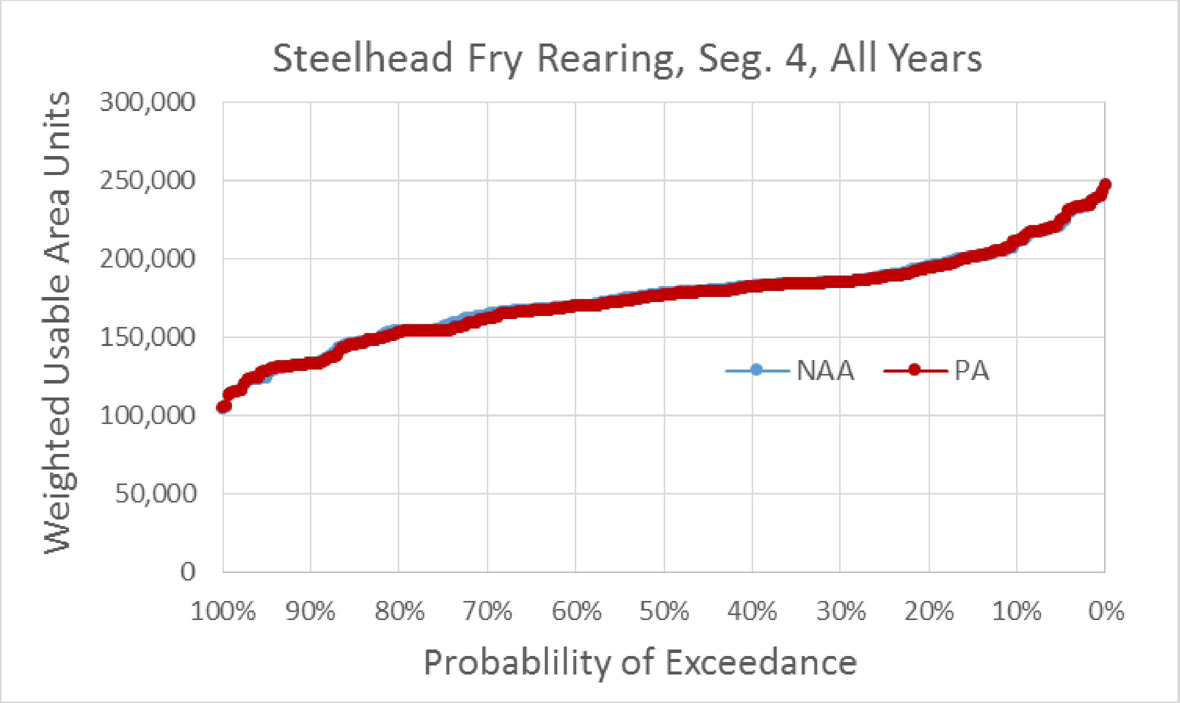

Figure 5.4-222. Exceedance Plot of CCV Steelhead Fry Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 4, All Water Years

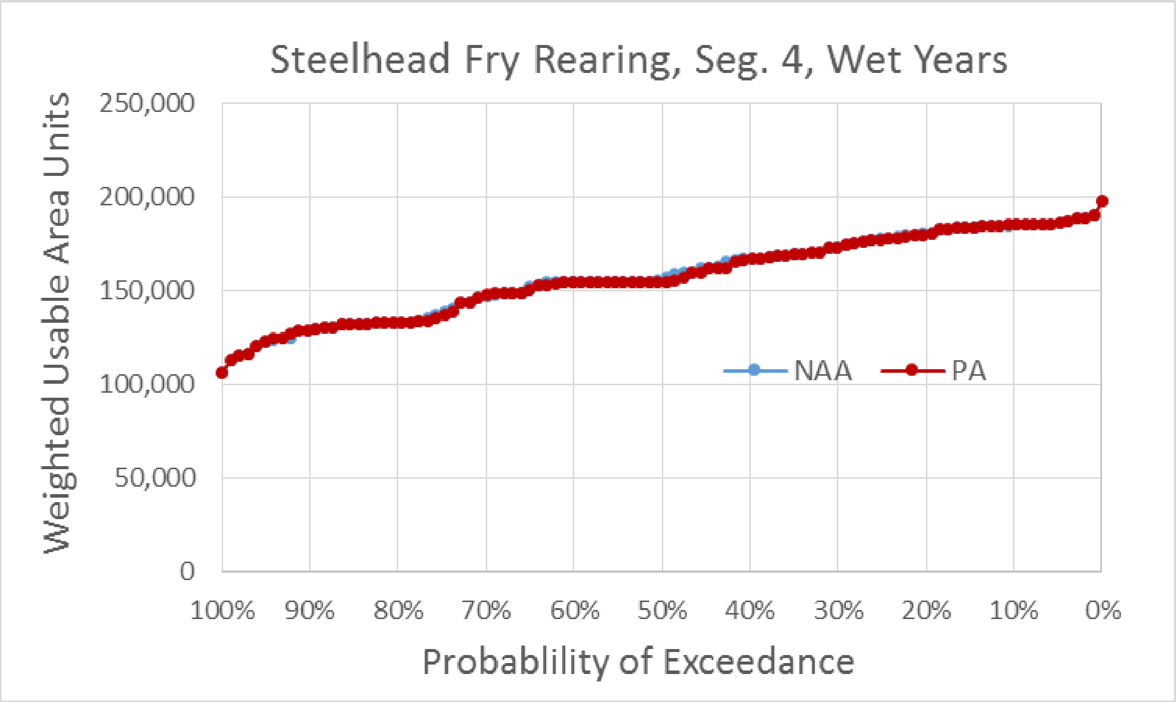

Figure 5.4-223. Exceedance Plot of CCV Steelhead Fry Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 4, Wet Water Years

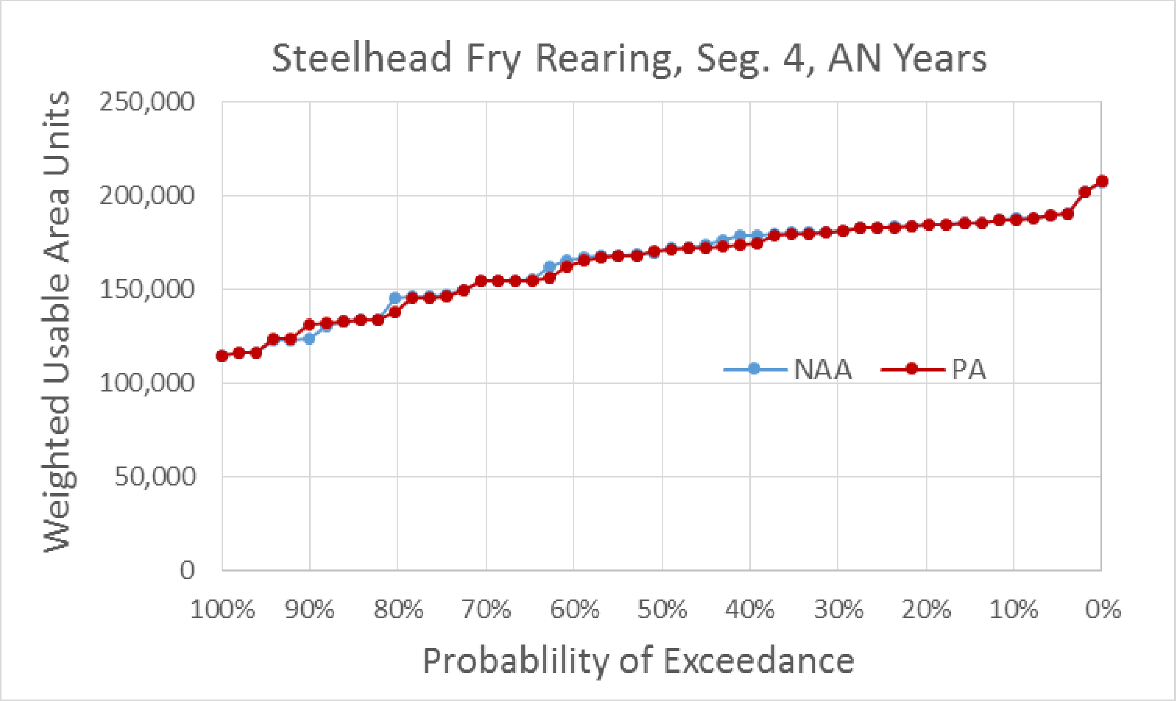

Figure 5.4-224. Exceedance Plot of CCV Steelhead Fry Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 4, Above Normal Water Years

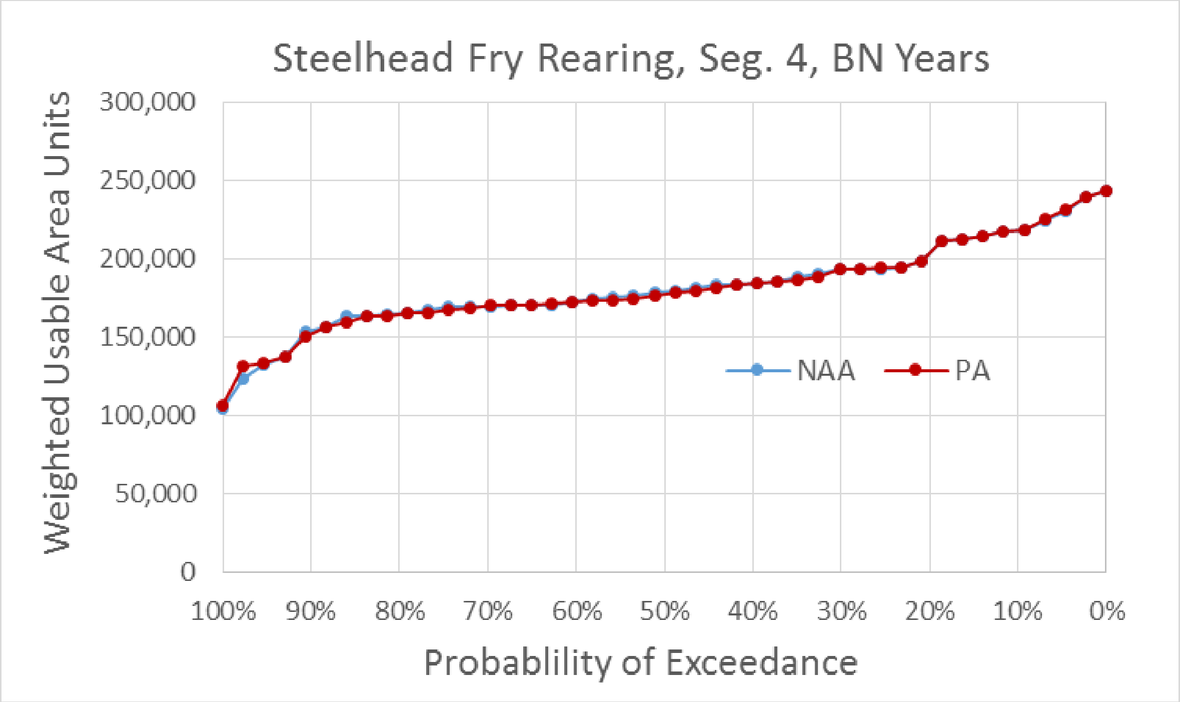

Figure 5.4-225. Exceedance Plot of CCV Steelhead Fry Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 4, Below Normal Water Years

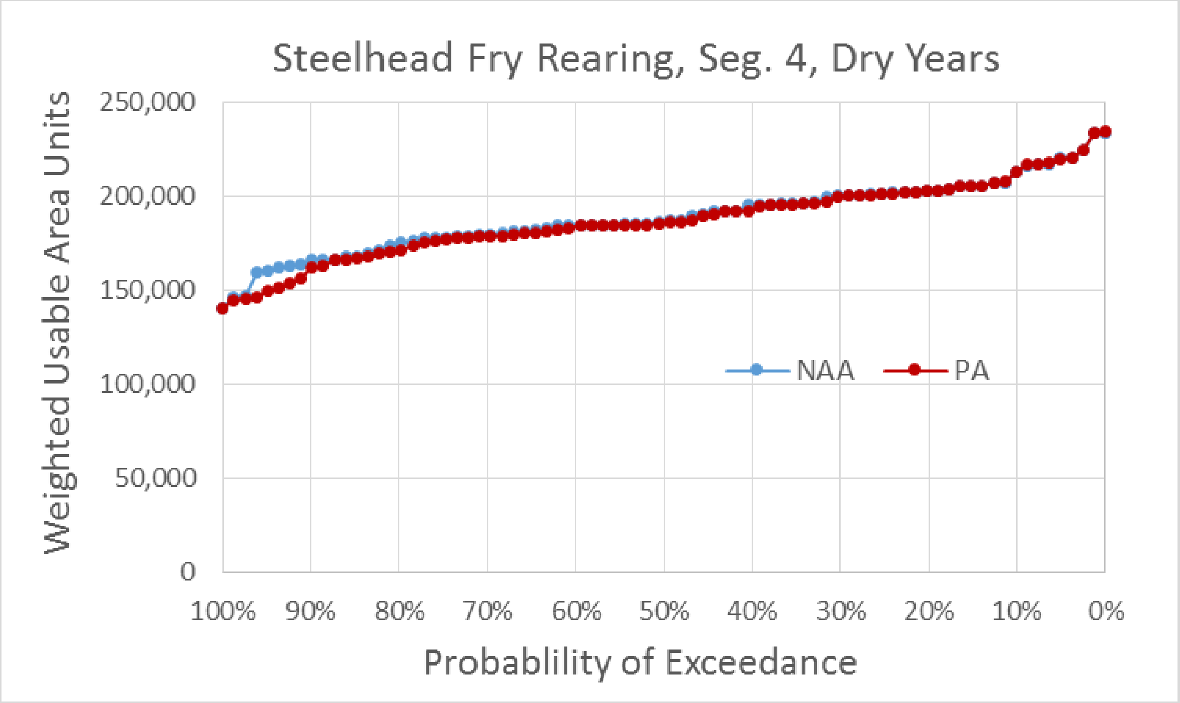

Figure 5.4-226. Exceedance Plot of CCV Steelhead Fry Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 4, Dry Water Years

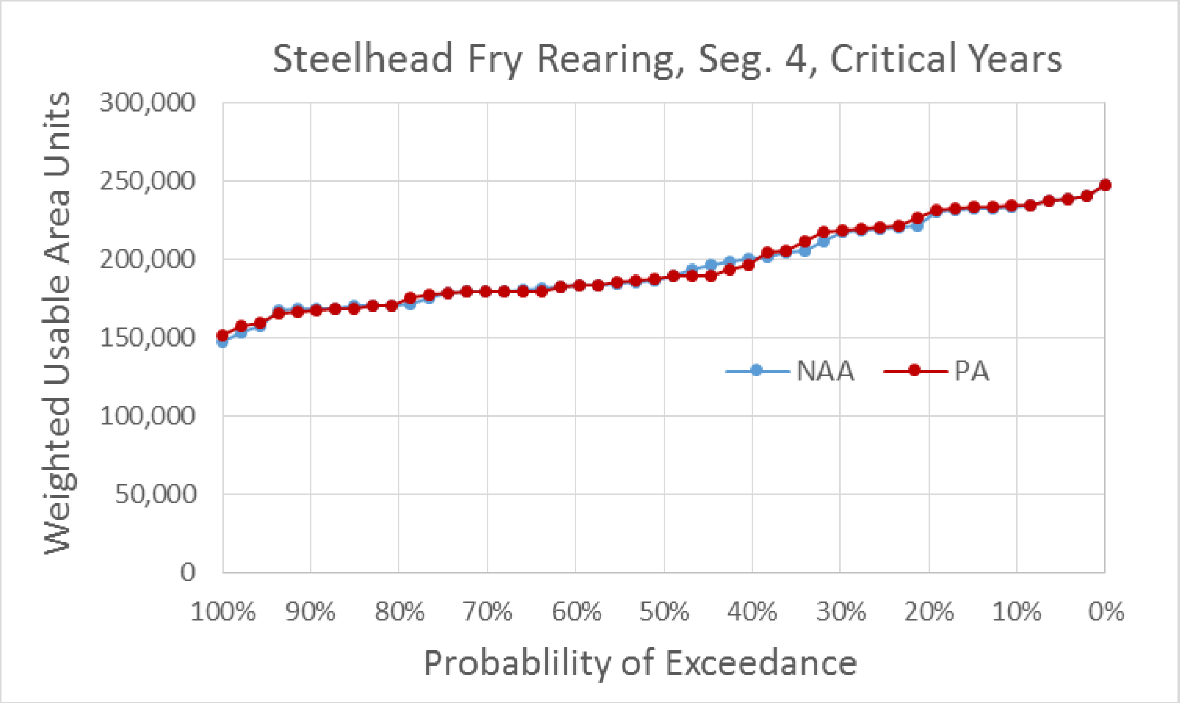

Figure 5.4-227. Exceedance Plot of CCV Steelhead Fry Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 4, Critical Water Years

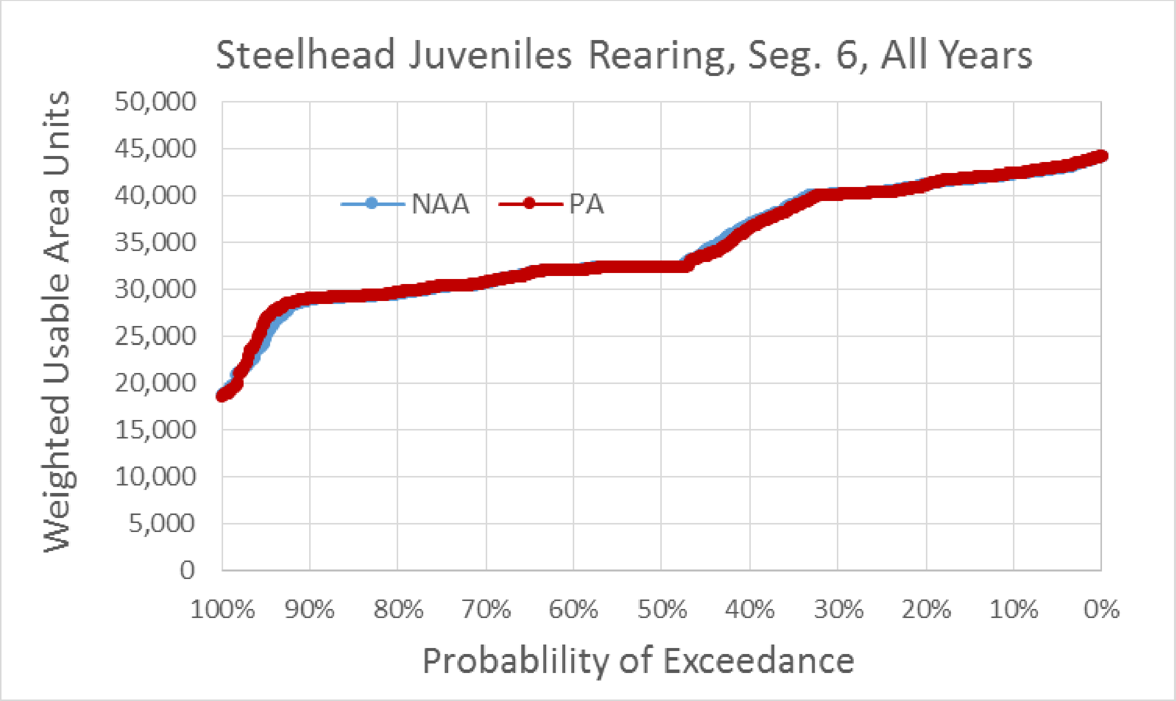

Figure 5.4-228. Exceedance Plot of CCV Steelhead Juvenile Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 6, All Water Years

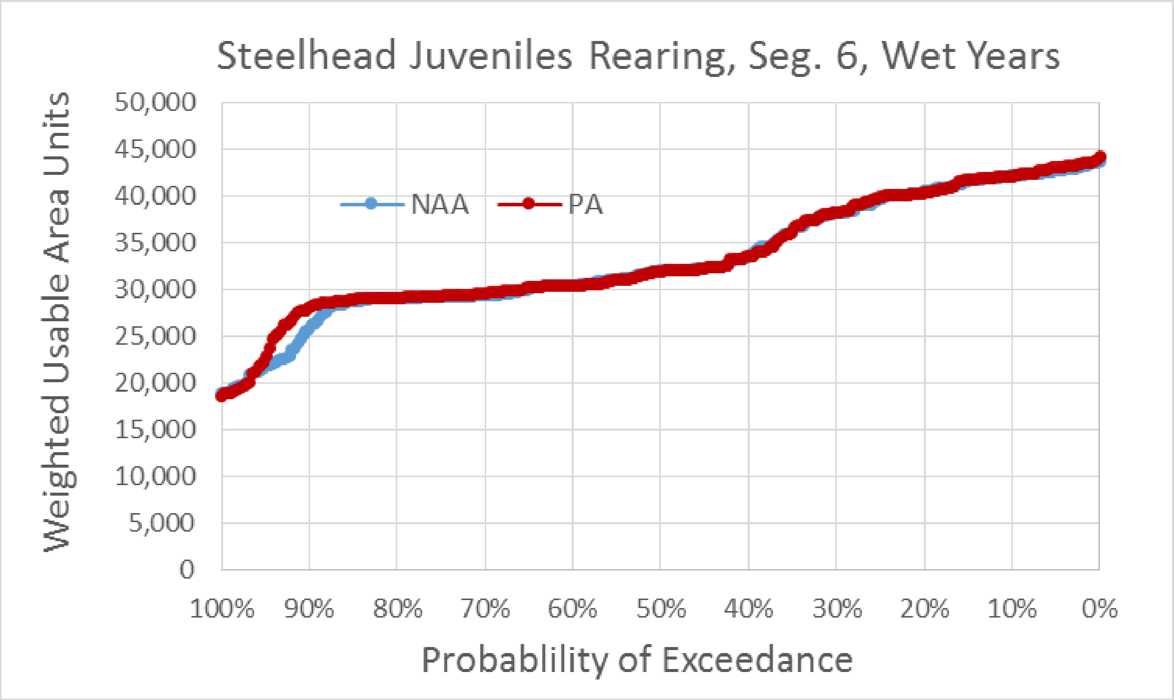

Figure 5.4-229. Exceedance Plot of CCV Steelhead Juvenile Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 6, Wet Water Years

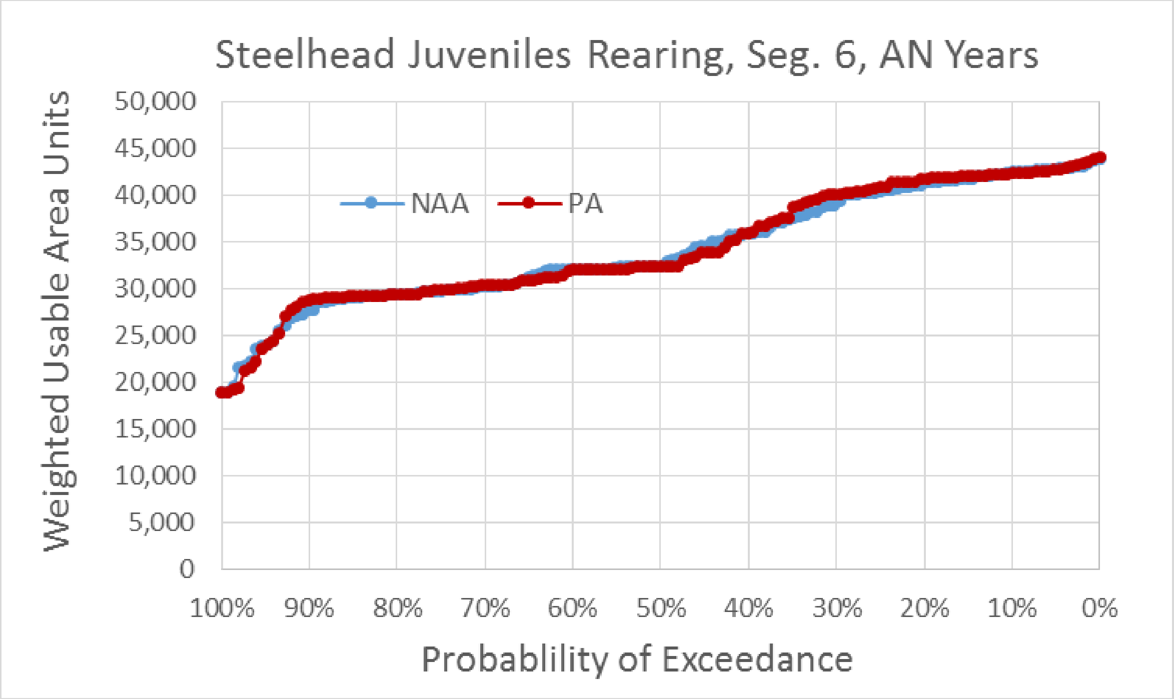

Figure 5.4-230. Exceedance Plot of CCV Steelhead Juvenile Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 6, Above Normal Water Years

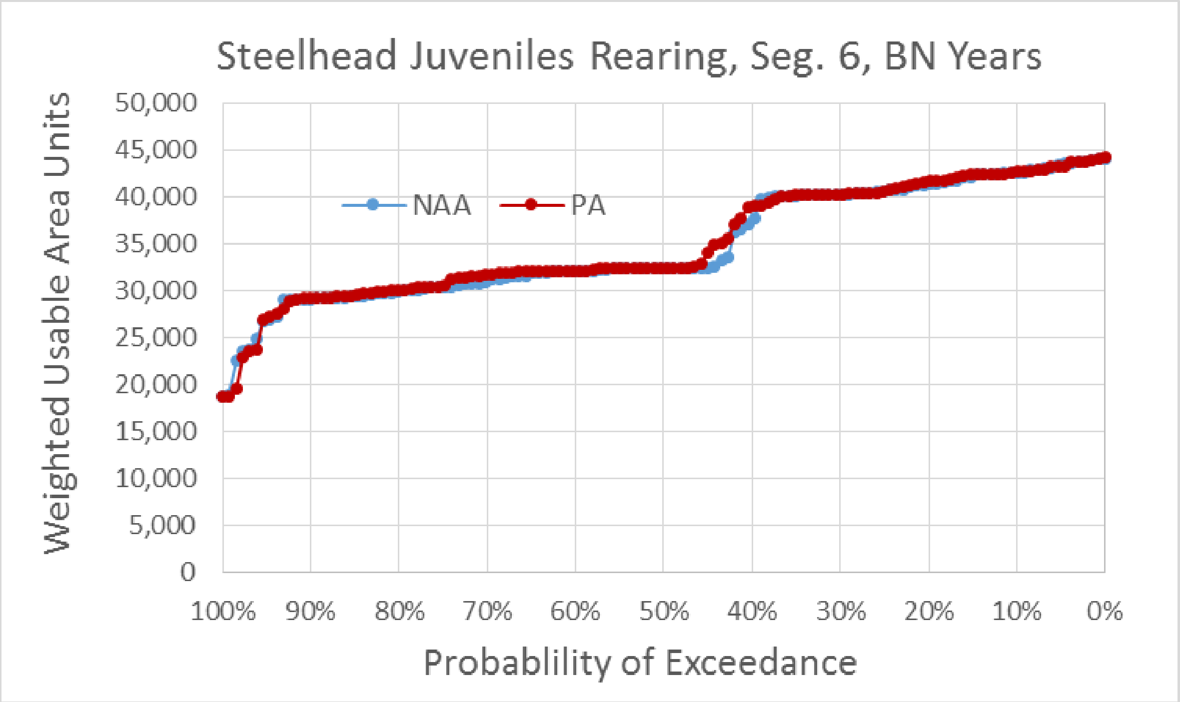

Figure 5.4-231. Exceedance Plot of CCV Steelhead Juvenile Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 6, Below Normal Water Years

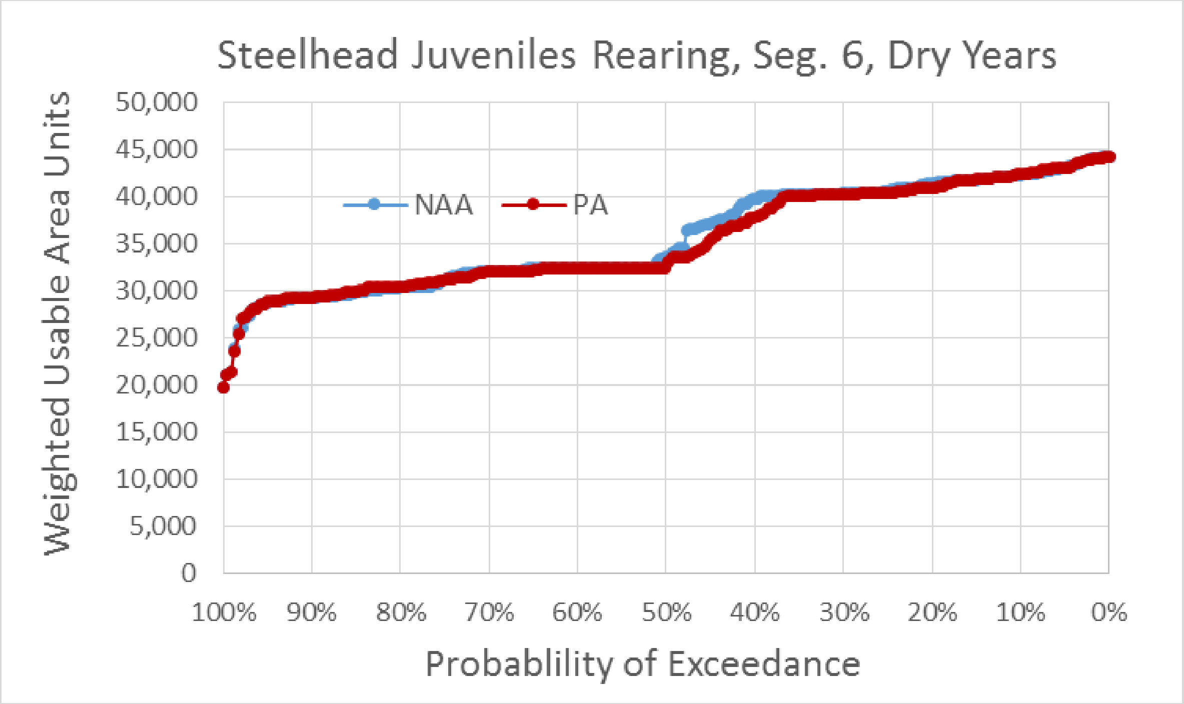

Figure 5.4-232. Exceedance Plot of CCV Steelhead Juvenile Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 6, Dry Water Years

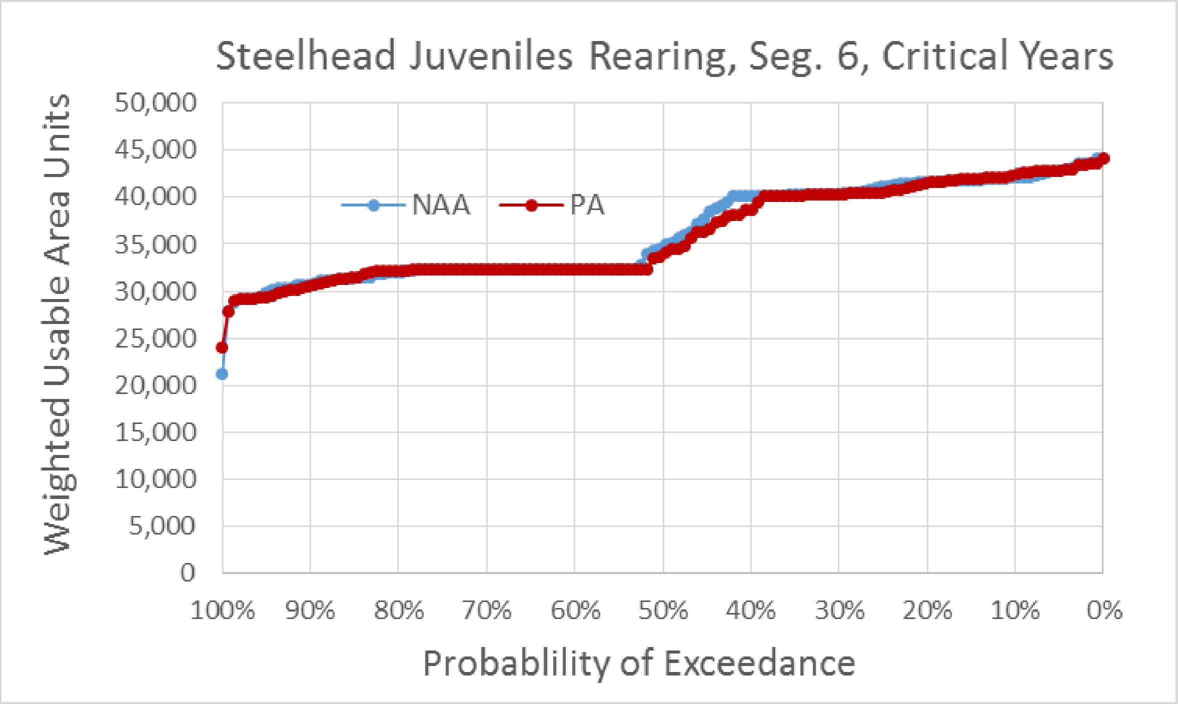

Figure 5.4-233. Exceedance Plot of CCV Steelhead Juvenile Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 6, Critical Water Years

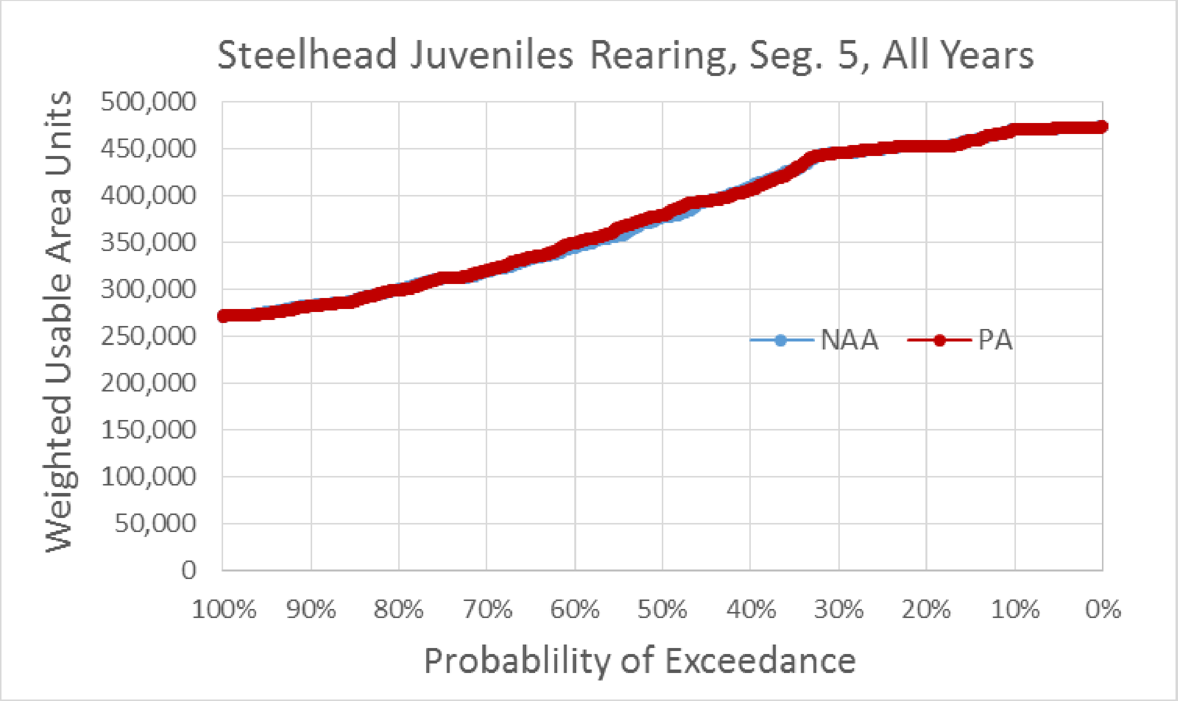

Figure 5.4-234. Exceedance Plot of CCV Steelhead Juvenile Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 5, All Water Years

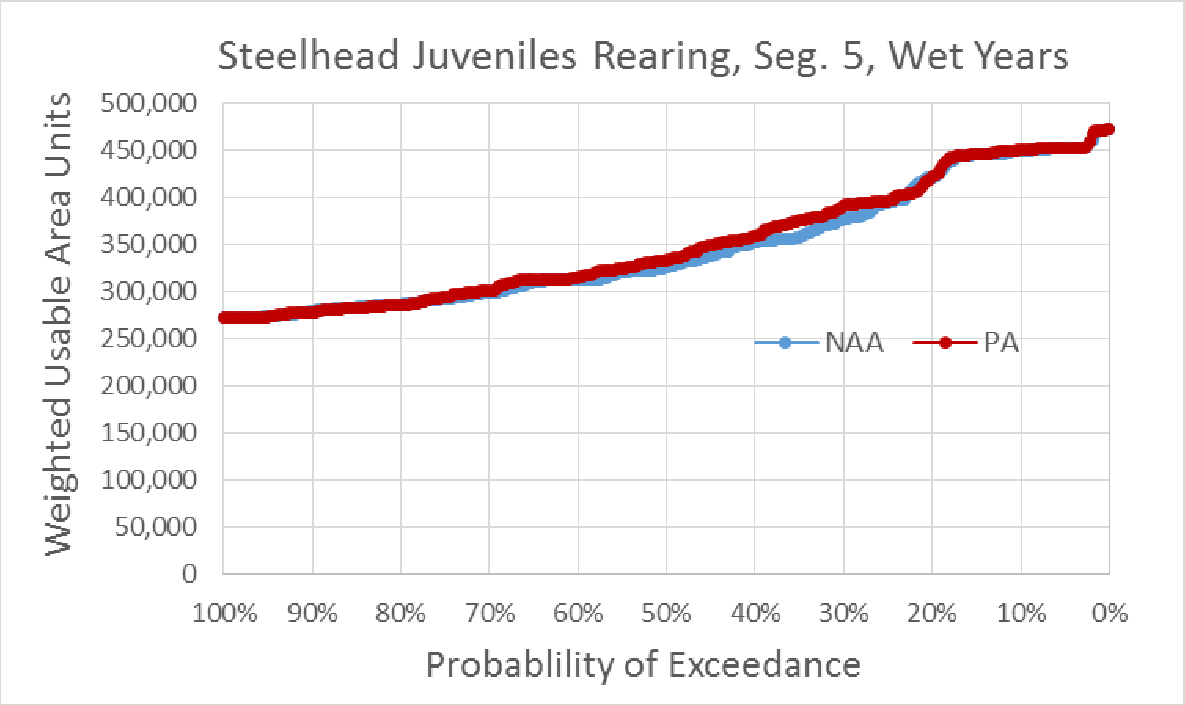

Figure 5.4-235. Exceedance Plot of CCV Steelhead Juvenile Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 5, Wet Water Years

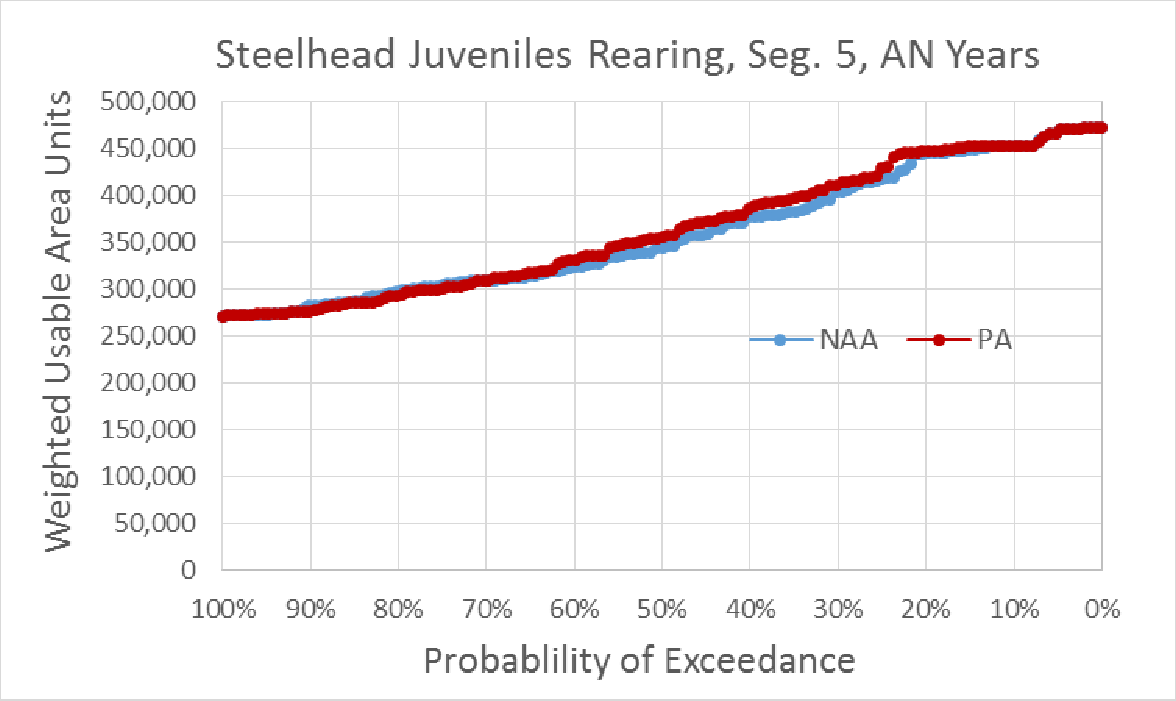

Figure 5.4-236. Exceedance Plot of CCV Steelhead Juvenile Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 5, Above Normal Water Years

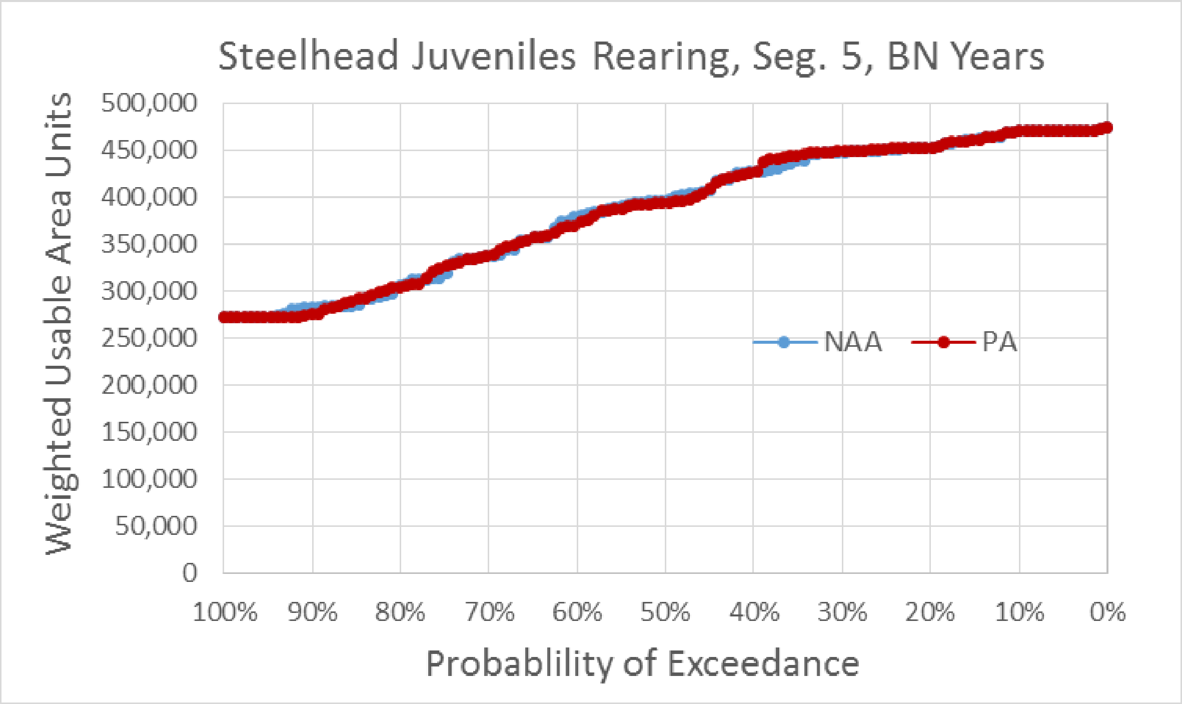

Figure 5.4-237. Exceedance Plot of CCV Steelhead Juvenile Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 5, Below Normal Water Years

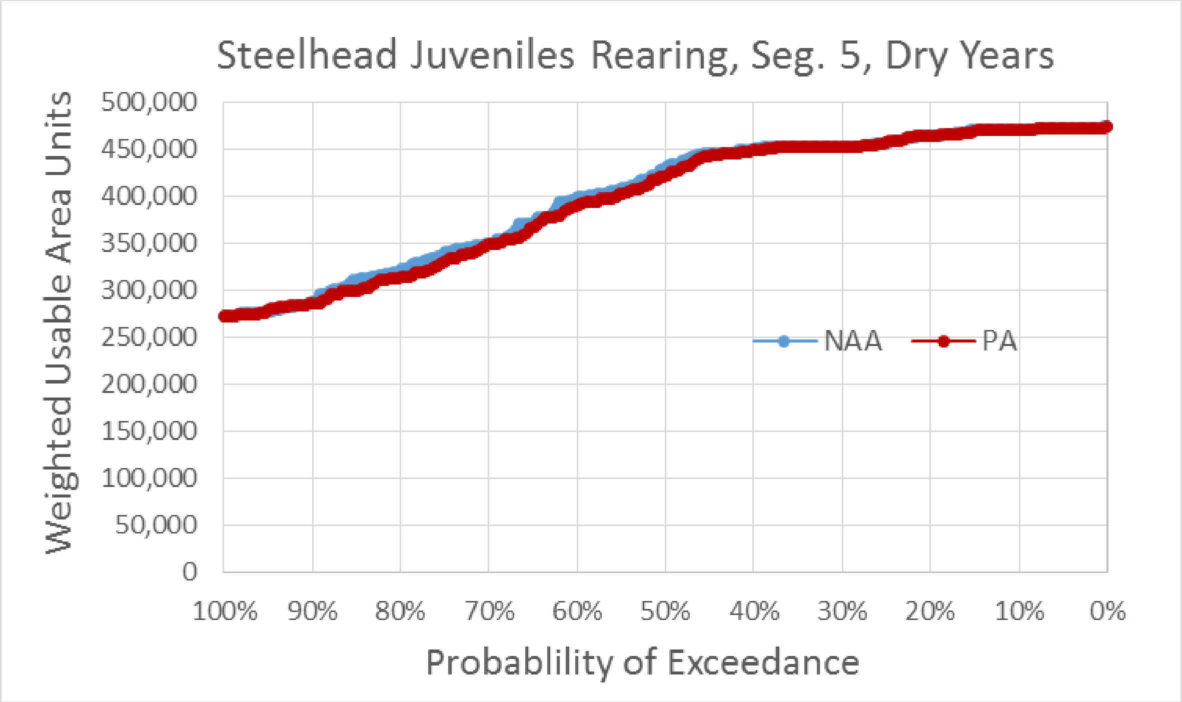

Figure 5.4-238. Exceedance Plot of CCV Steelhead Juvenile Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 5, Dry Water Years

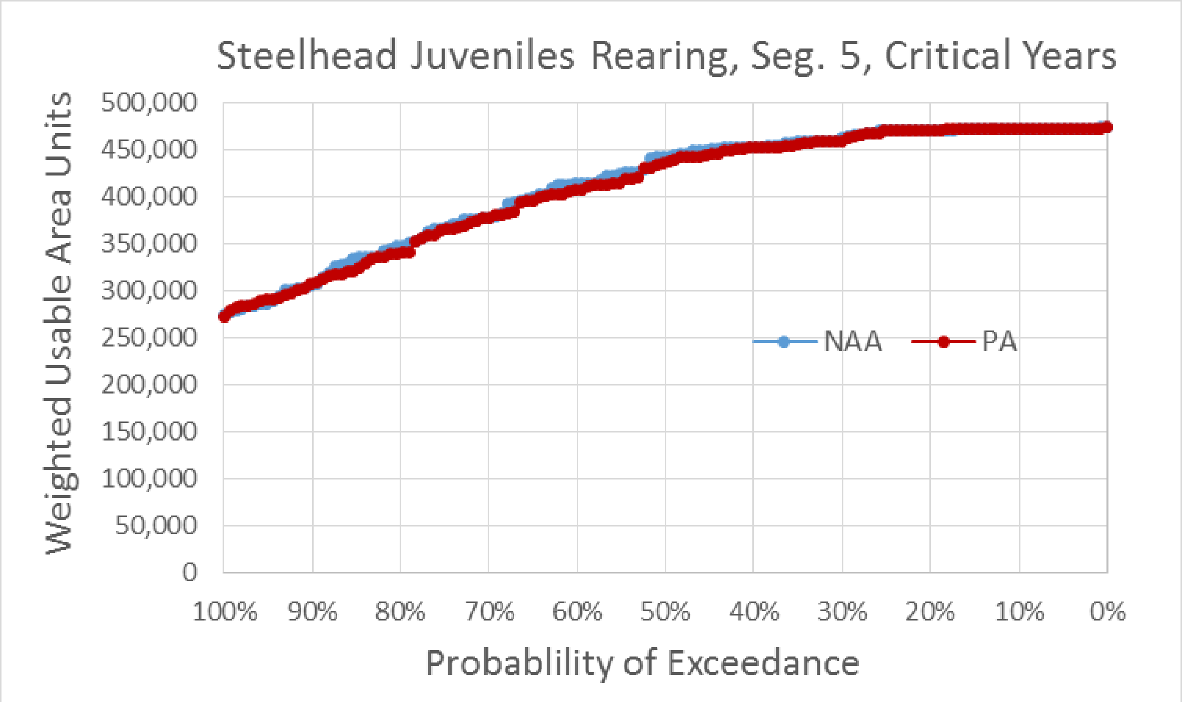

Figure 5.4-239. Exceedance Plot of CCV Steelhead Juvenile Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 5, Critical Water Years

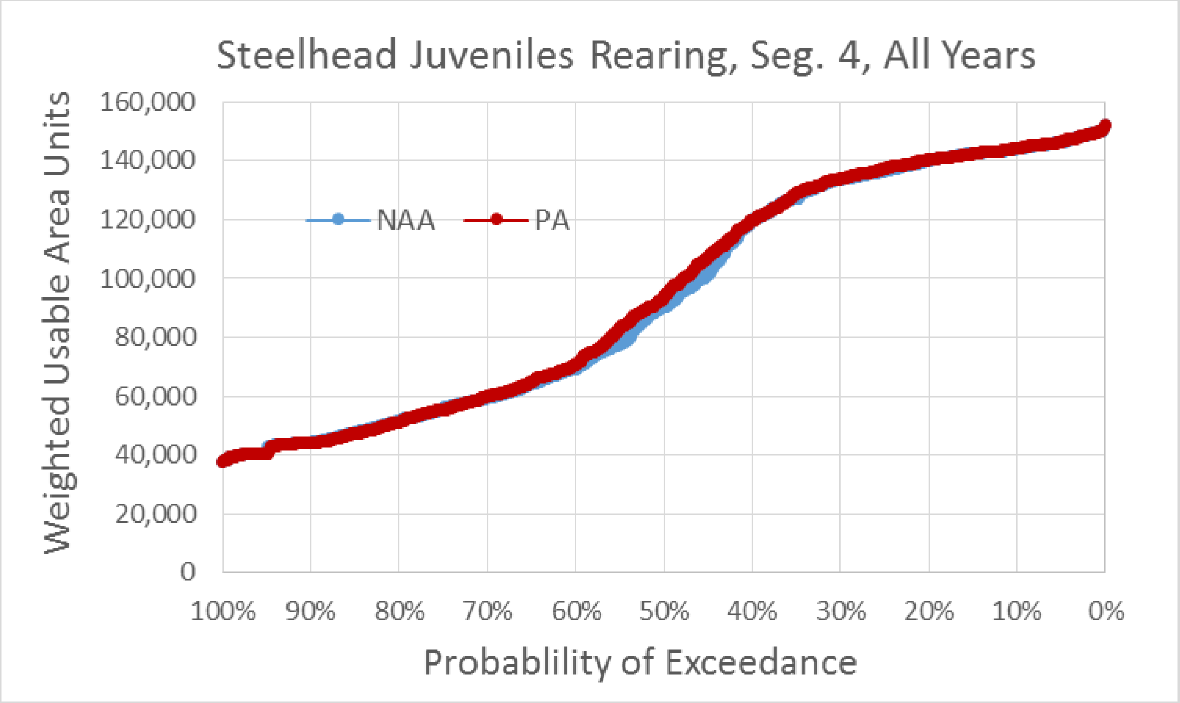

Figure 5.4-240. Exceedance Plot of CCV Steelhead Juvenile Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 4, All Water Years

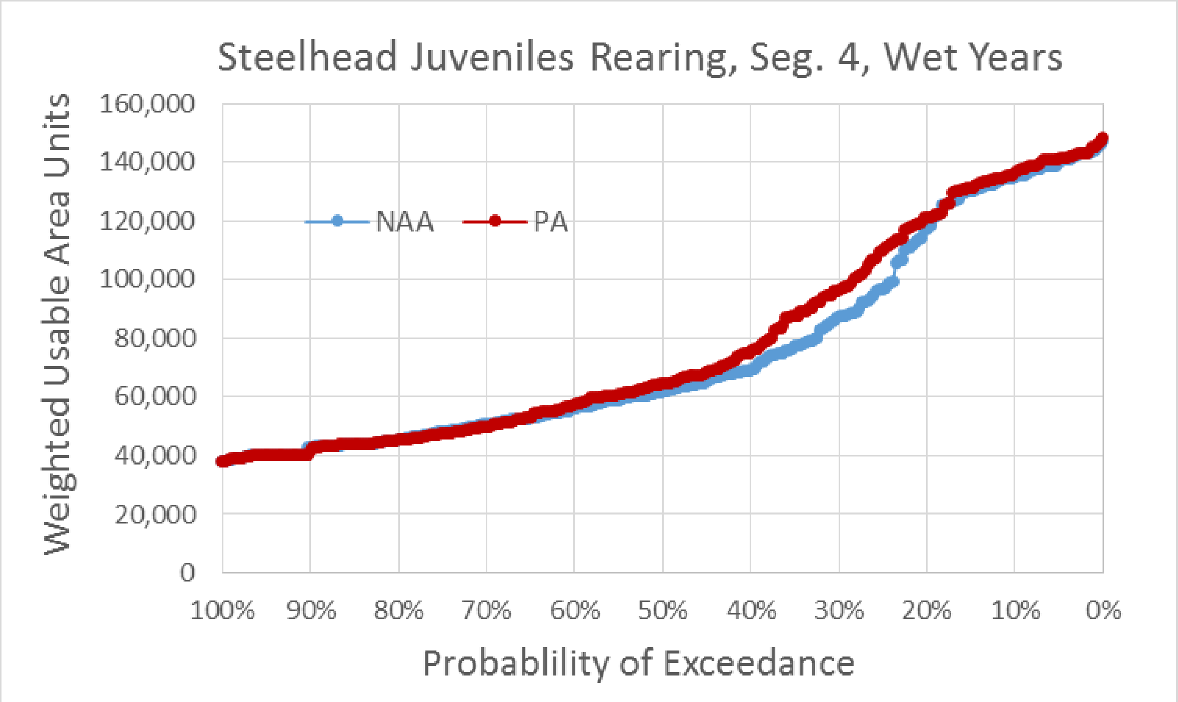

Figure 5.4-241. Exceedance Plot of CCV Steelhead Juvenile Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 4, Wet Water Years

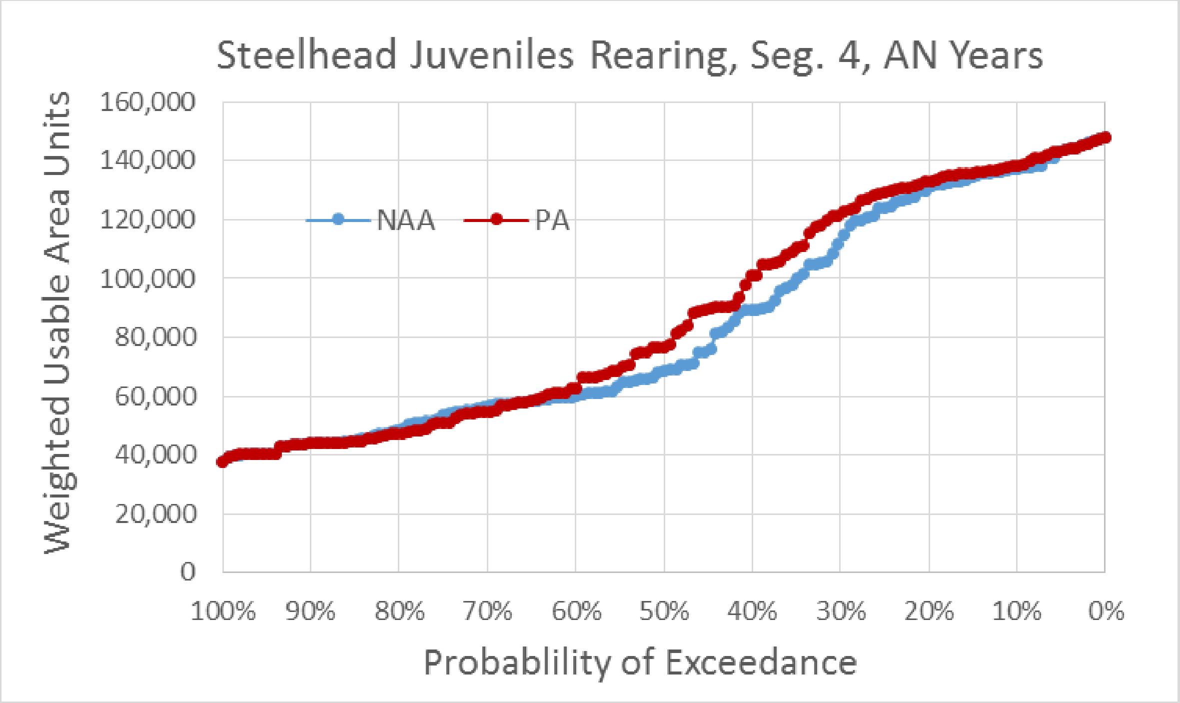

Figure 5.4-242. Exceedance Plot of CCV Steelhead Juvenile Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 4, Above Normal Water Years

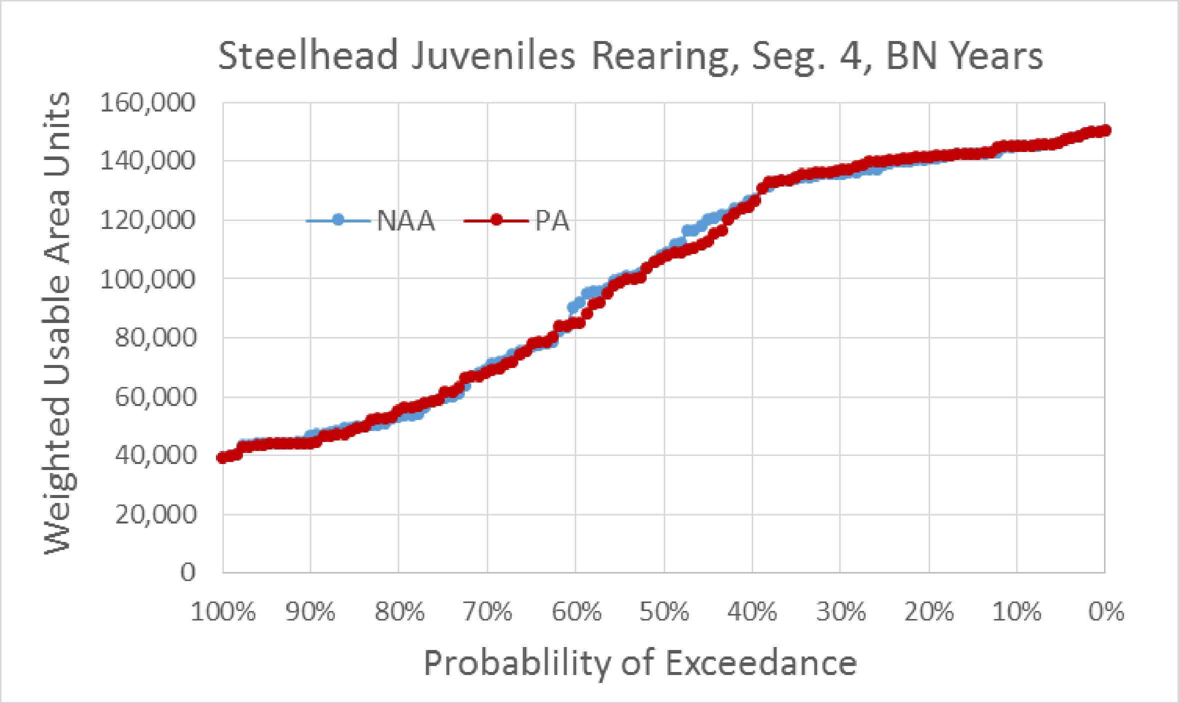

Figure 5.4-243. Exceedance Plot of CCV Steelhead Juvenile Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 4, Below Normal Water Years

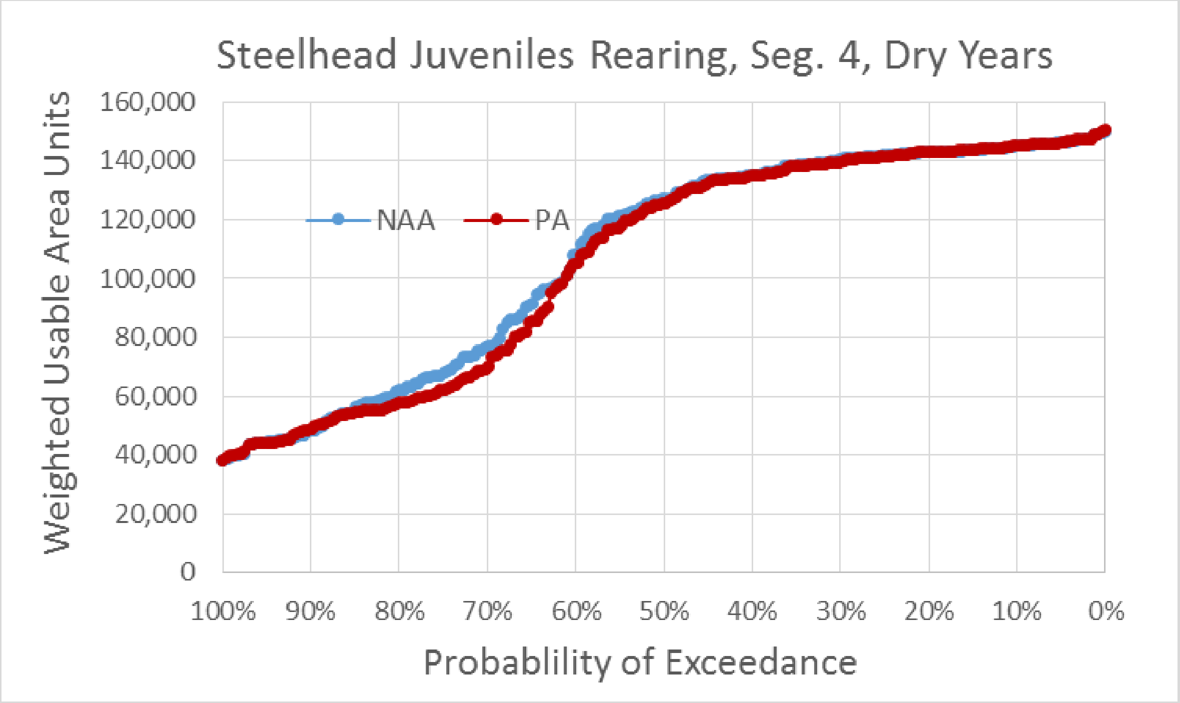

Figure 5.4-244. Exceedance Plot of CCV Steelhead Juvenile Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 4, Dry Water Years

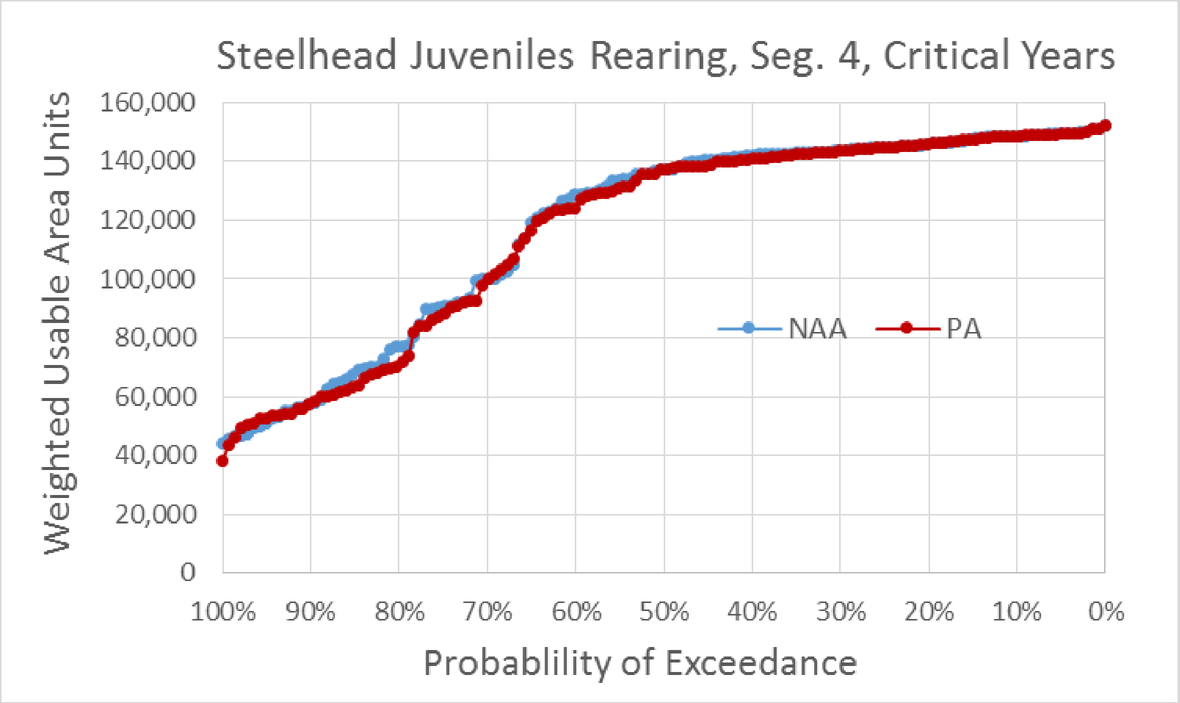

Figure 5.4-245. Exceedance Plot of CCV Steelhead Juvenile Rearing Weighted Usable Area (WUA) for NAA and PA Model Scenarios in River Segment 4, Critical Water Years

Differences in CCV steelhead fry and juvenile rearing WUA in each segment under the PAA and NAA were also examined using the grand mean rearing WUA for each month of the fry and juvenile rearing periods under each water year type and all water year types combined (Table 5.4-66 to Table 5.4-75). The means for fry rearing WUA differed by less than 5% for all months and water year types in Segments 5 and 4 (Table 5.4-71 and Table 5.4-72). In Segment 6, means differed by 5% or more only for February of below normal water years (6% increase) and May of dry years (5% reduction) (Table 5.4-70). The means for juvenile rearing WUA differed by less than 5% for most months and water year types in Segments 6 and 5 (Table 5.4-73 and Table 5.4-74), but differences were greater and more frequent in Segment 4 (Table 5.4-75). In Segment 6, the mean WUA for juvenile rearing under the PA was 5% lower than that under the NAA during June of dry years (Table 5.4-73), and in Segment 5 it was 6% lower during October of below normal years (Table 5.4-74). The mean juvenile rearing WUA was 6% higher under the PA than under the NAA in Segment 6 during August of below normal years and in Segment 5 during September of above normal years, and it was up to 15% and 17% greater in both segments during November of wet and above normal years, respectively (Table 5.4-73 and Table 5.4-74). In Segment 4, mean juvenile rearing habitat WUA under the PA was 8% lower in January of wet years, 6% lower in March of above normal years, 5% lower in May of dry years, 7% and 8% lower in June of dry and critical years, 6% lower in August of dry years, and 13% lower in October of below normal years (Table 5.4-75). Also in Segment 4, mean juvenile WUA under the PA was 10% higher than that under the NAA during August of below normal years, 17% and 6% higher in September of above normal and below normal years, 15% higher in October of wet years, and 44% and 57% higher in November of wet and above normal years. As indicated above for the WUA exceedance plot results, the WUA modeling indicates that the PA would reduce CCV steelhead rearing habitat in several months and water year types, especially for juveniles in Segment 4.

Table 5.4-70. CCV Steelhead Fry Rearing Weighted Usable Areas (WUA) and Differences (Percent Differences) between Model Scenarios in River Segment 6 (green indicates PA is at least 5% higher [raw difference] than NAA; red indicates PA is at least 5% lower)

Month	Water Year Type	NAA	PA	PA vs. NAA
February	Wet	69,319	69,315	-5 (-0.01%)
	Above Normal	73,692	72,500	-1,192 (-2%)
	Below Normal	61,965	65,693	3,728 (6%)
	Dry	61,294	61,669	375 (0.6%)
	Critical	62,526	62,940	414 (0.7%)
	All	66,074	66,536	462 (0.7%)
March	Wet	64,102	64,136	34 (0.1%)
	Above Normal	60,879	62,045	1,165 (2%)
	Below Normal	59,793	60,116	322 (0.5%)
	Dry	61,619	61,505	-114 (-0.2%)
	Critical	62,082	60,942	-1,140 (-2%)
	All	62,112	62,156	44 (0.1%)
April	Wet	91,860	91,331	-529 (-0.6%)
	Above Normal	98,286	98,308	22 (0.02%)
	Below Normal	101,393	102,071	678 (0.7%)
	Dry	110,620	107,689	-2,931 (-3%)

Month	Water Year Type	NAA	PA	PA vs. NAA
	Critical	98,133	95,152	-2,981 (-3%)
	All	99,651	98,427	-1,224 (-1%)
May	Wet	78,212	78,465	253 (0.3%)
	Above Normal	88,580	86,221	-2,359 (-3%)
	Below Normal	83,535	85,377	1,842 (2%)
	Dry	92,012	87,286	-4,726 (-5%)
	Critical	94,167	92,417	-1,750 (-2%)
	All	86,270	84,815	-1,455 (-2%)

Table 5.4-71. CCV Steelhead Fry Rearing Weighted Usable Areas (WUA) and Differences (Percent Differences) between Model Scenarios in River Segment 5 (green indicates PA is at least 5% higher [raw difference] than NAA; red indicates PA is at least 5% lower)

Month	Water Year Type	NAA	PA	PA vs. NAA
February	Wet	1,065,995	1,044,266	-21,729 (-2%)
	Above Normal	1,124,562	1,132,598	8,036 (0.7%)
	Below Normal	1,238,453	1,238,610	156 (0.01%)
	Dry	1,407,760	1,392,412	-15,347 (-1%)
	Critical	1,366,240	1,427,481	61,240 (4%)
	All	1,225,710	1,225,334	-376 (-0.03%)
March	Wet	1,046,678	1,046,819	141 (0.01%)
	Above Normal	1,149,168	1,110,060	-39,108 (-3%)
	Below Normal	1,358,136	1,303,846	-54,290 (-4%)
	Dry	1,371,907	1,371,289	-618 (-0.05%)
	Critical	1,429,713	1,405,462	-24,251 (-2%)
	All	1,240,086	1,222,948	-17,138 (-1%)
April	Wet	1,123,545	1,118,918	-4,627 (-0.4%)
	Above Normal	1,140,259	1,138,996	-1,263 (-0.1%)
	Below Normal	1,144,277	1,164,535	20,258 (2%)
	Dry	1,259,182	1,230,999	-28,183 (-2%)
	Critical	1,065,349	1,040,715	-24,634 (-2%)
	All	1,153,542	1,144,113	-9,429 (-0.8%)
May	Wet	906,548	908,702	2,154 (0.2%)
	Above Normal	958,558	948,654	-9,904 (-1%)
	Below Normal	941,548	951,632	10,083 (1%)
	Dry	1,039,173	1,005,901	-33,272 (-3%)
	Critical	1,027,540	1,009,911	-17,630 (-2%)
	All	969,542	959,313	-10,230 (-1%)

Table 5.4-72. CCV Steelhead Fry Rearing Weighted Usable Areas (WUA) and Differences (Percent Differences) between Model Scenarios in River Segment 4 (green indicates PA is at least 5% higher [raw difference] than NAA; red indicates PA is at least 5% lower)

Month	Water Year Type	NAA	PA	PA vs. NAA
February	Wet	156,731	155,422	-1,310 (-0.8%)
	Above Normal	156,421	157,078	657 (0.4%)
	Below Normal	179,947	180,611	663 (0.4%)
	Dry	197,086	196,371	-715 (-0.4%)
	Critical	210,670	219,778	9,108 (4%)
	All	177,532	178,469	936 (0.5%)
March	Wet	150,795	151,042	247 (0.2%)
	Above Normal	161,121	158,569	-2,552 (-2%)
	Below Normal	197,140	194,502	-2,638 (-1%)
	Dry	195,232	195,162	-70 (-0.04%)
	Critical	215,950	209,421	-6,530 (-3%)
	All	179,022	177,370	-1,653 (-0.9%)
April	Wet	163,985	163,897	-88 (-0.1%)
	Above Normal	172,564	172,563	-1 (-0.001%)
	Below Normal	180,540	181,257	717 (0.4%)
	Dry	189,289	187,614	-1,674 (-0.9%)
	Critical	184,159	183,685	-474 (-0.3%)
	All	176,690	176,280	-410 (-0.2%)
May	Wet	159,078	159,267	189 (0.1%)
	Above Normal	167,272	166,856	-417 (-0.2%)
	Below Normal	168,883	168,866	-18 (-0.01%)
	Dry	173,321	169,780	-3,541 (-2%)
	Critical	174,839	174,413	-426 (-0.2%)
	All	167,473	166,538	-935 (-0.6%)

Table 5.4-73. CCV Steelhead Juvenile Rearing Weighted Usable Areas (WUA) and Differences (Percent Differences) between Model Scenarios in River Segment 6 (green indicates PA is at least 5% higher [raw difference] than NAA; red indicates PA is at least 5% lower)

Month	Water Year Type	NAA	PA	PA vs. NAA
January	Wet	29,129	28,400	-729 (-3%)
	Above Normal	29,434	29,426	-8 (-0.03%)
	Below Normal	29,509	29,473	-36 (-0.1%)
	Dry	29,713	29,790	77 (0.3%)
	Critical	31,261	31,292	31 (0.1%)
	All	29,683	29,469	-214 (-0.7%)
February	Wet	29,438	29,351	-88 (-0.3%)
	Above Normal	28,607	28,520	-86 (-0.3%)
	Below Normal	29,040	28,867	-174 (-0.6%)
	Dry	31,689	31,676	-13 (-0.04%)
	Critical	31,838	32,374	536 (2%)
	All	30,153	30,164	11 (0.04%)
March	Wet	26,562	26,542	-20 (-0.1%)
	Above Normal	28,066	27,525	-541 (-2%)
	Below Normal	30,923	30,542	-381 (-1%)
	Dry	31,654	31,609	-46 (-0.1%)
	Critical	32,015	31,400	-615 (-2%)
	All	29,426	29,181	-244 (-0.8%)
April	Wet	38,038	38,143	106 (0.3%)
	Above Normal	40,355	40,351	-4 (-0.01%)
	Below Normal	41,781	41,831	51 (0.1%)
	Dry	41,581	41,620	39 (0.1%)
	Critical	41,408	41,830	422 (1%)
	All	40,265	40,376	111 (0.3%)
May	Wet	40,564	40,642	77 (0.2%)
	Above Normal	41,482	41,616	133 (0.3%)
	Below Normal	42,164	41,799	-365 (-0.9%)
	Dry	41,111	40,807	-304 (-0.7%)
	Critical	42,067	42,348	281 (0.7%)
	All	41,278	41,241	-36 (-0.1%)
June	Wet	38,289	37,899	-390 (-1%)
	Above Normal	35,211	33,831	-1,380 (-4%)
	Below Normal	35,207	35,327	120 (0.3%)
	Dry	36,548	34,685	-1,863 (-5%)
	Critical	38,428	37,290	-1,137 (-3%)
	All	36,983	36,036	-947 (-3%)
July	Wet	31,828	31,661	-167 (-0.5%)

Month	Water Year Type	NAA	PA	PA vs. NAA
	Above Normal	31,739	31,436	-303 (-1%)
	Below Normal	31,399	31,770	371 (1%)
	Dry	32,171	32,536	365 (1%)
	Critical	34,132	35,246	1,115 (3%)
	All	32,177	32,378	201 (0.6%)
August	Wet	37,184	36,932	-252 (-0.7%)
	Above Normal	36,724	36,975	252 (0.7%)
	Below Normal	36,295	38,389	2,094 (6%)
	Dry	39,998	39,116	-882 (-2%)
	Critical	40,084	39,070	-1,014 (-3%)
	All	38,102	37,980	-122 (-0.3%)
September	Wet	32,778	32,739	-39 (-0.1%)
	Above Normal	39,868	41,822	1,954 (5%)
	Below Normal	41,223	40,536	-687 (-2%)
	Dry	41,051	40,512	-539 (-1%)
	Critical	40,210	40,006	-204 (-0.5%)
	All	38,141	38,184	44 (0.1%)
October	Wet	41,526	41,903	377 (0.9%)
	Above Normal	42,223	41,934	-289 (-0.7%)
	Below Normal	41,700	42,635	936 (2%)
	Dry	41,478	42,091	613 (1%)
	Critical	40,175	39,012	-1,163 (-3%)
	All	41,441	41,625	184 (0.4%)
November	Wet	25,367	28,636	3,269 (13%)
	Above Normal	27,841	29,694	1,854 (7%)
	Below Normal	29,693	29,802	108 (0.4%)
	Dry	29,877	29,958	81 (0.3%)
	Critical	30,961	30,451	-510 (-2%)
	All	28,263	29,546	1,283 (5%)
December	Wet	28,705	29,188	483 (2%)
	Above Normal	29,674	29,032	-642 (-2%)
	Below Normal	29,987	29,928	-59 (-0.2%)
	Dry	30,308	30,029	-280 (-0.9%)
	Critical	32,077	32,168	91 (0.3%)
	All	29,918	29,914	-4 (-0.01%)

Table 5.4-74. CCV Steelhead Juvenile Rearing Weighted Usable Areas (WUA) and Differences (Percent Differences) between Model Scenarios in River Segment 5 (green indicates PA is at least 5% higher [raw difference] than NAA; red indicates PA is at least 5% lower)

Month	Water Year Type	NAA	PA	PA vs. NAA
January	Wet	397,419	381,586	-15,833 (-4%)
	Above Normal	408,747	408,732	-15 (-0.004%)
	Below Normal	405,140	404,956	-184 (-0.05%)
	Dry	407,975	406,745	-1,230 (-0.3%)
	Critical	454,578	447,163	-7,415 (-2%)
	All	411,190	404,758	-6,432 (-2%)
February	Wet	353,152	348,966	-4,186 (-1%)
	Above Normal	355,755	355,646	-109 (-0.03%)
	Below Normal	409,987	406,555	-3,432 (-0.8%)
	Dry	463,795	461,569	-2,226 (-0.5%)
	Critical	459,496	471,382	11,886 (3%)
	All	403,738	403,129	-608 (-0.2%)
March	Wet	342,746	342,757	10 (0.003%)
	Above Normal	387,907	376,683	-11,223 (-3%)
	Below Normal	450,055	441,394	-8,661 (-2%)
	Dry	457,711	457,191	-520 (-0.1%)
	Critical	468,699	462,847	-5,852 (-1.2%)
	All	410,773	406,852	-3,921 (-1%)
April	Wet	385,647	384,916	-731 (-0.2%)
	Above Normal	403,753	403,471	-282 (-0.1%)
	Below Normal	414,776	417,162	2,386 (0.6%)
	Dry	433,537	429,955	-3,582 (-0.8%)
	Critical	397,226	394,890	-2,336 (-0.6%)
	All	405,800	404,628	-1,172 (-0.3%)
May	Wet	360,972	361,641	669 (0.2%)
	Above Normal	378,137	377,364	-773 (-0.2%)
	Below Normal	378,041	379,629	1,589 (0.4%)
	Dry	389,954	379,530	-10,424 (-3%)
	Critical	394,079	391,549	-2,530 (-0.6%)
	All	377,897	375,287	-2,610 (-0.7%)
June	Wet	325,990	323,761	-2,229 (-0.7%)
	Above Normal	307,768	299,977	-7,791 (-3%)
	Below Normal	309,967	304,453	-5,514 (-2%)
	Dry	313,749	302,796	-10,953 (-3%)
	Critical	330,817	321,164	-9,653 (-3%)
	All	318,673	311,907	-6,766 (-2%)

Month	Water Year Type	NAA	PA	PA vs. NAA
July	Wet	284,079	283,073	-1,006 (-0.4%)
	Above Normal	274,903	275,756	853 (0.3%)
	Below Normal	277,076	277,024	-53 (-0.02%)
	Dry	288,136	288,370	234 (0.1%)
	Critical	302,335	307,296	4,961 (2%)
	All	285,346	285,938	592 (0.2%)
August	Wet	319,088	317,603	-1,486 (-0.5%)
	Above Normal	316,379	316,213	-166 (-0.1%)
	Below Normal	312,933	326,036	13,103 (4%)
	Dry	341,252	334,031	-7,221 (-2%)
	Critical	348,461	344,745	-3,716 (-1%)
	All	327,537	326,493	-1,045 (-0.3%)
September	Wet	290,880	292,099	1,219 (0.4%)
	Above Normal	342,762	361,634	18,872 (6%)
	Below Normal	426,776	443,066	16,290 (4%)
	Dry	440,826	448,417	7,591 (2%)
	Critical	439,491	442,949	3,458 (0.8%)
	All	375,655	383,577	7,921 (2%)
October	Wet	368,056	385,654	17,597 (5%)
	Above Normal	390,535	389,160	-1,375 (-0.4%)
	Below Normal	414,535	391,634	-22,902 (-6%)
	Dry	418,469	408,088	-10,381 (-2%)
	Critical	433,106	423,427	-9,678 (-2%)
	All	399,783	398,121	-1,662 (-0.4%)
November	Wet	331,245	380,767	49,522 (15%)
	Above Normal	346,354	404,807	58,454 (17%)
	Below Normal	424,548	433,126	8,578 (2%)
	Dry	436,339	438,833	2,494 (0.6%)
	Critical	456,650	446,478	-10,172 (-2%)
	All	390,682	415,511	24,830 (6%)
December	Wet	406,003	407,769	1,765 (0.4%)
	Above Normal	407,216	404,525	-2,691 (-0.7%)
	Below Normal	414,355	411,388	-2,967 (-0.7%)
	Dry	407,378	405,710	-1,669 (-0.4%)
	Critical	466,877	468,226	1,349 (0.3%)
	All	416,675	416,228	-447 (-0.1%)

Table 5.4-75. CCV Steelhead Juvenile Rearing Weighted Usable Areas (WUA) and Differences (Percent Differences) between Model Scenarios in River Segment 4 (green indicates PA is at least 5% higher [raw difference] than NAA; red indicates PA is at least 5% lower)

Month	Water Year Type	NAA	PA	PA vs. NAA
January	Wet	97,853	90,372	-7,480 (-8%)
	Above Normal	110,447	110,464	17 (0.02%)
	Below Normal	103,601	103,579	-22 (-0.02%)
	Dry	104,950	104,456	-494 (-0.5%)
	Critical	129,995	125,378	-4,616 (-4%)
	All	107,055	103,887	-3,168 (-3%)
February	Wet	69,936	68,146	-1,790 (-3%)
	Above Normal	77,689	77,735	46 (0.1%)
	Below Normal	106,251	105,096	-1,155 (-1%)
	Dry	136,350	135,011	-1,339 (-1%)
	Critical	139,995	146,033	6,038 (4%)
	All	102,488	102,329	-158 (-0.2%)
March	Wet	71,476	71,581	105 (0.1%)
	Above Normal	94,398	89,099	-5,299 (-6%)
	Below Normal	133,584	127,354	-6,229 (-5%)
	Dry	132,709	132,598	-111 (-0.1%)
	Critical	145,643	143,338	-2,305 (-2%)
	All	109,230	107,223	-2,007 (-2%)
April	Wet	94,253	93,866	-387 (-0.4%)
	Above Normal	105,842	105,770	-72 (-0.1%)
	Below Normal	115,424	117,414	1,990 (2%)
	Dry	128,546	125,460	-3,086 (-2%)
	Critical	113,038	111,395	-1,643 (-1%)
	All	110,044	109,183	-860 (-0.8%)
May	Wet	79,767	80,228	461 (0.6%)
	Above Normal	95,889	95,087	-802 (-0.8%)
	Below Normal	95,374	96,155	782 (0.8%)
	Dry	104,706	99,470	-5,236 (-5%)
	Critical	110,769	108,284	-2,485 (-2%)
	All	95,036	93,519	-1,517 (-2%)
June	Wet	63,094	62,254	-840 (-1%)
	Above Normal	56,914	54,112	-2,802 (-5%)
	Below Normal	58,642	56,280	-2,362 (-4%)
	Dry	59,726	55,659	-4,067 (-7%)
	Critical	70,307	64,770	-5,537 (-8%)
	All	61,751	58,921	-2,830 (-5%)

Month	Water Year Type	NAA	PA	PA vs. NAA
July	Wet	48,887	48,468	-419 (-0.9%)
	Above Normal	44,821	45,170	349 (0.8%)
	Below Normal	46,166	45,746	-421 (-0.9%)
	Dry	50,575	50,839	263 (0.5%)
	Critical	57,109	59,671	2,562 (4%)
	All	49,492	49,798	305 (0.6%)
August	Wet	63,617	62,843	-774 (-1%)
	Above Normal	62,801	61,796	-1,005 (-2%)
	Below Normal	61,174	67,131	5,957 (10%)
	Dry	77,174	72,790	-4,384 (-6%)
	Critical	80,766	79,494	-1,272 (-2%)
	All	68,976	68,115	-861 (-1%)
September	Wet	52,839	52,636	-202 (-0.4%)
	Above Normal	75,962	89,045	13,083 (17%)
	Below Normal	132,906	141,161	8,255 (6%)
	Dry	140,636	143,342	2,706 (2%)
	Critical	141,499	143,750	2,251 (2%)
	All	101,634	105,741	4,107 (4%)
October	Wet	89,341	103,106	13,764 (15%)
	Above Normal	106,157	104,776	-1,381 (-1%)
	Below Normal	123,137	107,044	-16,093 (-13%)
	Dry	125,338	120,272	-5,066 (-4%)
	Critical	138,530	137,326	-1,204 (-0.9%)
	All	112,597	113,196	599 (0.5%)
November	Wet	66,553	96,003	29,450 (44%)
	Above Normal	71,954	112,909	40,955 (57%)
	Below Normal	125,535	130,529	4,994 (4%)
	Dry	128,334	130,106	1,773 (1%)
	Critical	145,622	141,785	-3,837 (-3%)
	All	102,331	118,399	16,068 (16%)
December	Wet	110,968	110,752	-216 (-0.2%)
	Above Normal	107,891	108,500	609 (0.6%)
	Below Normal	110,687	110,366	-320 (-0.3%)
	Dry	108,714	107,759	-955 (-0.9%)
	Critical	142,796	143,253	457 (0.3%)
	All	114,633	114,442	-191 (-0.2%)

5.4.2.1.3.3.3.2 Water Temperature-Related Effects

Modeled mean monthly water temperatures during the year-round juvenile rearing period for steelhead in the Sacramento River between Keswick Dam and Red Bluff (Table 5.4-29) are presented in Appendix 5.C, *Upstream Water Temperature Methods and Results,* Section 5.C.7, *Upstream Water Temperature Modeling Results,* Table 5.C.7-3, Table 5.C.7-4, Table 5.C.7-5, Table 5.C.7-7, Table 5.C.7-8. Overall, the PA would change mean water temperatures very little (less than 1°F, or approximately 1%) throughout the juvenile rearing reach in all months and water year types. The largest increase in mean monthly water temperatures under the PA relative to NAA would be 0.6°F, or up to 1.1%, and would occur at Red Bluff in above normal years during August and above- and below normal years during September, and at Bend Bridge in below normal years during September.

Exceedance plots of monthly mean water temperatures were examined during each month throughout the juvenile rearing period (Appendix 5.C, *Upstream Water Temperature Methods and Results,* Section 5.C.7, *Upstream Water Temperature Modeling Results,* Figure 5.C.7.3-7, Figure 5.C.7.4-7, Figure 5.C.7.5-7, Figure 5.C.7.7-7, Figure 5.C.7.8-7). The values for the PA in these exceedance plots generally match those of the NAA. Further examination of August (Figure 5.4-59) and September (
Figure 5.4-60) during above normal years at Red Bluff, September of below normal years at Red Bluff (Figure 5.4-61), and September during below normal years at Bend Bridge (Figure 5.4-62), where the largest increases in mean monthly water temperatures were seen, reveals that there is a general trend towards marginally higher temperatures under the PA but that the difference of 0.6°F in mean monthly temperatures between NAA and PA, the largest throughout the juvenile rearing period, would cause little change to the curves.

Water temperature thresholds of 63°F and 69°F (7DADM) were used to evaluate water temperature threshold exceedances during the steelhead juvenile rearing life stage in the Sacramento River between Keswick Dam and Red Bluff (Appendix 5.D, Section 5.D.2.1, *Water Temperature Analysis Methods*, Table 5.D-49). The 63°F threshold was derived by taking the intermediate value of the ranges of optimal growth from several studies (Grabowski 1973; Wurtsbaugh and Davis 1977; Hokanson et al 1977; Myrick and Cech 2005; and Beakes et al. 2014). The 69°F 7DADM used was based on Sullivan (2000) and was converted to function with daily model outputs for each month separately (Appendix 5.D, Section 5.D.2.1, *Water Temperature Analysis Methods*, Table 5.D-51).

Results of the water temperature thresholds analysis are presented in Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Tables 5.D-113 through 5.D-122. At Keswick Dam, for both thresholds, there would be no months or water year types in which there would be both 5% more days under the PA compared to the NAA on which temperatures would exceed the threshold, and a more-than-0.5°F difference in the magnitude of average daily exceedance (Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-113, Table 5.D-114). There would be 1 month and water year type in which the percent of days exceeding the threshold would be 7.8% lower under the PA relative to the NAA, but the magnitude of average daily exceedance above the threshold would be 0.9°F higher under the PA.

At Clear Creek, for both thresholds, there would be no months or water year types in which there would be both 5% more days under the PA compared to the NAA on which temperatures would exceed the threshold, and a more-than-0.5°F difference in the magnitude of average daily exceedance (Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-115, Table 5.D-116). There would be one instance in which there would be both 5% more days under the PA compared to the NAA on which temperatures would exceed the 69°F threshold (September of critical water years, 5.3% increase), and two instances in which there would be a more-than-0.5°F increase in the magnitude of average daily exceedance above the 63°F threshold (September of critical years and all water year types combined, 0.6°F for both), but no instances would have both conditions met concurrently. Therefore, it is concluded that there would be no biologically meaningful effect at Clear Creek.

At Balls Ferry, for both thresholds, with one exception, there would be no months or water year types in which there would be both 5% more days under the PA compared to the NAA on which temperatures would exceed the threshold and a more-than-0.5°F difference in the magnitude of average daily exceedance (Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-117, Table 5.D-118). The one exception would occur under the 69°F 7DADM threshold in September of critical water years (6.7% increase). However, there would not be a concurrent more-than-0.5°F difference in the magnitude of average daily exceedance. Therefore, it was concluded that there would be no biologically meaningful effect.

At Bend Bridge, for both temperature thresholds, there would be no months or water year types in which there would be both 5% more days under the PA compared to the NAA on which temperatures would exceed the threshold and a more-than-0.5°F difference in the magnitude of average daily exceedance (Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-119, Table 5.D-120). There would be one instance for the 63°F threshold in which the percent of days exceeding the threshold would be lower under the PA relative to the NAA, September of critical water years (6.4% reduction), but there would be a 0.5°F increase in the magnitude of average daily exceedance.

At Red Bluff for both thresholds, with one exception, there would be no months or water year types in which there would be both 5% more days under the PA compared to the NAA on which temperatures would exceed the threshold and a more-than-0.5°F difference in the magnitude of average daily exceedance (Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-121, Table 5.D-122). The one exception would occur under the 69°F 7DADM threshold in September of critical water years (9.4% increase in frequency of exceedance). However, there would not be a concurrent more-than-0.5°F difference in the magnitude of average daily exceedance. Therefore, it was concluded that there would be no biologically meaningful effect.

An additional threshold analysis was conducted to determine how the PA would affect steelhead smoltification. A 54°F threshold was used and was based on an average of temperatures from Zaugg and Wagner (1973), Adams et al (1975), Zaugg (1981), and Hoar (1988), above which smoltification can be impaired. This analysis was conducted for January through March in the reach from Keswick Dam to Red Bluff.

Results of the water temperature thresholds analysis for steelhead smoltification are presented in Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-123 through Table 5.D-127. At all locations analyzed, Keswick Dam, Clear Creek, Balls Ferry, Bend Bridge, and Red Bluff, there would be no months or water year types with a more-than-5% increase in the percent of total days exceeding the threshold under the PA relative to the NAA or with a more-than-0.5°F difference in the magnitude of average daily exceedance. Therefore, it was concluded that there would be no biologically meaningful water temperature-related effects on CCV steelhead smoltification.

5.4.2.1.3.3.4 Smolt Emigration

This section refers specifically to emigrating smolts and does not include migrant parr. Effects to migrant parr would be similar to those presented in Section 5.4.2.1.3.3.3, *Juvenile Rearing*.

5.4.2.1.3.3.4.1 Flow-Related Effects

Mean monthly flows were evaluated in the Sacramento River at four locations along the downstream migration corridor of CCV steelhead smolts (i.e., Keswick, Red Bluff, Wilkins Slough and Verona) during the November through June emigration period, with peak migration during January through March (Table 5.4-29). Changes in flow potentially affect emigration of smolts, including the timing and rate of emigration, as well as conditions for feeding, protective cover, resting, temperature, turbidity, and other habitat factors. Crowding and stranding, especially in side-channel habitats, can also be affected (Moyle 2002; Quinn 2005; Williams 2006). As described in Appendix 5.D, Section 5.D.2.4, *Migration Flows Methods,* quantitative relationships between flow and downstream migration generally are highly variable and poorly understood, but on balance, except under very high flows, benefits of increased flow generally outweigh the costs. Therefore, it is assumed for the purposes of this effects analysis that increased flow would improve conditions for emigration of CCV steelhead smolts. Milner et al. (2012) and del Rosario et al. (2013) have found that migration cues for anadromous fish species are often the result of natural pulse flows, or pulse flows caused by natural events, such as an extensive rainfall event, which will not be affected by the PA.

Shasta Reservoir storage volume at the end of September may influence flows in the Sacramento River during much of the smolt emigration period, and Shasta storage volume at the end of May influences June flows. Mean Shasta September storage under the PA would be similar (less than 5% difference) to storage under NAA for all water year types, except for 7% higher mean storage during critical water years under the PA. Mean Shasta May storage under the PA would be similar (less than 5% difference) to storage under NAA for all water year types (Appendix 5.A, *CALSIM Methods and Results*, Table 5.A.6-3).

In general, mean flow under the PA would be similar to (less than 5% difference) or greater than flow under the NAA at the four Sacramento River locations during most months and water year types of the CCV steelhead smolt emigration period (Appendix 5.A, *CALSIM Methods and Results*, Table 5.A.6-10, Table 5.A.6-14, Table 5.A.6-35, Table 5.A.6-36). During November of wet and above normal water years, however, flow under the PA would be 26% lower than it would be under the NAA at Keswick Dam, 21% lower at Red Bluff, up to 24% lower at Wilkins Slough, and up to 17% lower at Verona. In November of critical water years, flow would be greater at all the locations (up to 13% greater in Keswick). Flow would also be lower in February of critical years (up to 13% lower at Keswick) at all the locations, except Verona. During

January, mean flow under the PA at Keswick would be 18% greater than it would be under the NAA in critical water year types and 8% greater in wet years. At Red Bluff, the mean January flow in critical years would be 7% greater under the PA; at the other two locations, all differences in January flow would be less than 5%. During February, in addition to the flow reductions described above, flow would be 8% greater in below normal years but only at Keswick. During March, flow under the PA at Keswick would be 9% greater in above normal and below normal years and 8% greater in critical years, but there would be no differences greater than 5% at the other locations. The flow differences during January through March occur during the peak smolt emigration period. During May, flow would be 5% to 8% greater in dry years, except at Verona. The greatest increases in flow would occur during June, when flow under the PA would be greater at all the locations, including all water year types at Verona and all water year types, except wet years, at the other locations. The increases for all water year types would be greater at Wilkins Sough and Verona (up to 25% greater in above normal years) than those at Keswick and Red Bluff.

The CALSIM modeling results given here indicate that the PA would reduce flow in some months and water year types, although this does not consider real-time operational management described in Section 3.1.5, *Real-Time Operations Upstream of the Delta*, and Section 3.3.3, *Real-Time Operational Decision-Making Process*, that would be used to avoid and minimize any modeled effects. Further discussion regarding flow-related effects during the June through November period are provided in Section 5.4.2.3, *Summary of Upstream Effects*.

5.4.2.1.3.3.4.2 Water Temperature-Related Effects

Modeled mean monthly water temperatures in the Sacramento River in the reach from Keswick Dam to Red Bluff during the November through June smolt emigration period, with a peak during January through March (Table 5.4-29) are presented in Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results*, Table 5.C.7-3, Table 5.C.7-4, Table 5.C.7-5, Table 5.C.7-7, Table 5.C.7-8. Overall, the PA would change mean water temperatures very little (less than 1°F, or approximately 1%) throughout the Sacramento River upstream of the Delta in all months and water year types in the period. The largest increase in mean monthly water temperatures under the PA relative to NAA would be 0.3°F (0.5 to 0.7%), and would occur at Keswick Dam, above Clear Creek, Balls Ferry, and Bend Bridge in below normal years during May, which is outside the peak period of smolt emigration. Despite this increase, temperatures would be in the low- to mid-50s range (°F) under both scenarios, which is well below temperatures of concern. Despite the uncertainty caused by comparing modeled results to threshold values, it is not likely that this difference would cause a biologically meaningful effect, especially considering the small magnitude (0.3°F).

Exceedance plots of monthly mean water temperatures were examined during each month throughout the smolt emigration period (Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results,* Figure 5.C.7.3-7, Figure 5.C.7.4-7, Figure 5.C.7.5-7, Figure 5.C.7.7-7, Figure 5.C.7.8-7). The values for the PA in these exceedance plots generally match those of the NAA. Further examination of below normal years during May at Keswick Dam (Figure 5.4-246), above Clear Creek (Figure 5.4-64), Balls Ferry (Figure 5.4-650), and Bend Bridge (Figure 5.4-247), where the largest increases in mean monthly water temperatures were seen, reveals that the curves were similar overall. The 0.3°F increase under the PA is the result of 1 year at Keswick Dam, above Clear Creek, and Balls

Ferry, and the result of 2 years at Bend Bridge. Further examination of these months and years reveals that this appears to be due to CALSIM II attempting to balance storage levels among the CVP reservoirs. There are no operational requirements, such as cold-water pool storage, temperature, or outflow requirements, that would cause these years to differ so widely in water temperatures. Therefore, there is no practical reason why real operations under the PA would be different from those under the NAA in these months and years.

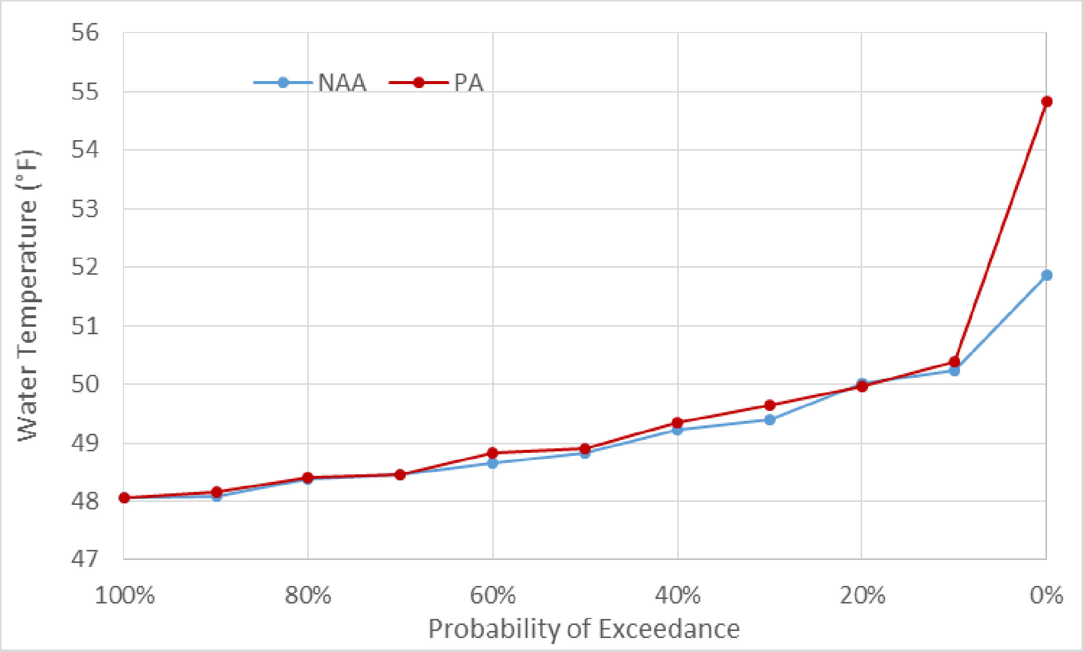

Figure 5.4-246. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the Sacramento River at Keswick Dam in May of Below Normal Water Years

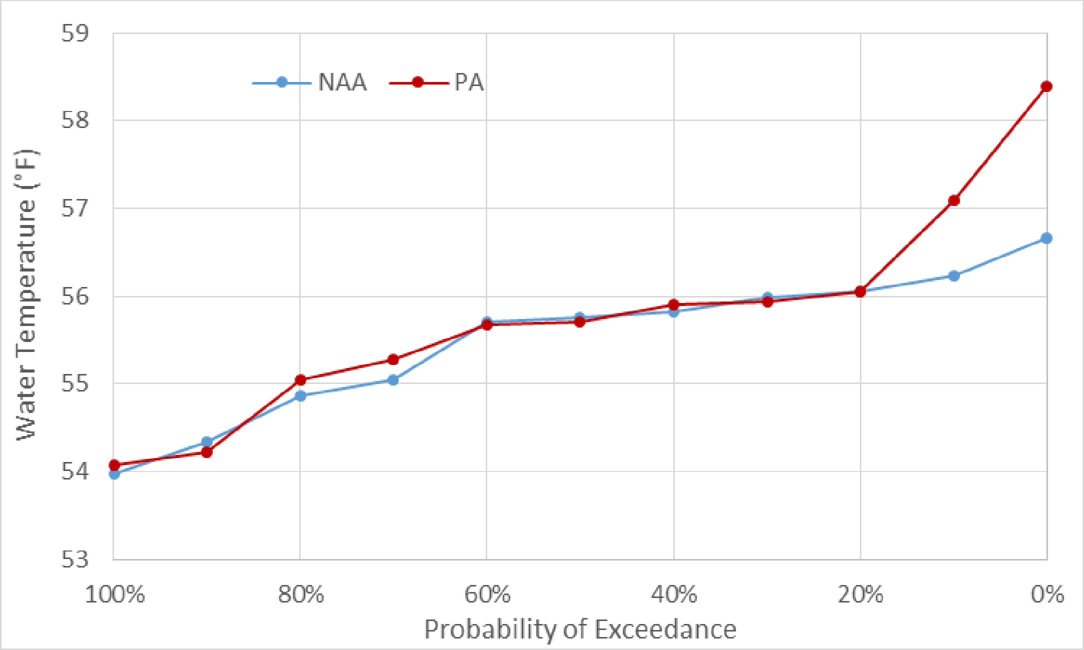

Figure 5.4-247. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the Sacramento River at Bend Bridge in May of Below Normal Water Years

The exceedance of temperature thresholds in the Sacramento River presented in Appendix 5.D, Section 5.D.2.1, *Water Temperature Analysis Methods*, Table 5.D-49 by modeled daily water temperatures were evaluated based on thresholds identified in the USEPA's temperature water quality guidance (U.S. Environmental Protection Agency 2003). Two thresholds, 61°F 7DADM and 64°F 7DADM, were evaluated. The 61°F value corresponds to the upper end of the optimal smolt emigration range and represents each site as a core habitat location, and the 64°F value corresponds to the upper end of the suboptimal range and represents each site as a non-core habitat location. The 7DADM values were converted by month to function with daily model outputs (Appendix 5.D, Section 5.D.2.1, *Water Temperature Analysis Methods*, Table 5.D-51). Both thresholds were evaluated from Keswick Dam to Red Bluff.

Results of the water temperature thresholds analysis are presented in Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Tables 5.D-128 through Table 5.D-137. At Keswick Dam, Clear Creek, Balls Ferry, Bend Bridge, and Red Bluff, there would be very few exceedances above either threshold. At all locations for both thresholds, there would be no months or water year types with both a more-than-5% increase in the percent of total days exceeding the threshold under the PA relative to the NAA and a more-than-0.5°F difference in the magnitude of average daily exceedance.

5.4.2.1.3.3.5 Adult Immigration

5.4.2.1.3.3.5.1 Flow-Related Effects

Mean monthly flows were evaluated in the Sacramento River at four locations along the upstream migration corridor of adult CCV steelhead (i.e., Keswick, Red Bluff, Wilkins Slough and Verona) during the August through March immigration period, with peak migration from

September through November (Table 5.4-29). Changes in flow potentially affect conditions for upstream migration of adults, including bioenergetic cost, water quality, crowding, cues for locating natal streams, and passage conditions, but the quantitative relationship between flow and upstream migration is poorly understood (Quinn 2005; Milner et al. 2012). As described in Appendix 5.D, Section 5.D.2.4, *Migration Flows Methods,* on balance, except under very high flows, the benefits of increased flow generally outweigh the costs and, therefore, it is assumed for the purposes of this effects analysis that increased flow would improve conditions for upstream migration of adult CCV steelhead. Milner et al. (2012) and del Rosario et al. (2013) have found that migration cues for anadromous fish species are often the result of natural pulse flows, or pulse flows caused by natural events, such as an extensive rainfall event, which will not be affected by the PA.

Shasta Reservoir storage volume at the end of September influences flows in the Sacramento River during much of the immigration period. Mean Shasta September storage under the PA would be similar (less than 5% difference) to storage under NAA for all water year types, except for 7% higher mean storage during critical water years under the PA (Appendix 5.A, *CALSIM Methods and Results,* Table 5.A.6-3).

In general, mean flow under the PA at the Keswick, Red Bluff, Wilkins Slough, and Verona locations in the Sacramento River would be similar to (less than 5% difference) or lower than flow under the NAA during the first 4 months of the CCV steelhead adult migration period and would be similar (less than 5% difference) or higher than under the NAA during the last 4 months, with some exceptions (Appendix 5.A, *CALSIM Methods and Results,* Table 5.A.6-10, Table 5.A.6-14, Table 5.A.6-35, Table 5.A.6-36). During August, mean flow in below normal years would be lower at all four locations (up to 18% lower flow at Wilkins Slough). During dry and critical years in August, flow under the PA would be greater (up to 10% greater) at Wilkins Slough and Verona. Mean flow during September would be lower for most water year types at all the locations (up to 24% lower in below normal years at Verona). During October, flow under the PA would lower at all the locations in wet years, ranging from 7% to 11% lower, but would be up to 17% higher in below normal and dry years. During November of wet and above normal water years, flow would be 26% lower under the PA than it would be under the NAA at Keswick Dam, 21% lower at Red Bluff, up to 24% lower at Wilkins Slough, and up to 17% lower at Verona, but in critical water years, flow would be greater at all the locations (up to 13% greater in Keswick). The large differences in flow from September through November coincide with the peak of the adult immigration period. During January, mean flow under the PA at Keswick would be 18% greater than it would be under the NAA in critical water year types and 8% greater in wet years. At Red Bluff, the mean January flow in critical years would be 7% greater under the PA, but at the other two locations, all differences in January flow would be less than 5%. During February, mean flow would be lower (up to 13% lower at Keswick) under the PA compared with the NAA at all the locations, except Verona. During March, flow under the PA at Keswick would be 9% greater in above normal and below normal years and 8% greater in critical years, but there would be no differences greater than 5% at the other locations.

The CALSIM modeling results given here indicate that the PA would reduce flow in some months and water year types, although this does not consider real-time operational management described in Section 3.1.5, *Real-Time Operations Upstream of the Delta,* and Section 3.3.3, *Real-Time Operational Decision-Making Process,* that would be used to avoid and minimize any modeled effects. Further discussion regarding flow-related effects during the June through November period are provided in Section 5.4.2.3, *Summary of Upstream Effects*.

As described in Appendix 5.D, Section 5.D.2.4, *Migration Flows Methods,* mean monthly flow below about 3,250 cfs is considered to have potentially adverse effects on Chinook salmon, CCV steelhead, and green sturgeon adult immigration conditions in the Sacramento River. The effect of the PA on the frequency of flows below this threshold was evaluated by comparing CALSIM flows between the PA and the NAA at three of the migration corridor locations in the river: Keswick, Red Bluff, and Wilkins Slough. Of the 656 months within the CCV steelhead migration period, mean flow at Keswick was less than 3,250 cfs for 6 months under the NAA and 5 months under the PA. Mean flow at Red Bluff was less than 3,250 cfs in 0 months under the NAA and 1 month under the PA, and mean flow at Wilkins Slough was less than 3,250 cfs in 2 months under both alternatives (Table 5.4-76). At all three locations, the months with flow less than 3,250 cfs were September, October or November of 1931, 1933, or 1934, except for November 1992 at Keswick Dam. All four of these years were critically dry. These results indicate that with respect to the frequency of flow below the 3,250 cfs threshold, differences between the PA and the NAA on adult CCV steelhead immigration conditions in the Sacramento River would be insignificant.

Table 5.4-76 Number and Percent of the 656 Months within the California Central Valley Steelhead Adult Immigration Period from the 82-year CALSIM Record with Flow < 3,250 cfs

	Months with Mean Flow < 3,250 cfs		**Percent with Mean Flow < 3,250 cfs**		**Difference in Months and Percent Difference**
Location	NAA	PA	NAA	PA	PA vs. NAA
Keswick	6	5	0.9	0.8	-1 (-17%)
Red Bluff	0	1	0.0	0.2	1 (NA1)
Wilkins Slough	2	2	0.3	0.3	0 (0%)

[1] NA = Could not calculate because dividing by 0

5.4.2.1.3.3.5.2 Water Temperature-Related Effects

Modeled mean monthly water temperatures in the Sacramento River at Keswick Dam, Bend Bridge, and Red Bluff during the August through March adult immigration period for steelhead (Table 5.4-29) are presented in Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results,* Table 5.C.7-3, Table 5.C.7-7, Table 5.C.7-8. Overall, mean water temperatures would change very little (predominantly less than 1°F, or approximately 1%) due to the PA at these locations in all months and water year types in the period. The largest increase in mean monthly water temperatures under the PA relative to NAA would be 0.6°F, or up to 1.1%, and would occur at Red Bluff in above normal years during August and above- and below normal years during September, and at Bend Bridge in below normal years during September. These largest increases during September would occur during the period of peak adult immigration (September through November).

Exceedance plots of monthly mean water temperatures were examined during each month throughout the adult immigration period (Appendix 5.C, *Upstream Water Temperature Methods*

and Results, Section 5.C.7, *Upstream Water Temperature Modeling Results,* Figure 5.C.7.3-7, Figure 5.C.7.7-7, Figure 5.C.7.8-7). The values for the PA in these exceedance plots generally match those of the NAA. Further examination of above normal water years during August at Red Bluff (Figure 5.4-59), above normal (
Figure 5.4-60) and below normal (Figure 5.4-61) water years during September at Red Bluff, and below normal water years during September at Bend Bridge (Figure 5.4-62), where the biggest water temperature increases of 0.6°F were seen, reveals that there is a general trend towards slightly higher temperatures under the PA but that the difference in mean monthly temperatures between NAA and PA has little effect on the values in the exceedance plots.

To evaluate water temperature threshold exceedance during the adult immigration life stage at Keswick Dam, Bend Bridge, and Red Bluff, the USEPA's 7DADM threshold value of 68°F (Appendix 5.D, Section 5.D.2.1, *Water Temperature Analysis Methods*, Table 5.D-49) was used. The threshold was converted to function with daily model outputs for each month separately (Appendix 5.D, Section 5.D.2.1, *Water Temperature Analysis Methods*, Table 5.D-51). In addition, the threshold of 70°F, the average of studies cited in Richter and Kolmes (2005) for the upper end of the suboptimal temperature range, was used.

Results of the water temperature thresholds analysis are presented in Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-138 through Table 5.D-143. At Keswick Dam and Red Bluff, for both thresholds there would be no months or water year types with either a more-than-5% increase in the percent of total days exceeding the threshold under the PA relative to the NAA or a more-than-0.5°F difference in the magnitude of average daily exceedance.

At Bend Bridge, the percent of days exceeding the 68°F 7DADM threshold under the PA would be more than 5% higher than under the NAA during August (5.1%) and September (5.3%) of critical water years (Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-140 and Table 5.D-141). However, in no month or water year type would there be a more-than-0.5°F difference between NAA and PA in the magnitude of average daily exceedance above the threshold. Also, there would be no months or water year types with either a more-than-5% increase in the percent of total days exceeding the 70°F threshold under the PA relative to the NAA or a more-than-0.5°F difference in the magnitude of average daily exceedance. Therefore, it was concluded that there would be no biologically meaningful effect at Bend Bridge.

Overall, the thresholds analysis indicates that there would be more exceedances (5% or greater) in certain months and water year types under the PA, which could have lethal or sublethal effects on immigrating adults, although this does not consider real-time operational management described in Section 3.1.5, *Real-Time Operations Upstream of the Delta*, and Section 3.3.3, *Real-Time Operational Decision-Making Process*, that would be used to avoid and minimize any modeled effects. The biological interpretation of these results, combined with all upstream results, in the context of real-time operational management is provided in Section 5.4.2.3, *Summary of Upstream Effects*, below.

5.4.2.1.3.3.6 Adult Holding

5.4.2.1.3.3.6.1 Flow-Related Effects

Mean monthly flow rates and reservoir storage volumes were examined for the PA and NAA in the Sacramento River at the Keswick Dam and Red Bluff locations during the September through November holding period for Central Valley steelhead (Table 5.4-29). Changes in flow likely affect holding habitat for steelhead, with higher flows potentially providing greater depths and improved water quality in pools. Shasta Reservoir storage volume at the end of September influences flow rates below the dam during much of the steelhead holding period. Mean Shasta September storage under the PA would be similar (less than 5% difference) to storage under NAA for all water year types, except for 7% higher mean storage during critical water years under the PA (Appendix 5.A, *CALSIM Methods and Results*, Table 5.A.6-3). The mean flows at the Keswick Dam and Red Bluff locations in the Sacramento River during September would range from 5% to 11% lower under the PA than the NAA for all water year types except wet years. During October, mean flow under the PA would be up to 11% lower in wet years and up to 17% higher in below normal and dry years. And during November, mean flow under the PA would be lower than flow under the NAA in all except critical water year types, with 26% lower flows under the PA than under the NAA for wet and above normal water year types at Keswick Dam and 21% lower flows at Red Bluff (Appendix 5.A, *CALSIM Methods and Results*, Table 5.A.6-10, Table 5.A.6-35). Flow would be 13% higher at Keswick Dam and 9% higher at Red Bluff during November of critical water years. The CALSIM modeling results given here indicate that the PA would reduce flow in some months and water year types, although this does not consider real-time operational management described in Section 3.1.5, *Real-Time Operations Upstream of the Delta*, and Section 3.3.3, *Real-Time Operational Decision-Making Process,* that would be used to avoid and minimize any modeled effects. Further discussion regarding flow-related effects during the June through November period are provided in Section 5.4.2.3, *Summary of Upstream Effects*..

5.4.2.1.3.3.6.2 Water Temperature-Related Effects

Modeled mean monthly water temperatures in the Sacramento River at Keswick Dam, Balls Ferry, and Red Bluff during the September through November CCV steelhead adult holding period (Table 5.4-29) are presented in Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results,* Table 5.C.7-3, Table 5.C.7-5, Table 5.C.7-8. Overall, the PA would change mean water temperatures very little (less than 1°F, or approximately 1%) at these locations in all months and water year types in the period. The largest increase in mean monthly water temperatures under the PA relative to NAA would be 0.6°F, or up to 1.1%, and would occur at Red Bluff in above- and below normal years during September.

Exceedance plots of monthly mean water temperatures were examined during each month throughout the adult holding period (Appendix 5.C, *Upstream Water Temperature Methods and Results,* Section 5.C.7, *Upstream Water Temperature Modeling Results,* Figure 5.C.7.3-7, Figure 5.C.7.5-7, Figure 5.C.7.8-7). The curves for PA generally match those of the NAA. Further examination of above normal (Figure 5.4-60) and below normal (Figure 5.4-61) years during September at Red Bluff, the month and water year types with the largest changes in water temperatures (0.6°F), reveals that there is a general trend towards marginally higher temperatures under the PA but that the difference of 0.6°F in mean monthly temperatures between NAA and PA would cause no substantial differences between curves for the NAA and PA in each exceedance plot.

To evaluate water temperature threshold exceedance during the steelhead adult holding life stage at Keswick Dam, Balls Ferry, and Red Bluff, the USEPA's 7DADM threshold value of 61°F was used Appendix 5.D, Section 5.D.2.1, *Water Temperature Analysis Methods*, Table 5.D-49) (U.S. Environmental Protection Agency 2003). The threshold was converted to function with daily model outputs for each month separately (Appendix 5.D, Section 5.D.2.1, *Water Temperature Analysis Methods*, Table 5.D-51).

Results of the water temperature thresholds analysis are presented in Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Tables 5.D-144 through 5.D-146. At Keswick Dam, there would be no months or water year types with both a more-than-5% increase in the percent of total days exceeding the threshold under the PA relative to the NAA and a more-than-0.5°F difference in the magnitude of average daily exceedance (Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-144).

At Balls Ferry, there would be no months or water year types with a more-than-5% increase in the percent of total days exceeding either threshold under the PA relative to the NAA (Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-145). However, there would be two more-than-5% reductions under the PA relative to the NAA in the percent of total days exceeding the 61°F 7DADM threshold: September (10% lower) and October (14% lower) of critical water years. During October of critical years, the difference in average daily exceedance above the threshold between the PA and NAA would be less than 0.5°F. In September, the average daily exceedance above the threshold under the PA would be 0.7°F higher than that under the NAA, indicating that the frequency of days above the threshold would decrease under the PA, but exceedances would be higher on average.

At Red Bluff for both thresholds, there would be no months or water year types with both a more-than-5% increase in the percent of total days exceeding the threshold under the PA relative to the NAA and a more-than-0.5°F difference in the magnitude of average daily exceedance (Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-146). There would be some instances when there would be a more-than-5% increase in the percent of total days exceeding the 61°F 7DADM threshold under the PA relative to the NAA, including August of below normal water years (9.4% increase) and September of above normal (7.7% increase), below normal (10.3% increase), and dry (5.5% increase) water years, but under the PA, none of these would see a concurrent increase of at least 0.5°F in the magnitude of average daily exceedance above the threshold.

Overall, the thresholds analysis indicates that there would be more exceedances (5% or greater) in certain months and water year types under the PA, which could have lethal or sublethal effects on holding adults, although this does not consider real-time operational management described in Section 3.1.5, *Real-Time Operations Upstream of the Delta*, and Section 3.3.3, *Real-Time Operational Decision-Making Process*, that would be used to avoid and minimize any modeled effects. Further, this does not consider the current revision process to OCAP RPA Action Suite 1.2 described in Section 3.1.4.5, *Annual/Seasonal Temperature Management Upstream of the*

Delta, to improve winter-run Chinook salmon egg-to-fry survival. This process may result in refinements and additions to the existing annual/seasonal temperature management processes, including spring storage targets, revised temperature compliance criteria and a range in summertime Keswick release rates. Although the process targets winter-run Chinook salmon, some benefits to steelhead holding may arise. The biological interpretation of these results, combined with all upstream results, in the context of real-time operational management is provided in Section 5.4.2.3, *Summary of Upstream Effects*, below.

5.4.2.1.3.4 Green Sturgeon

5.4.2.1.3.4.1 Spawning and Egg Incubation

5.4.2.1.3.4.1.1 Flow-Related Effects

Mean monthly flow rates and reservoir storage volumes were examined for the PA and NAA in the Sacramento River at Red Bluff (Appendix 5.A, *CALSIM Methods and Results*) during the March through July spawning and incubation period, with peak occurrence during April to June, for green sturgeon (Table 5.4-30). Changes in flow can affect the instream area available for spawning and egg incubation, the quality of the spawning and egg incubation habitat, and the downstream dispersal of larvae to rearing habitat in the bay and Delta. There is some evidence that green sturgeon year class strength is positively correlated with Delta outflow, perhaps as a result in part of improved downstream dispersal. This potential effect is evaluated as part of Delta outflow in Section 5.4.1.3.2.2.2.1, *Delta Outflow*. Shasta Reservoir storage volume at the end of May influences flow rates in the Sacramento River during much of the green sturgeon spawning and egg incubation period. Mean Shasta May storage under the PA would be similar (less than 5% difference) to storage under NAA for all water year types (Appendix 5.A, *CALSIM Methods and Results*, Table 5.A.6-3). During the majority of months and water year types of the green sturgeon spawning period, the PA would result in minor (less than 5% difference) changes in mean flow in the Sacramento River at Red Bluff (Appendix 5.A, *CALSIM Methods and Results*, Table 5.A.6-35). However, flows under the PA would be 5% to 7% higher during May of dry years and June of all water year types except wet years. The CALSIM modeling results given here indicate that the PA would reduce flow in some months and water year types, although this does not consider real-time operational management described in Section 3.1.5, *Real-Time Operations Upstream of the Delta*, and Section 3.3.3, *Real-Time Operational Decision-Making Process*, that would be used to avoid and minimize any modeled effects. Further discussion regarding flow-related effects during the June through November period are provided in Section 5.4.2.3, *Summary of Upstream Effects*.

5.4.2.1.3.4.1.2 Water Temperature-Related Effects

Modeled mean monthly water temperatures during the March through July spawning and embryo incubation period for green sturgeon in the Sacramento River at Bend Bridge, Red Bluff, and Hamilton City (Table 5.4-30) are presented in Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results*, Table 5.C.7-7, Table 5.C.7-8, Table 5.C.7-9. Overall, the PA would change mean water temperatures very little (predominantly less than 1°F, or approximately 1%) throughout the reach in all months of the period and water year types. The largest increase in mean monthly water temperatures under the PA relative to NAA would be 0.3°F (0.5%) at Bend Bridge in below normal water years during May and at Hamilton City in critical years during July. The largest change in May would coincide with peak spawning and egg incubation.

Exceedance plots of monthly mean water temperatures were examined during each month throughout the spawning and incubation period (Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results*, Figure 5.C.7.7-7, Figure 5.C.7.8-7, Figure 5.C.7.9-7). The values for the PA in these exceedance plots generally match those of the NAA for all locations, months, and water year types. Further examination of water temperature patterns in below normal water years during May at Bend Bridge (Figure 5.4-247), where the largest increases in mean monthly water temperatures were seen, reveals that this appears to be due to CALSIM II attempting to balance storage levels among the CVP reservoirs and there are no operational requirements, such as cold water pool storage, temperature, or outflow requirements, that would cause these years to differ so widely in water temperatures. Therefore, there is no practical reason why real operations under the PA would be different from those under the NAA in these months and years. Further examination of critical years during July at Hamilton City (Figure 5.4-248), also where the largest increases in mean monthly water temperatures were seen, reveals that the curves were similar overall and that the difference of 0.3°F in mean monthly temperatures between NAA and PA would cause no substantial differences between curves for the NAA and PA in each exceedance plot. Regardless, green sturgeon are not likely to spawn this far downstream in critical water years in July.

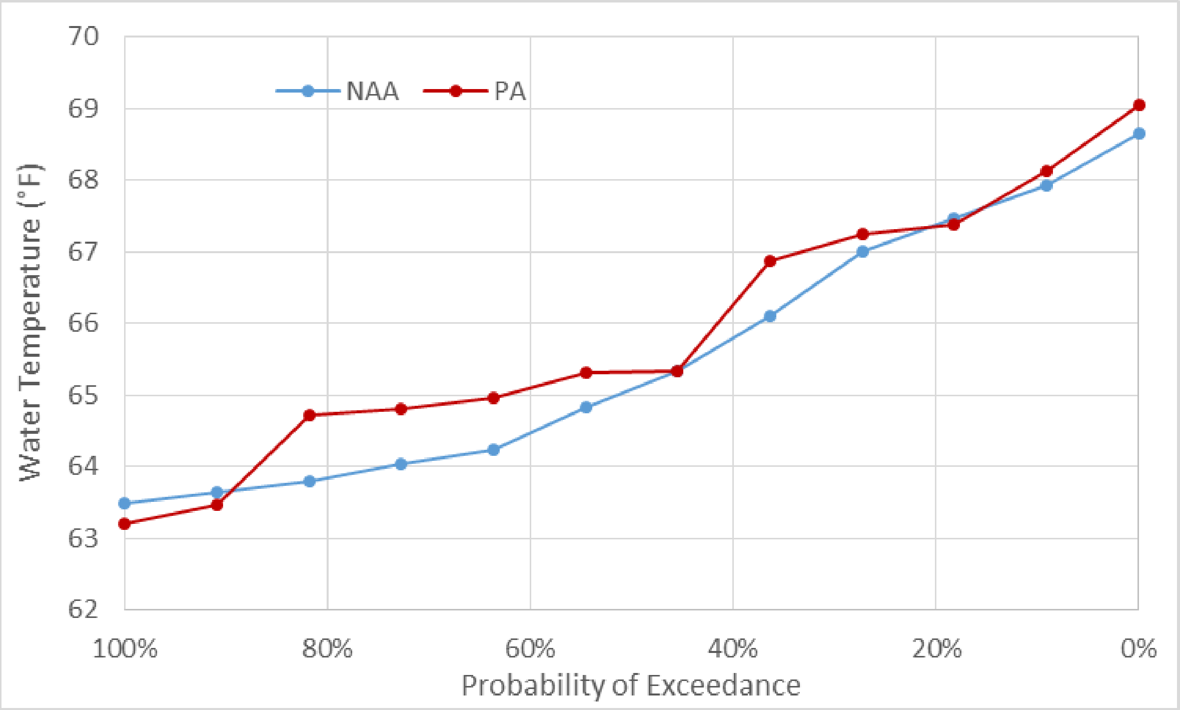

Figure 5.4-248. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the Sacramento River at Hamilton City in July of Critical Water Years

To evaluate water temperature threshold exceedance during the spawning and embryo incubation life stage at Bend Bridge, Red Bluff, and Hamilton City, the threshold value of 63°F for the upper end of the optimal range for embryonic development from Van Eenennaam et al. (2005) was used (Appendix 5.D, Section 5.D.2.1, *Water Temperature Analysis Methods*, Table 5.D-49).

Results of the water temperature thresholds analysis are presented in Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Tables 5.D-147 through 5.D-149. At Bend Bridge and Red Bluff, there would be no months or water year types in which there would be either more than 5% more days under the PA compared to the NAA on which temperatures would exceed the threshold or a more-than-0.5°F difference in the magnitude of average daily exceedance (Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-147, Table 5.D-148).

At Hamilton City, there would be one instance with more than 5% more days under the PA compared to the NAA on which temperatures would exceed the threshold: July of dry water years (5.3% higher) (Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-149). There would be several instances in which the percent of days would decrease by more than 5% under the PA relative to the NAA: June of above normal (6.7% reduction), below normal (7.0% reduction), and dry (10.3% reduction) water years, and for all water year types in June combined (5.8% reduction). However, in no case would there be a more-than-0.5°F difference in the magnitude of average daily exceedance. Therefore, it was concluded that there would be no biologically meaningful effect at Hamilton City between the NAA and PA.

Overall, the thresholds analysis indicates that there would be more exceedances (5% or greater) in certain months and water year types under the PA, which could have lethal or sublethal effects on green sturgeon spawning and egg incubation, although this does not consider real-time operational management described in Section 3.1.5, *Real-Time Operations Upstream of the Delta*, and Section 3.3.3, *Real-Time Operational Decision-Making Process*, that would be used to avoid and minimize any modeled effects. This also does not consider the current revision process to OCAP RPA Action Suite 1.2 described in Section 3.1.4.5, *Annual/Seasonal Temperature Management Upstream of the Delta*, to improve winter-run Chinook salmon egg-to-fry survival. This process may result in refinements and additions to the existing annual/seasonal temperature management processes, including spring storage targets, revised temperature compliance criteria and a range in summertime Keswick release rates. Although the process targets improving winter-run Chinook salmon egg to fry survival, there may be benefits gained by green sturgeon as a result of some of these refinements. The biological interpretation of these results, combined with all upstream results, in the context of real-time operational management and RPA revisions is provided in Section 5.4.2.3, *Summary of Upstream Effects*, below.

5.4.2.1.3.4.2 Pre- and Post-Spawn Adult Holding

Because adult green sturgeon hold near spawning areas both before and after spawning events, this section analyzes the pre-spawn and post-spawn adult holding periods combined.

5.4.2.1.3.4.2.1 Flow-Related Effects

Mean monthly flow rates and reservoir storage were evaluated during the March through December pre- and post-spawning adult holding period for green sturgeon in the Sacramento River at Red Bluff (Table 5.4-30). Changes in flow likely affect holding habitat for green sturgeon, with higher flows potentially providing greater depths and improved water quality in pools. Shasta Reservoir storage volumes at the end of May and end of September influence flow rates in the Sacramento River during much of the green sturgeon pre- and post-spawning holding period. Mean Shasta May storage under the PA would be similar (less than 5% difference) to storage under the NAA for all water year types (Appendix 5.A, *CALSIM Methods and Results*, Table 5.A.6-3), while mean Shasta September storage under the PA would be similar for all water year types except for 7% higher mean storage during critical water years. During the first several months of the green sturgeon holding period, changes in mean flow in the Sacramento River at Red Bluff due to the PA would be minor (less than 5% difference) or somewhat positive (less than 10% increase) (Appendix 5.A, *CALSIM Methods and Results*, Table 5.A.6-35). Flows under the PA would be 5% to 7% higher during May of dry years and June of all water year types except wet years. Greater changes in mean flow due to the PA would occur during August through November, including 9% to 10% reductions in flow during August of below normal years, September of above normal and below normal years, and October of wet years. During November, mean flows would be 21% lower under the PA for wet and above normal years. Increases in mean flow of 6% to 14% are expected during October of below normal and dry years and during November of critical years. Reductions in flow during the holding period would be somewhat greater than increases in flow, but they would occur during wetter year types when they would have less impact. The CALSIM modeling results given here indicate that the PA would reduce flow in some months and water year types, although this does not consider real-time operational management described in Section 3.1.5, *Real-Time Operations Upstream of the Delta*, and Section 3.3.3, *Real-Time Operational Decision-Making Process*, that would be used to avoid and minimize any modeled effects. Further discussion regarding flow-related effects during the June through November period are provided in Section 5.4.2.3, *Summary of Upstream Effects*.

5.4.2.1.3.4.2.2 Water Temperature-Related Effects

Modeled mean monthly water temperatures during the March through December pre- and post-spawning adult holding period for green sturgeon in the Sacramento River at Bend Bridge, Red Bluff, and Hamilton City (Table 5.4-30) are presented in Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results*, Table 5.C.7-7, Table 5.C.7-8, Table 5.C.7-9. Overall, the PA would change mean water temperatures very little (predominantly less than 1°F, or approximately 1%) throughout the spawning reach of Keswick Dam to Red Bluff in all months of the period and water year types. The largest increase in mean monthly water temperatures under the PA relative to NAA would be 0.8°F (1.2% to 1.3%) and would occur at Hamilton City in below normal years during August and above normal and below normal years during September.

Exceedance plots of monthly mean water temperatures were examined during each month throughout the spawning and incubation period (Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results*, Figure 5.C.7.7-7, Figure 5.C.7.8-7, Figure 5.C.7.9-7). The values for the PA in these exceedance plots generally match those of the NAA. Further examination of below normal years during August (Figure 5.4-249) and above normal (Figure 5.4-250) and below normal (Figure 5.4-251) years during September at Hamilton City, where the largest increases in mean monthly water temperatures were seen, reveals that the curves were similar overall, although there were multiple differences of more than 1°F at the colder end of the range in below normal years during both August and September.

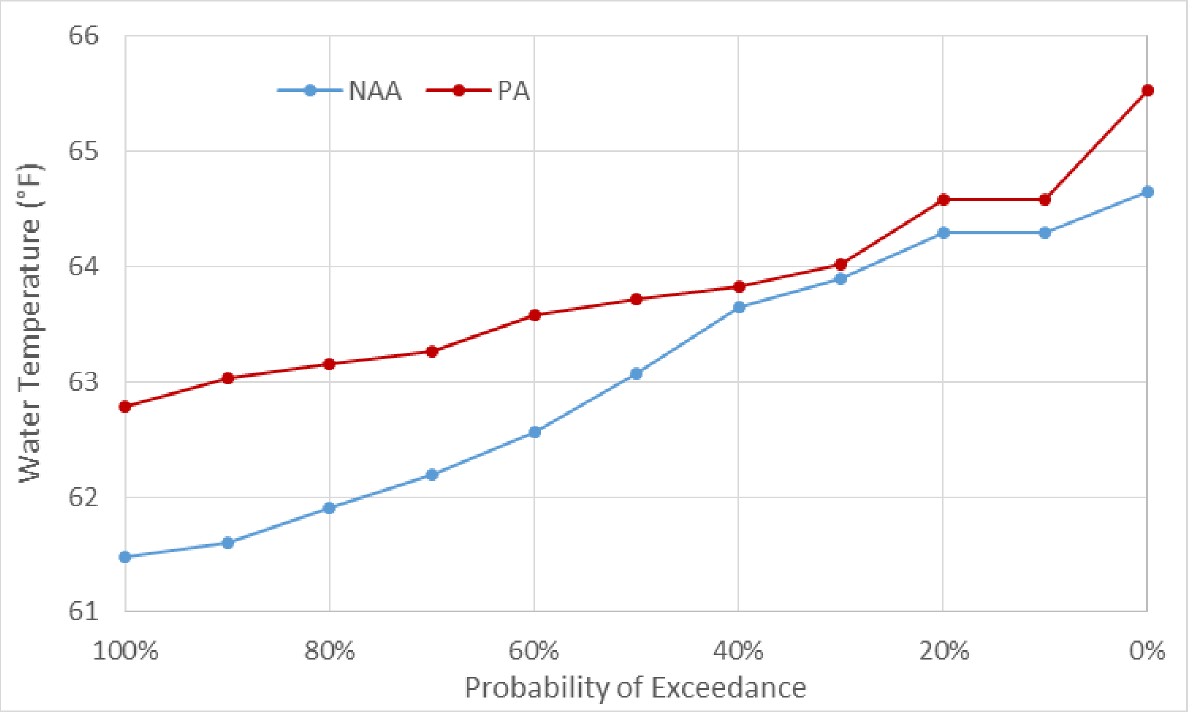

Figure 5.4-249. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the Sacramento River at Hamilton City in August of Below Normal Water Years

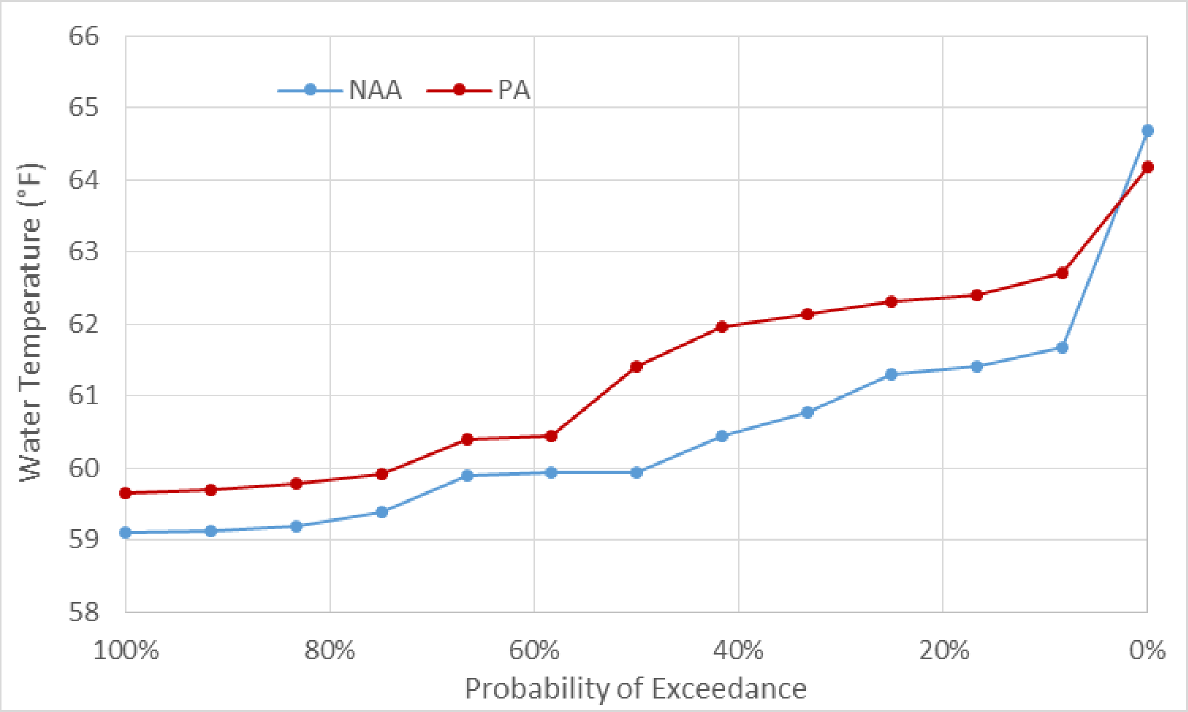

Figure 5.4-250. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the Sacramento River at Hamilton City in September of Above Normal Water Years

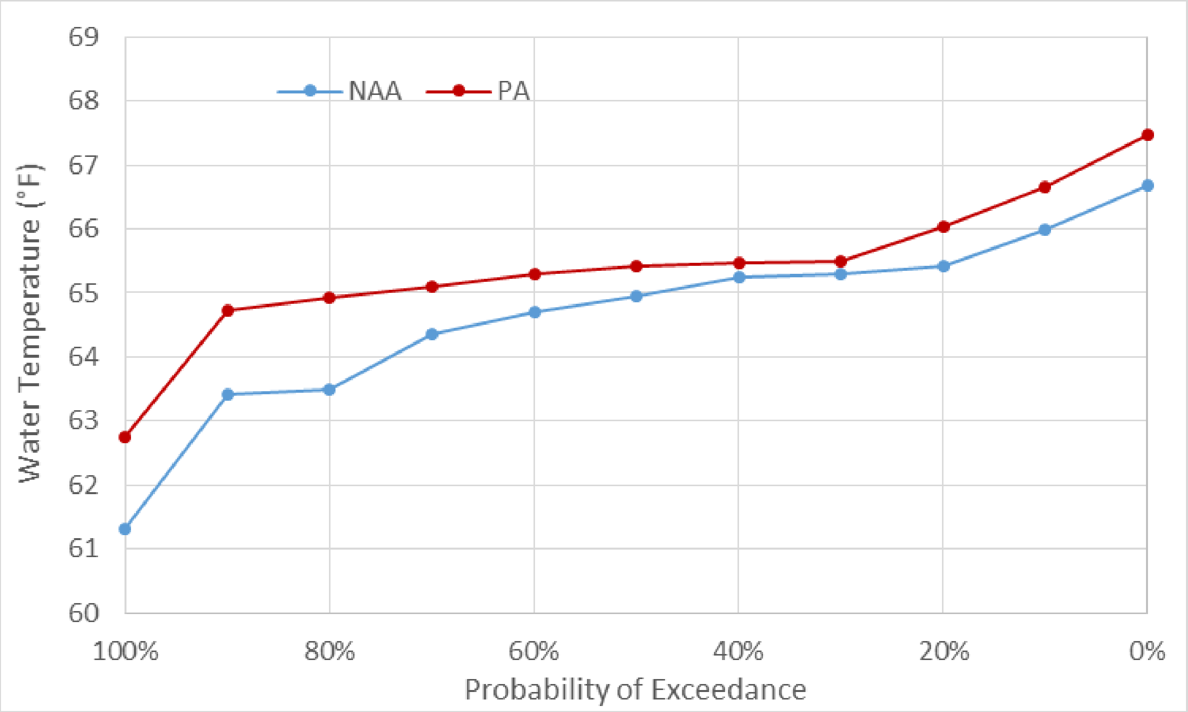

Figure 5.4-251. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the Sacramento River at Hamilton City in September of Below Normal Water Years

All non-spawning adult life stages, including pre-spawn and post-spawn holding and immigration and post-spawn emigration, were combined for the water temperature threshold analysis. Adult green sturgeon are present year-round at Bend Bridge, Red Bluff, and Hamilton City, although spawning adults are also present during March through July. A more conservative threshold evaluation specific to the spawning and egg incubation period is described above in Section 5.4.2.1.3.4.1, *Spawning and Egg Incubation*. The period of August through February, when green sturgeon are present but typically do not spawn, was evaluated here. Non-spawning green sturgeon adults are present year-round at Knights Landing. Therefore, all months were included in the threshold evaluation at this location.

For each location (Bend Bridge, Red Bluff, and Hamilton City, and Knights Landing), the exceedance of water temperature thresholds of 66°F and 73°F were used to evaluate potential effects of the PA (Appendix 5.D, Section 5.D.2.1, *Water Temperature Analysis Methods*, Table 5.D-49). The 66°F threshold was based on the conservative assumption that optimal temperatures for larvae and juveniles (from Mayfield and Cech 2004) would be sufficient for non-spawning adults. The 73°F threshold was based on Houston (1988) and Erickson et al. (2002).

Results of the water temperature thresholds analysis are presented in Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-150 through Table 5.D-157. At Bend Bridge and Red Bluff, for both thresholds, there would be no months or water year types in which there would be either more than 5% more days under the PA compared to the NAA on which temperatures would exceed the threshold or a more-than-0.5°F difference in the magnitude of average daily exceedance (Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-150 through Table 5.D-153).

At Hamilton City, for the 66°F threshold, there would be one instance in which temperatures would exceed the threshold on more than 5% more days under the PA compared to the NAA: September of below normal water years (14.2% higher) (Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-154). However, there would be no concurrent increase under the PA relative to the NAA of more than 0.5°F in the magnitude of average daily exceedance. There would also be two instances in which there would be a reduction under the PA in the percent of days exceeding the 66°F threshold: August of dry and critical water years (9.2% and 9.1% reductions, respectively). In dry years, there would be no difference between the PA and NAA in the magnitude of average daily exceedance above the threshold. In critical water years, there would be a 0.5°F increase in the magnitude of average daily exceedance above the threshold. This indicates that the frequency of days above the threshold would decrease under the PA, but exceedances would be higher on average. For the 73°F threshold, there would be no months or water year types in which there would be either more than 5% more days under the PA compared to the NAA on which temperatures would exceed the threshold or a more-than-0.5°F difference in the magnitude of average daily exceedance (Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-155).

At Knights Landing, for the 66°F threshold, there would be two instances in which temperatures would exceed the threshold on more than 5% more days under the PA compared to the NAA: September (18.7% higher) and October (5.6% higher) of above normal water years (Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-156). In September, there would be no difference of more than 5% in the magnitude of average daily exceedance above the threshold between the NAA and PA. However, for October, there would be a reduction of 1.1°F in the magnitude of average daily exceedance above the threshold. This indicates that, for October of above normal water years, the frequency of days above the threshold would increase under the PA, but exceedances would be lower on average. For the 73°F threshold, there would be more than 5% more days under the PA relative the NAA on which water temperature would exceed the threshold in July of critical water years (10.2% increase) and in August (11.4% higher) and September (5.2% higher) of below normal water years (Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-157). However, in no case would there be a more-than-0.5°F difference in the magnitude of average daily exceedance between the NAA and PA.

Overall, the thresholds analysis indicates that there would be more exceedances (5% or greater) in certain months and water year types under the PA, which could cause lethal or sublethal effects to greens sturgeon pre- and post-spawners, although this does not consider real-time operational management described in Section 3.1.5, *Real-Time Operations Upstream of the Delta*, and Section 3.3.3, *Real-Time Operational Decision-Making Process*, that would be used to avoid and minimize any modeled effects. Further, this does not consider the current revision process to OCAP RPA Action Suite 1.2 described in Section 3.1.4.5, *Annual/Seasonal Temperature Management Upstream of the Delta*, to improve winter-run Chinook salmon egg-to-fry survival. This process may result in refinements and additions to the existing annual/seasonal temperature management processes, including spring storage targets, revised temperature compliance criteria and a range in summertime Keswick release rates. Although the process targets improving winter-run Chinook salmon egg to fry survival, there may be benefits gained by green sturgeon as a result of some of these refinements. The biological interpretation of these results, combined with all upstream results, in the context of real-time operational management and RPA revisions is provided in Section 5.4.2.3, *Summary of Upstream Effects*, below.

5.4.2.1.3.4.3 Post-Spawn Adult Emigration

5.4.2.1.3.4.3.1 Flow-Related Effects

Mean monthly flows were evaluated in the Sacramento River during the April through January green sturgeon post-spawn adult emigration period at Red Bluff, Wilkins Slough, and Verona, which are located along the adult emigration corridor (Table 5.4-30). As described in Appendix 5.D, Section 5.D.2.4, *Migration Flows Methods*, on balance, except under very high flows, the benefits of increased flow generally outweigh the costs and, therefore, it is assumed for the purposes of this effects analysis that increased flow would improve conditions for emigration of post-spawn adult green sturgeon.

Shasta Reservoir storage volume at the end of May influences flow rates in the Sacramento River early in the adult emigration period, and Shasta storage volume at the end of September influences flow rates later in the period. Mean Shasta May storage under the PA would be similar (less than 5% difference) to storage under NAA for all water year types (Appendix 5.A, *CALSIM Methods and Results*, Table 5.A.6-3). Mean Shasta September storage under the PA would also be similar (less than 5% difference) to storage under NAA for all water year types, except for 7% higher mean storage during critical water years under the PA.

In general, mean flow under the PA at the Red Bluff, Wilkins Slough, and Verona locations in the Sacramento River would be similar to (less than 5% difference) or greater than flow under the NAA from April through June and during December and January but would be similar (less than 5% difference) or lower than flows under the NAA from July through November, with exceptions (Appendix 5.A, *CALSIM Methods and Results*, Table 5.A.6-14, Table 5.A.6-35, Table 5.A.6-36). During May of dry years, flow would be 5% and 8% greater at Red Bluff and Wilkins Slough, respectively, but flow would be similar (less than 5% difference) at Verona. The greatest increases in flow would occur during June, when flow under the PA would be greater at all the locations, including all water year types at Verona and all water year types, except wet years, at Red Bluff and Wilkins Slough. The increases for all water year types would be greater at Wilkins Sough and Verona (up to 25% greater in above normal years at Verona) compared with those at Red Bluff. During July, mean flow in critical water years under the PA would be 10% and 13% lower than under the NAA at Wilkins Slough and Verona, but the flows would be similar (less than 5% difference) at Red Bluff. During August of below normal years, mean flow would be lower at all three locations (up to 18% lower flow at Wilkins Slough). During August of dry and critical years, flow under the PA would be greater (up to 10% greater) at Wilkins Slough and Verona. Mean flow during September would be lower for most water year types at all the locations (up to 24% lower in below normal years at Verona). During October, flow under the PA would be lower in wet years at all the locations, ranging from 7% to 11% lower, but would be up to 17% higher in below normal and dry years. During November of wet and above normal water years, flow would be 21% lower under the PA than it would be under the NAA at Red Bluff, up to 24% lower at Wilkins Slough, and up to 17% lower at Verona, but in critical water years, flow would be greater at all the locations (up to 10% greater at Wilkins Slough). During January of critical water years, mean flow under the PA would be 7% greater than under the NAA at Red Bluff but would be similar to (less than 5% difference) flows under the NAA at the other two locations.

The CALSIM modeling results given here indicate that the PA would reduce flow in some months and water year types, although this does not consider real-time operational management described in Section 3.1.5, *Real-Time Operations Upstream of the Delta*, and Section 3.3.3, *Real-Time Operational Decision-Making Process*, that would be used to avoid and minimize any modeled effects. Further discussion regarding flow-related effects during the June through November period are provided in Section 5.4.2.3, *Summary of Upstream Effects*.

5.4.2.1.3.4.3.2 Water Temperature-Related Effects

Modeled mean monthly water temperatures during the April through January post-spawning adult emigration period for green sturgeon in the Sacramento River at Bend Bridge, Red Bluff, Hamilton City, and Knights Landing (Table 5.4-30) are presented in Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results*, Table 5.C.7-7, Table 5.C.7-8, Table 5.C.7-9, Table 5.C.7-10[59]. Overall, the PA would change mean water temperatures very little (predominantly less than 1°F, or approximately 1%) throughout the spawning reach of Keswick Dam to Red Bluff in all months of the period and water year types. The largest increase in mean monthly water temperatures under the PA relative

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[59] Water temperature results for Wilkins Slough were used to represent Knights Landing for this analysis

to NAA would be 1.0°F (1.4%) and would occur at Knights Landing in below normal years during August.

Exceedance plots of monthly mean water temperatures were examined during each month throughout the spawning and incubation period (Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results,* Figure 5.C.7.7-7, Figure 5.C.7.8-7, Figure 5.C.7.9-7, Figure 5.C.7.10-7[60]). The values for the PA in these exceedance plots generally match those of the NAA. Further examination of below normal years during August at Hamilton City, where the largest increase in mean monthly water temperature was seen, reveals that the curves were similar overall, although there were multiple difference of more than 1°F at the colder end of the range (Figure 5.4-249).

For the evaluation of threshold exceedances for post-spawn adult emigration, please see the combined non-spawning adult presence analysis in the Section 5.4.2.1.3.4.2, *Pre- and Post-Spawn Adult Holding*, which indicates that there would be no biologically meaningful water temperature-related effects on green sturgeon non-spawning adult presence.

5.4.2.1.3.4.4 Larval and Juvenile Rearing and Emigration

5.4.2.1.3.4.4.1 Flow-Related Effects

Mean monthly flows were evaluated in the Sacramento River at three locations (i.e., Red Bluff, Wilkins Slough, and Verona) along the downstream migration corridor of green sturgeon larvae and juveniles during the year-round emigration period (Table 5.4-30). Changes in flow can affect the instream area available for rearing, along with habitat quality, and downstream dispersal of larvae to rearing habitat in the bay and Delta. Changes in flow potentially affect emigration of green sturgeon larvae and juveniles, including the rate of downstream movement, as well as conditions for feeding, temperature, turbidity, and other habitat factors. Downstream dispersal of larvae to rearing habitat in the bay and Delta can also be affected. There is some evidence that green sturgeon year class strength is positively correlated with Delta outflow, perhaps as a result, in part, of improved downstream dispersal. This potential effect is evaluated as part of Delta outflow in Section 5.4.1.3.2.2.2.1, *Delta Outflow*. Quantitative relationships between flow and green sturgeon emigration are poorly understood. As described in Appendix 5.D, Section 5.D.2.4, *Migration Flows Methods,* on balance, except under very high flows, the benefits of increased flow generally outweigh the costs and, therefore, it is assumed for the purposes of this effects analysis that increased flow would improve conditions for emigration of green sturgeon larvae and juveniles.

Shasta Reservoir storage volume at the end of May and the end of September influence flow rates in the Sacramento River. Mean Shasta May storage under the PA would be similar (less than 5% difference) to storage under NAA for all water year types (Appendix 5.A, *CALSIM Methods and Results*, Table 5.A.6-3). Mean Shasta September storage under the PA would also be similar (less than 5% difference) to storage under NAA for all water year types, except for 7% higher mean storage during critical water years under the PA.

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[60] Water temperature results for Wilkins Slough were used to represent Knights Landing for this analysis

In general, mean flow under the PA at the Red Bluff, Wilkins Slough, and Verona locations in the Sacramento River would be similar to (less than 5% difference) or lower than flow under the NAA during the summer and fall months and would be similar to (less than 5% difference) or greater than flows under the NAA during the winter and spring months, with exceptions (Appendix 5.A, *CALSIM Methods and Results,* Table 5.A.6-14, Table 5.A.6-35, Table 5.A.6-36). During January of critical water years, mean flow under the PA would be 7% greater than it would be under the NAA at Red Bluff and would be similar to (less than 5% difference) flows under the NAA at the other two locations. During February of critical water years, mean flow would be 7% and 6% lower under the PA compared with the NAA at Red Bluff and Wilkins Slough, respectively, and would be similar for the two scenarios (less than 5% difference) at Verona. During March, flow under the PA at Keswick would be 9% greater in above normal and below normal years and 8% greater in critical years, and there would be no differences greater than 5% at the other locations. During May, flow would be 5% and 8% greater in dry years at Red Bluff and Wilkins Slough, respectively, but would be similar (less than 5% difference) at Verona. The greatest increases in flow would occur during June, when flow under the PA would be greater at all the locations, including all water year types at Verona and all water year types, except wet years, at Red Bluff and Wilkins Slough. The increases for all water year types would be greater at Wilkins Slough and Verona (up to 25% greater in above normal years at Verona) compared with those at Red Bluff. During July, mean flow in critical water years under the PA would be 10% and 13% lower than under the NAA at Wilkins Slough and Verona, but the flows would be similar (less than 5% difference) at Red Bluff. During August, mean flow in below normal years would be lower at all three locations (up to 18% lower at Wilkins Slough). During August of dry and critical years, flow under the PA would be greater (up to 10% greater) at Wilkins Slough and Verona. Mean flow during September would be lower for most water year types at all the locations (up to 24% lower in below normal years at Verona). During October, flow under the PA would be lower at all the locations, ranging from 7% to 11% lower in wet years, but would be up to 17% higher in below normal and dry years. During November of wet and above normal water years, flow would be 21% lower under the PA than it would be under the NAA at Red Bluff, up to 24% lower at Wilkins Slough, and up to 17% lower at Verona, but in critical water years, flow would be greater at all the locations (up to 10% greater at Wilkins Slough).

As described in Appendix 5.D, Section 5.D.2.3, *Rearing Flows Methods*, no WUA curves were located for green or white sturgeon in the Sacramento River, and therefore, effects of flow on rearing habitat for green sturgeon were evaluated qualitatively using the flow predictions described above for the year-round green sturgeon rearing period. Again, as described in Appendix 5.D, Section 5.D.2.3, *Rearing Flows Methods,* it is assumed for the purposes of this effects analysis that increased flow would increase the availability and quality of rearing habitat and thereby benefit green sturgeon. As such, effects of the PA on green sturgeon rearing habitat are expected to be beneficial during June for all water year types, except wet years, when there would be no effect. Effects would be negative during September, except in wet years, and during November, except in dry and critical years. In the critical years, the effects would be positive. During August and October, both positive and negative effects are expected, depending on the water year type and location (Appendix 5.A, *CALSIM Methods and Results*). It should be noted that the assumed monotonically increasing relationship between flow and green sturgeon rearing habitat, on which the above conclusions are based, has low certainty.

The CALSIM modeling results given here indicate that the PA would reduce flow in some months and water year types, although this does not consider real-time operational management described in Section 3.1.5, *Real-Time Operations Upstream of the Delta*, and Section 3.3.3, *Real-Time Operational Decision-Making Process,* that would be used to avoid and minimize any modeled effects. Further discussion regarding flow-related effects during the June through November period are provided in Section 5.4.2.3, *Summary of Upstream Effects*.

5.4.2.1.3.4.4.2 Water Temperature-Related Effects

Modeled mean monthly water temperatures during the year-round larval and juvenile rearing period for green sturgeon in the Sacramento River between Bend Bridge and Knights Landing (Table 5.4-30) are presented in Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results,* Table 5.C.7-7, Table 5.C.7-8, Table 5.C.7-9, Table 5.C.7-10[61]. Overall, the PA would change mean water temperatures very little (predominantly less than 1°F, or approximately 1%) throughout the juvenile rearing reach in all months and water year types. The largest increase in mean monthly water temperatures under the PA relative to NAA would be 1.0°F (1.4%) and would occur at Knights Landing in below normal years during August, which is outside of the June and July peak rearing period.

Exceedance plots of monthly mean water temperatures were examined during each month throughout the larval and juvenile rearing period (Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results,* Figure 5.C.7.7-7, Figure 5.C.7.8-7, Figure 5.C.7.9-7, Figure 5.C.7.10-7[62]). The values for the PA in these exceedance plots generally match those of the NAA. Further examination of below normal years during August at Hamilton City, where the largest increase in mean monthly water temperature was seen, reveals that the curves were similar overall, although there were multiple difference of more than 1°F at the colder end of the range (Figure 5.4-249).

The threshold water temperature of 66°F was used to evaluate water temperature threshold exceedances during the green sturgeon rearing life stage in the Sacramento River between Bend Bridge and Knights Landing (Appendix 5.D, Section 5.D.2.1, *Water Temperature Analysis Methods*, Table 5.D-49). This threshold is the upper end of the range of optimal bioenergetics performance of Age 0 and 1 sturgeon with full or reduced food supply (Mayfield and Cech 2004).

Results of the water temperature thresholds analysis are presented in Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-156 and Tables 5.D-158 through 5.D-160. At Bend Bridge and Red Bluff, there would be no months or water year types in which there would be either more than 5% more days under the PA compared to the NAA on which temperatures would exceed the threshold or a more-than-0.5°F difference in the magnitude of average daily exceedance (Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-158 and Table 5.D-159).

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[61] Water temperature results for Wilkins Slough were used to represent Knights Landing for this analysis

[62] Water temperature results for Wilkins Slough were used to represent Knights Landing for this analysis

At Hamilton City, there would be one instance in which temperatures would exceed the threshold on more than 5% more days under the PA compared to the NAA: September of below normal water years (14.2% higher) (Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-160). However, there would be no concurrent increase under the PA relative to the NAA of more than 0.5°F in the magnitude of average daily exceedance. There would also be two instances in which there would be a reduction under the PA in the percent of days exceeding the 66°F threshold: August of dry and critical water years (9.2% and 9.1% reductions, respectively). In dry years, there would be no difference between the PA and NAA in the magnitude of average daily exceedance above the threshold. In critical water years, there would be a 0.5°F increase in the magnitude of average daily exceedance above the threshold. This indicates that the frequency of days above the threshold would decrease under the PA, but exceedances would be higher on average.

At Knights Landing, for the 66°F threshold, there would be two instances in which temperatures would exceed the threshold on more than 5% more days under the PA compared to the NAA: September (18.7% higher) and October (5.6% higher) of above normal water years (Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-156). In September, there would be no difference of more than 5% in the magnitude of average daily exceedance above the threshold between the NAA and PA. However, for October, there would be a reduction of 1.1°F in the magnitude of average daily exceedance above the threshold. This indicates that, for October of above normal water years, the frequency of days above the threshold would increase under the PA, but exceedances would be lower on average.

Overall, the thresholds analysis indicates that there would be more exceedances (5% or greater) in certain months and water year types under the PA, which could cause lethal or sublethal effects to larval and juvenile green sturgeon, although this does not consider real-time operational management described in Section 3.1.5, *Real-Time Operations Upstream of the Delta*, and Section 3.3.3, *Real-Time Operational Decision-Making Process*, that would be used to avoid and minimize any modeled effects. Further, this does not consider the current revision process to OCAP RPA Action Suite 1.2 described in Section 3.1.4.5, *Annual/Seasonal Temperature Management Upstream of the Delta*, to improve winter-run Chinook salmon egg-to-fry survival. This process may result in refinements and additions to the existing annual/seasonal temperature management processes, including spring storage targets, revised temperature compliance criteria and a range in summertime Keswick release rates. Although the process targets improving winter-run Chinook salmon egg to fry survival, there may be benefits gained by green sturgeon as a result of some of these refinements. The biological interpretation of these results, combined with all upstream results, in the context of real-time operational management is provided in Section 5.4.2.3, *Summary of Upstream Effects*, below.

5.4.2.1.3.4.5 Adult Immigration

5.4.2.1.3.4.5.1 Flow-Related Effects

Mean monthly flows were evaluated in the Sacramento River during the February through June adult green sturgeon immigration period at Red Bluff, Wilkins Slough, and Verona, which are located along the upstream migration corridor (Table 5.4-30). Changes in flow affect conditions for upstream migration of adults, potentially including bioenergetic cost, water quality, crowding, and passage conditions, but quantitative relationships between flow and such conditions are poorly understood. As described in Appendix 5.D, Section 5.D.2.4, *Migration Flows Methods,* on balance, except under very high flows, the benefits of increased flow generally outweigh the costs and, therefore, it is assumed for the purposes of this effects analysis that increased flow would improve conditions for upstream migration of adult green sturgeon.

Shasta Reservoir storage volume at the end of September may influence flow rates in the Sacramento River during the early part of the green sturgeon immigration period, and Shasta storage volume at the end of May influences flows in June. Mean Shasta September storage under the PA would be similar (less than 5% difference) to storage under NAA for all water year types, except for 7% higher mean storage during critical water years under the PA. Mean Shasta May storage under the PA would also be similar (less than 5% difference) to storage under NAA for all water year types (Appendix 5.A, *CALSIM Methods and Results,* Table 5.A.6-3).

For most months and water year types of the adult immigration period, mean flow at Red Bluff, Wilkins Slough and Verona would be similar (less than 5% difference) between the PA and the NAA or would be greater under the PA (Appendix 5.A, *CALSIM Methods and Results,* Table 5.A.6-14, Table 5.A.6-35, Table 5.A.6-36). Only flow in February of critical water years at Red Bluff and Wilkins Slough would be lower under the PA than it would be under the NAA (up to 7% lower at Red Bluff). During May, flow under the PA would be greater (up to 8% greater at Wilkins Slough), except at Verona. During June, flow under the PA would be greater at all the locations, including all water year types at Verona and all water year types, except wet years, at the other locations. The increases for all water year types would be greater at Wilkins Slough and Verona (up to 25% greater in above normal years) than those at Red Bluff.

The CALSIM modeling results given here indicate that the PA would reduce flow in some months and water year types, although this does not consider real-time operational management described in Section 3.1.5, *Real-Time Operations Upstream of the Delta,* and Section 3.3.3, *Real-Time Operational Decision-Making Process,* that would be used to avoid and minimize any modeled effects. Further discussion regarding flow-related effects during the June through November period are provided in Section 5.4.2.3, *Summary of Upstream Effects*.

As described in Appendix 5.D, Section 5.D.2.4, *Migration Flows Methods,* mean monthly flow below about 3,250 cfs is considered to have potentially adverse effects on Chinook salmon, CCV steelhead, and green sturgeon adult immigration conditions in the Sacramento River. The effect of the PA on the frequency of flows below this threshold was evaluated for green sturgeon by comparing CALSIM flows between the PA and the NAA at the Red Bluff and Wilkins Slough migration corridor locations in the river. The CALSIM results indicate no flows below 3,250 cfs for the Sacramento River at either of these locations for any month of the green sturgeon adult immigration period.

5.4.2.1.3.4.5.2 Water Temperature-Related Effects

Modeled mean monthly water temperatures during the February through June green sturgeon adult immigration period in the Sacramento River between Bend Bridge and Knights Landing (Table 5.4-30) are presented in Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results,* Table 5.C.7-7, Table

5.C.7-8, Table 5.C.7-9, Table 5.C.7-10[63]. Overall, the PA would change mean water temperatures very little (less than 1°F, or approximately 1%) throughout the juvenile rearing reach in all months and water year types. The largest increase in mean monthly water temperatures under the PA relative to NAA would be 0.3°F (0.5%) and would occur at Bend Bridge in below normal years during May.

Exceedance plots of monthly mean water temperatures were examined during each month throughout the adult immigration period (Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results,* Figure 5.C.7.7-7, Figure 5.C.7.8-7, Figure 5.C.7.9-7, Figure 5.C.7.10-7[64]). The values for the PA in these exceedance plots generally match those of the NAA. Further examination of below normal water years during May at Bend Bridge (Figure 5.4-247), where the largest increase in mean monthly water temperature was seen, reveals that there would be two years in which water temperatures would be higher under the PA relative to the NAA. However, upon closer examination of these years reveals that this appears to be due to CALSIM II attempting to balance storage levels among the CVP reservoirs and there are no operational requirements, such as cold-water pool storage, temperature, or outflow requirements, that would cause these years to differ so widely in water temperatures. Therefore, there is no practical reason why real operations under the PA would be different from those under the NAA in these months and years.

For the evaluation of threshold exceedances for adult immigration, please see the combined non-spawning adult presence analysis in Section 5.4.2.1.3.4.2, *Pre- and Post-Spawn Adult Holding*, which indicates that there would be no biologically meaningful water temperature-related effects on green sturgeon non-spawning adult presence.

5.4.2.1.4 Assess Risk to Individuals

5.4.2.1.4.1 Winter-Run Chinook Salmon

Based on the responses of winter-run Chinook salmon exposed to the PA described in Section 5.4.2.1.3, *Assess Species Response to the Proposed Action*, above, the risk to individuals in the Sacramento River would generally be insignificant, with occasional moderate risk related to early life stages, although this does not consider real-time operational management described in Section 3.1.5, *Real-Time Operations Upstream of the Delta*, and Section 3.3.3, *Real-Time Operational Decision-Making Process,* which would be used to avoid and minimize any modeled effects. Fitness of individuals, including reproductive success during spawning, survival during embryo incubation, survival and growth during fry and juvenile rearing, survival and growth during immigration and emigration, and expression of life history as a result of spawning, rearing, and migration habitat availability, would mostly differ insignificantly between the NAA and PA. Modeling results indicate occasional instances in which there would be small effects to individuals resulting from changes in reservoir operations under the PA. Results also indicate an increased risk under the PA of small reductions in survival of egg, alevin, fry, and juvenile life stages of winter-run Chinook salmon due to increased water temperatures during August and September and increased risk of redd dewatering for June and August cohorts, as well as reduced survival and growth during juvenile emigration in September and November due to reduced

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[63] Water temperature results for Wilkins Slough were used to represent Knights Landing for this analysis

[64] Water temperature results for Wilkins Slough were used to represent Knights Landing for this analysis

instream flows. Please see Section 5.4.2.3, *Summary of Upstream Effects*, for a description of how actual operations of the PA and the current RPA revision process may reduce the likelihood that these effects would occur.

5.4.2.1.4.2 Spring-Run Chinook Salmon

Based on the responses of spring-run Chinook salmon exposed to the PA described in Section 5.4.2.1.3, *Assess Species Response to the Proposed Action*, above, the risk to individuals in the Sacramento River would mostly be insignificant, with occasional moderate risk related to early life stages, although this does not consider real-time operational management described in Section 3.1.5, *Real-Time Operations Upstream of the Delta*, and Section 3.3.3, *Real-Time Operational Decision-Making Process*, which would be used to avoid and minimize any modeled effects. Fitness of individuals, including reproductive success during spawning, survival during embryo incubation, survival and growth during fry and juvenile rearing, survival and growth during immigration and emigration, and expression of life history as a result of spawning, rearing, and migration habitat availability, would mostly differ insignificantly between the NAA and PA. Modeling results indicate occasional instances in which there would be small effects to individuals resulting from changes in reservoir operations under the PA. Results also indicate an increased risk under the PA of small reductions in survival of egg, alevin, fry, and juvenile life stages of spring-run Chinook salmon due to increased water temperatures during August and September and increased risk of redd dewatering for August cohorts, reductions in rearing WUA in June[65], reduced survival and growth during juvenile emigration in November and adult immigration in September due to reduced instream flows. Please see Section 5.4.2.3, *Summary of Upstream Effects*, for a description of how real-time operational management of the PA and the current RPA revision process may reduce the likelihood that these effects would occur.

5.4.2.1.4.3 California Central Valley Steelhead

Based on the responses of CCV steelhead salmon exposed to the PA described in Section 5.4.2.1.3, *Assess Species Response to the Proposed Action*, the risk to individuals in the Sacramento River would mostly be insignificant. Fitness of individuals, including reproductive success during spawning, survival during embryo incubation, survival and growth during juvenile rearing, survival and growth during immigration and emigration, and expression of life history as a result of spawning, rearing, and migration habitat availability, would mostly differ insignificantly between the NAA and PA. Modeling results indicate occasional instances in which there would be small effects to individuals resulting from changes in reservoir operations under the PA. Results also indicate an increased risk under the PA of small reductions in in rearing WUA in June[66], and reduced survival and growth during juvenile emigration and adult immigration in November due to reduced instream flows. Please see Section 5.4.2.3, *Summary of Upstream Effects*, for a description of how real-time operational management of the PA and the current RPA revision process may reduce the likelihood that these effects would occur.

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[65] Reductions in WUA would be of immediate concern if habitat was a limiting factor. Habitat limitation has not been a concern in recent years due to low population size, but it could be in the future if population size was to increase or there was a strong year class. Awareness of the effects to be managed in the best interest of the species is necessary, regardless of variability in population size.

[66] Habitat limitation has not been a concern in recent years due to low population size, but it could be in the future if population size was to increase or there was a strong year class. Awareness of the effects to be managed in the best interest of the species is necessary, regardless of variability in population size

5.4.2.1.4.4 Green Sturgeon

Based on the responses of green sturgeon exposed to the PA described in Section 5.4.2.1.3, *Assess Species Response to the Proposed Action*, above, the risk to individuals in the Sacramento River would be insignificant. See Section 3.1.5, *Real-Time Operations Upstream of the Delta*, and Section 3.3.3, *Real-Time Operational Decision-Making Process*, for descriptions of how real-time operational management would be used to avoid and minimize any modeled effects. In addition, see Section 3.1.4.5, *Annual/Seasonal Temperature Management Upstream of the Delta*, for a description of the process for refining the RPA to improve upstream temperature conditions. Fitness of individuals, including reproductive success during spawning, survival during embryo incubation, survival and growth during larval and juvenile rearing, survival and growth during immigration and emigration, and expression of life history as a result of spawning, rearing, and migration habitat availability, would mostly differ insignificantly between the NAA and PA.

5.4.2.1.5 Effects of the Action on Designated and Proposed Critical Habitat

The critical habitat designation final rules (winter-run Chinook salmon: June 16, 1993, 58 FR 33212; spring-run Chinook salmon and CCV steelhead: September 2, 2005, 70 FR 52488; green sturgeon: October 9, 2009, 74 FR 52300), provide the physical and biological features (PBFs) that are essential for the conservation of the species. The Sacramento River provides several PBFs that support one or more life stages of winter-run Chinook salmon, spring-run Chinook salmon, CCV steelhead, and green sturgeon. Because the Sacramento River upstream of the Delta is exclusively a freshwater riverine system, only PBFs pertaining to freshwater riverine systems are discussed here.

For each species, please refer to Section 5.4.2.3, *Summary of Upstream Effects*, for a description of how real-time operational management of the PA and the current RPA revision process may reduce the likelihood that the effects described here would occur.

5.4.2.1.5.1 Winter-Run Chinook Salmon

5.4.2.1.5.1.1 Access to Spawning Areas in the Upper Sacramento River

Access to spawning areas in the Upper Sacramento River by adult winter-run Chinook salmon is affected by flow- and water temperature-related conditions throughout the Sacramento River upstream of the Delta. Winter-run Chinook salmon spawning occurs between Keswick Dam and Red Bluff Diversion Dam, although the vast majority of spawning currently occurs upstream of Airport Bridge (CDFW unpubl. data). Section 5.4.2.1.3.1.4, *Adult Immigration*, evaluated flow- and water temperature-related effects of the PA on adult immigration relative to the NAA in the Sacramento River upstream of the Delta and found that effects of the PA on winter-run Chinook salmon migration habitat would be insignificant.. Therefore, the results indicate that there would be insignificant adverse effects of the PA on this physical and biological feature. This conclusion does not include consideration of real-time operational management described in Section 3.1.5, *Real-Time Operations Upstream of the Delta*, and Section 3.3.3, *Real-Time Operational Decision-Making Process*, that would be used to avoid and minimize any modeled effects.

5.4.2.1.5.1.2 The Availability of Clean Gravel for Spawning Substrate

The availability of clean gravel is a function of upstream supply and flow regimes that allow for periodic cleaning of fine sediment but are not high enough to mobilize the gravel. The PA would not affect the amount of upstream gravel supply or natural pulse flows. Further, the insignificant flow differences due to the PA (Section 5.4.2.1.3.1.1, *Spawning, Egg Incubation, and Alevins*; Appendix 5.A, *CALSIM Methods and Results*) are not expected to cause substantial changes in availability of clean gravel because these non-pulse flows are not responsible for cleaning gravel. Therefore, there would be no effect of the PA on this physical and biological feature.

5.4.2.1.5.1.3 Adequate River Flows for Successful Spawning, Incubation of Eggs, Fry Development and Emergence, and Downstream Transport of Juveniles

As indicated in Section 5.4.2.1.3.1.1, *Spawning, Egg Incubation, and Alevins*; Section 5.4.2.1.3.1.2, *Fry and Juvenile Rearing*; Section 5.4.2.1.3.1.3, *Juvenile Emigration*, there would be insignificant differences in flows between the NAA and PA throughout the Sacramento River upstream of the Delta during the winter-run Chinook salmon spawning, rearing, and emigration periods. Therefore, the results indicate there would be insignificant effects of the PA on this physical and biological feature. This conclusion does not include consideration of real-time operational management described in Section 3.1.5, *Real-Time Operations Upstream of the Delta*, and Section 3.3.3, *Real-Time Operational Decision-Making Process,* which would be used to avoid and minimize any modeled effects.

5.4.2.1.5.1.4 Water Temperatures for Successful Spawning, Egg Incubation, and Fry Development

As indicated in Section 5.4.2.1.3.1.1, *Spawning, Egg Incubation, and Alevins* and Section 5.4.2.1.3.1.2, *Fry and Juvenile Rearing*, water temperatures would differ insignificantly between the NAA and PA in spawning and rearing reaches throughout the Sacramento River upstream of the Delta during the winter-run Chinook salmon spawning and rearing periods with few exceptions. Therefore, the results indicate that there would be insignificant effects of the PA on this physical and biological feature. This conclusion does not include consideration of real-time operational management described in Section 3.1.5, *Real-Time Operations Upstream of the Delta*, and Section 3.3.3, *Real-Time Operational Decision-Making Process,* which would be used to avoid and minimize any modeled effects. Further, this does not consider the current revision process to OCAP RPA Action Suite 1.2 described in Section 3.1.4.5, *Annual/Seasonal Temperature Management Upstream of the Delta*, to improve winter-run Chinook salmon egg-to-fry survival.

5.4.2.1.5.1.5 Habitat Areas and Adequate Prey that Are not Contaminated

In the Sacramento River upstream of the Delta, the PA is not likely to adversely affect contaminant sources. As indicated throughout Section 5.4.2.1.3.1, *Winter-Run Chinook Salmon*, there would be insignificant differences in flows between the NAA and PA in winter-run Chinook salmon habitat areas throughout the Sacramento River upstream of the Delta. These flows could influence dilution of contaminants Therefore, the results indicate there would be insignificant effects of the PA on this physical and biological feature. This conclusion does not include consideration of real-time operational management described in Section 3.1.5, *Real-Time Operations Upstream of the Delta*, and Section 3.3.3, *Real-Time Operational Decision-Making Process,* which would be used to avoid and minimize any modeled effects.

5.4.2.1.5.1.6 Riparian Habitat that Provides for Successful Juvenile Development and Survival

In the Sacramento River upstream of the Delta, any change in riparian habitat is expected to be insignificant. The range of flows, which can influence riparian vegetation, would not change substantially under the PA. Therefore, the effect of the PA on this physical and biological feature would be insignificant.

5.4.2.1.5.1.7 Access Downstream so that Juveniles Can Migrate from Spawning Grounds to San Francisco Bay and the Pacific Ocean

Juvenile winter-run Chinook salmon emigration from spawning grounds would be limited by flow- and water temperature-related conditions throughout the Sacramento River upstream of the Delta. Section 5.4.2.1.3.1.3, *Juvenile Emigration*, evaluated flow- and water temperature-related effects of the PA relative to the NAA in the Sacramento River upstream of the Delta and found that there would predominantly be insignificant differences in flows and water temperatures between the PA and NAA in juvenile winter-run Chinook salmon migration habitat. Therefore, there would predominantly be insignificant effects of the PA on this physical and biological feature, However, there would be reductions in flow between the NAA and PA during November, which indicate that there would be a potential risk during November of negative effects of the PA on this PBF. This does not consider real-time operational management described in Section 3.1.5, *Real-Time Operations Upstream of the Delta*, and Section 3.3.3, *Real-Time Operational Decision-Making Process,* which would be used to avoid and minimize any modeled effects.

5.4.2.1.5.2 Spring-Run Chinook Salmon

5.4.2.1.5.2.1 Spawning Habitat

As indicated in Section 5.4.2.1.3.2.1, *Spawning, Egg Incubation, and Alevins*, there would be insignificant differences in flow and water temperature between the PA and NAA in spring-run Chinook salmon spawning habitat in the Sacramento River. Therefore, the results indicate that there would be insignificant effects of the PA on this PBF. This conclusion does not include consideration of real-time operational management described in Section 3.1.5, *Real-Time Operations Upstream of the Delta*, and Section 3.3.3, *Real-Time Operational Decision-Making Process*, which would be used to avoid and minimize any modeled effects. Further, this does not consider the current revision process to OCAP RPA Action Suite 1.2 described in Section 3.1.4.5, *Annual/Seasonal Temperature Management Upstream of the Delta*, to improve winter-run Chinook salmon egg-to-fry survival.

5.4.2.1.5.2.2 Freshwater Rearing Habitat

As indicated in Section 5.4.2.1.3.2.2, *Fry and Juvenile Rearing*, there would be insignificant differences in flow and water temperature between the PA and NAA in fry and juvenile spring-run Chinook salmon rearing habitat in the Sacramento River upstream of the Delta. Therefore, the results indicate that there would be insignificant effects of the PA on this PBF. This conclusion does not include consideration of real-time operational management described in Section 3.1.5, *Real-Time Operations Upstream of the Delta*, and Section 3.3.3, *Real-Time Operational Decision-Making Process*, which would be used to avoid and minimize any modeled effects.

5.4.2.1.5.2.3 Freshwater Migration Corridors

As indicated in Section 5.4.2.1.3.2.3, *Juvenile Emigration*, and Section 5.4.2.1.3.2.4 *Adult Immigration*, there would predominantly be insignificant differences in flow and water temperature between the PA and NAA in juvenile and adult spring-run Chinook migration habitat in the Sacramento River upstream of the Delta. Therefore, the results indicate that there would predominantly be insignificant effects of the PA on this PBF. However, there would be reductions in flow between the NAA and PA during November, which indicate that there would be a potential risk during November of negative effects of the PA on this PBF. This conclusion does not include consideration of real-time operational management described in Section 3.1.5, *Real-Time Operations Upstream of the Delta*, and Section 3.3.3, *Real-Time Operational Decision-Making Process*, which would be used to avoid and minimize any modeled effects.

5.4.2.1.5.3 California Central Valley Steelhead

5.4.2.1.5.3.1 Spawning Habitat

As indicated in Section 5.4.2.1.3.3.1, *Spawning, Egg Incubation, and Alevins*, there would be insignificant differences in flow and water temperature between the PA and NAA in CCV steelhead spawning habitat in the Sacramento River. Therefore, the results indicate that there would be insignificant effects of the PA on this PBF. This conclusion does not include consideration of real-time operational management described in Section 3.1.5, *Real-Time Operations Upstream of the Delta*, and Section 3.3.3, *Real-Time Operational Decision-Making Process*, which would be used to avoid and minimize any modeled effects. Further, this does not consider the current revision process to OCAP RPA Action Suite 1.2 described in Section 3.1.4.5, *Annual/Seasonal Temperature Management Upstream of the Delta*, to improve winter-run Chinook salmon egg-to-fry survival.

5.4.2.1.5.3.2 Freshwater Rearing Habitat

As indicated in Section 5.4.2.1.3.3.3, *Juvenile Rearing*, there would be insignificant differences in flow and water temperature between the PA and NAA in juvenile CCV steelhead rearing habitat in the Sacramento River upstream of the Delta. Therefore, the results indicate that there would be insignificant effects of the PA on this PBF. This conclusion does not include consideration of real-time operational management described in Section 3.1.5, *Real-Time Operations Upstream of the Delta*, and Section 3.3.3, *Real-Time Operational Decision-Making Process*, which would be used to avoid and minimize any modeled effects.

5.4.2.1.5.3.3 Freshwater Migration Corridors

As indicated in Section 5.4.2.1.3.3.2, *Kelt Emigration*, Section 5.4.2.1.3.3.4, *Smolt Emigration*, and Section 5.4.2.1.3.3.5, *Adult Immigration*, there would predominantly be insignificant differences in flow and water temperature between the PA and NAA in kelt, smolt, and adult CCV steelhead migration habitat in the Sacramento River upstream of the Delta. Therefore, the results indicate that there would predominantly be insignificant effects of the PA on this PBF. However, there would be reductions in flow between the NAA and PA during November, which indicate that there would be a potential risk during November of negative effects of the PA on this PBF. This conclusion does not include consideration of real-time operational management described in Section 3.1.5, *Real-Time Operations Upstream of the Delta*, and Section 3.3.3, *Real-Time Operational Decision-Making Process*, which would be used to avoid and minimize any modeled effects.

5.4.2.1.5.4 Green Sturgeon

5.4.2.1.5.4.1 Food Resources

The PA would not directly affect food resources in the Sacramento River upstream of the Delta, although food availability could potentially be affected by changes in flows and water temperatures. As described throughout Section 5.4.2.1.3.4, *Green Sturgeon*, there would be insignificant reductions in flows and increases in water temperature in the Sacramento River. These results indicate there would be insignificant effects to this PBF. This conclusion does not include consideration of real-time operational management described in Section 3.1.5, *Real-Time Operations Upstream of the Delta*, and Section 3.3.3, *Real-Time Operational Decision-Making Process,* which would be used to avoid and minimize any modeled effects.

5.4.2.1.5.4.2 Substrate Type or Size

The PA would not directly affect substrate type of size, although substrate could potentially be affected by changes in flows in the Sacramento River. As described throughout Section 5.4.2.1.3.4, *Green Sturgeon*, there would be insignificant reductions in flows in the Sacramento River. These results indicate there would be insignificant effects to this PBF. This conclusion does not include consideration of real-time operational management described in Section 3.1.5, *Real-Time Operations Upstream of the Delta*, and Section 3.3.3, *Real-Time Operational Decision-Making Process*, which would be used to avoid and minimize any modeled effects.

5.4.2.1.5.4.3 Water Flow

As described throughout Section 5.4.2.1.3.4, *Green Sturgeon*, there would be insignificant reductions in flows in the Sacramento River. These results indicate there would be insignificant effects to this PBF. This conclusion does not include consideration of real-time operational management described in Section 3.1.5, *Real-Time Operations Upstream of the Delta*, and Section 3.3.3, *Real-Time Operational Decision-Making Process*, which would be used to avoid and minimize any modeled effects.

5.4.2.1.5.4.4 Water Quality

In the critical habitat designation final rule for green sturgeon (October 9, 2009, 74 FR 52300), the Water Quality PBF includes "temperature, salinity, oxygen content, and other chemical characteristics, necessary for normal behavior, growth, and viability of all life stages". These factors could potentially be affected by changes in flows and increases in water temperatures in the Sacramento River. As described throughout Section 5.4.2.1.3.4, *Green Sturgeon*, there would be insignificant reductions in flows and increases in water temperatures in the Sacramento River. These results indicate there would be insignificant effects to this PBF. This conclusion does not include consideration of real-time operational management described in Section 3.1.5, *Real-Time Operations Upstream of the Delta*, and Section 3.3.3, *Real-Time Operational Decision-Making Process*, which would be used to avoid and minimize any modeled effects. Further, this does not consider the current revision process to OCAP RPA Action Suite 1.2 described in Section 3.1.4.5, *Annual/Seasonal Temperature Management Upstream of the Delta,* to improve winter-run Chinook salmon egg-to-fry survival.

5.4.2.1.5.4.5 Migratory Corridor

As described in Section 5.4.2.1.3.4.3, *Post-Spawn Adult Emigration*, Section 5.4.2.1.3.4.4, *Larval and Juvenile Rearing and Emigration*, and Section 5.4.2.1.3.4.5 *Adult Immigration*, there would mostly be insignificant reductions in flows in the Sacramento River. These results indicate there would mostly be insignificant effects to this PBF. However, there would be reductions in flow between the NAA and PA during November, which indicate that there would be a potential risk during November of negative effects of the PA on this PBF. This conclusion does not include consideration of real-time operational management described in Section 3.1.5, *Real-Time*

Operations Upstream of the Delta, and Section 3.3.3, *Real-Time Operational Decision-Making Process*, which would be used to avoid and minimize any modeled effects.

5.4.2.1.5.4.6 Water Depth

The PA would not directly affect the number of deep holding pools for green sturgeon in the Sacramento River, but could potentially affect the depth and water quality of these pools indirectly through changes in flows in the Sacramento River. As described throughout Section 5.4.2.1.3.4, *Green Sturgeon*, there would be insignificant reductions in flows in the Sacramento River. These results indicate there would be insignificant effects to this PBF. This conclusion does not include consideration of real-time operational management described in Section 3.1.5, *Real-Time Operations Upstream of the Delta*, and Section 3.3.3, *Real-Time Operational Decision-Making Process*, which would be used to avoid and minimize any modeled effects.

5.4.2.1.5.4.7 Sediment Quality

The PA would not directly affect sediment quality for green sturgeon in the Sacramento River, but could potentially affect it indirectly through changes in flows in the Sacramento River. As described throughout Section 5.4.2.1.3.4, *Green Sturgeon*, there would be insignificant reductions in flows in the Sacramento River. These results indicate there would be insignificant effects to this PBF. This conclusion does not include consideration of real-time operational management described in Section 3.1.5, *Real-Time Operations Upstream of the Delta*, and Section 3.3.3, *Real-Time Operational Decision-Making Process*, which would be used to avoid and minimize any modeled effects.

5.4.2.2 American River

5.4.2.2.1 Deconstruct the Action

The PA could cause changes in cold-water pool storage in American Reservoir and operations of Folsom Lake, which could cause changes to instream flows and water temperatures in the American River. Changes in the magnitude, duration, frequency, timing, and rate of change of flows in the American River can all affect habitat characteristics of the life stages of CCV steelhead that are present. For spawning and egg incubation, this analysis evaluates flow-related effects on weighted usable area of spawning habitat, redd dewatering, and redd scour. Changes in flow rates can affect the amount of weighted usable area of spawning habitat, which is characterized by velocity, depth, and substrate type (U.S. Fish and Wildlife Service 2003a, 2005a, 2006). Redd dewatering occurs when flows are reduced when eggs and alevins are still in the gravel after a spawning event (U.S. Fish and Wildlife Service 2006). Redd scour and entombment can occur when flood flows are of a high enough magnitude to mobilize the gravel, although attempts are made to spread flood control releases out when possible.

For fry and juveniles, this analysis evaluates flow-related effects on weighted usable area of rearing habitat and juvenile stranding. Changes in flow rates can affect the amount of weighted usable area of rearing habitat, which is characterized by velocity, depth, and substrate type (U.S. Fish and Wildlife Service 2005b). Juvenile stranding occurs when flows are reduced rapidly and individuals are unable to escape an area that is isolated from the main channel, often leading to mortality (U.S. Fish and Wildlife Service 2006). Appendix 5.D, Section 5.D.2.3, *Rearing Flows Methods*, provides detail on the methods used to evaluate flow effects of the PA.

As cold-water species, salmonids are sensitive to water temperatures. Changes to water temperatures may influence the suitability of habitat for each life stage present in the American River and can lead to sublethal impairments that include reduced growth, inhibited smoltification, altered migration, disease, and ultimately death. Appendix 5.D, Section 5.D.2.1, *Water Temperature Analysis Methods,* provides detail on the methods used to evaluate water temperature effects of the PA.

5.4.2.2.2 Assess Species Exposure

5.4.2.2.2.1 California Central Valley Steelhead

The PA would expose CCV steelhead to changes in flows and water temperatures throughout their presence in the American River. Table 5.4-77 presents the timing of the upstream presence of each life stage for steelhead in the American River.

Table 5.4-77. Temporal Occurrence of California Central Valley Steelhead by Life Stage, American River

Life Stage	J	F	M	A	M	J	J	A	S	O	N	D
Spawning, egg incubation, and alevins[1]	■	■	■	▨	▨							▨
Kelt emigration[2]		▨	▨	▨								
Juvenile rearing[1]	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Smolt emigration[3]	▨	■	■	■	▨	▨						▨
Adult immigration[2]	■	■	▨	░						▨	▨	■
Adult holding[4]										▨	▨	
	■	High				▨	Med			░	Low	
Sources:; [1] Reclamation 2008; [2] Inferred from spawning period; [3] SWRI 2001; Does not include migrant parr; [4] Inferred from adjacent life stages												

CCV steelhead spawn in the American River and eggs and alevins remain in the gravel primarily between December and May, with a peak during January through March. It was assumed that, because of constraints on water temperature and other habitat features, steelhead spawn throughout the reach from Hazel Avenue to Watt Avenue.

After spawning, steelhead adults either die or kelts emigrate back to the ocean between February and April.

Juvenile steelhead rear for 1 to 3 years; therefore, individuals are present in the river throughout the year. It was assumed that, because of constraints on water temperature and other habitat features, steelhead rear throughout the reach from Hazel Avenue to Watt Avenue.

Smolts, not including migrant parr, begin migrating downstream towards the ocean beginning in December and continue until June, with a peak migration period of February through April.

Adult CCV steelhead migrate upstream during October and April with a peak between December and February. Adults hold from October and November.

Changes in hydrologic conditions caused by the PA could affect migratory life stages of CCV steelhead throughout the American River because they are present throughout the river.

5.4.2.2.3 Assess Species Response to the Proposed Action

5.4.2.2.3.1 California Central Valley Steelhead

5.4.2.2.3.1.1 Spawning, Egg Incubation, and Alevins

5.4.2.2.3.1.1.1 Flow-Related Effects

Mean monthly flow rates and reservoir storage volumes were examined for the PA and NAA during the December through May spawning and incubation period for Central Valley Steelhead (Table 5.4-77). Changes in flow can affect the instream area available for spawning and egg incubation, along with the quality of the habitat, and can result in dewatering or scour of the redds. Folsom Reservoir storage volume at the end of September influences flow rates below the dam during some of the steelhead spawning and egg incubation period in some years. Mean Folsom September storage under the PA would be similar (less than 5% difference) to storage under NAA for all water year types, except for 8% lower mean storage during dry water years under the PA (Appendix 5.A, *CALSIM Methods and Results*, Table 5.A.6-5). Mean flow of the American River at Nimbus Dam would generally be similar (less than 5% difference) between the PA and the NAA throughout the steelhead spawning period, with maximum changes including a reduction under the PA of about 10% during March of critical water years and an increase of about 7% in February of below normal years (Appendix 5.A, *CALSIM Methods and Results*, Table 5.A.6-16).

5.4.2.2.3.1.1.1.1 Spawning WUA

Spawning WUA for steelhead in the American River was determined by USFWS (2003b) for several river segments located within about 6 miles of Nimbus Dam, where most steelhead spawning occurs. To evaluate the effects of the PA on steelhead spawning habitat, steelhead spawning WUA was estimated for CALSIM II flows at Nimbus Dam under the NAA and the PA during the December through May spawning period for all of the river segments combined (see Appendix 5.D, Section 5.D.2.2, *Spawning Flows Methods*).

Differences in steelhead spawning WUA under the PA and NAA were examined using exceedance plots of monthly mean WUA during the steelhead spawning period for each water year type and all water year types combined. The exceedance curves with all water years combined (Figure 5.4-252) and those broken out by water year type (Figure 5.4-253 through Figure 5.4-257 are similar between the PA and the NAA.

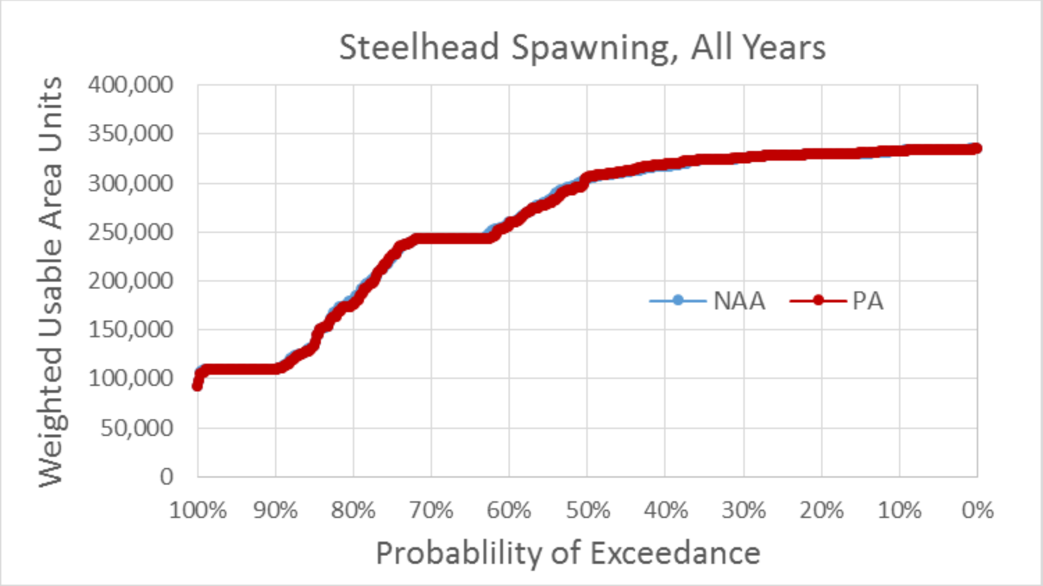

Figure 5.4-252. Exceedance Plot of Central Valley Steelhead Spawning Weighted Usable Area (WUA) for NAA and PA Model Scenarios, All Water Years

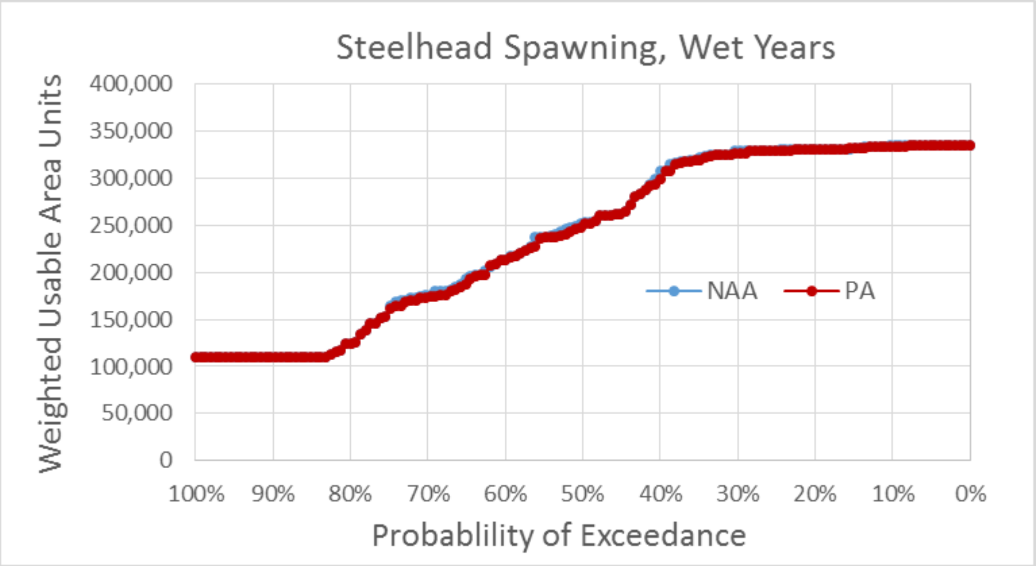

Figure 5.4-253. Exceedance Plot of Central Valley Steelhead Spawning Weighted Usable Area (WUA) for NAA and PA Model Scenarios, Wet Water Years

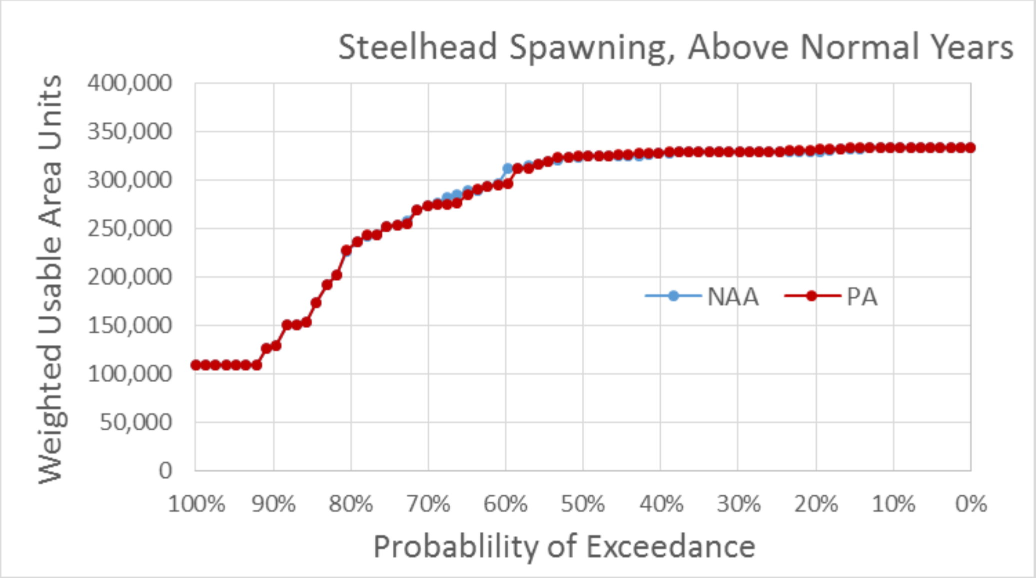

Figure 5.4-254. Exceedance Plot of Central Valley Steelhead Spawning Weighted Usable Area (WUA) for NAA and PA Model Scenarios, Above Normal Water Years

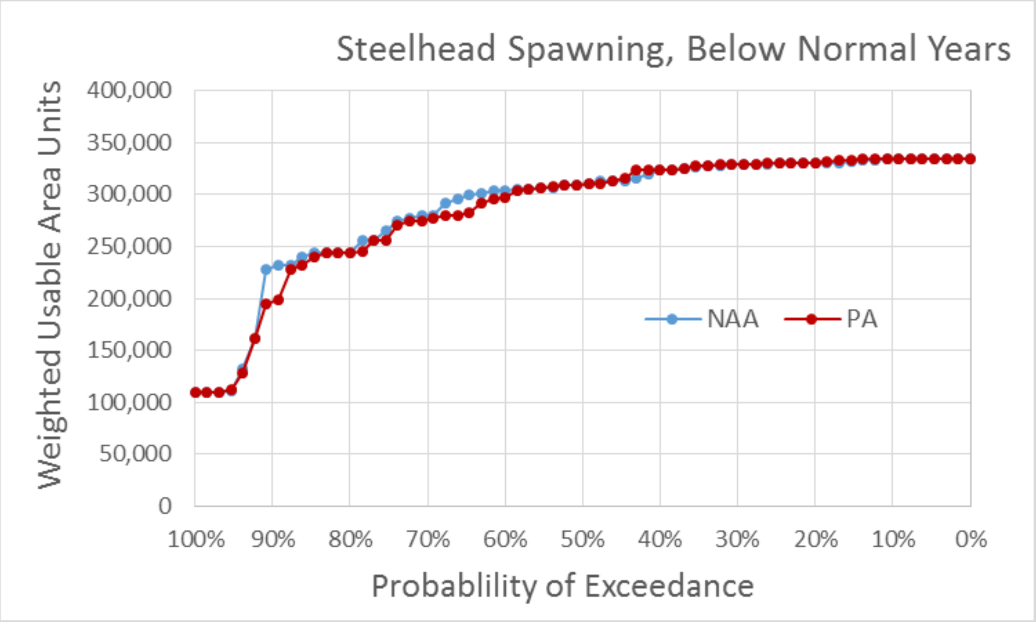

Figure 5.4-255. Exceedance Plot of Central Valley Steelhead Spawning Weighted Usable Area (WUA) for NAA and PA Model Scenarios, Below Normal Water Years

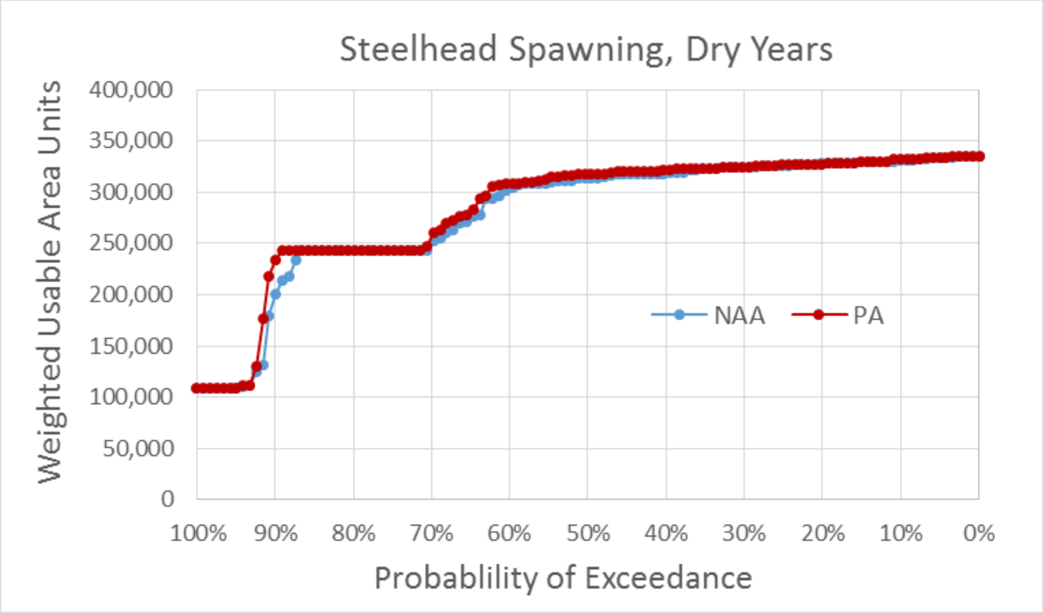

Figure 5.4-256. Exceedance Plot of Central Valley Steelhead Spawning Weighted Usable Area (WUA) for NAA and PA Model Scenarios, Dry Water Years

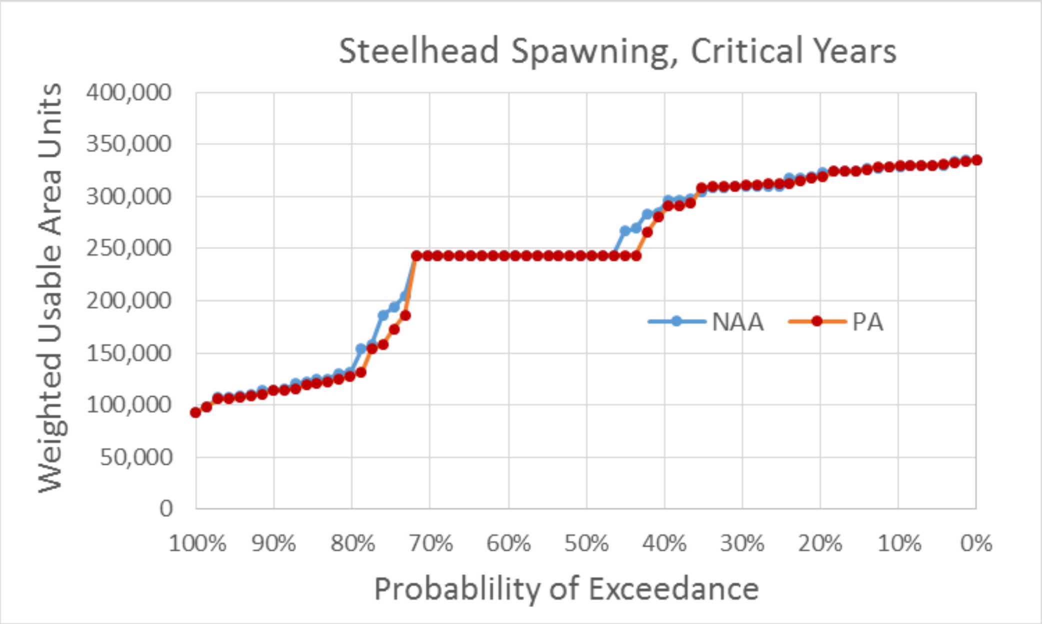

Figure 5.4-257. Exceedance Plot of Central Valley Steelhead Spawning Weighted Usable Area (WUA) for NAA and PA Model Scenarios, Critical Water Years

Differences in the mean spawning WUA for the months of the spawning period under each water year type and all water year types combined also indicate that spawning WUA would be little affected by the PA (less than 5% difference), except for a 5% increase in mean WUA during January of dry years and a 9% reduction in mean WUA during March of critical years (Table 5.4-78). As described above, March of critical years had the largest reduction in mean flow during the steelhead spawning period.

Table 5.4-78. Central Valley Steelhead Spawning Weighted Usable Area (WUA) and Differences (Percent Differences) between Model Scenarios (green indicates PA is at least 5% higher [raw difference] than NAA; red indicates PA is at least 5% lower)

Month	WYT	NAA	PA	PA vs. NAA
December	Wet	289,486	285,118	-4,368 (-2%)
	Above Normal	308,417	307,818	-599 (-0.2%)
	Below Normal	295,864	291,133	-4,731 (-1.6%)
	Dry	268,622	268,556	-66 (0%)
	Critical	243,160	240,549	-2,612 (-1.1%)
	All	281,475	278,962	-2,513 (-1%)
January	Wet	257,434	256,711	-723 (-0.3%)
	Above Normal	286,887	287,327	440 (0.2%)
	Below Normal	254,906	253,543	-1,363 (-0.5%)
	Dry	243,976	256,523	12,547 (5%)
	Critical	226,444	235,865	9,420 (4.2%)
	All	253,947	258,043	4,097 (1.6%)
February	Wet	173,420	172,412	-1,009 (-0.6%)
	Above Normal	215,102	216,238	1,137 (0.5%)
	Below Normal	274,961	268,561	-6,400 (-2%)
	Dry	298,601	299,131	530 (0.2%)
	Critical	248,422	248,480	58 (0%)
	All	235,157	234,297	-861 (-0.4%)
March	Wet	222,098	222,118	19 (0.01%)
	Above Normal	240,540	237,783	-2,758 (-1%)
	Below Normal	300,002	300,512	510 (0.2%)
	Dry	281,382	285,819	4,438 (2%)
	Critical	252,093	228,802	-23,291 (-9%)
	All	254,321	251,633	-2,689 (-1.1%)
April	Wet	251,017	251,001	-16 (-0.01%)
	Above Normal	301,209	301,342	133 (0.04%)
	Below Normal	298,534	295,493	-3,041 (-1%)
	Dry	288,950	290,083	1,133 (0.4%)
	Critical	245,781	246,103	322 (0.1%)
	All	273,834	273,766	-68 (0%)
May	Wet	240,778	240,939	162 (0.07%)
	Above Normal	320,030	320,089	59 (0.02%)
	Below Normal	300,813	300,835	22 (0%)
	Dry	304,879	305,996	1117 (0.4%)
	Critical	250,842	248,455	-2387 (-1%)
	All	278,503	278,490	-13 (0%)

5.4.2.2.3.1.1.1.2 Redd scour

The probability of flows in the American River occurring under the PA and the NAA that would be high enough to mobilize sediments and scour Central Valley steelhead redds was estimated from CALSIM II estimates of mean monthly flows, using a relationship determined from the historical record between actual mean monthly and maximum daily flow (Appendix 5.D, Section 5.D.2.2, *Spawning Flows Methods*). The actual monthly and daily flow data used in the analysis are from gage records at Hazel Avenue, and the CALSIM II estimates used to compare probabilities of redd scour for the PA and the NAA are for the Nimbus Dam location. As discussed in Appendix 5.D, Section 5.D.2.2, *Spawning Flows Methods*, 40,000 cfs is treated as the minimum daily flow at which redd scour occurs in the American River. The analysis of the Hazel Avenue gage data shows that for months with a mean monthly flow of at least 19,350 cfs, the maximum daily flow in that month is always at least 40,000 cfs. Therefore, redd scour probabilities for the PA and the NAA were evaluated by comparing frequencies of CALSIM II flows greater than 19,350 cfs at Nimbus during the steelhead December through May spawning and incubation period. Further information on the redd scour analysis methods is provided in Appendix 5.D, Section 5.D.2.2, *Spawning Flows Methods*.

Of the months in the CALSIM II record during the spawning and incubation period of Central Valley steelhead in the American River (December through May), fewer than 2% would have flows of more than 19,350 cfs at Hazel Avenue under both the PA and the NAA (Table 5.4-79).

Table 5.4-79. Water Years and Months with Mean Flow > 19,350 cfs at Hazel Avenue during the Central Valley Steelhead Spawning and Incubation Period in the American River

			Flow (cfs)	
Water Year	**Month**	**WYT**	**NAA**	**PA**
1964	December	Dry	21,494	21,414
1968	January	Below Normal	23,260	23,929
1969	January	Wet	25,092	25,092
1983	March	Wet	19,927	19,927
1983	December	Wet	22,909	22,909
1986	February	Wet	37,305	37,305
1995	March	Wet	19,730	19,721
1996	January	Wet	38,218	38,218

5.4.2.2.3.1.1.1.3 Redd dewatering

The percentage of steelhead redds dewatered by reductions in American River flow was estimated from CALSIM II estimates of monthly mean flows during the 3 months following each of the months that steelhead spawn (Appendix 5.D, Section 5.D.2.2, *Spawning Flows Methods,* Table 5.D-54) because the period of egg incubation is assumed to last about three months after the eggs are spawned. No model for predicting percentages of redds dewatered, such as that developed for the Sacramento River (U.S. Fish and Wildlife Service 2006), has been developed for the American River. Therefore, the maximum reduction in American River flow for the 3 months following each of the months during which steelhead spawn was used as a proxy for percent of redds dewatered. CALSIM II flows at Nimbus were used for this analysis. Larger maximum reductions are assumed to increase the percent of redds dewatered and, therefore, to have a negative effect on steelhead. Further information on the redd dewatering analysis methods is provided in Appendix 5.D, Section 5.D.2.2, *Spawning Flows Methods*.

Differences in maximum flow reductions under the PA and NAA were examined using exceedance plots of mean monthly maximum flow reductions, expressed as a percentage of the spawning flows, for the months that American River steelhead spawn (December through February) (Figure 5.4-258 through Figure 5.4-263). The exceedance curves for all water year types combined (Figure 5.4-258) and those for wet, above normal, below normal, and dry water years (Figure 5.4-259 through Figure 5.4-262) indicate that the PA would generally have slightly greater flow reductions than the NAA. The exceedance curve for critical years appears to indicate a pronounced increase in flow reductions for the PA. However, further inspection reveals that the increased reductions result from differences in only three months out of the 36 critical water year months of the CCV steelhead spawning period in the American River. Moreover, all three of these months are in the same water year (1933), and the increased flow reductions under the PA for all of them result from a flow in March 1933 that is more than 1000 cfs lower under the PA than under the NAA (1,445 cfs under the NAA and 392 cfs under the PA). The March 1933 reduced flow under the PA appears to be due to CALSIM II attempting to balance storage levels among the CVP reservoirs, resulting in higher releases from Keswick Dam and lower releases from Folsom for this month.

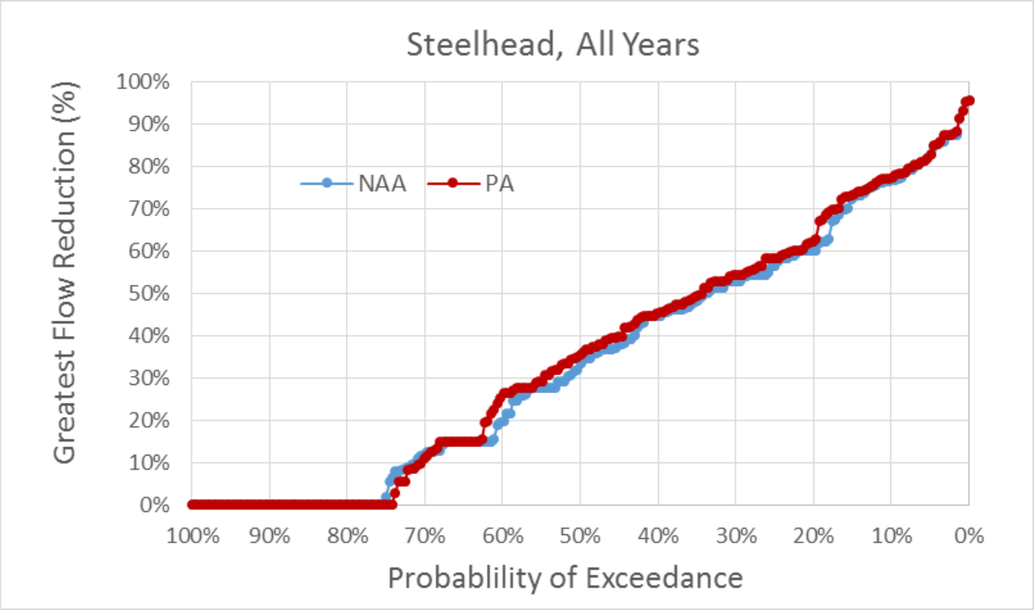

Figure 5.4-258. Exceedance Plot of Maximum Flow Reductions (%) for 3-Month Period after Central Valley Steelhead Spawning for NAA and PA Model Scenarios, All Water Years

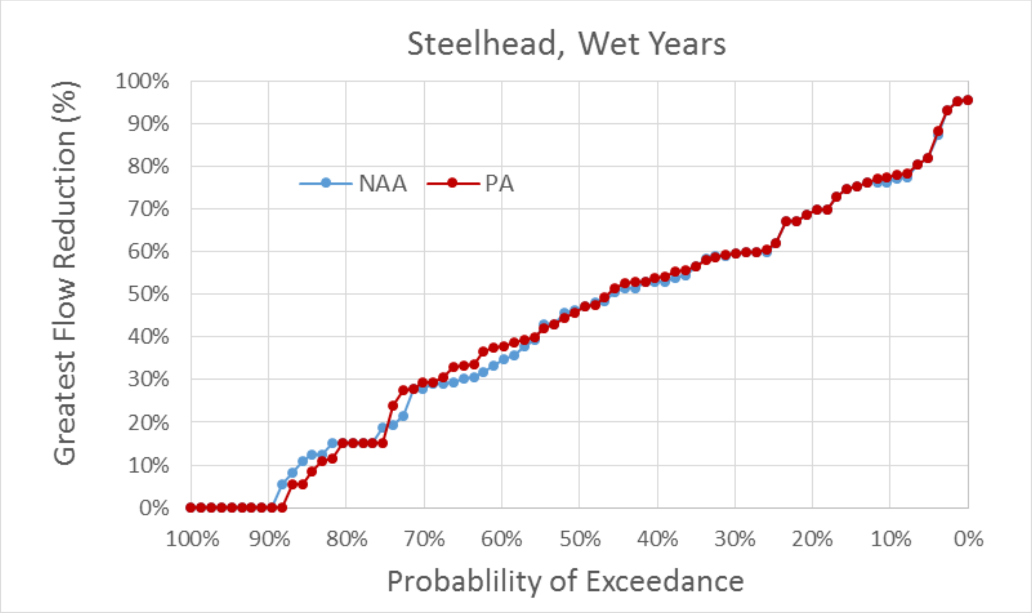

Figure 5.4-259. Exceedance Plot of Maximum Flow Reductions (%) for 3-Month Period after Central Valley Steelhead Spawning for NAA and PA Model Scenarios, Wet Water Years

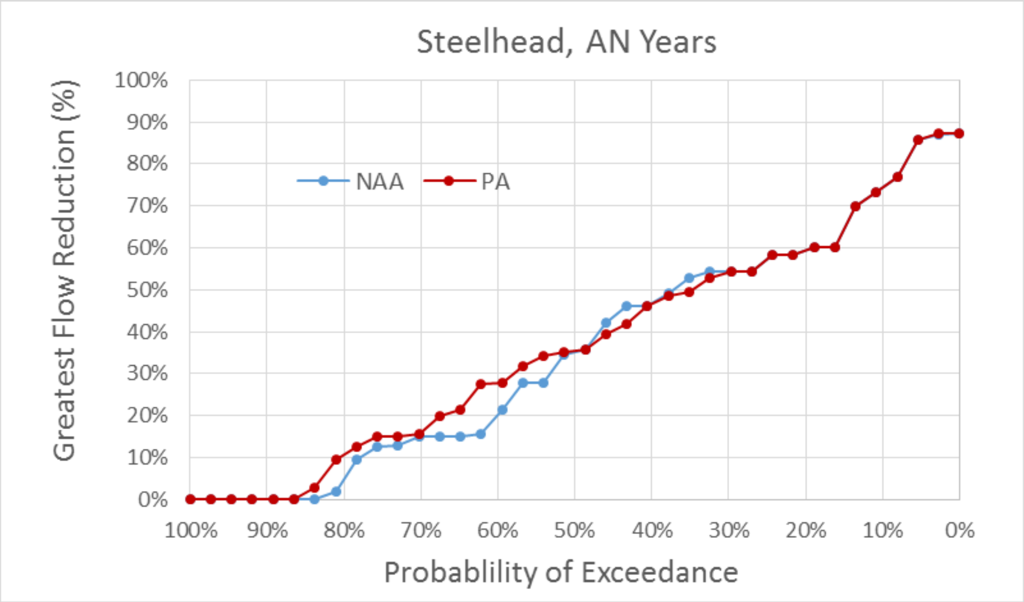

Figure 5.4-260. Exceedance Plot of Maximum Flow Reductions (%) for 3-Month Period after Central Valley Steelhead Spawning for NAA and PA Model Scenarios, Above Normal Water Years

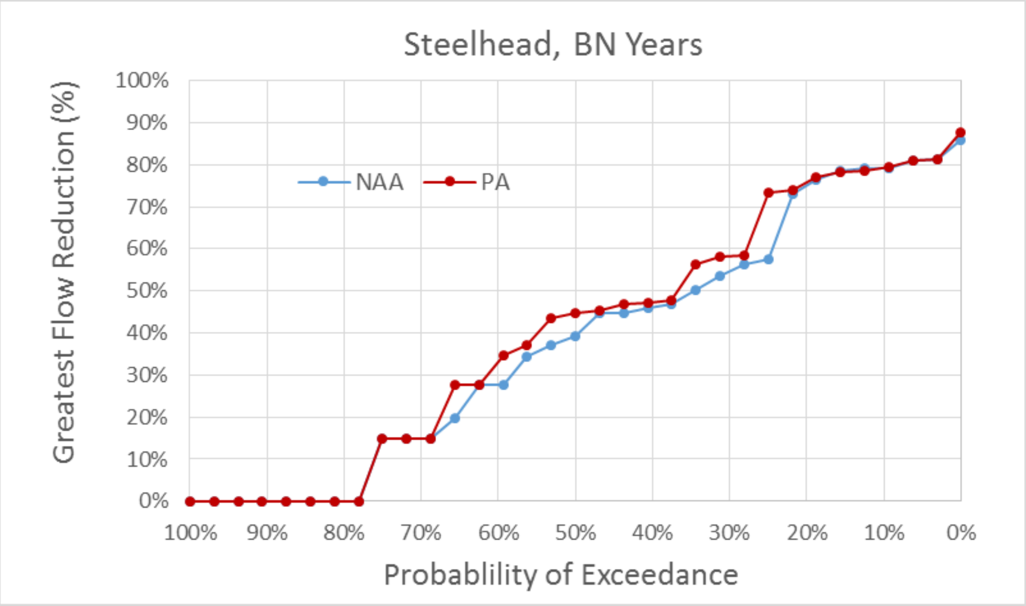

Figure 5.4-261. Exceedance Plot of Maximum Flow Reductions (%) for 3-Month Period after Central Valley Steelhead Spawning for NAA and PA Model Scenarios, Below Normal Water Years

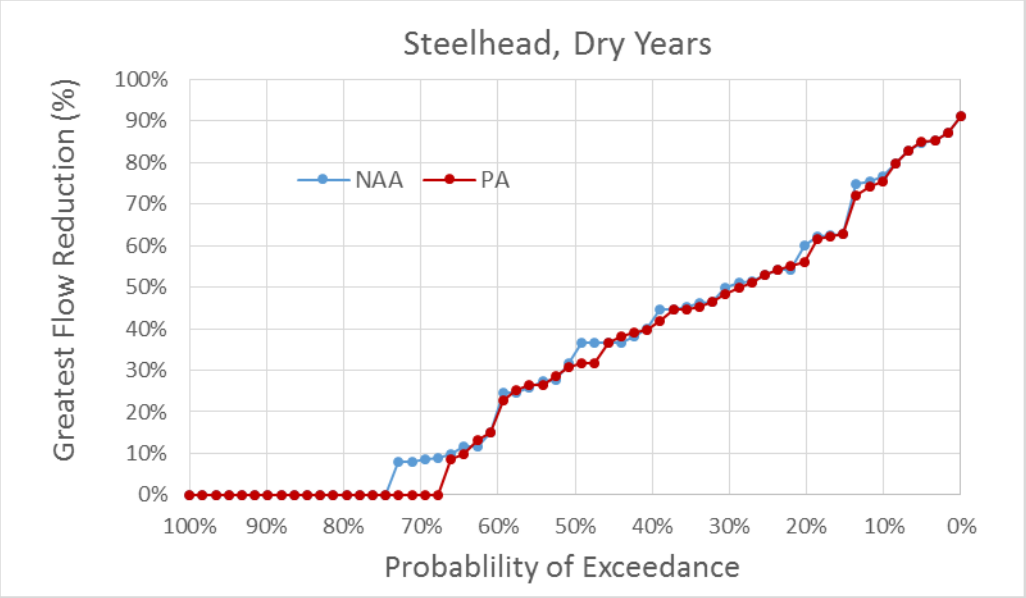

Figure 5.4-262. Exceedance Plot of Maximum Flow Reductions for 3-Month Period after Central Valley Steelhead Spawning for NAA and PA Model Scenarios, Dry Water Years

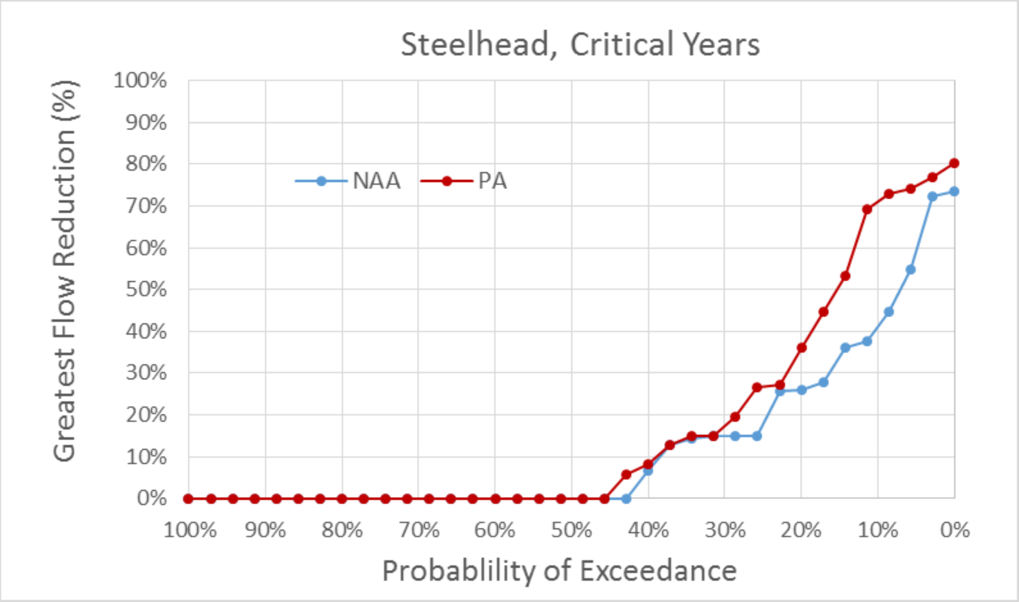

Figure 5.4-263. Exceedance Plot of Maximum Flow Reductions for 3-Month Period after Central Valley Steelhead Spawning for NAA and PA Model Scenarios, Critical Water Years

Differences in the mean maximum flow reduction, expressed as a percentage of the spawning flow, for each month of spawning under each water year type and all water year types combined indicate that steelhead redd dewatering would generally be little affected by the PA (less than 5% raw difference), except for a 5% increase in the maximum flow reduction for January of critical years and 6% and 7% increases for February of below normal and critical years, respectively (Table 5.4-80). As previously noted, increases in flow reduction are assumed to increase redd dewatering, negatively affecting steelhead, but the critical year flow reductions may largely be the result of the March 1933 flow difference discussed in the previous paragraph.

Table 5.4-80. Maximum Flow Reductions (cfs) for 3-Month Period after Central Valley Steelhead Spawning, and Differences in the Maximums (Percent Differences) between Model Scenarios (green indicates PA is at least 5% lower [raw difference] than NAA; red indicates PA is at least 5% higher)[1]

		Mean Greatest Flow Reduction, as Percent		Raw Difference	Relative (Percent) Difference
Month	**WYT**	**NAA**	**PA**	**PA vs. NAA**	**PA vs. NAA**
December	Wet	33.3%	33.5%	0.2%	0.7%
	Above Normal	29.1%	29.0%	-0.1%	-0.2%
	Below Normal	24.3%	24.3%	0.0%	-0.2%
	Dry	35.8%	32.9%	-2.9%	-8.2%
	Critical	15.8%	17.1%	1.3%	8.2%
	All	29.5%	29.0%	-0.5%	-1.6%
January	Wet	42.4%	42.3%	0.0%	-0.1%
	Above Normal	27.0%	26.9%	-0.2%	-0.6%
	Below Normal	40.2%	40.3%	0.1%	0.2%
	Dry	35.8%	36.1%	0.2%	0.6%

		Mean Greatest Flow Reduction, as Percent		**Raw Difference**	**Relative (Percent) Difference**
Month	**WYT**	**NAA**	**PA**	**PA vs. NAA**	**PA vs. NAA**
	Critical	8.1%	13.2%	5.0%	61.8%
	All	33.0%	33.8%	0.8%	2.3%
February	Wet	53.5%	54.3%	0.8%	1.4%
	Above Normal	50.7%	54.6%	3.9%	7.7%
	Below Normal	50.5%	56.5%	6.0%	11.9%
	Dry	28.1%	27.7%	-0.4%	-1.3%
	Critical	15.8%	22.8%	7.0%	44.5%
	All	41.0%	43.6%	2.6%	6.4%

[1] Increased flow reduction is assumed to increase redd dewatering, negatively affecting steelhead.

5.4.2.2.3.1.1.2 Water Temperature-Related Effects

Modeled mean monthly water temperatures during the December through May spawning and egg incubation/alevins period for steelhead in the American River reach between Hazel Avenue and Watt Avenue (Table 5.4-77) are presented in Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results*, Table 5.C.7-14, Table 5.C.7-15. Overall, the PA would change mean water temperatures very little (less than 1°F, or less than 1%) throughout the reach in all months and water year types of the period. The largest increase in mean monthly water temperatures under the PA relative to NAA would be 0.2°F, or 0.4%, and would occur at Watt Avenue during critical years in March. This greatest increase would occur during the peak spawning and egg incubation/alevins period (January through March).

Exceedance plots of monthly mean water temperatures were examined during each month throughout the spawning and incubation period (Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results*, Figure 5.C.7.14-7, Figure 5.C.7.15-7). The values for the PA in these exceedance plots generally match those of the NAA. Further examination of critical water years during March at Watt Avenue, where the largest increase in mean monthly water temperature was seen, reveals that the curves were similar overall and that that the difference of 0.2°F in mean monthly temperatures between NAA and PA would cause no substantial differences between curves for the NAA and PA in the exceedance plot (Figure 5.4-264).

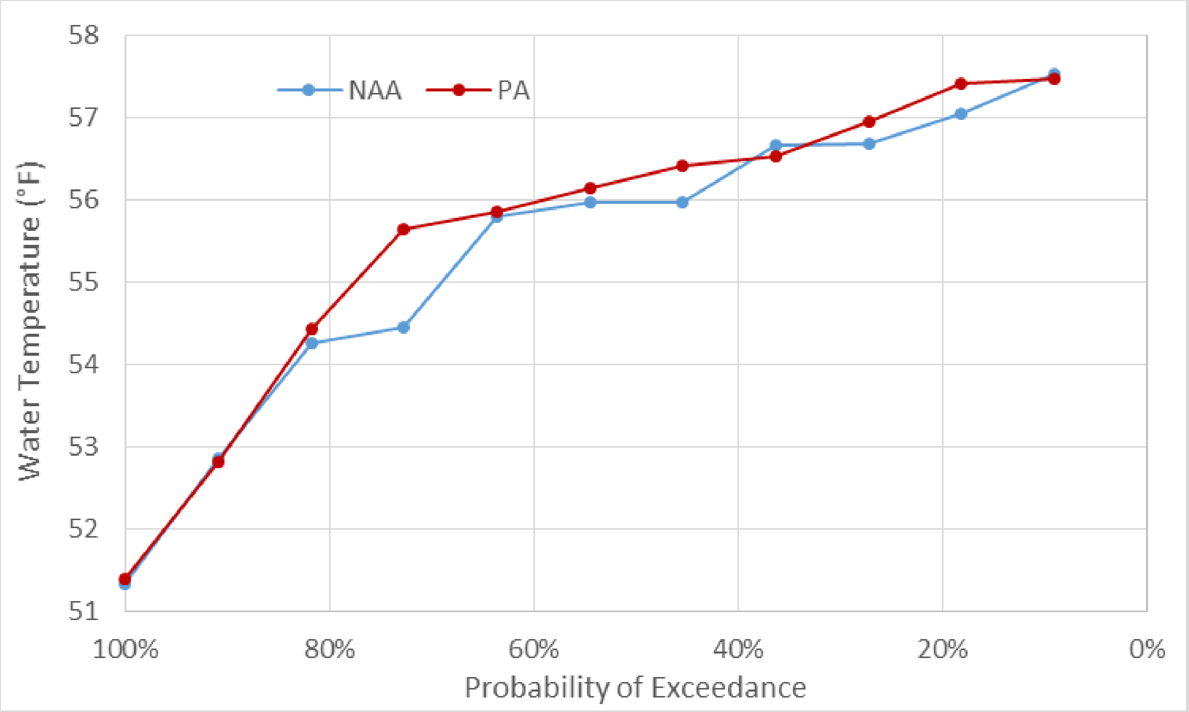

Figure 5.4-264. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the American River at Watt Avenue in March of Critical Water Years

The exceedance of temperature thresholds in the American River presented in Appendix 5.D, Section 5.D.2.1, *Water Temperature Analysis Methods*, Table 5.D-50 by modeled daily water temperatures were evaluated based on thresholds identified from the literature. For steelhead spawning and egg/alevin incubation, the threshold used was 53°F (McCullough et al. 2001).

Results of the water temperature thresholds analysis are presented in Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-161 through Table 5.D-162. At both Hazel Avenue and Watt Avenue, there would be no months or water year types in which there would be either 5% more days under the PA compared to the NAA on which temperatures would exceed the threshold or a more-than-0.5°F difference in the magnitude of average daily exceedance. Therefore, it was concluded that there would be no biologically meaningful water temperature-related effects on CCV steelhead spawning, egg incubation, and alevins.

5.4.2.2.3.1.2 Kelt Emigration

5.4.2.2.3.1.2.1 Flow-Related Effects

Mean monthly flows were evaluated in the American River at Nimbus Dam and the confluence with the Sacramento River during the February through May emigration period for CCV steelhead kelts (Table 5.4-77). Changes in flow potentially affect conditions for emigrating kelts, including bioenergetic cost, water quality, crowding, and passage conditions, but the quantitative relationship between flow and downstream migration is poorly understood. As described in Appendix 5.D, Section 5.D.2.4, *Migration Flows Methods*, on balance, except under very high flows, the benefits of increased flow generally outweigh the costs and, therefore, it is assumed for the purposes of this effects analysis that increased flow would improve conditions for emigration of CCV steelhead kelts. It is known that migration cues for anadromous fish species are often the result of natural pulse flows, which will not be affected by the PA (Milner et al. 2012; del Rosario et al. 2013). It should be noted, however, that natural pulse flows are less important for anadromous fish in the American River than in the Sacramento River because there are no significant tributaries in the lower American River, and except at very high flows, the flow is heavily controlled by Folsom Dam.

Folsom storage volume at the end of September may influence flows in the American River during kelt emigration period in some years. Mean Folsom September storage under the PA would be similar (less than 5% difference) to storage under NAA for all water year types, except for 8% lower mean storage during dry water years under the PA (Appendix 5.A, *CALSIM Methods and Results*, Table 5.A.6-5).

Differences in mean flow between the PA and the NAA would be consistently similar at the Nimbus and confluence locations (Appendix 5.A, *CALSIM Methods and Results*, Table 5.A.6-16, Table 5.A.6-17). Mean flow under the PA would be similar to (less than 5% difference) flow under the NAA during most months and water year types of the CCV steelhead kelt emigration period. The only notable differences (greater than 5% difference) would occur in February of below normal water years and March and April of critical years. Mean flow under the PA would be 7% higher during February, 10% to 11% lower during March, and 7% to 8% lower during April.

The CALSIM modeling results given here indicate that the PA would have little effect on flow during the kelt migration period.

5.4.2.2.3.1.2.2 Water Temperature-Related Effects

Modeled mean monthly water temperatures during the February through May kelt emigration period for steelhead in the American River from Hazel Avenue to Watt Avenue (Table 5.4-77) are presented in Appendix 5.C, *Upstream Water Temperature Methods and Results,* Section 5.C.7, *Upstream Water Temperature Modeling Results,* Table 5.C.7-14, Table 5.C.7-15. Overall, the PA would change mean water temperatures very little (predominantly less than 1°F, or less than 1%) throughout the reach in all months and water year types of the period. The largest increase in mean monthly water temperatures under the PA relative to NAA would be 0.2°F, or 0.4%, and would occur at Watt Avenue during critical years in March.

Exceedance plots of mean monthly water temperatures were examined during each month and water year type throughout the kelt migration period (Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results,* Figure 5.C.7.14-7, Figure 5.C.7.15-7). The values for the PA in these exceedance plots generally match those of the NAA. Further examination of critical water years during March at Watt Avenue, where the largest increase in mean monthly water temperature was seen, reveals that the curves were similar overall and that that the difference of 0.2°F in mean monthly temperatures between NAA and PA would cause no substantial differences between curves for the NAA and PA in the exceedance plot (Figure 5.4-265).

There have been no known studies evaluating specific temperature effects on emigrating kelts. Therefore, adult immigration thresholds of 68°F 7DADM and 70°F were used for kelt migration, with an assumption that kelts migrating downstream would be affected by water temperatures similarly to adults migrating upstream (Appendix 5.D, Section 5.D.2.1, *Water Temperature Analysis Methods*, Table 5.D-50). The 68°F 7DADM threshold was taken from USEPA (2003) and the 70°F threshold represents the average of the studies cited in Richter and Kolmes (2005) for the upper end of the suboptimal temperature range. The 7DADM threshold was converted to function with daily model outputs for each month separately (Appendix 5.D, Section 5.D.2.1, *Water Temperature Analysis Methods*, Table 5.D-52).

Results of the water temperature thresholds analysis are presented in Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-163 through Table 5.D-166. At both Hazel Avenue and Watt Avenue, there would be no months or water year types with either a more-than-5% increase in the percent of total days exceeding the 68°F 7DADM or 70°F threshold under the PA relative to the NAA, or a more-than-0.5°F difference in the magnitude of average daily exceedance. Therefore, it was concluded that there would be no biologically meaningful water temperature-related effects on CCV steelhead kelt immigration.

5.4.2.2.3.1.3 Juvenile Rearing

5.4.2.2.3.1.3.1 Flow-Related Effects

As discussed above in the winter-run fry and juvenile rearing section and in Appendix 5.D, Section 5.D.2.3, *Rearing Flows Methods*, the stranding of juvenile salmonids is not evaluated in the effects analysis due to limitations of CALSIM modeling. However, as described in Appendix 5.D, Section 5.D.2.3, *Rearing Flows Methods*, current operations of the American River include ramping rate restrictions, designed to minimize juvenile stranding, that limit the rate at which river flow can be changed. These restrictions would be kept in place for the PA.

Mean monthly flow rates and reservoir storage volumes were examined for the PA and NAA in the American River at the Nimbus Dam and confluence with the Sacramento River locations during the CCV steelhead year-round juvenile rearing period (Table 5.4-77). Changes in flow can affect the instream area available for rearing, along with habitat quality, and stranding of juveniles, especially in side-channel habitats.

Folsom Reservoir storage volume at the end of May and the end of September influences flow rates in the Lower American River. Mean Folsom May storage under the PA would be similar (less than 5% difference) to storage under NAA for all water year types (Appendix 5.A, *CALSIM Methods and Results*, Table 5.A.6-5). Mean Folsom September storage under the PA would also be similar to (less than 5% difference) storage under NAA for all water year types, except for 8% lower mean storage during dry water years under the PA.

Mean flow due to the PA at the Nimbus Dam and confluence locations would generally be similar to (less than 5% difference) flow under the NAA during winter and spring months but would often be different than flow under the NAA during the summer and fall, with exceptions (Appendix 5.A, *CALSIM Methods and Results*, Table 5.A-6-16, Table 5.A.6-17). Differences in flow between the scenarios would be predominantly similar between Nimbus Dam and the confluence with the Sacramento River so all results for Nimbus Dam are similar to results for the confluence presented here. Flows under the PA during December through February would be similar to (less than 5% difference) those under the NAA for all months and water year types, except for 5% higher flows in December of wet and below normal years and 7% higher flow in February of below normal years. Flows during March through May would be similar to (less than 5% difference) those under the NAA for all months and water year types, except for March and April of critical water years, when flows would be up to 11% lower under the PA. During June through November, flow under the PA would be as much 32% higher than flow under the NAA, and as much as 19% lower. The flows would differ by more than 5% for at least three of the five water year types, including all of the critical water years, in each of these months. The differences in the critical water years would range from 19% lower flow to 15% higher flow under the PA. In June, flow under the PA would range from 5% to 32% higher during wet, above normal, below normal and dry years, and would be 12% lower in critical years. Flow under the PA would be up to 11% higher and 19% lower than flow under the NAA during July, up to 23% higher and 10% lower during August, up to 19% lower during September, and up to 15% higher and 13% lower in October. In November, flow under the PA would be more than 5% lower than flow under the NAA in all water year types except below normal water years, ranging up to 14% lower in wet years.

As described in Appendix 5.D, Section 5.D.2.3, *Rearing Flows Methods*, no rearing habitat WUA curves were available for CCV steelhead or any other salmonid in the American River and, therefore, effects of flow on rearing habitat for steelhead in the American River were evaluated qualitatively, using the flow predictions described above for the year-round steelhead rearing period. Although, as evidenced by the rearing habitat WUA curves for Sacramento River Chinook salmon provided in Appendix 5.D, Section 5.D.2.3, *Rearing Flows Methods,* effects of river flow on rearing habitat are generally complex, it is assumed for the purposes of this effects analysis that increased flow would increase the availability and quality of rearing habitat and thereby benefit steelhead. As such, effects of the PA on CCV steelhead rearing habitat are expected to be positive during June for all water year types except critical water years, when the effects are expected to be negative. Effects during the months of September and November would also be negative for most water year types. During July, August and October, both positive and negative effects are predicted, depending on the water year type (Appendix 5.A, *CALSIM Methods and Results*). It should be noted that the assumed monotonically increasing relationship between flow and CCV steelhead rearing habitat, on which the above conclusions are based, has low certainty. The CALSIM modeling results given here indicate that the PA would reduce flow in several months and water year types and thereby potentially negatively affect juvenile rearing habitat for CCV steelhead. Further discussion regarding flow-related effects during the June through November period is provided in Section 5.4.2.3, *Summary of Upstream Effects*.

5.4.2.2.3.1.3.2 Water Temperature-Related Effects

Modeled mean monthly water temperatures during the year-round juvenile rearing period for steelhead in the American River between Hazel Avenue and Watt Avenue (Table 5.4-77) are presented in Appendix 5.C, *Upstream Water Temperature Methods and Results,* Section 5.C.7, *Upstream Water Temperature Modeling Results,* Table 5.C.7-14, Table 5.C.7-15. Overall, the PA would change mean water temperatures very little (predominantly less than 1°F, or approximately 1%) throughout the juvenile rearing reach in all months and water year types. The largest increase in mean monthly water temperatures under the PA relative to NAA would be 1.0°F, or up to 1.4%, and would occur at Watt Avenue in critical water years during August.

Exceedance plots of mean monthly water temperatures were examined during each month and water year type throughout the juvenile rearing period (Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results*, Figure 5.C.7.14-7, Figure 5.C.7.15-7). The values for the PA in these exceedance plots generally match those of the NAA. Further examination of critical water years during August at Watt Avenue, where the largest increase in mean monthly water temperature was seen, reveals that the colder end of the curves overlap substantially, but the higher end of the PA curves up to approximately 4°F higher for individual months depending on the exceedance percentile (Figure 5.4-265). The potential biological impacts of these differences are described below under the temperature thresholds analysis.

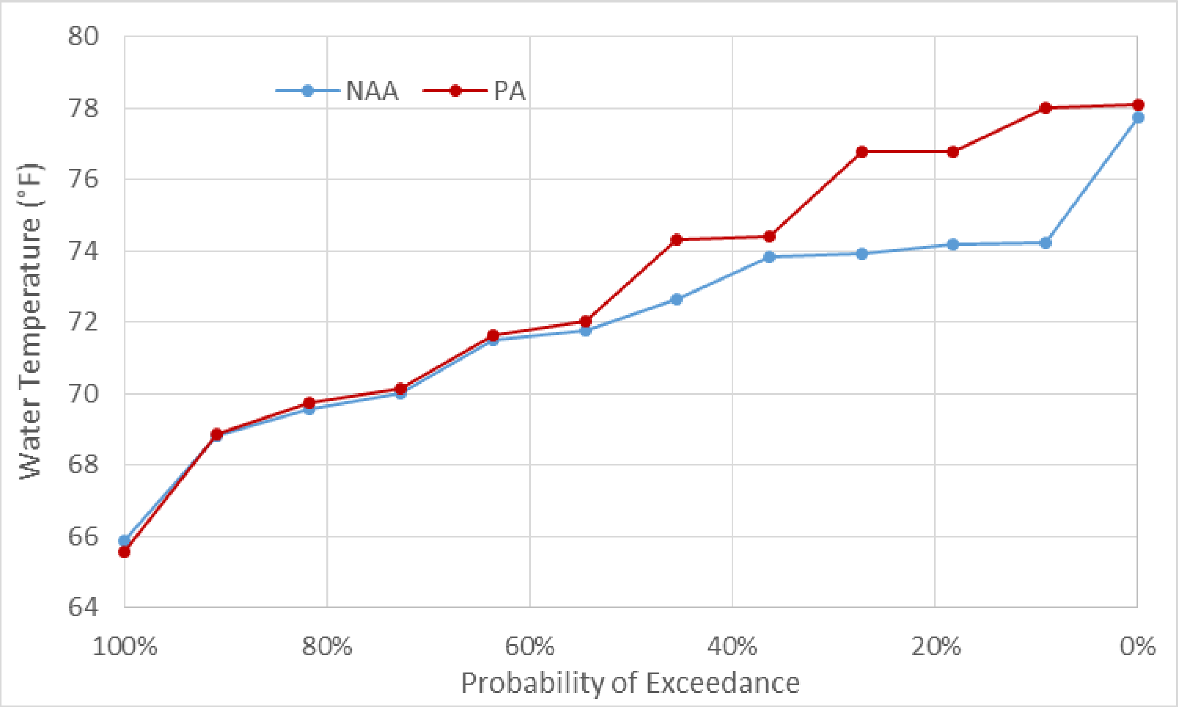

Figure 5.4-265. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the American River at Watt Avenue in August of Critical Water Years

Thresholds water temperatures of 63°F and 69°F (7DADM) were used to evaluate water temperature threshold exceedances during the steelhead juvenile rearing life stage in the American River between Hazel Avenue and Watt Avenue (Appendix 5.D, Section 5.D.2.1, *Water Temperature Analysis Methods*, Table 5.D-50). The 63°F threshold was derived by taking the intermediate value of the ranges of optimal growth from several studies (Grabowski 1973; Wurtsbaugh and Davis 1977; Hokanson et al 1977; Myrick and Cech 2005; and Beakes et al. 2014). The 69°F 7DADM was used based on Sullivan (2000) and was converted to function with daily model outputs for each month separately (Appendix 5.D, Section 5.D.2.1, *Water Temperature Analysis Methods*, Table 5.D-52).

Results of the water temperature thresholds analysis are presented in Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Tables 5.D-167 through 5.D-170. At Hazel Avenue, there would be two instances in which there would be more than 5% more days under the PA compared to the NAA on which temperatures would exceed the 63°F threshold: June (7.7% higher) and October (8.6% higher) of above normal water years. In neither instance would the magnitude of average daily exceedance under the PA be more than 0.5°F greater than that under the NAA. For the 69°F 7DADM threshold, there would be three instances in which there would be more than 5% more days under the PA compared to the NAA on which temperatures would exceed the threshold: July of below normal water years (5.6% higher), August of critical water years (21.0% higher), and September of dry years (5.3% higher). In July of below normal years, the average daily exceedance above the threshold under the PA would also be 1.0°F higher than that under the NAA. Furthermore, in August of critical water years, the average daily exceedance above the threshold under the PA would also be 0.7°F higher than that under the NAA. These two instances could represent biologically meaningful negative effects on rearing juvenile steelhead, although see Section 5.4.2.3, *Summary of Upstream Effects*, for a description of CALSIM limitations and real-time operations and decision making processes. In September of dry years, there would be no concurrent increase of more than 0.5°F in the magnitude of average daily exceedance under the PA relative to the NAA.

At Watt Avenue, there would be no instances in which there would be more than 5% more days under the PA compared to the NAA on which temperatures would exceed the 63°F threshold (Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-169). There would be one water year type within 1 month in which the magnitude of average daily exceedance under the PA would be more than 0.5°F greater than that under the NAA: August of critical water years (1.0°F increase). There would be no instances in which there would be more than 5% more days under the PA compared to the NAA on which temperatures would exceed the 69°F threshold (Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-170), and the magnitude of average daily exceedance would be less than 0.5°F for this instance. These results indicate that there would be no biologically meaningful effect at Watt Avenue on juvenile rearing.

An additional threshold analysis was conducted to determine how the PA would affect smoltification. A 54°F threshold was used, based on an average of temperatures from Zaugg and Wagner (1973), Adams et al (1975), Zaugg (1981), and Hoar (1988), and above which smoltification can be impaired. This analysis was conducted for January through March in the reach from Hazel Avenue to Watt Avenue.

Results of the water temperature thresholds analysis for steelhead smoltification are presented in Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results,* Tables 5.D-173 and 5.D-174. At Hazel Avenue and Watt Avenue, there would be no months or water year types with either a more-than-5% increase in the percent of total days exceeding the threshold under the PA relative to the NAA, or a more-than-0.5°F difference in the magnitude of average daily exceedance. Therefore, it was concluded that there would be no biologically meaningful water temperature-related effects on CCV steelhead smoltification.

5.4.2.2.3.1.4 Smolt Emigration

5.4.2.2.3.1.4.1 Flow-Related Effects

Mean monthly flows were evaluated in the American River at Nimbus Dam and the confluence with the Sacramento River during the December through June emigration period, with peak migration from February through April (Table 5.4-77). Changes in flow potentially affect emigration of smolts, including the timing and rate of emigration, as well as conditions for feeding, protective cover, resting, temperature, turbidity, and other habitat factors. Crowding and stranding, especially in side-channel habitats, can also be affected (Moyle 2002; Quinn 2005; Williams 2006). While there is uncertainty in the mechanism that relates greater survival rate with greater flow, it is well-documented that juvenile salmonids migrate on flow pulses and benefit from higher flows (Milner et al. 2012; del Rosario et al. 2013). Therefore, as described in Appendix 5.D, Section 5.D.2.4, *Migration Flows Methods*, it is assumed for the purposes of this effects analysis that increased flow would improve conditions for emigration of CCV steelhead smolts. It should be noted that natural pulse flows are less important for anadromous fish in the American River than in the Sacramento River because there are no significant tributaries in the lower American River, and except at very high flows, the flow is heavily controlled by Folsom Dam.

Folsom storage volume at the end of September potentially influences flows in the American River during the first part of the smolt emigration period, and Folsom storage at the end of May influences flows in June. Mean Folsom September storage under the PA would be similar (less than 5% difference) to storage under NAA for all water year types, except for 8% lower mean storage during dry water years under the PA. Mean Folsom May storage under the PA would also be similar (less than 5% difference) to storage under NAA for all water year types (Appendix 5.A, *CALSIM Methods and Results*, Table 5.A-6-5).

Differences in mean flow between the PA and the NAA would be consistently similar at the Nimbus and confluence locations (Appendix 5.A, *CALSIM Methods and Results*, Table 5.A-6-16, Table 5.A.6-17). In general, mean flow under the PA would be similar to (less than 5% difference) or greater than flow under the NAA during most months and water year types of the CCV steelhead smolt emigration period. The largest changes in flow between the PA and the NAA would occur during June. Mean flow under the PA would be 5% greater during June of wet years and would range from 22% to 32% greater than flow under the NAA in above normal, below normal, and dry years. During June of critical years, flow would be 11% or 12% lower under the PA. During December, mean flows would be similar (less than 5% difference) between the PA and the NAA, except for 5% to 6% greater flow under the PA for wet and below normal years. During February of below normal years, flow under PA would be 7% higher. During March and April of critical water years, flow would be 7% to 11% lower under the PA than it would be under the NAA. The peak of the smolt emigration period occurs from February through April, so the March and April average flow reductions during critical water years would potentially have a negative effect on emigrating smolts.

5.4.2.2.3.1.4.2 Water Temperature-Related Effects

Modeled mean monthly water temperatures in the American River in the reach from Hazel Avenue to Watt Avenue during the December through June smolt emigration period, with a peak during January through March (Table 5.4-77) are presented in Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results*, Table 5.C.7-14, Table 5.C.7-15. Overall, the PA would change mean water temperatures very little (less than 1°F, or approximately 1%) throughout the American River in the reach from Hazel Avenue to Watt Avenue in all months and water year types in the period. The largest increase in mean monthly water temperatures under the PA relative to NAA would be 0.4°F (0.5 to 0.6%), and would occur at Hazel Avenue during June of above normal water years and at Watt Avenue in June of critical years. These largest increases would be outside the peak period of presence.

Exceedance plots of mean monthly water temperatures were examined during each month and water year type throughout the smolt emigration period (Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results*, Figure 5.C.7.14-7, Figure 5.C.7.15-7). The curves for PA generally match those of the NAA. Further examination of June of above normal water years at Hazel Avenue (Figure 5.4-266) and in June of critical years at Watt Avenue (Figure 5.4-267), where the largest increases in mean monthly water temperatures were seen, reveals that the curves were mostly similar overall with the exception of a few differences of more than 1°F in the middle of the range.

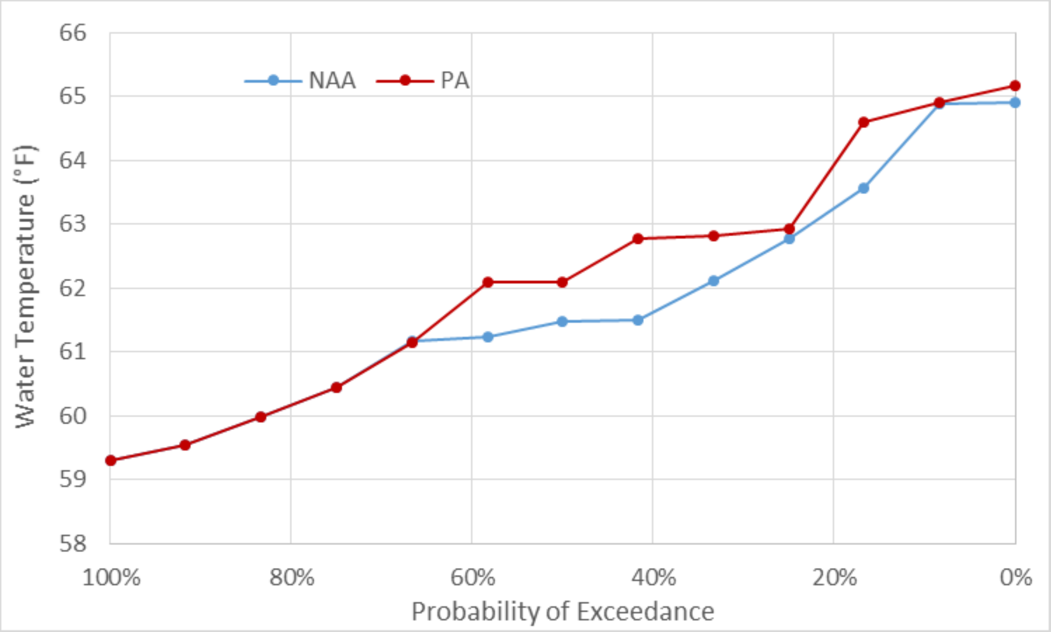

Figure 5.4-266. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the American River at Hazel Avenue in June of Above Normal Water Years

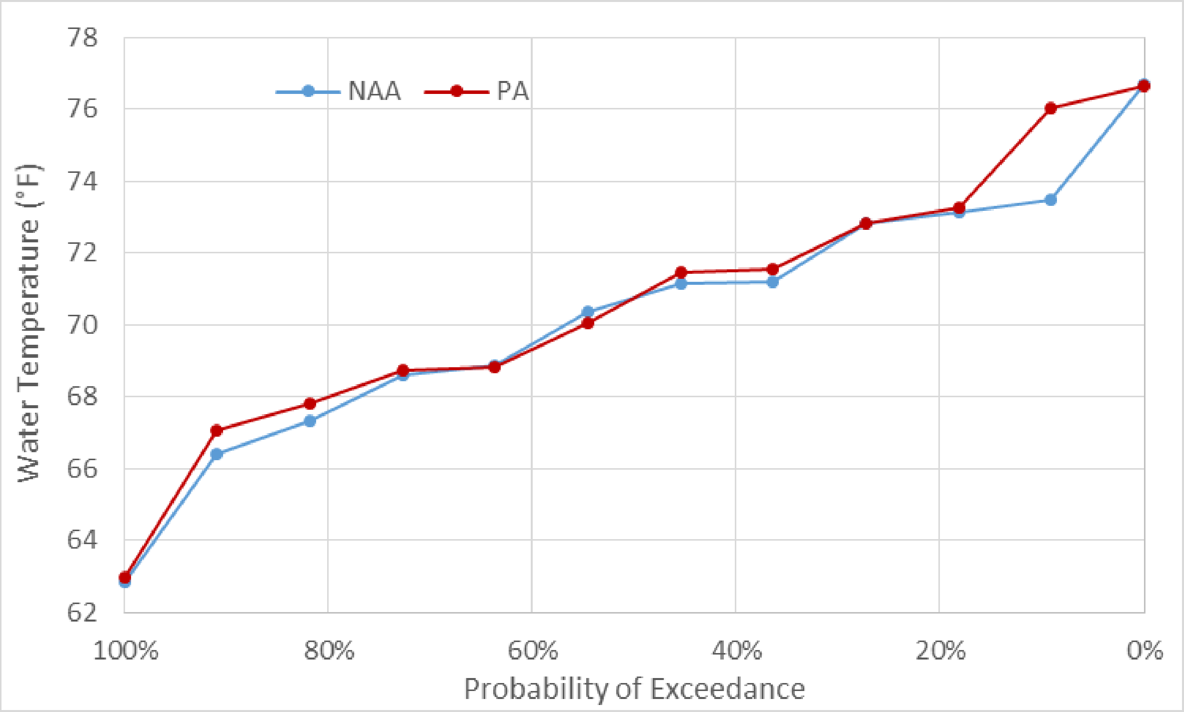

Figure 5.4-267. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the American River at Watt Avenue in June of Critical Water Years

The exceedance of temperature thresholds in the American River between Hazel Avenue and Watt Avenue presented in Appendix 5.D, Section 5.D.2.1, *Water Temperature Analysis Methods*, Table 5.D-50 by modeled daily water temperatures were evaluated based on thresholds identified in USEPA's temperature water quality guidance (U.S. Environmental Protection Agency 2003). Two thresholds, 61°F 7DADM and 64°F 7DADM, were evaluated. The 61°F value represents the core, defined by USEPA (2003) as "moderate to high density", location of Hazel Avenue and the 64°F value represents non-core, defined by USEPA (2003) as "low to moderate density", location of Watt Avenue. The 7DADM values were converted by month to function with daily model outputs (Appendix 5.D, Section 5.D.2.1, *Water Temperature Analysis Methods*, Table 5.D-52).

Results of the water temperature thresholds analysis for steelhead smolt emigration are presented in Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5-D-171 and Table 5.D-172. At both Hazel Avenue and Watt Avenue, there would be no months or water year types with a more-than-5% increase in the percent of total days exceeding the threshold under the PA relative to the NAA, or with a more-than-0.5°F difference in the magnitude of average daily exceedance. Therefore, it was concluded that there would be no biologically meaningful water temperature-related effects on CCV steelhead smolt emigration.

5.4.2.2.3.1.5 Adult Immigration

5.4.2.2.3.1.5.1 Flow-Related Effects

Mean monthly flows were evaluated in the American River at Nimbus Dam and the confluence with the Sacramento River during the October through April immigration period, with peak migration from December through February (Table 5.4-77). Changes in flow potentially affect conditions for upstream migration of adults, including bioenergetic cost, water quality, crowding, cues for locating natal streams, and passage conditions, but the quantitative relationship between flow and upstream migration is poorly understood (Quinn 2005; Milner et al. 2012). As described in Appendix 5.D, Section 5.D.2.4, *Migration Flows Methods*, on balance, except under very high flows, the benefits of increased flow generally outweigh the costs and, therefore, it is assumed for the purposes of this effects analysis that increased flow would improve conditions for upstream migration of adult CCV steelhead. It is known that migration cues for anadromous fish species are often the result of natural pulse flows, which will not be affected by the PA (Milner et al. 2012; del Rosario et al. 2013). It should be noted, however, that natural pulse flows are less important for anadromous fish in the American River than in the Sacramento River because there are no significant tributaries in the lower American River, and except at very high flows, the flow is heavily controlled by Folsom Dam.

Folsom storage volume at the end of September influences flows in the American River during much of the immigration period. Mean Folsom September storage under the PA would be similar (less than 5% difference) to storage under NAA for all water year types, except for 8% lower mean storage during dry water years under the PA (Appendix 5.A, *CALSIM Methods and Results* Table 5.A.6-5).

The differences in mean flow between the PA and the NAA at the Nimbus location would consistently be similar to the differences at the confluence location (Appendix 5.A, *CALSIM Methods and Results*, Table 5.A-6-16, Table 5.A.6-17). During November, mean flow under the PA would be lower (up to 13% lower at Nimbus and 14% lower at the confluence) in all water year types, except below normal years, when there would be little difference in flow. Flow would also be 13% lower in October of wet years and up to 11% lower in March and April of critical years. The largest increases in flow would occur during October of critical years (14% greater at Nimbus and 15% greater at the confluence) and below normal years (8% greater flow at both locations). During the December through February peak of the adult immigration period, mean flows would be similar (less than 5% difference) between the PA and the NAA or would be slightly greater under the PA. The CALSIM modeling results given here indicate that the PA would reduce flow in some months and water year types, although this does not consider real-time operational management described in Section 3.1.5, *Real-Time Operations Upstream of the Delta*, and Section 3.3.3, *Real-Time Operational Decision-Making Process*, that would be used to avoid and minimize any modeled effects. Further discussion regarding flow-related effects during the June through November period are provided in Section 5.4.2.3, *Summary of Upstream Effects*.

As described in Appendix 5.D, Section 5.D.2.4, *Migration Flows Methods*, mean monthly flow below about 1,000 cfs is considered to have potentially adverse effects on CCV steelhead adult immigration conditions in the American River. The effect of the PA on the frequency of flows below this threshold was evaluated by comparing CALSIM flows between the PA and the NAA at Nimbus Dam and the confluence with the Sacramento River. Mean flow at the Nimbus Dam was less than 1,000 cfs for 92 of the 574 months (16.0%) within the CCV steelhead migration period under the NAA and for 93 months (16.2%) of migration period under the PA. Mean flow at the confluence was less than 1,000 cfs in 112 months (19.5%) under the NAA and 106 months (18.5%) under the PA (Table 5.4-81). These results indicate that the PA would have an insignificant effect, with respect to the frequency of flow below the 1,000 cfs threshold, on adult CCV steelhead immigration conditions in the American River.

Table 5.4-81. Number and Percent of the 574 Months within the California Central Valley Steelhead Adult Immigration Period from the 82-year CALSIM Record with Flow < 1,000 cfs

	Months with Mean Flow < 1,000 cfs		Percent with Mean Flow < 1,000 cfs		Difference in Months and Percent Difference
Location	NAA	PA	NAA	PA	PA vs. NAA
Nimbus	92	93	16.0	16.2	1 (1%)
Confluence	112	106	19.5	18.5	-6 (-5%)

5.4.2.2.3.1.5.2 Water Temperature-Related Effects

Modeled mean monthly water temperatures in the American River at Hazel Avenue and Watt Avenue during the October through April adult immigration period for steelhead (Table 5.4-77) are presented in Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results*, Table 5.C.7-14, Table 5.C.7-15. Overall, the PA would change mean water temperatures very little (less than 1°F, or approximately 1%) at these locations in all months and water year types in the period. The largest increase in mean monthly water temperatures under the PA relative to NAA would be 0.2°F (0.4%), and would occur at Hazel Avenue during October of above normal water years, and at Watt Avenue during March of critical water years and October of above normal water years.

Exceedance plots of monthly mean water temperatures were examined during each month throughout the adult immigration period (Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results*, Figure 5.C.7.14-7, Figure 5.C.7.15-7). The values for the PA in these exceedance plots generally match those of the NAA period. Further examination of October of above normal water years at Hazel Avenue (Figure 5.4-268), March of critical water years at Watt Avenue (Figure 5.4-264), and October of above normal water years at Watt Avenue (Figure 5.4-269), where the largest increases in mean monthly water temperatures were seen, reveals that the curves were largely similar overall and that the difference of 0.2°F in mean monthly temperatures between NAA and PA would cause no substantial differences between curves for the NAA and PA in each exceedance plot. A difference of 0.2°F is likely within the uncertainty of the CALSIM and HEC5Q models, as described in Appendix 5.A, *CALSIM Methods and Results*, Section 5.A.4.5, *Limitations and Appropriate Use of Model Results*, and Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.2.5, *Model Limitations*. One exception would be at Hazel Avenue in October of above normal water years, in which there would be 2 years during which water temperatures under the PA would be approximately 1°F higher than those under the NAA (Figure 5.4-268). Further examination of these years reveals that this appears to be due to CALSIM II attempting to balance storage levels among the CVP reservoirs and there are no operational requirements, such as cold-water pool storage, temperature, or outflow requirements, that would cause these years to differ so widely in water temperatures. Mean Folsom September storage under the PA would be similar (less than 5% difference) to storage under NAA for all water year types, except for 8% lower mean storage during dry water years under the PA (Appendix 5.A, *CALSIM*

Methods and Results).Therefore, there is no practical reason why actual operations under the PA would be different from those under the NAA in these months and years.

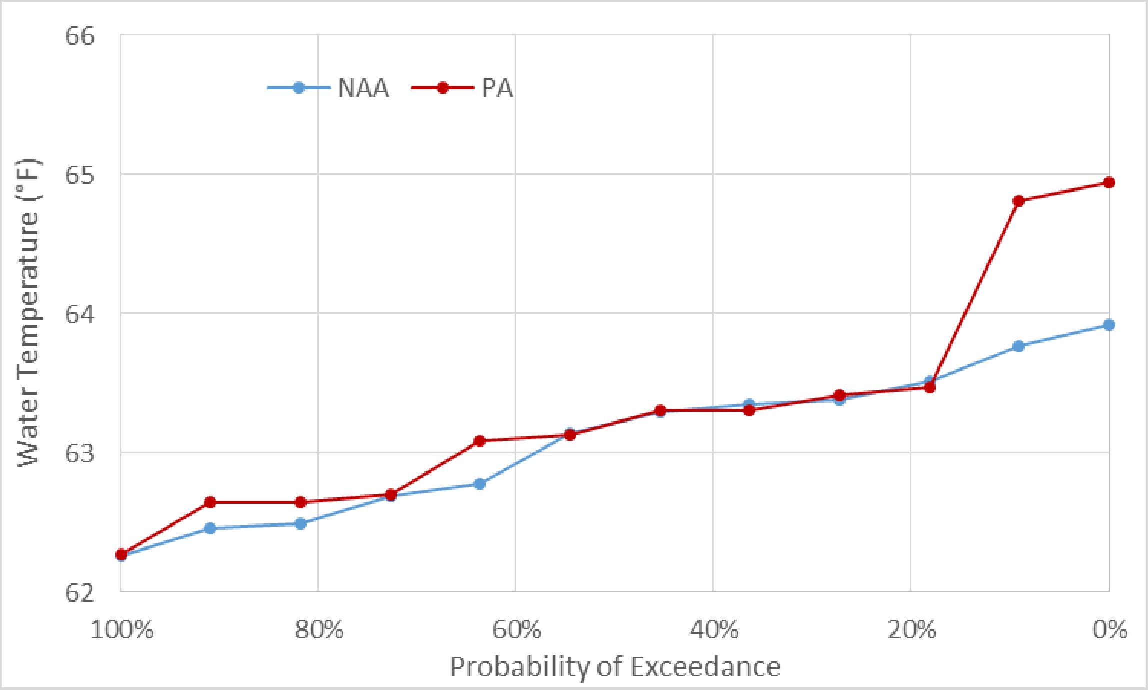

Figure 5.4-268. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the American River at Hazel Avenue in October of Above Normal Water Years

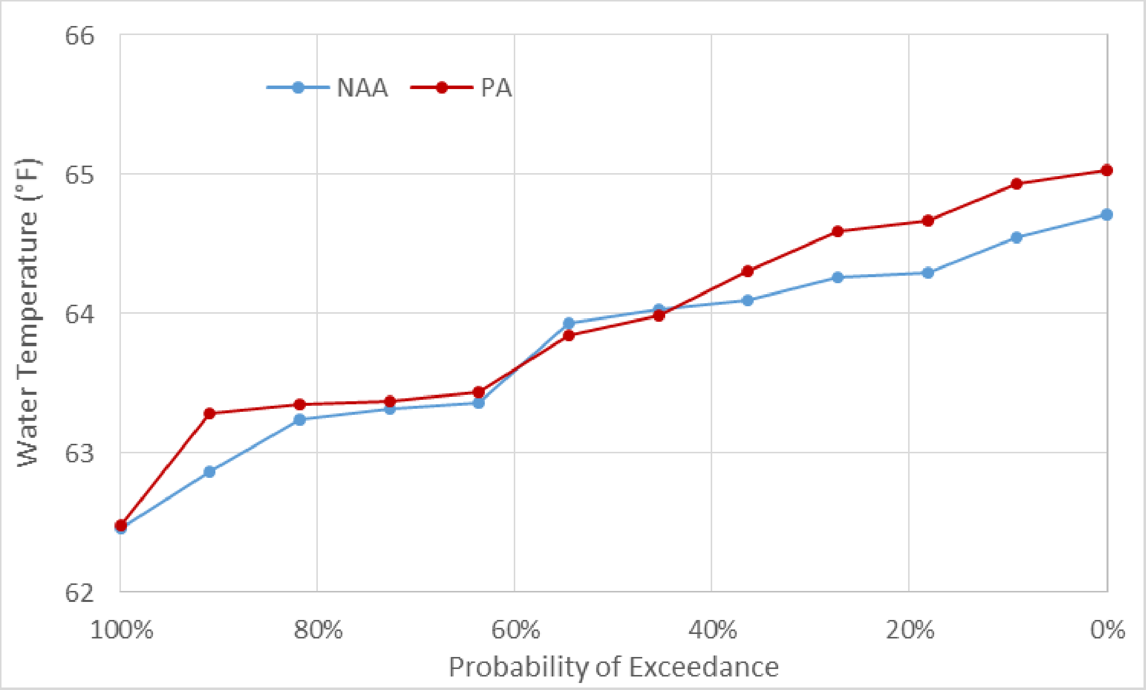

Figure 5.4-269. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the American River at Watt Avenue in October of Above Normal Water Years

To evaluate water temperature threshold exceedance during the steelhead adult immigration life stage at Hazel Avenue and Watt Avenue, thresholds of 68°F 7DADM and 70°F were used (Appendix 5.D, Section 5.D.2.1, *Water Temperature Analysis Methods,* Table 5.D-50). The 68°F 7DADM threshold was taken from USEPA (2003) and the 70°F threshold represents the average of the studies cited in Richter and Kolmes (2005) for the upper end of the suboptimal temperature range. The 7DADM threshold was converted to function with daily model outputs for each month separately (Appendix 5.D, Section 5.D.2.1, *Water Temperature Analysis Methods*, Table 5.D-52).

Results of the water temperature thresholds analysis for adult steelhead immigration are presented in Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-175 through Table 5.D-178. At both Hazel Avenue and Watt Avenue, there would be no months or water year types with a more-than-5% increase in the percent of total days exceeding the threshold under the PA relative to the NAA, or with a more-than-0.5°F difference in the magnitude of average daily exceedance. Therefore, it was concluded that there would be no biologically meaningful water temperature-related effects on adult CCV steelhead immigration.

5.4.2.2.3.1.6 Adult Holding

5.4.2.2.3.1.6.1 Flow-Related Effects

Mean monthly flow rates and reservoir storage volumes were examined for the PA and NAA in the American River during the October and November holding period for Central Valley steelhead (Table 5.4-77). Changes in flow likely affect holding habitat for steelhead, with higher flows potentially providing greater depths and improved water quality in pools. Folsom Reservoir storage volume at the end of September influences flow rates below the dam during the steelhead holding period. Mean Folsom September storage under the PA would be similar (less than 5% difference) to storage under NAA for all water year types, except for 8% lower mean storage during dry years under the PA (Appendix 5.A, *CALSIM Methods and Results*, Table 5.A-6-5). The mean flows at the Nimbus Dam location in the American River during October would be 8% and 14% higher under the PA than the NAA for below normal and critical water year types, respectively, and would be 13% lower for wet years (Appendix 5.A, *CALSIM Methods and Results*, Table 5.A-6-16). During November, mean flow under the PA would be 8% to 13% lower than flow under the NAA in all except below normal water years, for which there would be little difference (less than 5%). On balance, the changes in flow are expected to have an insignificant effect on Central Valley steelhead holding habitat.

5.4.2.2.3.1.6.2 Water Temperature-Related Effects

Modeled mean monthly water temperatures in the American River at Hazel Avenue and Watt Avenue during the October and November steelhead adult holding period (Table 5.4-77) are presented in Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results,* Table 5.C.7-14, Table 5.C.7-15. Overall, the PA would change mean water temperatures very little (less than 1°F, or approximately 1%) at these locations in all months and water year types in the period. The largest increase in mean monthly water temperatures under the PA relative to NAA would be 0.2°F (0.4%), and would occur at both locations during October of above normal water years.

Exceedance plots of monthly mean water temperatures were examined during each month throughout the adult holding period (Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.7, *Upstream Water Temperature Modeling Results*, Figure 5.C.7.14-7, Figure 5.C.7.15-7). The values for the PA in these exceedance plots generally match those of the NAA. Further examination of October in above normal years at Watt Avenue (Figure 5.4-267), where the largest increase in mean monthly water temperatures were seen, reveals that the curves were largely similar overall and that the difference of 0.2°F in mean monthly temperatures between NAA and PA would cause no substantial differences between curves for the NAA and PA in the exceedance plot. A difference of 0.2°F is likely within the uncertainty of the CALSIM and HEC5Q models, as described in Appendix 5.A, *CALSIM Methods and Results*, Section 5.A.4.5, *Limitations and Appropriate Use of Model Results*, and Appendix 5.C, *Upstream Water Temperature Methods and Results*, Section 5.C.2.5, *Model Limitations*. Further examination of October of above normal water years at Hazel Avenue (Figure 5.4-266), also where the largest increase in mean monthly water temperatures were seen, reveals that there would be 2 years during which water temperatures under the PA would be approximately 1°F higher than those under the NAA. However, upon closer examination, this is appears to be due to CALSIM II attempting to balance storage levels among the CVP reservoirs and there are no operational requirements, such as cold-water pool storage, temperature, or outflow requirements, that would cause these years to differ so widely in water temperatures. Therefore, there is no practical reason why actual operations under the PA would be different from those under the NAA in these months and years.

To evaluate water temperature threshold exceedance during the steelhead adult holding life stage at Hazel Avenue and Watt Avenue, the USEPA's 7DADM threshold value of 61°F was used Appendix 5.D, Section 5.D.2.1, *Water Temperature Analysis Methods*, Table 5.D-50) (U.S. Environmental Protection Agency 2003). The threshold was converted to function with daily model outputs for each month separately (Appendix 5.D, Section 5.D.2.1, *Water Temperature Analysis Methods*, Table 5.D-52).

Results of the water temperature thresholds analysis for adult steelhead holding are presented in Appendix 5.D, Section 5.D.2.5, *Detailed Water Temperature Threshold Analysis Results*, Tables 5.D-179 and 5.D-180. At both Hazel Avenue and Watt Avenue, there would be no months or water year types with a more-than-5% increase in the percent of total days exceeding the threshold under the PA relative to the NAA, or with a more-than-0.5°F difference in the magnitude of average daily exceedance. Therefore, it was concluded that there would be no biologically meaningful water temperature-related effects on adult CCV steelhead holding.

5.4.2.2.4 Assess Risk to Individuals

5.4.2.2.4.1 California Central Valley Steelhead

Based on the responses of CCV steelhead salmon exposed to the PA described in Section 5.4.2.1.3, *Assess Species Response to the Proposed Action*, above, the risk to individuals would be small to insignificant in the American River. This conclusion does not include consideration of real-time operational management described in Section 3.1.5, *Real-Time Operations Upstream of the Delta*, and Section 3.3.3, *Real-Time Operational Decision-Making Process*, which would be used to avoid and minimize any modeled effects. Fitness of individuals, including reproductive success during spawning, survival during embryo incubation, survival and growth during juvenile rearing, survival and growth during immigration and emigration, and expression of life history as a result of spawning, rearing, and migration habitat availability, would mostly differ insignificantly between the NAA and PA. As described above, modeling results indicated one month (November at Nimbus and the Sacramento River confluences during most water year types) in which there would be reductions in flow under the PA. These reductions would potentially increase mortality risk during the adult migration period. Please see Section 5.4.2.3, *Summary of Upstream Effects,* for a description of how real-time operational management of the PA may reduce the likelihood that these effects would occur.

5.4.2.2.5 Effects of the Action on Designated and Proposed Critical Habitat

The Central Valley steelhead critical habitat designation final rule (September 2, 2005, 70 FR 52488) provides PBFs that are essential to the conservation of the species. The American River provides several PBFs that support one or more life stages of CCV steelhead. Because the American River is exclusively a freshwater riverine system, only PBFs pertaining to freshwater riverine systems are discussed here.

Please see Section 5.4.2.3, *Summary of Upstream Effects,* for a description of how real-time operational management of the PA may reduce the likelihood that the effects described here would occur.

5.4.2.2.5.1 California Central Valley Steelhead

5.4.2.2.5.1.1 Spawning Habitat

As indicated in Section 5.4.2.2.3.1.1, *Spawning, Egg Incubation, and Alevins,* effects of the PA on flows and water temperatures relative to the NAA in the CCV steelhead spawning reach in the American River during the spawning period would be insignificant. Therefore, the results indicate that there would be insignificant effects of the PA on this PBF. This conclusion does not include consideration of real-time operational management described in Section 3.1.5, *Real-Time Operations Upstream of the Delta,* and Section 3.3.3, *Real-Time Operational Decision-Making Process,* which would be used to avoid and minimize any modeled effects.

5.4.2.2.5.1.2 Freshwater Rearing Habitat

As indicated in Section 5.4.2.2.3.1.3, *Juvenile Rearing,* effects of the PA on flows and water temperatures relative to the NAA in the juvenile rearing reach of CCV steelhead in the American River during the rearing period would insignificant. Therefore, the results indicate that there would be insignificant effects of the PA on this PBF.

5.4.2.2.5.1.3 Freshwater Migration Corridors

As indicated in Section 5.4.2.2.3.1.2, *Kelt Emigration* and Section 5.4.2.2.3.1.4, *Smolt Emigration,* effects of the PA on flows and water temperatures relative to the NAA in the CCV steelhead migration corridor in the American River during the kelt and smolt migration periods would insignificant. As indicated in Section 5.4.2.2.3.1.5, *Adult Immigration,* there would be reductions in flow between the NAA and PA, especially during November. These results indicate that there would be a potential risk during November of negative effects of the PA on this PBF. This conclusion does not include consideration of real-time operational management described in Section 3.1.5, *Real-Time Operations Upstream of the Delta,* and Section 3.3.3, *Real-Time*

Operational Decision-Making Process, which would be used to avoid and minimize any modeled effects.

5.4.2.3 Summary of Upstream Effects

The results presented in Section 5.4.2.1 *Sacramento River*, and Section 5.4.2.2, *American River*, indicate that, overall, upstream effects of the PA on winter- and spring-run Chinook salmon, CCV steelhead, and green sturgeon are expected to be predominantly small to insignificant. There are a few particular upstream changes described here that are noteworthy because physical conditions under the PA may potentially cause degraded conditions relative to the NAA for these species, although there is considerable uncertainty in the likelihood of a biological effect resulting from the changes in the physical conditions. Under each change stated below, differences in the physical conditions under the PA relative to the NAA that are the key drivers are identified. The noted upstream changes are primarily a result of reductions in the September and November flows under the PA relative to the NAA, as modeled using CalSim II. An explanation of whether the physical drivers that may cause degraded conditions for the species under PA as modeled can be avoided during actual PA operations is also provided.

1. **Increased frequency of exceedance of water temperature thresholds for rearing winter- and spring-run Chinook salmon during September from Keswick to Red Bluff, especially in below normal water years, under the PA relative to the NAA.** These increases in the modeled frequency of water temperature threshold exceedances likely result primarily from reduced Shasta releases associated with the PA’s operational modeling. Modeling of the coldwater pool volume, which is more indicative of temperature management suggests PA end-of-September (EOS) storage similar to that of the NAA (Appendix 5.C, Table 5.C.7.21-1, *Shasta Cold Water Pool Volume*). If real-time cold water pool management efforts under the PA use similar decision making tools and criteria as currently utilized (i.e. NAA), then releases from Shasta Lake under the PA would actually be sustained at similar levels as the NAA during September. Thus, it is likely that the PA would not experience higher water temperatures relative to the NAA during September, as was modeled in this analysis. Further, Reclamation is committed to participating in the OCAP RPA revision process with NMFS and other federal and state agencies to improve egg-to-fry survival to Red Bluff, as described below.

2. **Increased frequency of exceedance of water temperature thresholds for spawning winter- and spring-run Chinook salmon during August and September (and into October) in the Sacramento River from Clear Creek to Bend Bridge, especially in above normal and below normal water years, under the PA relative to the NAA.** As noted above the increased temperatures in the reach of the Sacramento River downstream of Clear Creek are primarily a result of the lower Shasta releases under the PA relative to the NAA. Given that winter-run Chinook salmon spawning is limited to the Sacramento River upstream of Clear Creek (see Section 5.4.2.1.2, *Assess Species Exposure*), and the temperatures within this reach under the PA are similar to the NAA, it is likely that there would be insignificant, if any, effects on the spawning winter-run Chinook salmon under the PA relative to the NAA. The majority of spring-run Chinook salmon in the Sacramento River spawn upstream of Battle Creek, so there is some overlap with the reach in which the frequency of exceeding water temperature thresholds increase under

the PA relative to the NAA. In addition, for all water year types during these months in which there is an increase of 5% in the frequency of exceedance under the PA relative to the NAA, the actual difference in mean magnitude of exceedance would be insignificant (<0.5°F) (Section 5.4.2.1.3.1.1.2, *Water Temperature-Related Effects*, and Section 5.4.2.1.3.2.2.2, *Water Temperature-Related Effects*). Therefore, although there are more exceedances under the PA during these months, the magnitude would be insignificant. Moreover, as discussed above, in reviewing the modeled cold water pool conditions in the Shasta Reservoir leading to the releases in the late summer months and assuming similar real-time cold water pool management decisions under the PA and the NAA, the PA is likely to result in similar conditions as the NAA (Appendix 5C, Table 5.C.7.21-1, *Shasta Cold Water Pool Volume*). Thus, it is likely that the PA would not experience higher water temperatures relative to the NAA during August and September, as was modeled in this analysis. Further, Reclamation is committed to participating in the OCAP RPA revision process with NMFS and other federal and state agencies to improve egg-to-fry survival to Red Bluff, as described below.

3. **Increased risk of redd dewatering for June cohorts of winter-run Chinook salmon and August cohorts of winter-run and spring-run Chinook salmon in the Sacramento River from Keswick to Battle Creek under the PA relative to the NAA.** This increase risk is a result of the lower Shasta releases in September and November under the PA relative to the NAA. However, it is unlikely that the increased risk of redd dewatering seen in this analysis would occur during future operations because, as discussed above, Sacramento River flows in September would likely be sustained at similar levels as the NAA to meet cold water pool requirements.

4. **Decreased rearing weighted usable area for spring-run Chinook salmon and CCV steelhead juveniles under the PA relative to the NAA during June in the Sacramento River reaches from Keswick to A.C.I.D. Dam and from Cow Creek to Battle Creek[67].** These decreases are due to increased Sacramento River flow under the PA relative to the NAA during June. As described earlier, weighted usable area estimate is a potential indicator of suitable habitat for rearing juveniles. However, the direct biological effect of reduction in the weighted usable area in limited reaches of the Sacramento River on the rearing juveniles is uncertain. As described in the footnote below, this may only be a concern if population numbers in the Sacramento River were high enough that the habitat was limiting, which currently is not the case. Higher modeled Shasta Reservoir releases during June under the PA relative to the NAA are primarily the reason for the reduction in the weighted usable area estimates found in this analysis.

5. **Reduced flows during September, primarily in above normal, below normal, and dry water years, which may result in degraded migration conditions for juvenile winter-run and adult spring-run Chinook salmon, CCV steelhead, and green sturgeon in the Sacramento River under the PA relative to the NAA.** These reduced

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[67] Habitat limitation has not been a concern in recent years due to low population size, but it could be in the future if population size was to increase or there was a strong year class. Awareness of the effects to be managed in the best interest of the species is necessary, regardless of variability in population size

flows are primarily a result of reductions in modeled Shasta Reservoir releases. However, as described above, assuming similar real-time cold water pool management decisions under the PA and the NAA, actual differences in September Shasta Reservoir releases between the PA and the NAA would be small and reductions in migration flows, therefore, may not occur. Further, there is low certainty in the assumed positive linear relationship between flow and migration success (see Appendix 5.D, Section 5.D.2.4, *Migration Flow Methods*). Finally, migration cues for anadromous fish species are often the result of pulse flows (Milner et al. 2012; del Rosario et al. 2013), which will not be affected by the PA.

6. **Reduced flows during November, primarily in wet and above normal water years, which may result in degraded migration conditions for juvenile winter-run Chinook salmon, spring-run Chinook salmon, CCV steelhead, and green sturgeon in the Sacramento River, and CCV steelhead adults in the Sacramento and American Rivers.** These reduced flows are the result of lower releases from Shasta Reservoir and Folsom Reservoir, respectively. As noted above, there is a low certainty in the assumed positive linear relationship between flow and migration success (see Appendix 5.D, Section 5.D.2.4, *Migration Flow Methods*). Also, migration cues for anadromous fish species are often the result of pulse flows (Milner et al. 2012; del Rosario et al. 2013), which will not be affected by the PA. It should be noted, however, that natural pulse flows are less important for anadromous fish in the American River than in the Sacramento River because there are no significant tributaries in the lower American River, and except at very high flows, the flow is heavily controlled by Folsom Dam.

In summary, these CalSim II results show that the upstream storage conditions under the PA would generally be similar to the NAA. With the increased flexibility offered by the proposed north Delta diversion under the PA, additional natural excess runoff in the winter and spring months are expected to be available for the Delta exports, thereby reducing stored water releases in some fall months and improving carryover storage and cold water pool in the following year. In modeling of the NAA, given the winter and spring export restrictions under the BiOps, higher releases continue for Delta exports through the fall months unlike the PA. Thus typically model results show lower river flows in the fall months (primarily in September and November) under the PA compared to the NAA. The September flow reductions modeled under PA result in slightly higher water temperatures in the rivers compared to the NAA. These modeling outcomes do not reflect the totality of the annual, seasonal, and real-time considerations that would be used to determine how to make reservoir releases.

CalSim II, used to represent the operations of the NAA and PA, is a long-term planning model that allows for quantitative simulation of the CVP and SWP operations on a monthly time-step across a wide range of hydrologic, regulatory and operations instances. The CalSim II model uses a set of pre-defined generalized rules that represent the assumed regulations and to specify the operations of the CVP/SWP systems. These inputted rules are often specified as a function of year type or a prior month’s simulated storage or flow condition. As described above, the model has no capability of adjusting these rules to respond to specific events that may have occurred historically, e.g., fish presence, levee failures, fluctuations in barometric pressure that may have affected delta tides and salinities, facility outages, etc. These generalized rules have been developed based on historical operational trends and on limited CVP/SWP operator input and only provide a coarse representation of the project operations over the inputted hydrologic conditions. Thus, results do not exactly match what operators might do in a specific month or year within the simulation period since the latter would be informed by numerous real-time considerations that cannot be inputted into the CalSim II model. Rather, results are intended to be a reasonable representation of long-term operational trends of CVP and SWP, providing the ability to compare and contrast the effect of current and assumed future operational conditions.

Day-to-day decision-making by the CVP-SWP operators considers the recommendations from many of the decision-making/advisory teams, such as the Sacramento River Temperature Technical Group (SRTTG), Water Operations Management Team (WOMT), b2 interagency team (B2IT) and American River Operations Group. CalSim II cannot consider all of these factors. Instead, CalSim II simulates a generalized representation of likely long-term operations under each scenario. Appendix 5A, *CALSIM Methods and Results*, provides a detailed description of the CalSim II model, assumptions used to model the NAA and the PA scenarios, and the many limitations of the tool, including limitations with respect to application of model outputs to analyses such as those used in this effects analysis. These analyses cannot consider the research and monitoring results that will be obtained during the Adaptive Management Program.

Most of the teams listed above include representatives from the three fishery agencies (NMFS, USFWS, and CDFW), operators, other regulatory agencies, and stakeholders. These teams provide forums for real-time information exchange between biologists and reservoir operators, leading to recommendations on the reservoir operations and compliance with existing water temperature requirements per SWRCB WRO 90-05, and to 2009 NMFS BiOp Action I.2. For example, the SRTTG provides recommendations on short-term operational aspects of reservoir management including coordinating real-time operations and reporting on the temperature requirements specified by SWRCB WRO 90-05 and the 2009 NMFS BiOp RPAs, based on the factors such as run timing, location of redds, air and surface water temperature modeling, and projected versus actual extent of the cold water pool. The current decision-making processes and the advisory groups will continue and will be improved under the PA (see Chapter 3, Section 3.1.5, *Real-Time Operations Upstream of the Delta*, and Section 3.3, *Operations and Maintenance for the New and Existing Facilities*). A separate real time operations coordination team (RTOCT) will meet to assist DWR and Reclamation in fulfilling their responsibility to inform the SWP and CVP participants regarding available information and real-time decisions. This coordination effort may also periodically review how to enhance or strengthen the scientific and technical information used to inform decision-making, and how to communicate with the public and other interested parties. This revised process and RTOCT will allow for minimization of modeled effects identified above to listed species under future operations of the PA.

In addition, Reclamation will work with NMFS and other state and Federal agencies to adjust the RPA Action Suite 1.2, as described in Section 3.1.4.5, *Annual/Seasonal Temperature Management Upstream of the Delta*. The adjustment will be made pursuant to the 2009 NMFS BiOp section 11.2.1.2. *Research and Adaptive Management*, where it states: “After completion of the annual review, NMFS may initiate a process to amend specific measures in this RPA to reflect new information, provided that the amendment is consistent with the Opinion’s underlying analysis and conclusions and does not limit the effectiveness of the RPA in avoiding jeopardy to listed species or adverse modification of critical habitat.” This process is anticipated to conclude in the fall of 2016, and may include refinements and additions to the existing annual/seasonal temperature management processes, including spring storage targets, revised temperature compliance criteria and a range in summertime Keswick release rates. The adjusted RPA Action Suite I.2 will apply to Reclamation's Shasta operations. This RPA revision process is intended to improve egg-to-fry survival of winter-run Chinook salmon to Red Bluff, but would likely improve survival of other races of Chinook salmon, steelhead, and green sturgeon, depending on the timing of refinements that will be made.

5.5 Effects of Construction and Maintenance of Conservation Measures[68]

5.5.1 Tidal, Channel Margin, and Riparian Habitat Protection and Restoration

5.5.1.1 Deconstruct the Action

As summarized in Table 3.4-1 in Chapter 3, *Description of the Proposed Action*, tidal wetland restoration would be undertaken to mitigate permanent and temporary impacts from construction of the NDD, the HOR gate, and barge landings. Typical activities to be undertaken at tidal wetland restoration sites are discussed in Section 3.4.3.1, *Tidal Wetland Restoration*. The main activities include excavating channels; modifying ditches, cuts, and levees; removal/breaching and/or setting back of existing levees/embankments; and altering land surface elevations by scalping higher elevation land or importing dredge/fill. Channel margin habitat would also be restored (Table 3.4-1). As discussed in Section 3.4.3.2, *Channel Margin Siting and Design Considerations*, typical activities would include riprap removal; bench creation through grading; installation of large woody material; and planting of riparian/emergent wetland vegetation on created benches.

5.5.1.2 Assess Species Exposure

5.5.1.2.1.1 Salmonids

Construction at habitat restoration sites will be undertaken during approved in-water work windows (summer/fall) and therefore most winter-run and spring-run Chinook salmon and steelhead individuals are unlikely to be exposed; any exceptions are most likely to be adult steelhead moving upstream in fall. Once constructed, Chinook salmon and steelhead could be exposed to the restoration sites during their periods of occurrence within the Delta.

5.5.1.2.1.2 Green Sturgeon

Green sturgeon have the potential to be near restoration areas at any time of the year and therefore could be exposed to construction effects, in addition to the effects of the sites following restoration.

5.5.1.3 Assess Fish Species Response

5.5.1.3.1.1 Salmonids

As previously noted, restoration construction effects are expected to be limited given the proposed timing of in-water work. For any individuals that are present, the types of construction

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[68] Although not a conservation meaure, localized reduction of predatory fishes to minimize predator density at north and south Delta export facilities is considered in this section (see also Appendix 3.H).

effects at restoration sites are likely to be similar to those described in Section 5.2, *Effects of Water Facility Construction on Fish*, for construction of the NDD, although the magnitude of these effects will be substantially less given the minimal in-water work necessary and the area affected. These include temporary increased turbidity, effects on water quality, direct injury from equipment, and general disturbance. Construction of restoration sites will require very little in-water work and will be temporary and AMMs described in Chapter 3, *Description of the Proposed Action* (and in detail in Appendix 3.F, *General Avoidance and Minimization Measures*) will minimize construction-related effects to salmonids.

To the extent that individual migrating Chinook salmon and steelhead encounter restoration sites, the restoration may enhance habitat value in these areas, relative to the unrestored state of the habitat where the restoration is undertaken, e.g., by increasing production of prey, and providing new resting areas and cover. These newly restored areas will be designed in coordination with NMFS and DFW to maximize the potential for these new habitat areas to provide habitat values to salmon and sturgeon, while minimizing potential adverse effects. The restoration is intended to offset adverse effects from loss of habitat from water facility construction and operations, e.g., loss of physical habitat because of the NDD construction and less frequent inundation of riparian benches because of NDD operations. The extent to which this offsetting occurs is based on the acreage and linear extent of habitat that is affected, with typical restoration ratios applied (Table 3.4-1 in Chapter 3, *Description of the Proposed Action*). Potential adverse effects to Chinook salmon and steelhead from restored habitat include degraded water quality (e.g., liberation of contaminants such as mercury from soils, if such contaminants have not been removed by soil grading activities) and increased predation risk depending on site characteristics, although the latter can be avoided by careful design of restoration sites to limit potential for colonization by invasive aquatic vegetation. Such potential effects are expected to be limited in scale, given the limited size of the areas to be restored.

5.5.1.3.1.2 Green Sturgeon

As noted for salmonids, the types of construction effects from restoration are likely to be similar to those described in Section 5.2, *Effects of Water Facility Construction on Fish*, for construction of the NDD and include increased turbidity, effects on water quality, direct injury from equipment, and general disturbance, although the magnitude of these effects will be substantially less given the minimal in-water work necessary and the area affected. Construction of restoration sites will require very little in-water work and will be temporary. AMMs described in Chapter 3, *Description of the Proposed Action* (and in detail in Appendix 3.F, *General Avoidance and Minimization Measures*) will minimize construction-related effects on green sturgeon.

As described for salmonids, to the extent that individual green sturgeon encounter restoration sites, the restoration may enhance habitat value in these areas, e.g., by increasing suitable benthic habitat, which is intended to offset adverse effects from loss of habitat because of water facility construction. The extent to which this offsetting occurs is based on the acreage and linear extent of habitat that is affected, with typical restoration ratios applied (Table 3.4-1 in Chapter 3, *Description of the Proposed Action*). Potential adverse effects to green sturgeon from restored habitat include degraded water quality (e.g., liberation of contaminants from soils). Such potential effects are expected to be limited in scale, given the limited size of the areas to be restored

5.5.1.4 Assess the Effects of the Action on Designated Critical Habitat

Potential effects to designated critical habitat for listed salmonids and green sturgeon from habitat restoration would be expected to be minimal in terms of temporary construction effects because the footprint of in-water work would be contained within the breach or setback area and the immediate surroundings, AMMs would be implemented to avoid and minimize construction-related effects, and the overall time to complete in-water construction would be within a single year or less. Timing of construction would avoid species occurrence except adult steelhead and green sturgeon. All of the effects to critical habitat would be temporary, and very little construction activity would occur within critical habitat itself, as most would occur adjacent to the water. In general, however, the habitat restoration conservation measures would be expected to beneficially affect designated critical habitat of listed salmonids and green sturgeon.

5.5.2 Localized Reduction of Predatory Fishes to Minimize Predator Density at North and South Delta Export Facilities

5.5.2.1 Deconstruct the Action

As described in Appendix 3.H, localized reduction of predatory fishes will be undertaken at the NDD and Clifton Court Forebay, if approved by NMFS and DFW, using physical reduction methods, including boat electrofishing, hook-and-line fishing, passive capture by net or trap (e.g., gillnetting, hoop net, fyke trap), and active capture by net (e.g., beach seine). Predator removal efforts will require additional feasibility evaluations prior to any actual activities in the water. Several considerations, including the most effective locations, methods, target species, and measures to avoid listed species need to be considered. As outlined in the description of this AMM, DWR and Reclamation will work with NMFS and DFW to design and implement these feasibility studies. Because of uncertainties regarding reduction methods and efficacy, implementation of this AMM will involve discrete study projects and research actions coupled with an adaptive management and monitoring program to evaluate effectiveness.

The purpose of a predatory fish reduction program is to reduce the abundance of predators, thereby reducing the mortality rates of protected or target species (in this case, listed salmonids) and increasing their abundance. To achieve this goal, the predator control programs will be focused on the winter/spring period (~December-June) when juvenile salmonids are migrating through the Delta and will aim to limit the overall opportunity for fish predators to consume listed salmonids, potentially by decreasing predator numbers, modifying habitat features that provide an advantage to predators over prey, reducing encounter frequency between predators and prey, or reducing capture success of predators.

Given the uncertainties and constraints associated with this AMM, the predator reduction AMM will initially be implemented as an experimental feasibility assessment study and a series of connected research actions. The potential effects of the predator removal activities are described below.

5.5.2.2 Assess Species Exposure

5.5.2.2.1.1 Salmonids

The timing and locations of this AMM are intended to minimize predatory fish density at two locations where juvenile salmonids occur in appreciable numbers and therefore these juvenile salmonids will be exposed to the action. The seasonal timing of the action also indicates the potential for adult upstream migrants to be exposed to the action, in particular winter-run and spring-run Chinook salmon, but also steelhead. Most exposure will be expected to occur during the predatory fish reduction at the NDD, given its location on the main migratory route to and from the Sacramento River basin. In this regard, effects to San Joaquin River basin steelhead and spring-run Chinook salmon would not be expected to occur at the NDD, but could occur in Clifton Court Forebay.

5.5.2.2.1.2 Green Sturgeon

Year-round occurrence of green sturgeon juveniles in the Delta means that they will have the potential to be exposed to the predatory fish reduction AMM.

5.5.2.3 Assess Fish Species Response

5.5.2.3.1.1 Salmonids

The methods that could be used to implement predatory fish minimization at the NDD and Clifton Court Forebay will have some potential to adversely affect downstream-migrating juvenile salmonids, with the main effect perhaps being startling of individuals during gear deployment (which could increase predation susceptibility) or injury if contacting nets before escape through the mesh, for example. Capture of juvenile winter-run Chinook salmon, spring-run Chinook salmon, or steelhead by hook-and-line fishing will be unlikely to occur because hook sizes will target larger predatory fish. Passive or active capture methods involving traps or nets will involve mesh sizes targeting predatory fishes, through which juvenile salmonids will be able to escape. However, it is possible that juvenile salmonids could be gilled in the netting of fyke traps or enter the trap and be eaten by larger fish within the trap (National Marine Fisheries Service 2003). Electrofishing gear will be set to target fish of the size likely to be predators on juvenile salmonids, and as such will be unlikely to affect juvenile salmonids because at a given voltage gradient, total body voltage increases with length, resulting in greater potential to capture larger fish without effects to smaller fish (Reynolds and Kolz 2012). Any juvenile salmonids incidentally caught by electrofishing will be carefully handled, and if necessary held in a bucket of water until recovered, then released.

As described in the predation effects assessments for the north Delta (Section 5.4.1.3.1.1.1.3 *Predation*) and south Delta (Section 5.4.1.3.1.1.2.2 *Predation*), to the extent that predatory fish density reduction is successful, it could reduce predation on juvenile salmonids occurring near the NDD and in Clifton Court Forebay by decreasing predator densities in areas where juvenile salmon occur, and providing an increased potential for survival and successful through-Delta migration. There is uncertainty in the ability to effectively reduce predation, given that previous efforts in Clifton Court Forebay did not produce measurable decreases in predatory density (Brown et al. 1996). However, more recent evaluations in Delta channels have found that there is the potential for measurable reductions in predation (increases in survival) given sustained efforts (Cavallo et al. 2013; Sabal 2014, Sabal et al. 2016).

Adult salmonids will be more susceptible to the adverse effects of localized predatory fish reduction than juvenile salmonids, given their larger body sizes. Adult salmonids could be caught by hook and line, but any fish collected in this manner will be carefully handled and released, after being held under water to recover if necessary. Common hook and line injuries include damage to the skeletal structure of the mouth, injury to gills, and secondary infections (National Marine Fisheries Service 2003). If adult or juvenile Chinook salmon or steelhead are inadvertently shocked by the electrofishing equipment, measures will be in place to reduce mortality of these individuals. For example, field staff will be trained to quickly identify listed species and will release live, mobile fish quickly to minimize handling stress; immobilized adult steelhead or Chinook salmon will be held under the water until they recover and then they will be released. Striped bass capture with fyke nets and gill nets during the Adult Striped Bass Monitoring Project provides perspective on the rate of incidental capture of salmonids in relation to target predatory fish. The capture of striped bass was 2-3 orders of magnitude greater than the capture of Chinook salmon or steelhead (Table 5.5-1 and Table 5.5-2). Note that this program targets the time of year when adult striped bass are moving upstream to spawn, but this is coincident with the timing of upstream movement of listed salmonids, spring-run Chinook salmon, in particular. All incidentally captured listed fish were released in excellent or good condition. Additionally, if initial efforts show that this measure is ineffective and/or harmful to salmonids, it will be suspended.

Table 5.5-1. Collections of Striped Bass and Listed Fish by Fyke Trapping during April-May for the Adult Striped Bass Monitoring Project at Knights Landing, Sacramento River, 2008-2012.

Species	2008	2009	2010	2011	2012
Striped Bass	2,907	1,830	2,952	5,696	6,671
Chinook salmon	45	2	1	6	37
Steelhead	2	0	0	0	1
Green Sturgeon	4	0	0	0	1
Sources: California Department of Fish and Game (2008b), DuBois and Mayfield (2009), and DuBois et al. (2010, 2011, 2012).					

Table 5.5-2. Collections of Striped Bass and Listed Fish by Gill-Netting during April-May for the Adult Striped Bass Monitoring Project in the Lower Sacramento River and San Joaquin River, 2008-2009

Species	2008	2009
Striped Bass	2,462	1,415
Chinook salmon	4	1
Steelhead	3	1
Green Sturgeon	1	0
Sources: California Department of Fish and Game (2008) and DuBois and Mayfield (2009).		

5.5.2.3.1.2 Green Sturgeon

As with salmonids, there is the risk that green sturgeon could be inadvertently captured during predatory fish reduction. Given the species' demersal position in the water column, capture of green sturgeon by gillnetting is unlikely. Green sturgeon caught by other gears, e.g., trapping, seining, hook-and-line fishing, or electrofishing will be carefully released. As shown for adult salmonids, the rate of capture of green sturgeon may be low in relation to capture of targeted species such as striped bass (Table 5.5-1 and Table 5.5-2).

5.5.2.4 Assess the Effects of the Action on Designated Critical Habitat

As previously described, localized reduction of predatory fishes would have a very small potential to affect listed fishes, principally adults through bycatch. This would constitute an effect to the migratory corridor and access upstream PBFs of designated critical habitat.

5.5.3 Georgiana Slough Nonphysical Fish Barrier

5.5.3.1 Deconstruct the Action

As described in Section 3.4, *Conservation Measures*, the Georgiana Slough Nonphysical Fish Barrier (NPB) will consist of a permanent NPB to reduce the likelihood of Sacramento River-origin juvenile salmonids entering the interior Delta through Georgiana Slough. Several pilot studies have been implemented to test this concept, but no final design has been selected. Additional pilot studies will be implemented to further improve understanding and the efficacy of the future permanent barrier. The construction effects of a NPB have been outlined in previous consultations on the pilot projects that have been implemented to date (Chapter 2, *Consultation History*). The final design of the NPB may differ from those that have been tested to date, but the general types and magnitudes of construction and operational effects would not exceed those described in the previous BiOps. Based on a recent evaluation of different technology to achieve the goal of minimizing entrance of juvenile salmon into the interior Delta via Georgiana Slough, a bioacoustic fish fence (BAFF) appears to offer more potential than a floating fish guidance structure (FFGS) for this location (California Department of Water Resources 2015b), although these and other options are possibilities. The analysis presented herein focuses on the potential effects of these types of NPB, as there is precedent for their installation at this location: a BAFF was tested in 2011 and 2012, and a FFGS was tested in 2014. Both technologies block the upper portion of the water column because the focus for protection is surface-oriented juvenile salmonids. The BAFF consists of acoustic deterrence stimuli broadcast from loudspeakers and contained within a bubble curtain that is illuminated with strobe lights (to allow the fish to orient away from the sound stimulus better), whereas the FFGS is a floating series of metal plates that deters fish based on them seeing the barrier and sensing the change in flow. Whereas the pilot studies of these technologies and their construction occurred in winter/spring, for the PA, construction will occur prior to the main period of juvenile salmonid (November/December–June) occurrence, and removal will occur after this period (e.g., July).

5.5.3.2 Assess Species Exposure

5.5.3.2.1.1 Salmonids

Juvenile salmonids emigrating from the Sacramento River will be exposed to NPB operations, but will be unlikely to be exposed to construction/removal effects. Adult winter-run and spring-run Chinook salmon migrating upstream to natal tributaries in the Sacramento River basin will be exposed to NPB operations, but will be unlikely to overlap the construction or removal period. Adult steelhead returning to the Sacramento River basin will have the potential to overlap the construction period and the operations period.

5.5.3.2.1.2 Green Sturgeon

Green sturgeon occur year-round in the Delta and therefore could be subject to both construction and operations effects of the NPB.

5.5.3.3 Assess Fish Species Response

5.5.3.3.1.1 Salmonids

Any pile driving for NPB construction will be done with a vibratory hammer, which will minimize the potential for injury and likely limit adverse effects to avoidance by adult steelhead, the only listed salmonid likely to overlap construction. In-water work will be conducted using appropriate measures to minimize effects, as was done during the pilot implementations of the BAFF (National Marine Fisheries Service 2011) and FFGS (National Marine Fisheries Service 2014a).).

The potential effectiveness of the NPB for deterring juvenile salmonids from entry into Georgiana Slough was discussed in the context of operations in Section 5.4.1.3.1.2.1.2.2 *Nonphysical Fish Barrier at Georgiana Slough*. Operational effects also could include enhanced risk of predation near the NPB, as NPBs include in-water structures that predatory fish may use as ambush habitat, and there may be increased susceptibility to predation if migrating juvenile salmonids are startled by the NPB (particularly the BAFF, with its acoustic deterrence) and swim rapidly away. However, there was no evidence from acoustic tracking that juvenile salmonids were being preyed upon at higher rates near the BAFF compared to farther away in 2011 and 2012, and little evidence from acoustic tracking of predators that they occupied areas near the BAFF more frequently than other areas (DWR 2012, 2015). Indeed, the 2011 and 2012 BAFF pilot studies provided evidence that predatory fish were deterred by the BAFF being turned on,[69] with general evidence for increasing avoidance over time, although some species may have become conditioned to the BAFF over time and therefore will not have been deterred. Studies of the 2014 FFGS have not been completed to address these topics.

Migrating adult salmonids encountering the NPB could have upstream passage blocked or disrupted by the NPB, particularly if attempting to move upstream from Georgiana Slough to the Sacramento River, although based on the configurations used during the pilot studies[70], passage will be available under/around the FFGS, or under the BAFF. Installation of a nonphysical barrier at this location generally would not be anticipated to affect downstream-migrating juvenile San Joaquin River-origin steelhead and spring-run Chinook salmon, including fish from the Mokelumne/Cosumnes Rivers, assuming fish are generally going in a downstream direction (flow in Georgiana Slough generally being downstream). However, Del Real et al. (2012) found that a portion (20%) of acoustically tagged wild steelhead juveniles migrating from the Mokelumne River to Chipps Island migrated upstream through Georgiana Slough to the Sacramento River before moving towards Chipps Island. Upstream migration of juvenile steelhead in Georgiana Slough could lead to some individuals encountering the NPB. An FFGS

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[69] The BAFF was switched on and off every ~25 hours in order to test its effectiveness in deterring migrating juvenile salmonids.

[70] The BAFF pilot studies in 2011 and 2012 blocked the entire entrance to Georgiana Slough (allowing several feet of passage below the barrier), whereas the FFGS pilot study in 2014 had the FFGS slightly upstream of the entrance to Georgiana Slough to deter juvenile salmonids away from the left bank.

would be unlikely to pose much of a delay (assuming the whole channel mouth is not blocked), whereas a BAFF could result in passage delay or some risk of near-field predation, as discussed previously. The potential to swim under a BAFF would be good at Georgiana Slough, based on pilot studies wherein the sound stimulus and bubble-generating apparatus were in the middle of the water column in order to maintain the integrity of the bubble curtain. Alternatively, juvenile steelhead could migrate back downstream, which would lower the prospects for survival because this migration route generally results in greater mortality than the mainstem Sacramento River (Singer et al. 2013).

5.5.3.3.1.2 Green Sturgeon

As with adult steelhead, there may be limited construction effects to green sturgeon from disturbance, e.g., underwater noise from vibratory pile driving, but any construction effects will be limited with appropriate avoidance and minimization measures, as undertaken for the pilot studies and addressed in previous consultations (National Marine Fisheries Service 2011, 2014a). There will be limited potential for operational effects of the NPB on green sturgeon because the species' generally demersal position in the water column will allow passage under the NPB (with an above-bottom configuration, as employed for the BAFF in the 2011/2012 studies), and because green sturgeon that encounter the BAFF at close range would be expected to have a much more limited response to the acoustic stimuli of a BAFF compared to the response of the juvenile salmonids that the BAFF is targeting. The auditory thresholds of green sturgeon have not been determined, but the thresholds for a congeneric species (lake sturgeon, *Acipenser fulvescens*) are ~20-25 dB greater than the thresholds for juvenile Chinook salmon (Lovell et al. 2005; Oxman et al. 2007). For example, at 250 Hz, the threshold for lake sturgeon is ~130 dB re 1µPa (Lovell et al. 2005), whereas for juvenile Chinook salmon, it is just over 105 dB re 1µPa (Oxman et al. 2007). Avoidance of acoustic deterrents increases as the sound pressure level above the auditory threshold increases, with sound levels of 50-90 dB above threshold generally giving a stronger reaction than lower levels, by the majority of individuals (Nedwell et al. 2007). Given the BAFF's sound pressure levels (e.g., 146 to 159 dB re 1 µPa [mean = 152 dB re 1 µPa] for the 2011 study; Perry et al. 2014), the effects on green sturgeon would be expected to be much more limited than those for juvenile Chinook salmon, if the sturgeon encountered the BAFF and did not swim beneath it. .

5.5.3.4 Assess the Effects of the Action on Designated Critical Habitat

Designated critical habitat for listed salmonids (principally for adult steelhead) and green sturgeon could be affected by NPB construction, although the effects would be expected to be minimal and would be avoided or minimized by standard AMMs. The permanent footprint of the NPB is unknown, but given it is meant to be 'non-physical' to minimally affect flow, the footprint of the structure will be minimal and within the range described in previous consultations. Operations of the NPB would be expected to generally be beneficial to juvenile listed salmonids by keeping them in the mainstem Sacramento River; this would increase the proportion of winter-run Chinook salmon juveniles remaining within designated critical habitat, as only the mainstem Sacramento River is designated as critical habitat within this portion of the action area. As previously described, delay of adult salmonids (or juvenile steelhead from the Mokelumne River) migrating upstream through Georgiana Slough could occur, which would be an effect to migratory corridor or upstream access PBFs; however, passage around or under the NPB would be available. Green sturgeon tend to be demersal and have limited hearing ability in the range of the acoustic deterrent compared to the juvenile salmonids targeted by a BAFF (see discussion in Section 5.5.3.3.1.2 above), so effects from the NPB on critical habitat would be minimal and limited to temporary occupation of benthic habitat by supporting piles, for example.

5.6 Effects on Southern Resident Killer Whale

The Southern Resident killer whale DPS had 83 members as of April 13, 2016, excluding "Lolita", the confined individual at the Miami Seaquarium (Orca Network 2016). The DPS has a variable productivity rate (National Marine Fisheries Service 2009).

Two factors that could change under the PA and could affect Southern Resident killer whale are prey availability and exposure to contaminants.

5.6.1 Effects on Prey Availability

The PA will be implemented in freshwater and estuarine systems, but its effect may reach the marine system occupied by Southern Resident killer whales because Chinook salmon, the predominant prey of Southern Resident killer whales (Hanson et al. 2010, National Marine Fisheries Service 2014b), reside in the ocean for three to five years until returning to freshwater to spawn. A change in Southern Resident killer whale prey abundance could affect foraging efficiency, including the amount of energy expended per prey capture, ultimately affecting overall nutrition, reproductive capacity, immunity, and, if severe enough, survival. Changes in the average size and caloric density of prey fish can also influence the number of captures necessary to meet energetic requirements (O'Neill et al. 2014). Photographs of thin whales and observations of the "peanut-head syndrome" (loss of the nuchal fat pad behind the skull) in Southern Resident killer whales suggest that a few individuals in some seasons are significantly emaciated, although the ultimate cause of such malnutrition could be disease and other factors rather than a food shortage (NMFS 2010).

Changes to prey availability can act synergistically with other threats to produce a beneficial or adverse effect. For example, insufficient prey abundance could force whales to rely upon their fat stores, which may contain high contaminant levels (Ross et al. 2000). An increase in contaminant levels in the blood stream could induce immune suppression, impair reproduction, and produce other adverse physiological effects.

The PA has a potential to affect overall Chinook salmon abundance in the ocean. Fall-run Chinook salmon compose the large majority of Chinook salmon produced in the Central Valley, averaging an estimated 89% of total Chinook salmon escapement from 2006 to 2015 (CDFW 2016), and are the most common Central Valley Chinook salmon race eaten by Southern Resident killer whales (Hanson et al. 2010, National Marine Fisheries Service 2014b). Wild individuals make up 10 ± 6% of the overall fall-run Chinook salmon ocean fishery (Barnett-Johnson et al. 2007). Combined, these two values suggest that hatchery fall-run constitute a substantial proportion of all Chinook salmon entering the ocean from the Central Valley. This analysis of prey availability focuses on the fall-run Chinook, with special emphasis on hatchery produced fall-run, since this race, of all Central Valley salmon races, is currently the predominant prey of Southern Resident killer whales.

5.6.1.1 Effects of the Proposed Action on Central Valley Chinook Salmon Populations

The PA has the potential to result in incidental take of fall-run Chinook salmon associated with construction and operations. Construction effects include underwater noise from pile driving, in-water use of construction equipment, fish rescue efforts, and accidental discharge of contaminants (Section 5.2, *Effects of Water Facility Construction on Fish*). The effects of construction activities will be minimized through avoidance and minimization measures, and temporary and permanent habitat losses will be offset by channel margin enhancement and tidal wetland restoration.

As described in Appendix 5E, *Essential Fish Habitat Assessment*, the following changes have a potential to affect fall-run Chinook salmon in the Sacramento and American Rivers, upstream of the Delta. These changes are expected to result from operational effects of the PA: (1) increased frequency of water temperature threshold exceedances in the Sacramento River during September and October, coinciding with a portion of the spawning and juvenile rearing period; (2) decreased rearing habitat Weighted Usable Area (WUA) during June in some portions of the Sacramento River; (3) reduced flows in the Sacramento and American Rivers during some water year types in September and November that coincide with portions of the adult migration period; and (4) increased risk of redd dewatering for egg cohorts spawned in October in the Sacramento and American Rivers.

As discussed in Section 5.4.2.3, *Summary of Upstream Effects*, all upstream quantitative analyses are based on CalSim II modeling, and the uncertainties associated with using CalSim II outputs must be considered in interpreting biological analyses, as noted in Appendix 5.A, *CALSIM Methods and Results*. Results of CalSim II modeling do not exactly match what operators might do in a specific month or year within the simulation period because the latter would be informed by numerous real-time considerations that cannot be input to CalSim II. Rather, results are intended to be a reasonable representation of long-term operational trends of CVP and SWP, providing the ability to compare and contrast the effect of current and assumed future operational conditions.

The current real-time operations decision-making processes and the advisory groups will continue and will be improved under the PA (see Chapter 3, Section 3.1.5 *Real-Time Operations Upstream of the Delta*, and Section 3.3, *Operations and Maintenance for the New and Existing Facilities*). A separate real time operations coordination team (RTOCT) will meet to assist DWR and Reclamation in fulfilling their responsibility to inform the SWP and CVP participants regarding available information and real-time decisions. This coordination effort may also periodically review how to enhance or strengthen the scientific and technical information used to inform decision-making, and how to communicate with the public and other interested parties. This revised process and RTOCT will allow for minimization of modeled effects identified above to listed species under future operations of the PA.

In the Delta, the PA has the potential to affect fall-run Chinook salmon through entrainment (Appendix 5E, Section 5.E.5.3.1.2.1.1.1 *North Delta Exports* and Section 5.E.5.3.1.2.1.1.2, *Entrainment*), impingement (Appendix 5E, Section 5.E.5.3.1.2.1.1.1 *North Delta Exports*), predation at the NDD and south Delta facilities (Appendix 5E, Section 5.E.5.3.1.2.1.1.3 *Head of Old River Gate* and Section 5.E.5.3.1.2.1.1.1 *Predation*), and changes in flows that may affect migratory success, including both near-field and far-field effects (Appendix 5E, Section 5.E.5.3.1.2.1.2.1, *Indirect Mortality Within the Delta*) or availability of inundated riparian bench habitat (Appendix 5E, Section 5.E.5.3.1.2.1.2.2 *Habitat Suitability*). The principal near-field effect is predation at the NDD. The far-field effects primarily include NDD water diversions leading to lower flow velocity and therefore greater potential for predation; potential for greater entry into the interior Delta via Georgiana Slough (a lower survival route compared to the main stem Sacramento River); and less inundation of restored riparian bench habitats along the Sacramento River. For the south Delta, the PA is expected to reduce operational effects on fall-run Chinook salmon compared to the NAA based on improved south Delta channel flows, lower entrainment, and lower entry into the south Delta because of the HOR gate. Actions taken in compliance with NMFS (2009) and the proposed operational criteria for south Delta, NDD, and DCC provide protection during the winter and spring, thereby reducing the impact of CVP/SWP Delta operations on migrating fall-run Chinook salmon. In general, potential effects of the PA on fall-run Chinook salmon are expected to be less than those for winter-run and spring-run Chinook salmon because the timing of fall-run migration coincides more with the spring period, during which Sacramento River flows under the PA would be more similar to those under the NAA compared to other times of year.

The RTOCT and the Adaptive Management Program included in the PA provide additional opportunities to better define the operating criteria and make adjustments to CVP/SWP Delta operations to minimize the risk of incidental take while maximizing water supply. Identified operational effects of the PA on Sacramento winter-run and Central Valley spring-run Chinook salmon would be mitigated, and this mitigation is expected to reduce effects on fall-run Chinook salmon. The mitigation includes restoring channel margin habitat (Section 5.4.1.3.1.2.2.1.2 *Operational Effects*) and installing a nonphysical barrier at the Sacramento River-Georgiana Slough divergence (Section 5.4.1.3.1.2.1.2.2 *Nonphysical Fish Barrier to Georgiana Slough*). Projected operation of other Delta facilities (for example, the North Bay Aqueduct, Rock Slough Diversion, and the Suisun Marsh Salinity Control Gates [SMSCG]) is expected to result in discountable take of Chinook salmon (Sections 5.4.1.3.1.1.5 through 5.4.1.3.1.1.7, *Suisun Marsh Facilities, North Bay Aqueduct, Other Facilities*, respectively). With the implementation of real-time operations and these mitigation measures, effects from water facility operations on fall-run Chinook salmon would not be expected to produce measurable changes in population status, compared to existing conditions.

The potential effects of the PA on fall-run Chinook salmon described above apply to wild fall-run fish, but only apply for a subset of hatchery fish. Since the mid-1980s, the proportion of hatchery fall-run Chinook salmon juveniles released downstream of the Delta has varied from around 20% to 60% (Huber and Carlson 2015). These fish would not be susceptible or minimally susceptible to effects of the PA. However, hatchery fish released upstream would be subject to changes affecting juvenile migration habitat as well as all changes in the Delta, which could affect their abundance in the ocean.

Effects of the PA to late fall-, spring-, and winter-run Chinook salmon are similar to those described above for fall-run Chinook salmon, with small differences primarily resulting from differences in the timing of occurrence of the life stages. As previously indicated, these runs currently constitute about 11% of the total Central Valley Chinook salmon production, and are not known to constitute a substantial portion of the prey base for Southern Resident killer whale (relative to Central Valley fall-run Chinook salmon). However, the survival of the late fall-, spring-, and winter-run Chinook salmon increases the diversity of the prey available to Southern Resident killer whales, potentially contributing to the long-term sustainability of their prey base (NMFS 2009). The following three summaries list the changes upstream of the Delta with the most potential to affect the three runs.

The changes in the Delta as summarized above are the same for all the runs, except that effects occurring in the south Delta would be somewhat more important for fall-run Chinook salmon because they spawn and rear in the San Joaquin River Basin in addition to the Sacramento River Basin, whereas late fall- and winter-run Chinook salmon spawn and rear only in the Sacramento River Basin. Spring-run Chinook salmon spawn and rear primarily in the Sacramento River Basin, but, as previously described in Section 4.5.2 *Chinook Salmon, Central Valley Spring-Run ESU*, they are currently being reintroduced to the San Joaquin River Basin and have been observed in the San Joaquin River tributaries in recent years (NMFS 2016). The discussions above concerning effects of CalSim II modeling uncertainties and real-time operations apply to late fall-, spring-, and winter-run Chinook salmon, as well. In fact, spring- and winter-run may benefit more from real-time operations because the operations target these ESUs due to their protected status.

As described in Appendix 5E *Essential Fish Habitat Assessment*, the following changes, which have a potential to affect late fall-run Chinook salmon in the Sacramento River upstream of the Delta, are expected to result from the PA: (1) increased frequency of water temperature threshold exceedances in the Sacramento River during September and October, coinciding with portions of the spawning and juvenile rearing periods; (2) decreased rearing habitat Weighted Usable Area (WUA) during June in some portions of the Sacramento River; and (3) reduced flows in the Sacramento River during September, coinciding with a portion of the juvenile migration period, and during November, coinciding with portions of the juvenile and adult migration periods; and (4) increased risk of redd dewatering for egg cohorts spawned in October in the Sacramento River.

As provided in Chapter 7 *Effects Determination*, the following changes, which have a potential to affect spring-run Chinook salmon in the Sacramento River upstream of the Delta, are expected to result from the PA: (1) increased frequency of water temperature threshold exceedances during August through October, coinciding with portions of the spawning and rearing periods; (2) increased risk of redd dewatering for egg cohorts spawned in August; (3) decreased rearing WUA during June in some portions of the Sacramento River, and (4) reduced flows during September, which could affect adult migration, and during November, which could affect juvenile migration.

As provided in Chapter 7 *Effects Determination*, the following changes, which have a potential to affect winter-run Chinook salmon in the Sacramento River upstream of the Delta, are expected to result from the PA: (1) increased frequency of water temperature threshold exceedances during August through October, coinciding with portions of the spawning and rearing periods; (2) increased risk of redd dewatering for egg cohorts spawned in June and August; and (3) reduced flows during September and November that could affect juvenile migration.

The PA has the potential to affect the abundance and/or size distribution of Central Valley late fall-, spring-, and winter-run Chinook salmon adults in the ocean. Mitigation measures and real-time operations (described above) under the PA would minimize potential impacts. These runs currently constitute about 10% of the total Central Valley Chinook salmon production (CDFW 2016), and are not known to constitute a significant portion of the prey base for Southern Resident killer whale (relative to the fall-run Chinook salmon). The survival of the late fall-, spring-, and winter-run Chinook salmon increases the diversity of the prey available to Southern Resident killer whales, potentially contributing to the long-term sustainability of their prey base (NMFS 2009).

5.6.1.2 Effects of the Proposed Action on Southern Resident Killer Whales

Overall ocean abundance estimates for Chinook salmon are provided by the Pacific Fisheries Management Council (2016). Estimates for 2016 indicate an ocean abundance for Central Valley Chinook salmon stocks of 299,600 fish. The only other tracked stock south of the Columbia River, the Klamath River, is estimated to have a 2016 ocean abundance of 142,200 fish. The Columbia River stocks account for a further 1,317,700 fish, with other stocks south of the Strait of Juan de Fuca providing another 65,500 fish. Puget Sound, Hood Canal, and the Strait of Juan de Fuca provide another 150,600 fish. Thus, total Chinook salmon abundance from sources in the action area amounts to 1,975,600 fish, of which 299,600/1,975,600=15% originate from the Central Valley.

If the PA is to affect prey availability of Southern Resident killer whales, there must be overlap in the spatial and temporal distributions of the whales and Central Valley salmon. Some overlap must exist under current conditions because Central Valley fall-run Chinook salmon have been documented in the diet of Southern Resident killer whale (Hanson 2010), but the frequency of occurrence of such overlap is poorly known.

During summer, most Southern Resident killer whales reside in the protected inland waters of Washington State and southern British Columbia, where they feed primarily on Fraser River Chinook salmon (Hanson et al. 2013, 2010). Their distribution during winter and spring is less well known, but less than a third of the whales remain in their summer habitat, with many moving into coastal waters primarily south of their summer range (NMFS 2010, Hanson 2013). They have been sighted as far south as Monterey Bay in central California (NMFS 2014b). Passive acoustic monitors sited from Cape Flattery, Washington, to Point Reyes, north of San Francisco Bay, during January through June, have detected Southern Resident killer whales at all locations, but predominantly near and north of the Columbia River (Hanson et al. 2013). During 2011, the one year when results were available from all the monitors, seven detections, or about 5% of the total, were obtained from locations south of the Columbia River. These results and others (NMFS 2010) indicate that Southern Resident killer whales occur in California coastal waters, but infrequently.

Weitkamp’s (2010) study of recoveries of coded wire tagged (CWT) hatchery Chinook salmon in ocean fisheries provides strong evidence that marine distributions vary greatly according to the origin of the stocks. The Central Valley stocks were recovered as far north as Vancouver Island, but 94% were recovered south of the Columbia River. Bellinger et al. (2015) conducted a more fine-grained study of the ocean distributions of Chinook salmon south of the Columbia

River using genetic stock identification data rather than CWT recoveries. Central Valley Chinook salmon (primarily fall-run) made up about 22% of the Chinook salmon sampled off the Oregon coast and about 50% of those sampled off the California coast (south to Big Sur) (data from Appendix 3, Bellinger et al. 2015). Note that for both studies, the results were from late-spring to early-autumn, when Southern Resident killer whales are believed not to inhabit the coast south of the Columbia River. However, except when salmon are migrating to spawn, the winter and spring distributions are assumed to be similar.

Given that Southern Resident killer whales occur during winter months as far south as Monterey Bay (NMFS 2014b) and that Central Valley chinook salmon compose a large percentage of the Chinook salmon available south of the Columbia River (Bellinger et al. 2015), it is reasonable to expect that the whales could be affected by a change in the availability of Central Valley Chinook salmon. Because the population of Southern Resident killer whales is low, loss of a single individual or reduction in its reproductive capacity could adversely affect recovery of the population (NMFS 2009). As indicated in the previous section, the PA is expected to have some effects on Chinook salmon, but given the complexity of the effects, including that there are both positive and negative effects, it is not feasible to identify either the magnitude or even the sign of changes in population abundance of the Central Valley Chinook salmon resulting from project implementation. In addition, with regard to an evaluation of the potential effects of reduced ocean harvest of Chinook salmon on Southern Resident killer whale, Ward et al. (2013) found that, although there would likely be short-term benefits to Southern Resident killer whale, they had low confidence in their ability to detect differences resulting from the increase in prey abundance. A similar finding was noted by Strange (2016), which implicated wide confidence intervals resulting from uncertainties and assumptions of multiple model parameters as the cause for a lack of differences in Southern Resident killer whale population response to various hatchery production and ocean harvest rate scenarios. Similarly, there may be effects of the PA, but there is low confidence in the ability to detect these differences. Regardless of the uncertainties related to the effect on Southern Resident killer whale due to changes in their prey base, with implementation of real-time operations, the Cooperative Science and Adaptive Management Program, and proposed mitigation measures, effects of the PA on Central Valley Chinook salmon ocean abundances, and thus on use of that prey base by the Southern Resident killer whale, are expected to be insignificant.

5.6.2 Effects on Exposure to Contaminants

Southern resident killer whales are susceptible to accumulating high contaminant loads from their prey because of their position atop the food web and long life expectancy (Ylitalo et al. 2001; Grant and Ross 2002; National Marine Fisheries Service 2014). Killer whales are exposed to many anthropogenic contaminants, but persistent organic pollutants such as PCBs, DDT, dioxins, and furans are of particular concern because they bioaccumulate in aquatic food chains and are toxic to biota (O'Shea 1999; Reijnders and Aguilar 2002).

The PA would cause negligible differences in the contaminant load of Chinook salmon during their residence in fresh water. Selenium would not increase in salmon because species in which selenium accumulates are long lived and epibenthic, such as sturgeon. Chinook salmon are in the Delta for short periods (less than one year) and are not epibenthic. As described in Section 5.4.1.3.1.2.2.3, *Selenium*, this was confirmed by quantitative analyses of potential effects on trophic level 3 species, which include Chinook salmon, showing essentially no difference between PA and NAA scenarios in particulate, invertebrate, or whole-body estimates of selenium concentration (see Appendix 5.F, *Selenium Analysis*).

Minor or negligible increases in methylmercury may occur as a result of tidal marsh restoration that would be undertaken to offset losses caused by water facility construction. With AMMs to address the potential for methylmercury production at the tidal restoration site(s) and the relatively small area proposed for restoration, no measurable effects on Chinook salmon are expected. Microcystis does not generally overlap with salmonids and, therefore Chinook salmon would not be affected by Microcystis. As such the PA does not result in changes in any contaminants and salmonids acquire most of their contaminant loads while in marine waters (O'Neill et al. 1998; Grant and Ross 2002). Therefore, any changes in contaminants under the PA are not expected to result in adverse bioaccumulation effects on southern resident killer whales because the PA would not result in changes in contaminant loads in the whale's prey base.

5.6.3 Effects on Critical Habitat

Critical habitat for the Southern Resident killer whale was designated in November 2006 (71 CFR 229). Three specific areas are designated, (1) the Summer Core Area in Haro Strait and waters around the San Juan Islands; (2) Puget Sound; and (3) the Strait of Juan de Fuca, which comprise approximately 2,560 square miles (6,630 sq km) of marine habitat. The designation includes the following PBFs essential for conservation of the Southern Resident killer whale:

1. Water quality to support growth and development; and
2. Prey species of sufficient quantity, quality, and availability to support individual growth, reproduction, and development, as well as overall population growth; and
3. Passage conditions to allow for migration, resting, and foraging.

NMFS is currently conducting a 12-month review of critical habitat and will consider including an additional PBF related to in-water sound levels (80 CFR 36).

Southern Resident killer whales rely on 23 different species as prey, with salmon being the preferred prey (71 CFR 229). Given that critical habitat occurs within Puget Sound and the Strait of Juan de Fuca, the majority of prey consumed within critical habitat consists of populations native to rivers tributary to that habitat. The precise proportion of Central Valley-origin Chinook salmon consumed in the Southern Resident killer whale diet when they are feeding within critical habitat has not been determined, but fewer than 10% of Central Valley-origin Chinook salmon are collected from as far north as Tillamook Head on the northern Oregon coast (Satterthwaite et al. 2013), and Southern Resident killer whale critical habitat is several hundred kilometers north of that area. The principal source of prey for Southern Resident killer whale within critical habitat is Fraser River-origin Chinook salmon, with chum salmon also important for fall foraging in Puget Sound (National Marine Fisheries Service 2014b).

In summary, the PA has no potential to affect water quality within Southern Resident killer whale critical habitat; the PA has low potential to affect the production of Central Valley–origin

Chinook salmon; and the proportion of Central Valley-origin Chinook salmon occurring within designated critical habitat is very low and thus has negligible potential to affect the Southern Resident killer whale prey base within critical habitat.

5.6.4 Conclusion

The PA would not be expected to result in change in the abundance of Southern Resident killer whales' Chinook salmon prey in the ocean, and no other mechanism has been identified through which the PA could affect the Southern Resident killer whale.

5.7 Cumulative Effects on Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale

Cumulative effects are those effects of future state or private activities that are reasonably certain to occur within the action area of the Federal action subject to consultation (50 CFR 402.02). Future Federal actions that are unrelated to the PA are not considered in this section because they require separate consultation pursuant to Section 7 of the ESA. A list of specific projects considered for the cumulative effects analysis is included as Appendix 5.G, *Projects to Be Included in Cumulative Effects Analysis for the Conveyance Section 7 Biological Assessment*. The EIR/EIS includes a cumulative analysis consistent with NEPA and CEQA and can further inform the potential for cumulative effects.

5.7.1 Water Diversions

Water diversions for irrigated agriculture, municipal and industrial use, and managed wetlands are found throughout the Central Valley. Thousands of small and medium-size water diversions exist along the Sacramento River, San Joaquin River, their tributaries, and the Delta, and many of them remain unscreened. For example, as of 1997, 98.5% of the 3,356 diversions included in a Central Valley database were either unscreened or screened insufficiently to prevent fish entrainment (Herren and Kawasaki 2001). Most of the 370 water diversions operating in Suisun Marsh are unscreened (Herren and Kawasaki 2001).

Depending on the size, location, and season of operation, these unscreened diversions may entrain and kill many life stages of aquatic species, including juvenile listed anadromous species.

5.7.2 Agricultural Practices

Agricultural practices occur throughout the Central Valley adjacent to waterways used by Chinook, steelhead, and green sturgeon. These activities, including burning or removal of vegetation on levees and livestock grazing, may negatively affect riparian and wetland habitats through upland modifications that lead to increased siltation or reductions in water flow in stream channels flowing into the action area, including the Sacramento River and Delta. Agricultural practices may also introduce nitrogen, ammonia, and other nutrients into the basin, which then flow into receiving waters. Stormwater and irrigation discharges related to both agricultural and urban activities contain numerous pesticides and herbicides that may negatively affect salmonid and sturgeon reproductive success and survival rates (Dubrovsky et al. 1998; Kuivila and Moon 2004; Scholz et al.2012). Discharges occurring outside the action area but that flow downstream into the action area also contribute to cumulative effects.

5.7.3 Increased Urbanization

The Delta Protection Commission's Economic Sustainability Plan for the Delta reported a growth rate of about 54% within the statutory Delta between 1990 and 2010, as compared with a 25% growth rate statewide during the same period (Delta Protection Commission 2012). The report also indicated that population growth had occurred in the Secondary Zone of the Delta but not in the Primary Zone and that population in the central and south Delta areas had decreased since 2000. Growth projections through 2050 indicate that all counties overlapping the Delta are projected to grow at a faster rate than the state as a whole. Total population in the Delta counties is projected to grow at an average annual rate of 1.2% through 2030 (California Department of Finance 2012). Table 5.7-1 illustrates past, current, and projected population trends for the five counties in the Delta. As of 2010, the combined population of the Delta counties was approximately 3.8 million. Sacramento County contributed 37.7% of the population of the Delta counties, and Contra Costa County contributed 27.8%. Yolo County had the smallest population (200,849 or 5.3%) of all the Delta counties.

Table 5.7-1. Delta Counties and California Population, 2000–2050

Area	2000 Population (millions)	2010 Population (millions)	2020 Projected Population (millions)	2025 Projected Population (millions)	2050 Projected Population (millions)
Contra Costa County	0.95	1.05	1.16	1.21	1.50
Sacramento County	1.23	1.42	1.56	1.64	2.09
San Joaquin County	0.57	0.69	0.80	0.86	1.29
Solano County	0.40	0.41	0.45	0.47	0.57
Yolo County	0.17	0.20	0.22	0.24	0.30
Delta Counties	3.32	3.77	4.18	4.42	5.75
California	34.00	37.31	40.82	42.72	51.01

Source: California Department of Finance 2012.

Table 5.7-2 presents more detailed information on populations of individual communities in the Delta. Growth rates from 2000 to 2010 were generally higher in the smaller communities than in larger cities such as Antioch and Sacramento. This is likely a result of these communities having lower property and housing prices, and their growth being less constrained by geography and adjacent communities.

Table 5.7-2. Delta Communities Population, 2000 and 2010

Community	2000	2010	Average Annual Growth Rate 2000–2010
Contra Costa County			
Incorporated Cities and Towns			
Antioch	90,532	102,372	1.3%
Brentwood	23,302	51,481	12.1%
Oakley	25,619	35,432	3.8%
Pittsburg	56,769	63,264	1.1%
Small or Unincorporated Communities			
Bay Point	21,415	21,349	-0.0%
Bethel Island	2,252	2,137	-0.5%
Byron	884	1,277	4.5%
Discovery Bay	8,847	13,352	5.1%
Knightsen	861	1,568	8.2%
Sacramento County			
Incorporated Cities and Towns			
Isleton	828	804	-0.3%
Sacramento	407,018	466,488	1.5%
Small or Unincorporated Communities			
Courtland	632	355	-4.4%
Freeport and Hood	467	309[a]	-3.4%
Locke	1,003	Not available	—
Walnut Grove	646	1,542	13.9%
San Joaquin County			
Incorporated Cities and Towns			
Lathrop	10,445	18,023	7.3%
Stockton	243,771	291,707	2.0%
Tracy	56,929	82,922	4.6%
Small or Unincorporated Communities			
Terminous	1,576	381	-7.6%
Solano County			
Incorporated Cities and Towns			
Rio Vista	4,571	7,360	6.1%
Yolo County			
Incorporated Cities and Towns			
West Sacramento	31,615	48,744	5.4%
Small or Unincorporated Communities			
Clarksburg	681	418	-3.9%

Sources: U.S. Census Bureau 2000; U.S. Census Bureau 2011.

[a] Freeport had a population of 38; Hood had a population of 271.

Increases in urbanization and housing developments can impact habitat by altering watershed characteristics, and changing both water use and stormwater runoff patterns. Increased growth will place additional burdens on resource allocations, including natural gas, electricity, and water, as well as on infrastructure such as wastewater sanitation plants, roads and highways, and public utilities. Some of these actions will not require Federal permits and thus will not undergo review through the Section 7 consultation process.

Adverse effects on Chinook, steelhead, and green sturgeon and their critical habitat may result from urbanization-induced point and non-point source chemical contaminant discharges within the action area. These contaminants include, but are not limited to ammonia and free ammonium ion, numerous pesticides and herbicides, and oil and gasoline product discharges. Increased urbanization also is expected to result in increased recreational activities in the region. Among the activities expected to increase in volume and frequency is recreational boating and fishing. Boating activities typically result in increased wave action and propeller wash in waterways. This potentially will degrade riparian and wetland habitat by eroding channel banks and mid-channel islands, thereby causing an increase in siltation and turbidity. Wakes and propeller wash also churn up benthic sediments thereby potentially resuspending contaminated sediments and degrading areas of submerged vegetation. This, in turn, would reduce habitat quality for the invertebrate forage base required for the survival of juvenile salmonids and green sturgeon moving through the system. Increased recreational boat operation in the Delta is anticipated to result in more contamination from the operation of gasoline and diesel powered engines on watercraft entering the water bodies of the Delta.

5.7.4 Wastewater Treatment Plants

Two wastewater treatment plants (one located on the Sacramento River near Freeport and the other on the San Joaquin River near Stockton) have received special attention because of their discharge of ammonia. The Sacramento Regional Wastewater Treatment Plan (SRWTP), in order to comply with Order no. R5-2013-0124, has begun implementing compliance measures to reduce ammonia discharges. Construction of treatment facilities for three of the major projects required for ammonia and nitrate reduction was initiated in March 2015 (Sacramento Regional County Sanitation District 2015) Order no. R5-2013-0124, which was modified on October 4, 2013, by the Central Valley Regional Water Quality Control Board–imposed new interim and final effluent limitations, which must be met by May 11, 2021 (Central Valley Regional Water Quality Control Board 2013). By May 11, 2021, the SRWTP must reach a final effluent limit of 2.0 milligrams per liter (mg/L) per day from April to October, and 3.3 mg/L per day from November to March (Central Valley Regional Water Quality Control Board 2013). However, the treatment plant is currently releasing several tons of ammonia in the Sacramento River each day.

EPA published revised national recommended ambient water quality criteria for the protection of aquatic life from the toxic effects of ammonia in 2013.

Few studies have been conducted to assess the effects of ammonia on Chinook salmon, steelhead, or sturgeon. However, studies of ammonia effects on various fish species have shown numerous effects including membrane transport deficiencies, increases in energy consumption, immune system impairments, gill lamellae fusions deformities, liver hydropic degenerations, glomerular nephritis, and nervous and muscular system effects leading to mortality (Connon et al. 2011). Additionally, a study of Coho salmon and rainbow trout exposed to ammonia showed a decrease in swimming performance due to metabolic challenges and depolarization of white muscle (Wicks et al. 2002).

5.7.5 Activities within the Nearshore Pacific Ocean

Future tribal, state and local government actions will likely be in the form of legislation, administrative rules, or policy initiatives and fishing permits. Activities are primarily those conducted under state, tribal or Federal government management. These actions may include changes in ocean policy and increases and decreases in the types of activities that currently occur, including changes in the types of fishing activities, resource extraction, or designation of marine protected areas, any of which could impact listed species or their habitat. Government actions are subject to political, legislative and fiscal uncertainties. These realities, added to the geographic scope, which encompasses several government entities exercising various authorities, and the changing economies of the region, make analysis of cumulative effects speculative.

A Final Recovery Plan for Southern Resident killer whales was published in 2008 (National Marine Fisheries Service 2008). Although state, tribal and local governments have developed plans and initiatives to benefit marine fish species, ESA-listed salmonids, green sturgeon, and Southern Residents, they must be applied and sustained in a comprehensive way before NMFS can consider them “reasonably certain to occur” in its analysis of cumulative effects. Private activities are primarily associated with commercial and sport fisheries, construction, and marine pollution. These potential factors are ongoing and expected to continue in the future, and the level of their impact is uncertain. For these reasons, it is not possible to predict beyond what is included in the subsections pertaining to cumulative effects, above whether future non-Federal actions will lead to an increase or decrease in prey available to Southern Resident, or have other effects on their survival and recovery.

5.7.6 Other Activities

Other future, non-Federal actions within the action area that are likely to occur and may adversely affect Chinook, steelhead, and green sturgeon and their critical habitat include: the dumping of domestic and industrial garbage that decreases water quality; oil and gas development and production that may affect aquatic habitat and may introduce pollutants into the water; and state or local levee maintenance that may also destroy or adversely affect habitat and interfere with natural, long term habitat-maintaining processes.

Power plant cooling system operations can also affect aquatic habitat. Contra Costa Power Plant, which was owned and operated by NRG Delta, LLC, was retired in 2013 and replaced with the new natural gas power plant, Marsh Landing Generating Station. The Pittsburg Generating Station (PGS) remains in operation and consisted of seven once-through cooling systems, four of which have been retired, one of which is in the process of being retired, and two of which remain in operation. The once-through cooling system intake process can cause the impingement and entrainment of marine animals, kill organisms from all levels of the food chain, and disrupt the normal processes of the ecosystem. Additionally, the plant can discharge heated water that can reach temperatures as high as 100°F into the action area. This sudden influx of hot water can adversely affect the ecosystem and the animals living in it (San Francisco Baykeeper 2010).

On May 4, 2010, the SWRCB adopted a Statewide Policy on the Use of Coastal and Estuarine Water for Power Plant Cooling under Resolution No. 2010–0020, which required existing cooling water intake structures to reflect the best technology available for minimizing adverse environmental impacts (State Water Resources Control Board 2010). The PGS was required to submit an implementation plan to comply with this policy by December 31, 2017. The PGS chose to comply by retrofitting two of the existing units and retiring one unit. The retrofit and retirement of these units is underway (GenOn 2011).

5.8 Effects of Monitoring Activities

As described in Section 3.4.8, *Monitoring and Research Program*, effectiveness monitoring for fish would consist of a combination of continuation of existing monitoring authorized under the 2008/2009 BiOps (i.e., principally salvage and larval smelt monitoring at the south Delta export facilities), as well as additional monitoring of the NDD (principally entrainment and impingement monitoring). Entrainment monitoring at the NDD would consist of sampling entrained fish behind the fish screens with a fyke net (see Table 3.4-5 in Chapter 3); impingement monitoring methods are not specified at this time, but on the basis of existing monitoring (e.g., Freeport Regional Water Authority intake's fish screen), would be likely to consist of visual observation by diver survey or acoustic imaging camera. Other monitoring activities that are part of the PA would be unlikely to affect listed salmonids or green sturgeon and are not discussed here. Existing monitoring activities that would inform operations of the PA (e.g., trawl and seines surveys by DFW and USFWS) are not part of the PA. Although monitoring activities at restoration sites have not been determined, they are not expected to include in-water work with any potential to harm salmonids or green sturgeon.

5.8.1 Salmonids

As discussed in Section 5.4.1.3.1.1.1.1, *Entrainment*, for the NDD, the NDD fish screens would exclude juvenile salmonids from entrainment, so there would be no effect from entrainment monitoring at the NDD. If impingement monitoring were to consist of visual observation by diver survey, there would be minor potential for migrating salmonids occurring immediately adjacent to the fish screens to be startled and leave the immediate area if encountering the divers; there would be no effect if conducting observations with an acoustic imaging camera. At the south Delta export facilities, salvage of juvenile salmonids would be done in the same way under NAA and PA. Some juvenile salmonids collected during sampling of salvaged fish would die; however, as shown in Section 5.4.1.3.1.1.2, *Impingement, Screen Contact, and Screen Passage Time*, entrainment at the south Delta export facilities is expected to be lower under the PA than NAA, therefore any effects to juvenile salmonids from salvage monitoring would be lower under the PA than NAA. Given that monitoring informs adjustments to operations to protect migrating juvenile salmonids, the ultimate net effect of monitoring would be expected to be positive from a population-level perspective. Monitoring would have no effects on designated critical habitat for listed salmonids.

5.8.2 Green Sturgeon

Much of the prior discussion for salmonids also applies to green sturgeon with respect to the potential for effects from monitoring activities. As discussed in Section 5.4.1.3.2.1.1.1, *Entrainment*, for the NDD, the NDD fish screens would exclude juvenile salmonids from entrainment, so there would be no effect from entrainment monitoring at the NDD. As noted for salmonids, diver observation during impingement monitoring could startle any sturgeon near the NDD, whereas such effects would be absent with video monitoring. Less green sturgeon would be expected to be sampled under the PA compared to NAA during monitoring of south Delta salvage, because of lower south Delta exports under the PA (see Section 5.4.1.3.2.1.2.1, *Entrainment*). Monitoring would have no effects on designated critical habitat for green sturgeon.

5.9 References

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5.9.1 Personal Communications

Israel, Josh. Fisheries Biologist, U.S. Bureau of Reclamation. February 20, 2012—Telephone communication with Rick Wilder discussing flow correlates of white sturgeon year class strength, possible mechanisms for relationships, and previous analyses to determine correlations and reporting of them.

Marcinkevage, Cathy. Biomodeler, Bay Delta Conservation Planning Branch, California Central Valley Office, NOAA Fisheries, Sacramento, CA. June 5, 2015—Memorandum to Theresa Olson (US Bureau of Reclamation), Gwen Buchholz (CH2M HILL), and Rick Wilder (ICF International). June 5, 2015.

Marcinkevage, Cathy. Biomodeler, Bay Delta Conservation Planning Branch, California Central Valley Office, NOAA Fisheries, Sacramento, CA. June 27, 2016—Email containing salvage data (CVP_SWP CWT_WY16.xlsx) for 2016 experimental releases of SJR spring-run Chinook salmon sent to Brooke Miller-Levy (US Bureau of Reclamation), Jennifer Pierre (ICF International), Gwen Buchholz (CH2M HILL), and Ryan Wulff (NMFS). June 27, 2016.

Phyllis, Corey C. Resource Specialist, Metropolitan Water District of Southern California. Sacramento, CA. May 25, 2016—Telephone and email communication summary of results from winter-run Chinook salmon otolith microchemistry studies provided to Marin Greenwood, aquatic ecologist, ICF International, Sacramento, CA.