## 4.3 Take of Sacramento River Winter-run Chinook Salmon

### 4.3.1 Introduction

The potential effects of the proposed project (PP) on Sacramento River winter-run Chinook salmon are evaluated in this section. The species is evaluated with regard to the effects of the PP, i.e., water facility construction, water facility maintenance, water facility operations, mitigation, monitoring activities, and cumulative effects.

Take estimation for the purposes of the direct effects, cumulative effects, and climate change assessments is based upon the likelihood of physical injury or mortality to individuals of winter-run Chinook salmon. It is not possible to predict the number of individuals that would be subject to such take; in general, that would be a density-dependent phenomenon, e.g., with more fish subject to take in years when a relatively large run passes through the Sacramento-San Joaquin Delta. Instead, the risk of take is assessed through proxies such as the area of habitat affected, the duration of impact pile driving, or the probability of a contaminant release. Each section of the take analysis identifies the mechanisms by which take could occur and the probability that take would occur. If that probability is substantial, so that some individuals are likely to suffer mortality, then factors influencing the magnitude of take are detailed or qualitatively assessed; typically these include take minimization measures (detailed in Chapter 5 *Mitigation*), as well as the take proxies mentioned above. Mitigation is described (in Chapter 5 *Mitigation*) that is proportionate to the take, so as to show full mitigation for the take. The take analysis considers mechanisms of take for which authorization is needed (such as, conveyance facility construction and operations), as well as mechanisms of take for which authorization is not here requested (such as, maintenance activities or construction of mitigation sites) or is not needed (such as, CVP operations, cumulative effects, or climate change), because all such mechanisms are considered in determining whether the PP is likely to jeopardize winter-run Chinook salmon.

Scientific uncertainty exists with respect to the potential effects of the PP on winter-run Chinook salmon. As described in Section 6.2 *Collaborative Science and Adaptive Management Program*, 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.

### 4.3.2 Effects of Water Facility Construction

#### *4.3.2.1 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 winter-run Chinook salmon. Approximately 100 over-water borings are currently proposed to collect geotechnical data at the NDDs, 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[1]. Overwater borings for the NDDs and river crossings for tunnels will be carried out by a drill ship and barge-mounted drill rigs. A number of take minimization measures are proposed to avoid or minimize potential turbidity, suspended sediment, and other water quality impacts (e.g., bentonite or contaminant spills) on winter-run Chinook salmon and aquatic habitat during geotechnical activities: AMM1 *Worker Awareness Training;* AMM2 *Construction Best Management Practices and Monitoring;* AMM3 *Stormwater Pollution Prevention Plan (SWPPP);* AMM4 *Erosion and Sediment Control Plan;* AMM5 *Spill Prevention, Containment, and Countermeasure Plan;* AMM6 *Disposal and Reuse of Spoils, Reusable Tunnel Material, and Dredged Material;* AMM7 *Barge Operations Plan;* and AMM14 *Hazardous Material Management* (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 winter-run Chinook salmon and primary migration seasons of adults in the Delta. There is some potential for winter-run juveniles (less than 60 mm in length) to occur in the lower Sacramento River and Delta in September/October but this is uncommon; typically, the earliest that juveniles would be expected to occur in the project area is November or December (del Rosario et al. 2013). However, rotary screw trapping at Knights Landing in September 2016[2] has collected small numbers of small (30–51 mm) winter-run Chinook salmon juveniles, indicating that a small number of individuals of the species could enter the Delta and be exposed to the activities occurring in the summer work window.

With containment of all in-water drilling activities to closed systems and implementation of the take minimization measures 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. Winter-run Chinook salmon that may be present during the in-water work period could consist of large, active adults that are capable of avoiding such disturbances with minimal harassment or risk of injury, but also small numbers of small juveniles. Therefore, there could be take of a small number of winter-run Chinook salmon juveniles.

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[1] See Permit Resolution Log item #26 for further information on this point.

[2] Rotary screw trapping in previous years commenced in October.

Geotechnical activities may affect habitat of winter-run Chinook salmon through suspension and deposition of sediment or direct disturbance of channel sediments and benthic food resources at the drilling sites[3]. However, these effects are expected to be negligible 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 winter-run Chinook salmon at the proposed facilities and tunnel alignment crossings  (see Section 4.3.2.2.7 *Loss/Alteration of Habitat*, Section 4.3.2.3.7 *Loss/Alteration of Habitat*, Section 4.3.2.4.7 *Loss/Alteration of Habitat*, and Section 4.3.2.5.7 *Loss/Alteration of Habitat*). Consequently, with implementation of the proposed in-water work window and take minimization measures, geotechnical exploration is not likely to result in more than minimal take of winter-run Chinook salmon.

### *4.3.2.2 North Delta Diversions*

#### *4.3.2.2.1 Overview*

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 and consist 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 an 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[4]. All in-water activities will be restricted to June 1 to 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.,

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[3] See Permit Resolution Log item #29 for further information on this point.

[4] See Permit Resolution Log item #30 for further information on this point.

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.

After the intakes are completed, the area in front of each intake will be dredged to provide appropriate flow conditions at the intake entrance[5]. Dredging will only occur during the approved in-water work window and will be minimized to the extent practicable.

Construction of the NDDs will result in permanent and temporary impacts on aquatic habitat in the Sacramento River. Approximately 6.6 acres of tidal perennial habitat and 1.02 linear miles of channel margin habitat will 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, will affect approximately 20.1 acres of tidal perennial habitat. Temporary impacts on channel margin habitat will occur within the same footprint as permanent impacts.

Construction activities that could affect winter-run Chinook salmon include cofferdam installation, levee clearing and grading[6], 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.

##### *4.3.2.2.2 Turbidity and Suspended Sediment*

Construction activities that disturb the riverbed and banks within the footprints of the NDDs may temporarily increase turbidity and suspended sediment levels in the Sacramento River. These activities include cofferdam installation and removal, levee clearing and grading[7], 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 an in-water work window from June 1 to October 31. In addition, DWR will implement a number of take minimization measures to avoid or minimize potential turbidity, suspended sediment, and other water quality impacts on winter-run Chinook salmon and aquatic habitat: AMM1 *Worker Awareness Training; Construction Best Management Practices and Monitoring;* AMM3 *Stormwater Pollution Prevention Plan (SWPPP);* AMM4 *Erosion and Sediment Control Plan;* AMM5 *Spill Prevention, Containment, and Countermeasure Plan;* AMM6 *Disposal and Reuse of Spoils, Reusable Tunnel Material, and Dredged Material;* AMM7 *Barge Operations Plan;* and AMM14 *Hazardous Material Management* (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)

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[5] See Permit Resolution Log item #31 for further information on this point.
[6] See Permit Resolution Log item #32 for further information on this point.
[7] See Permit Resolution Log item #32 for further information on this point.

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 work window will be minimal.

###### 4.3.2.2.2.1 Assess Species Exposure

The Sacramento River is the primary migration route used by adult winter-run Chinook salmon to access upstream spawning areas, and the primary migration route for juveniles entering the Delta and estuary from upstream spawning and rearing areas. Restricting all in-water construction activities to June 1 to October 31 avoids the primary migration and rearing seasons of winter-run Chinook salmon. In some years, a small proportion of the spawning run of winter-run Chinook salmon may be migrating through the project area as late as June and July although water temperatures frequently exceed suitable ranges by late June or early July. In addition, winter-run juveniles (less than 60 mm in length) may occur in the project area in September/October but this is uncommon; juveniles are typically not detected in the lower Sacramento River and Delta until November or December following the first major rain event and flows of at least 14,000 cfs in the Sacramento River (measured at Wilkins Slough) (del Rosario et al. 2013).

###### 4.3.2.2.2.2 Assess Species Response

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[8], 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 such activities could result in turbidity levels exceeding 25–75 NTUs and potentially result in disruption of 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 on listed fish species will be limited to brief exposures and likely avoidance of channel areas subjected to elevated turbidity and suspended sediment levels during active in-water work. Dredging will likely generate the most continuous sources of elevated turbidity and suspended sediment but will affect a relatively small portion of the channel during daylight hours only, resulting in minor disruptions in migration, holding, and rearing behavior. Adult salmonids are 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 may increase their vulnerability to predators, potentially increasing mortality. However, use of nearshore areas by juvenile salmon 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)[9].

In addition to temporary 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. 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 can be expected to cause some sedimentation of the channel downstream of the construction sites, potential reductions in abundance or production of benthic invertebrates are not expected to affect the availability of food or foraging habitat for winter-run Chinook salmon because of the localized, temporary nature of the disturbance, and adaptations of the local invertebrate fauna to sediment disturbance.

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[8] See Permit Resolution Log item #32 for further information on this point.

[9] See Permit Resolution Log item #43 for further information on this point.

###### 4.3.2.2.2.3 Assess Risk to Individuals

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 winter-run Chinook salmon. Direct effects will be likely be limited to behavioral effects only (i.e., harassment). Juveniles, 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 result in incidental take of individual salmonids. However, there could be indirect effects due to increased predation mortality.

##### *4.3.2.2.3 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.

###### 4.3.2.2.3.1 Accidental Spills

Construction at the NDDs may 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. Other construction activities that occur in upland areas or are isolated from fish-bearing waters have little or no risk of contaminant effects on aquatic habitat or listed fish species.

Implementation of Appendix 3.F *General Avoidance and Minimization Measures,* AMM5 *Spill Prevention, Containment, and Countermeasure Plan* and AMM14 *Hazardous Materials Management* will 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., AMM3 *Stormwater Pollution Prevention Plan*), the risk of contaminant spills or discharges to the Sacramento River from in-water or upland sources is effectively minimized.

###### 4.3.2.2.3.2 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 et al. 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 cause physiological stress in fish by causing localized increases in chemical oxygen demand in waters in or near plumes.

The proposed NDD 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 during proposed construction and maintenance dredging at the proposed NDDs. Current estimates indicate the total dredging and channel disturbance will affect 12.1 acres of the riverbed adjacent to the intake structures. Measured sediment plumes from hydraulic dredging operations (Hayes et al. 2000) suggest that less than 0.1% of disturbed sediments and associated contaminants will 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 (Central Valley Water Board 1998) will be an important measures for limiting dispersal of contaminated sediments during dredging and other in-water construction activities.

#### 4.3.2.2.3.3 Assess Species Exposure

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. Exposure to contaminants may occur at other times of the year through other mechanisms, including resuspension of newly exposed sediment by high flows or contaminant uptake in food organisms (e.g., benthic invertebrates). Based on the general timing of winter-run Chinook salmon adults and juveniles in the project area, the risk of exposure to potential spills will be limited primarily to small numbers of adults that may migrate as late as June and July in some years. In addition, winter-run juveniles (less than 60 mm in length) may arrive in the lower Sacramento River and Delta in October following a major fall rain event when flows in the Sacramento River can trigger the downstream movement of juveniles from upstream spawning and rearing areas to the lower Sacramento River and Delta, or in small numbers in September (as indicated by 2016 rotary screw trapping at Knights Landing). .

#### 4.3.2.2.3.4 Assess Species Response

The potential effects of contaminants on fish 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, PCBs, 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 and Clarkson 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 could enter the Sacramento River 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 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).

#### 4.3.2.2.3.5 Assess Risk to Individuals

Implementation of the proposed AMM3 *Stormwater Pollution Prevention Plan*, AMM5 *Spill Prevention, Containment, and Countermeasure Plan*, and AMM14 *Hazardous Material Management*, 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.

### *4.3.2.2.4 Underwater Noise*

During construction of the NDDs, activities likely to generate underwater noise include in-water pile driving, riprap placement, dredging, and barge operations. Of these, pile driving poses the greatest risk to fish because the levels of underwater noise produced by impulsive types of sounds can 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 each intake, underwater noise levels of sufficient intensity to cause injury or mortality of fish could occur over a period of 42 days during the first in-water construction season (June 1-October 31) and 14-19 days during the second in-water construction season. Restriction of pile driving activities to June 1-October 31 will avoid the primary adult and juvenile winter-run Chinook salmon migration seasons. However, because of the potential presence of adults in June and July and juveniles in September/October, 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 winter-run Chinook salmon and other 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[10]. Typically, such actions include additional physical or operational measures to reduce the intensity and/or duration of underwater noise levels.

#### 4.3.2.2.4.1 Assess Species Exposure

Restriction of pile driving activities to June 1-October 31 will avoid the primary adult and juvenile winter-run Chinook salmon migration periods in the project area. In some years, a small proportion of the spawning run of winter-run Chinook salmon may be migrating through the project area as late as June and July although water temperatures frequently exceed suitable ranges by late June or early July. In addition, winter-run juveniles (less than 60 mm in length) may arrive in the lower Sacramento River and Delta in September/October, for example following a major fall rain event when flows in the Sacramento River can trigger the downstream movement of juveniles from upstream spawning and rearing areas to the lower Sacramento River and Delta.

#### 4.3.2.2.4.2 Assess Species Response

Pile driving and other sources of anthropogenic noise have the potential to 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 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 have been established to provide guidance for assessing the potential for injury of fish resulting from pile driving noise (Fisheries Hydroacoustic Working Group 2008) (Table 4.3-1). 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. Peak SPL is considered the maximum sound pressure level a fish can receive from a single strike

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[10] See Permit Resolution Log item #33 for further information on this point.

without injury. Cumulative SEL 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 4.3-1. 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<br>183 dB re: 1µPa$^2$-sec—for fish size < 2 grams |

In the following analysis, the potential for physical 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 identifying the potential for behavioral effects until new information indicates otherwise (e.g., National Marine Fisheries Service 2015).

Table 4.3-2 presents the extent, timing, and duration of pile driving noise levels predicted to exceed the interim injury and behavioral thresholds at the north Delta intake sites based on application of the NMFS spreadsheet model and the assumptions in Appendix 3.E *Pile Driving Assumptions for the Proposed Project*. 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 4.3-2. 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 and 183 dB SEL Injury Thresholds or Effective Quiet (150 dB SEL)[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) rather than 187 dB or 183 dB cumulative SEL injury thresholds. Computed distances assume that cumulative exposure to single strike SELs <150 dB does not 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 will 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 (). Based on the distance to effective quiet (150 dB SEL), the risk of injury will 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. The predictions in Table 4.3-2 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 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 project 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 will 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 will 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, cofferdam sheet piles will be installed over a period of 42 days at each intake location, within the in-water construction season (June 1-October 31; curtailed to 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.

#### 4.3.2.2.4.3 Assess Risk to Individuals

Pile driving noise may cause injury or mortality of adult and juvenile winter-run Chinook salmon that are holding, migrating, or rearing near the intake sites. During pile driving activities, underwater noise levels sufficient to cause injury or mortality will extend across the entire width of the river and up to 3,280 feet away from the source piles[11]. As previously discussed, exposure of winter-run Chinook salmon to pile driving noise during the in-water construction period will be limited to a small proportion of adults that may be migrating downstream through the project area in June and July, and potentially to early-arriving juveniles, especially if pile driving extends into October or follows the first major rain event of the season. Peak SPLs exceeding the injury criteria will be limited to small areas immediately adjacent to source piles (20–46 feet) and thus will 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 will 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, adults that may be present during impact pile driving activities 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 (up to 4 feet per second [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. However, juveniles that may be present in September/October would be at greater risk of harm because of their small size, limited swimming ability, and association with nearshore areas.

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[11] See Permit Resolution Log item #34 for further information on this point.

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 for adults because of their rapid migration rates and daily opportunities 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 some injury of winter-run Chinook salmon to occur at the NDD 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 period for winter-run Chinook salmon 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 will be used is unknown at this time but is expected to reduce the extent, intensity, and duration of pile driving noise 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.

#### *4.3.2.2.5 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 to October 31) to avoid the peak abundance of listed fish species in the project area. When listed fish species may be present, DWR will 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 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.

#### 4.3.2.2.5.1 Assess Species Exposure

Restriction of cofferdam construction and other in-water activities to June 1-October 31 avoids the primary migration and rearing periods of winter-run Chinook salmon. As described in Section 4.3.2.2.2.1 *Assess Species Exposure*, adults may be present in June and July and juveniles may be present in September/October.

#### 4.3.2.2.5.2 Assess Species Response

Winter-run Chinook salmon that may be present in the project area in June and July will be large, migrating adults that are capable of readily avoiding or moving away from active construction areas, minimizing their risk of being stranded. Smaller, rearing juveniles that may be present in September/October would be at a higher risk of entrapment[12]. 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 construction activities within the enclosed cofferdam.

#### 4.3.2.2.5.3 Assess Risk to Individuals

With the implementation of a fish rescue and salvage plan (AMM8), the likelihood of stranding and subsequent injury or mortality of individual winter-run Chinook salmon 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).

### *4.3.2.2.6 Direct Physical Injury*

During construction of the NDDs, 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 will be minimized by limiting the duration of in-water construction activities and implementing the take minimization measures described in Appendix 3.F *General Avoidance and Minimization Measures*. Applicable take minimization measures include AMM1 *Worker Awareness Training;* AMM4 *Erosion and Sediment Control Plan; Disposal of Spoils, Reusable Tunnel Material, and Dredged Material; Barge Operations Plan;* and AMM8 *Fish Rescue and Salvage Plan*.

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[12] See Permit Resolution Log item #36 for further information on entrapment risk.

#### 4.3.2.2.6.1 Assess Species Exposure

Restriction of in-water activities to June 1 to October 31 will avoid the primary migration and rearing periods of winter-run Chinook salmon. As described in Section 4.3.2.2.2.1 *Assess Species Exposure*, adults may be present in June and July and juveniles may be present in September/October.

#### 4.3.2.2.6.2 Assess Species Response

Winter-run Chinook salmon that may be present in the project area in June and July will be large, migrating adults that are capable of readily avoiding or moving away from active construction areas, minimizing their risk of being injured. Smaller, rearing juveniles that may be present in September/October would be at a higher risk of injury.

#### 4.3.2.2.6.3 Assess Risk to Individuals

The risk of injury or mortality of winter-run Chinook salmon will be highest in September/October, especially following a major fall rain event when flows in the Sacramento River can trigger the downstream movement of juveniles from upstream spawning and rearing areas to the lower Sacramento River and Delta.

### *4.3.2.2.7 Loss/Alteration of Habitat*

Construction of the proposed intake facilities will result in temporary and 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 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), will 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 will 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, 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 winter-run Chinook salmon habitat through restoration of tidal marsh and channel margin habitat at an approved restoration site or the purchase of conservation credits at an approved conservation bank.

#### 4.3.2.2.7.1 Assess Species Exposure

Virtually all of the of the winter-run Chinook salmon adults and juveniles that migrate annually through the lower Sacramento River and Delta will pass the construction sites at the three intake sites during the construction period, and thus will be potentially exposed to the physical changes in aquatic and channel margin habitat (i.e., changes in water depths, velocities, substrate, and bank structure) within the footprints of the intake structures.

#### 4.3.2.2.7.2 Assess Species Response

The leveed, channelized reaches of the Sacramento River near the NDDs primarily function as a migration corridor for adult and juvenile winter-run Chinook salmon. Rearing habitat at the proposed intake sites has been degraded from historical conditions, and is unlikely to support high densities of rearing juvenile winter-run Chinook salmon, based on the observed lower density with higher substrate hardness (i.e., lowest density with rip-rap), lower density with steeper slope, and lower density with less riparian-woody debris (McLain and Castillo 2009). The temporary and permanent footprints of each NDD 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 in passage conditions (water depths and velocities) for adults are expected because they use deeper, offshore portions of the channel for holding and migration. However, permanent loss and alteration of shoreline and nearshore areas resulting from the installation of cofferdams and riprap, removal of vegetation, and construction and maintenance dredging will permanently reduce the quality of channel margin and nearshore habitat for rearing and migrating juveniles within the footprint of each intake.

#### 4.3.2.2.7.3 Assess Risk to Individuals

Permanent loss or alteration of habitat at the intake sites will have insignificant effects on migrating adult winter-run Chinook salmon; passage conditions for adults will remain unobstructed (apart from short-term effects from turbidity or underwater noise during construction, discussed above) during and following the construction of the intake facilities. Although the intake locations currently provide low quality rearing habitat for juvenile salmonids, construction of the intakes will further degrade this habitat by eliminating shallow water habitat and associated rearing and refuge functions, including protection from predatory fish that occupy deeper waters of the Sacramento River. In addition, cofferdams, riprap, and other artificial structures provide physical and hydraulic conditions that may attract certain predatory fishes (e.g., striped bass, largemouth bass, Sacramento pikeminnow) and potentially increase their opportunities to ambush juvenile salmonids and other fishes.

### *4.3.2.3 Barge Landings*

#### *4.3.2.3.1 Overview*

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 Project*) 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)

Barge docks are also proposed at the Intake 3 and Intake 5 construction sites, 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 Section 3.2.10.9 *Barge Landing Construction and Operations*.

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. Each barge landing will have a dock supported by steel piles. Each dock will 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 necessary to provide access and protect the levee from wave erosion; all such effects are included within the footprint estimate (30 acres total) for barge landings.

Following construction, these facilities will operate for 5-6 years. During construction of the tunnels and other water conveyance facilities, up to 15,000 barge trips may occur in addition to the daily vessel traffic in the project 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 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 (Appendix 3.F *General Avoidance and Minimization Measures*, AMM7 *Barge Operations Plan*) 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 will result in temporary impacts on water quality and permanent impacts on physical habitat within the footprints of the barge landings. The barge landings 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.

### *4.3.2.3.2 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 also result in temporary increases in turbidity and suspended sediment along the routes that will be used to transport construction equipment and materials between the barge loading and unloading facilities.

Potential turbidity and sediment impacts on listed fish species and aquatic habitat will be minimized by restricting in-water construction activities to August 1-October 31 at most locations[13]. In addition, DWR proposes to develop and implement a *Barge Operations Plan* (Appendix 3.F *General Avoidance and Minimization Measures*, AMM7), which includes specific measures to minimize bed scour, bank erosion, loss of submerged and emergent vegetation, and disturbance of benthic communities. Other AMMs that will serve to avoid or minimize potential turbidity, suspended sediment, and other water quality impacts include AMM1 *Worker Awareness Training; Construction Best Management Practices and Monitoring;* AMM3 *Stormwater Pollution Prevention Plan;* AMM4 *Erosion and Sediment Control Plan;* AMM5 *Spill Prevention, Containment, and Countermeasure Plan;* AMM6 *Disposal and Reuse of Spoils, Reusable Tunnel Material, and Dredged Material;* and AMM14 *Hazardous Material Management* (Appendix 3.F *General Avoidance and Minimization Measures*)[14].

Some potential exists for construction-related turbidity 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.

#### 4.3.2.3.2.1 Assess Species Exposure

The proposed timing of in-water construction activities at the barge landings (August 1 to October 31) avoids the adult migration period and the primary juvenile migration and rearing periods of winter-run Chinook salmon in the Delta. As described in Section 4.3.2.2.2.1 *Assess Species Exposure*, winter-run juveniles may arrive in the lower Sacramento River and Delta in September/October, particularly following a major fall rain event when flows in the Sacramento River can trigger the downstream movement of juveniles from upstream spawning and rearing areas to the lower Sacramento River and Delta. Under these conditions, juveniles may enter the east and south Delta via the Delta Cross Channel, Georgiana Slough, or Three Mile Slough, where they may encounter increases in turbidity and suspended sediment during in-water construction activities at the barge landings. Following construction, year-round barge operations could result in exposure of juveniles and adults to elevated turbidity and suspended sediment

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[13] 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.

[14] See Permit Resolution Log item #37 for further information of controls of resuspended sediments.

levels at the barge landings and along the barge transport routes throughout the rearing and migration seasons.

#### 4.3.2.3.2.2 Assess Species Response

As described in Section 4.3.2.2.2.2 *Assess Species Response*, turbidity and suspended sediment levels generated by pile driving, riprap placement, and barge operations will not reach levels that would cause direct injury to listed salmonids. Increases in nearshore turbidity and suspended sediment levels from waves generated by passing barges and towing vessels will be short lived and infrequent based on the average increase of 7.5 trips per day throughout the entire project area. With implementation of the proposed erosion and sediment control AMMs and other measures to limit turbidity and suspended sediment levels generated by active barges and towing vessels (AMM7), these activities are expected to result in temporary, localized increases in turbidity and suspended sediment levels that dissipate rapidly and return to baseline levels following cessation of activities, with temporary and non-lethal effects on winter-run Chinook salmon that encounter turbidity plumes.

Increases in suspended sediment during in-water construction activities may result in localized sediment deposition in the vicinity of the barge landings, potentially degrading food-producing areas by burying benthic substrates that support food organisms (benthic invertebrates) for juvenile winter-run Chinook salmon. However, the amount of habitat potentially affected by the deposition of suspended sediment generated at the barge landings represents a small proportion of the available foraging habitat in the project area, and thus is unlikely to affect salmonid feeding success or growth.

#### 4.3.2.3.2.3 Assess Risk to Individuals

Increases in turbidity and suspended sediment levels during in-water construction activities at the barge landings and along the barge transport routes will be temporary and localized, and unlikely to reach levels causing incidental take of winter-run Chinook salmon.

### *4.3.2.3.3 Contaminants*

Construction of the barge landings poses an exposure risk to winter-run Chinook salmon 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 NDDs (Section 4.3.2.2.3 *Contaminants*) due to the proximity of construction activities to the waters of the Delta. As described in Appendix 3.F *General Avoidance and Minimization Measures*, AMM5 *Spill Prevention, Containment, and Countermeasure Plan* and AMM14 *Hazardous Material Management* are 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., AMM3 *Stormwater Pollution Prevention Plan*), the risk of contaminant spills or discharges to Delta waters from in-water and overwater sources will be 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 will 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 4.3.2.2.3 *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 (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 SAP to characterize contaminants and determine appropriate BMPs to minimize or avoid mobilization of contaminated sediments during in-water construction. 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 (Central Valley Water Board 1998) will be an important measures for limiting dispersal of contaminated sediments during dredging and other in-water construction activities.

#### 4.3.2.3.3.1 Assess Species Exposure

The potential for contaminant spills will exist throughout the construction period but the highest risk to listed fish species and aquatic habitat will occur during in-water construction activities. Restriction of in-water work to August 1-October 31 avoids the adult migration period and primary migration and rearing periods of winter-run Chinook salmon in the Delta. In some years, in-water construction activities may overlap with the potential occurrence of juvenile winter-run Chinook salmon in the Delta in September/October (see Section 4.3.2.3.2.1 *Assess Species Exposure).*

#### 4.3.2.3.3.2 Assess Species Response

As described in 4.3.2.2.3.4 *Assess Species Response*, 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.

#### 4.3.2.3.3.3 Assess Risk to Individuals

As described in Appendix 3.F *General Avoidance and Minimization Measures*, implementation of AMM3 *Stormwater Pollution Prevention Plan*, AMM5 *Spill Prevention, Containment, and Countermeasure Plan*, and AMM6 *Hazardous Material Management* 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 is expected to render incidental take of winter-run Chinook salmon extremely unlikely. 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 will 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.

### *4.3.2.3.4 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 will potentially produce underwater noise levels of sufficient intensity and duration to cause injury to fish. Each barge landing will 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 is expected to occur over a period of 2 days at each barge landing.

DWR will minimize the potential exposure of listed fish species to pile driving noise at barge landings by conducting all pile driving between August 1 and October 31 when winter-run Chinook salmon are unlikely to occur in the project area in anything but small numbers. In addition, DWR will implement AMM9 *Underwater Sound Control and Abatement Plan* (Appendix 3.F *General Avoidance and Minimization Measures*) to minimize the effects of underwater construction noise on winter-run Chinook salmon. 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[15]. Typically, such actions include additional physical or operational measures to reduce the intensity and/or duration of underwater noise levels.

#### 4.3.2.3.4.1 Assess Species Exposure

Restriction of impact pile driving to the in-water work period (August 1–October 31) will avoid the adult migration season and the primary juvenile rearing and migration seasons of winter-run

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[15] See Permit Resolution Log item #33 for further information on this point.

Chinook salmon in the Delta. In some years, pile driving activities may overlap with the potential occurrence of juvenile winter-run Chinook salmon in the Delta in September/October (see Section 4.3.2.3.2.1 *Assess Species Exposure)*.

#### 4.3.2.3.4.2 Assess Species Response

As described in Section 4.3.2.2.4.2 *Assess Species Response*, 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 . 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. Underwater noise generated by other in-water construction activities (e.g., barge operations) generally falls within this range and therefore may alter the behavior of fish within a certain distance from the source.

Table 4.3-3 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 Project*. 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 4.3-3. 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 and 183 dB SEL Injury Thresholds or Effective Quiet (150 dB SEL)[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 1–Oct 31 | 2 |

[1] Computed distances to injury thresholds are governed by the distance to “effective quiet” (150 dB SEL) rather than 187 dB and 183 dB cumulative SEL thresholds. Computed distances assume that cumulative exposure to single strike SELs <150 dB do not 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 will be limited to areas within 46 feet of the source piles (3). Based on the distance to effective quiet, the risk of injury is calculated to extend 1,774 feet away from the source piles.[16] Based on a threshold of 150 dB RMS, the potential for behavioral effects is calculated to extend 9,607 feet. However, the extent of noise levels exceeding the injury and behavioral thresholds will 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 Assumptions for the Proposed Project*).

#### 4.3.2.3.4.3 Assess Risk to Individuals

Restriction of pile driving activities to August 1-October 31 will avoid the adult migration period and the primary juvenile rearing and migration periods of winter-run Chinook salmon in the Delta. However, as discussed previously, the potential exists for juveniles to arrive in the Delta as early as September/October, especially if early fall rains increase flows in the Sacramento River sufficiently to initiate the downstream migration of juveniles from upstream spawning and rearing areas. Over a period of two days at each barge landing site, potential injury from exposure to peak sound levels exceeding 206 dB are predicted to occur within a radius of 46 feet around the source piles, affecting approximately 4-17% of the channel width adjacent to each barge landing (Appendix 3.E *Pile Driving Assumptions for the Proposed Project*). However, cumulative SELs exceeding the 183 dB or 187 dB thresholds are predicted to extend across the entire channel width and upstream and downstream up to 1,774 feet away from the source piles, potentially resulting in injury of any juveniles that remain in these areas over the course of a pile driving day. As discussed in Section 4.3.2.2.4.3 *Assess Risk to Individuals*, pile driving noise may also cause behavioral effects (e.g., avoidance or fright responses) that could temporarily disrupt migration and foraging activities and increase the exposure of juveniles to predators or other stressors. These effects could occur over distances up to 9,607 feet away from the source piles assuming an unimpeded propagation path.

To minimize the risk of injury and mortality of winter-run Chinook salmon 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[17]. Typically, such actions include additional physical or operational measures to reduce the intensity and/or duration of underwater noise levels. In addition, DWR

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[16] In this case, the distance to the injury thresholds are governed by the distance to "effective quiet" (150 dB SEL) rather than the 187 dB and 183 dB cumulative SEL thresholds.

[17] See Permit Resolution Log item #33 for further information on this point.

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.

### *4.3.2.3.5 Fish Stranding*

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

### *4.3.2.3.6 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 or mooring piles, and struck or entrained by 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 take minimization measures described in Appendix 3.F *General Avoidance and Minimization Measures*: AMM1 *Worker Awareness Training;* AMM4 *Erosion and Sediment Control Plan;* AMM6 *Disposal and Reuse of Spoils, Reusable Tunnel Material, and Dredged Material;* AMM7 *Barge Operations Plan; and* AMM8 *Fish Rescue and Salvage Plan*.

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).

#### 4.3.2.3.6.1 Assess Species Exposure

Restriction of in-water construction activities to August 1–October 31 will avoid the adult migration season and the primary juvenile rearing and migration seasons of winter-run Chinook salmon in the Delta. In some years, in-water activities may overlap with the potential occurrence of juvenile winter-run Chinook salmon in the Delta in September/October (see Section 4.3.2.3.2.1 *Assess Species Exposure).* Following construction, year-round barge operations could result in exposure of juveniles and adults to elevated turbidity and suspended sediment levels at the barge landings and along the barge transport routes throughout the adult migration period and juvenile rearing and migration periods in the Delta.

#### 4.3.2.3.6.2 Assess Species Response

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 can injure or kill 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 et al., 1976; Holland, 1986; Killgore et al., 2001; Wolter and Arlinghaus 2003).

Adult winter-run Chinook salmon are capable of readily avoiding active construction areas and direct encounters with operating barges because of their swimming abilities and use of deeper, offshore portions of the channel for holding and migration. Migrating and rearing juveniles may also exhibit an avoidance response but may be less able to avoid direct contact with construction equipment, materials (e.g., riprap), and vessels based on their swimming abilities and greater nearshore and surface orientation. The potential effects of barge operations also include wave-induced disturbances that can affect nearshore juvenile fishes by causing disorientation and stranding during vessel passage (Wolter and Arlinghaus 2003).

#### 4.3.2.3.6.3 Assess Risk to Individuals

During construction of the barge landings, there is a low risk of injury of adult winter-run Chinook salmon because of the timing of in-water construction activities and their ability to avoid direct encounters with construction equipment, materials, and vessels. Juvenile winter-run Chinook salmon are at higher risk of direct injury during in-water construction activities (September/October only) and subsequent barge operations during the primary juvenile migration and rearing periods in the Delta (November through April). No information exists on the characteristics of vessels that are most likely to interact with juvenile salmonids or the rates of these interactions. Although implementation of AMM7 *Barge Operations Plan* (Appendix 3.F *General Avoidance and Minimization Measures*) is expected to minimize potential interactions, the frequency of such interactions will likely increase and result in an elevated risk of injury or mortality (e.g., propeller strikes) of juveniles. Year-round barge traffic will also increase the frequency of wave-induced shoreline disturbances, which could 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 project area is small compared to existing traffic, so increases in injury or harassment of winter-run Chinook salmon are likely to be small.

### *4.3.2.3.7 Alteration/Loss of Habitat*

Construction and operation of the barge landings will result in temporary and permanent losses or alteration of aquatic habitat in several channels of the east, south, and north Delta. 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 will encompass as estimated 0.34 acre of overwater structures, approximately 300 linear feet of shoreline, and 5-19% of the total width of the adjacent channel or slough. These conditions will exist throughout the 7-8-year construction period.

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 AMM7 *Barge Operations Plan* (Appendix 3.F *General Avoidance and Minimization Measures*), which includes specific measures to minimize bed scour, bank erosion, loss of submerged and emergent vegetation, and disturbance of benthic communities. DWR proposes to offset unavoidable impacts to winter-run Chinook salmon habitat 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[18].

#### 4.3.2.3.7.1 Assess Species Exposure

Exposure of winter-run Chinook salmon to losses or alteration of habitat associated with construction and operation of the barge landings will be limited primarily to adults and juveniles that enter the east and south Delta via the Delta Cross Channel, Georgiana Slough, Three Mile Slough, and the San Joaquin River (junction of Sacramento and San Joaquin River at Sherman Island). The potential for exposure also exists at the NDDs if barge docks are required at one or more of the intake facilities.

#### 4.3.2.3.7.2 Assess Species Response

Habitat conditions for winter-run Chinook salmon in the vicinity of the proposed barge landings are degraded from historical conditions by altered flow patterns, levee construction, extensive riprapping, and loss of natural wetland and floodplain habitat. Because the barge landings will be sited in areas with steep levees, deep nearshore areas, and minimal obstructions to barge access and operations, construction and operation of the barge landings has limited potential to substantially degrade habitat conditions. During and following construction, adult winter-run Chinook salmon will be unaffected by changes in channel widths or passage conditions (water depths and velocities) because of their use of deeper, offshore portions of the channel for holding and migration. Localized reductions 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 winter-run Chinook salmon 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. Although these sites lack high-quality rearing habitat, the addition of 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 opportunities 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 will result in localized reductions in benthic food production that are likely to persist for the duration of barge operations.

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[18] See Permit Resolution Log item #42 for further information on this point.

#### 4.3.2.3.7.3 Assess Risk to Individuals

Temporary and permanent losses or alteration of habitat at the proposed barge landing sites are expected to have no effect on migrating adult winter-run Chinook salmon; passage conditions for adults will remain unobstructed throughout the construction period. Although construction and operation of the barge landings will result in localized reductions in the quality of passage and rearing conditions for juveniles, these changes are unlikely to result in direct mortality, or to significantly affect the growth of juvenile winter-run Chinook salmon, because of the low quality and minimal use of this habitat by juveniles under existing conditions. However, the lack of cover for juvenile fish and presence of structural and overhead cover for predators may increase the risk of predation at the proposed barge landing sites.

### *4.3.2.4 Head of Old River Gate*

#### *4.3.2.4.1 Overview*

An operable gate (Head of Old River [HOR] gate) will be constructed to prevent migrating juvenile salmonids from entering the head of Old 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 Project*). 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 appear in Section 3.2.8 *Head of Old River Gate*.

Construction of the HOR gate will 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, will be restricted to August 1-October 31 to minimize or avoid potential effects on listed fish species, including winter-run Chinook salmon. In addition, all pile driving occurring in or near open water (cofferdams and foundation piles) will be restricted to the in-water work period to avoid or minimize exposure of winter-run Chinook salmon 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; dredge activity will also be restricted to the in-water work period. The need for 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 long-term to permanent impacts on physical habitat within the footprint of the gate and channel segments that will be affected by dredging. These impacts encompass a total of approximately 2.9 acres of tidal perennial aquatic habitat that include the in-water work areas and the permanent footprint of the gate, fish passage structure, and boat lock.

### *4.3.2.4.2 Turbidity and Suspended Sediment*

Construction activities will disturb 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[19], riprap placement, and barge operations. All other sediment-disturbing activities will be outside or isolated from the active channel and will 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, the following take minimization measures will be implemented to avoid or minimize potential impacts on water quality and listed fish species during construction of the HOR gate (described in Appendix 3.F *General Avoidance and Minimization Measures*): AMM1 *Worker Awareness Training; Construction Best Management Practices and Monitoring;* AMM3 *Stormwater Pollution Prevention Plan;* AMM4 *Erosion and Sediment Control Plan;* AMM5 *Spill Prevention, Containment, and Countermeasure Plan;* AMM6 *Disposal and Reuse of Spoils, Reusable Tunnel Material, and Dredged Material;* and AMM14 *Hazardous Material Management*.

#### 4.3.2.4.2.1 Assess Species Exposure

Restriction of in-water construction activities to August 1–October 31 avoids the primary adult migration period and primary juvenile migration and rearing periods of winter-run Chinook salmon in the Delta. Adult winter-run Chinook salmon may enter the lower San Joaquin River in November but are unlikely to occur as far upstream as the HOR gate based on their attraction to Sacramento River water which may be drawn into the San Joaquin River side of the Delta through the DCC (when open), Georgiana Slough, and Three Mile Slough. Similarly, juvenile winter-run Chinook salmon, which may enter this region of the Delta as early as September/October via these same pathways, are not expected to occur in significant numbers as far upstream as the HOR gate based on the general effects of flow and export pumping on route selection in the Delta.

#### 4.3.2.4.2.2 Assess Species Response

As described in Section 4.3.2.2.2.2 *Assess Species Response*, turbidity and suspended sediment levels generated by pile driving, riprap placement, and barge operations will not reach levels that would cause direct injury to salmonids. With implementation of the take minimization measures, in-water construction activities will 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.

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. However, this is unlikely to affect juvenile winter-run Chinook salmon because the affected area represents a small proportion of the available rearing habitat in the Delta, and occurs outside the principal juvenile migration pathways in the Delta.

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[19] See Permit Resolution Log item #32 for further information on this point.

#### 4.3.2.4.2.3 Assess Risk to Individuals

Based on the seasonal timing and location of in-water construction activities, any affects to winter-run Chinook salmon will be limited to brief exposures to elevated turbidity and suspended sediment levels that are unlikely to cause adverse effects.

### *4.3.2.4.3 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 will be similar to that described for the NDDs (see Section 4.3.2.2.3 *Contaminants*) due to the proximity of construction activities to the waters of the Delta. Implementation of AMM5 *Spill Prevention, Containment, and Countermeasure Plan* and AMM14 *Hazardous Material Management* (Appendix 3.F *General Avoidance and Minimization Measures*) will 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., AMM3 *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 4.3.2.2.3 *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. 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* (Appendix 3.F *General Avoidance and Minimization Measures*). These measures include the preparation and implementation of a pre-construction 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 (Central Valley Water Board 1998) will be an important measures for limiting dispersal of contaminated sediments during dredging and other in-water construction activities.

#### 4.3.2.4.3.1 Assess Species Exposure

The potential for contaminant spills or releases would exist throughout the construction period but the highest risk would occur during in-water construction activities. Restriction of in-water construction activities to August 1–October 31 will avoid the primary adult migration period and primary juvenile migration and rearing periods of winter-run Chinook salmon in the Delta. Adult winter-run Chinook salmon may enter the lower San Joaquin River in November but are unlikely to occur as far upstream as the HOR gate based on their attraction to Sacramento River water which may be drawn into the San Joaquin River side of the Delta through the DCC (when open), Georgiana Slough, and Three Mile Slough. Similarly, juvenile winter-run Chinook salmon, which may enter this region of the Delta as early as September/October via these same pathways, are not expected to occur in significant numbers as far upstream as the HOR gate based on the general effects of flow and export pumping on route selection in the Delta.

#### 4.3.2.4.3.2 Assess Species Response

As described in 4.3.2.2.3.4 *Assess Species Response*, 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.

#### 4.3.2.4.3.3 Assess Risk to Individuals

As described in Appendix 3.F *General Avoidance and Minimization Measures*, implementation of the AMM3 *Stormwater Pollution Prevention Plan*, AMM5 *Spill Prevention, Containment, and Countermeasure Plan*, and AMM6 *Hazardous Materials Management*, is expected to minimize the potential for spills or discharges of contaminants into the Delta waterways during construction of the barge landings. Implementation of these take minimization measures is expected to minimize the potential for spills or discharges of contaminants into Old River and the lower San Joaquin River during construction of the HOR gate. Adherence to all preventative, response, and disposal measures in the approved plans will minimize potential effects to winter-run Chinook salmon to the point that incidental take is unlikely. No information is available on potential contaminant risks associated with disturbance and exposure of sediments resulting from dredging and other construction activities at the HOR gate. However, this risk will 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 winter-run Chinook salmon to sediment-borne contaminants may be unavoidable, these exposures are expected to be brief and limited to very small numbers of individuals based on the distribution of juveniles, 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. Thus, mortality or injury are unlikely to occur as a result of such exposure.

### *4.3.2.4.4 Underwater Noise*

During construction of the HOR gate, activities 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 will potentially produce underwater noise levels of sufficient intensity and duration to cause injury to fish. Construction of the HOR gate will require installation of 550 temporary sheet piles (275 piles per season) to construct the cofferdams and 100 permanent 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 will be expected to occur for 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 will minimize the potential exposure of listed fish species to pile driving noise by conducting all in-water construction activities between August 1 and October 31. In addition, DWR will 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. Some degree of sound 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). 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*).

#### 4.3.2.4.4.1 Assess Species Exposure

Restriction of pile driving activities to August 1–October 31 avoids the primary adult migration periods and primary juvenile migration and rearing periods of winter-run Chinook salmon in the Delta. Adult winter-run Chinook salmon may enter the lower San Joaquin River in November but are unlikely to occur as far upstream as the HOR gate based on their attraction to Sacramento River water which may be drawn into the San Joaquin River side of the Delta through the DCC (when open), Georgiana Slough, and Three Mile Slough. Similarly, juvenile winter-run Chinook salmon, which may enter this region of the Delta as early as September/October via these same pathways, are not expected to occur in significant numbers as far upstream as the HOR gate based on the general effects of flow and export pumping on route selection in the Delta.

#### 4.3.2.4.4.2 Assess Species Response

As described in Section 4.3.2.2.4.2 *Assess Species Response,* 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 4.3-1. 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 widely assumed that 150 dB RMS is an appropriate threshold for behavioral effects. Underwater noises generated by other in-water construction activities (e.g., dredging) generally fall within this range and therefore may alter the behavior of fish within a certain distance from the source.

Table 4.3-4 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 Project*.

**Table 4.3-4. 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 dB and 183 dB SEL Injury Thresholds or Effective Quiet (150 dB SEL [1,2] (feet) | Distance to 150 dB RMS Behavioral Threshold[2] (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 | 9,607 | 2 | Aug–Nov | 4 |
| Foundation (with attenuation) | 20 | 823 | 4,458 | 2 | Aug–Nov | 4 |

[1] Computed distances to injury thresholds are governed by the distance to "effective quiet" (150 dB SEL) rather than 187 dB and 183 dB cumulative SEL thresholds. Computed distances assume that cumulative exposure to single strike SELs <150 dB do not 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 likely 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 4.3-4). Based on the distance to effective quiet, 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 will 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 create a major impediment to sound propagation. The potential for effects could occur during two construction seasons (August 1-

October 31) for up to 19 days during cofferdam installation and 4 days during foundation pile installation.

#### 4.3.2.4.4.3 Assess Risk to Individuals

Pile driving activities occurring between August 1 and October 31 may overlap with the occurrence of juvenile winter-run Chinook salmon in September/October although the potential risk is low based on the general distribution and timing of adults and juveniles in the Delta. During cofferdam and foundation pile installation, peak SPLs exceeding the injury criteria will be limited to areas immediately adjacent to the source piles (20-46 feet), affecting approximately 27-61% of the total channel width (75 feet). However, juveniles passing the construction site during active pile driving operations would be potentially subject to cumulative noise exposures exceeding injury thresholds across the entire width of Old River and upstream and downstream up to 2,063 feet away. 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[20]. Based on the general migration rates and reported swimming speeds of adult salmon (see 4.3.2.2.4.3 *Assess Species Response*), adults are 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. Any delays in migration due to avoidance behavior are expected to be minor because of the rapid migration rates of adults and daily opportunities to pass the affected areas at night when pile driving activities will cease. Nevertheless, juveniles that may be rearing or migrating in these areas may be unable to avoid such exposures or exhibit behavioral responses that could make them more vulnerable to predators.

Thus, the potential exists for injury or mortality of winter-run Chinook 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[21]. Typically, such actions include additional physical or operational measures to reduce the intensity and/or duration of underwater noise levels.

### *4.3.2.4.5 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

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[20] See Permit Resolution Log item #44 for further information on this point.

[21] See Permit Resolution Log item #33 for further information on this point.

enclosed cofferdams. Sheet pile installation will be limited to the proposed in-water construction period (August 1–October 31) to avoid the peak abundance of listed fish species in the project area. When listed fish species may be present, DWR proposes to minimize potential stranding losses by implementing AMM8 *Fish Rescue and Salvage Plan* (Appendix 3.F *General Avoidance and Minimization Measures*). 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.

#### 4.3.2.4.5.1 Assess Species Exposure

Closure of the cofferdams between August 1 and October 31 avoids the primary adult migration periods and primary juvenile migration and rearing periods of winter-run Chinook salmon in the Delta. Adult winter-run Chinook salmon may enter the lower San Joaquin River in November but are unlikely to occur as far upstream as the HOR gate based on their attraction to Sacramento River water which may be drawn into the San Joaquin River side of the Delta through the DCC (when open), Georgiana Slough, and Three Mile Slough. Similarly, juvenile winter-run Chinook salmon, which may enter this region of the Delta as early as September/October via these same pathways, are not expected to occur in significant numbers as far upstream as the HOR gate based on the general effects of flow and export pumping on route selection in the Delta.

#### 4.3.2.4.5.2 Assess Species Response

Winter-run Chinook salmon adults that may be present in the project area in November will be large, migrating adults that are capable of readily avoiding or moving away from active construction areas, minimizing their risk of being stranded. Smaller, rearing juveniles that may be present in September, October, and November would be at a higher risk of being stranded.

#### 4.3.2.4.5.3 Assess Risk to Individuals

Based on the timing and location of cofferdam installation at the HOR gate, the likelihood of stranding of adult and juvenile winter-run Chinook salmon is low. Furthermore, the risk of injury or mortality of any stranded fish will be reduced by conducting fish rescue and salvage activities following closure of the cofferdams. Although fish rescue and salvage activities using accepted fish collection methods can result in injury or mortality, these effects are typically minor, and can often be avoided with appropriate training. However, some losses may still occur because of varying degrees of effectiveness of the collection methods and potential indirect losses associated with capture and handling (e.g., stress and disorientation of fish at the release site, leading to predation).

### *4.3.2.4.6 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 at the HOR gate site between August 1 and October 31. The potential for injury of listed fish species will be further minimized to the extent practicable by limiting the duration of in-water construction activities and implementing the following take minimization measures described in Appendix 3.F *General Avoidance and Minimization Measures*: AMM1 *Worker Awareness Training;* AMM4 *Erosion and Sediment Control Plan;* AMM6 *Disposal and Reuse of Spoils, Reusable Tunnel Material, and Dredged Material;* AMM7 *Barge Operations Plan; and* AMM8 *Fish Rescue and Salvage Plan*.

#### 4.3.2.4.6.1 Assess Species Exposure

Restriction of in-water construction activities to August 1 to October 31 will avoid the primary migration and rearing periods of winter-run Chinook salmon in the Delta. Adult winter-run Chinook salmon may enter the lower San Joaquin River in November but are unlikely to occur as far upstream as the HOR gate based on their attraction to Sacramento River water which may be drawn into the San Joaquin River side of the Delta through the DCC (when open), Georgiana Slough, and Three Mile Slough. Similarly, juvenile winter-run Chinook salmon, which may enter this region of the Delta as early as September/October via these same pathways, are not expected to occur in significant numbers as far upstream as the HOR gate based on the general effects of flow and export pumping on route selection in the Delta.

#### 4.3.2.4.6.2 Assess Species Response

Winter-run Chinook salmon adults that may be present in the project area in November will be large, migrating adults that are capable of readily avoiding or moving away from active construction areas, minimizing their risk of injury. Smaller, rearing juveniles that may be present in September, October, and November would be at a higher risk of injury.

#### 4.3.2.4.6.3 Assess Risk to Individuals

During construction of the HOR gate, there is a low risk of injury of adult winter-run Chinook salmon because of the timing of in-water construction activities and their ability to avoid direct encounters with construction equipment, materials, and vessels. Juvenile winter-run Chinook salmon are at higher risk of direct injury during in-water construction activities and barge operations, which however is minimized by avoidance of in-water work during the primary juvenile migration and rearing periods in the Delta (November through April). Although implementation of AMM7 *Barge Operations Plan* (Appendix 3.F *General Avoidance and Minimization Measures*) is expected to minimize potential interactions, the frequency of such interactions will result in an elevated risk of injury or mortality (e.g., propeller strikes) of juveniles.

### *4.3.2.4.7 Loss/Alteration of Habitat*

Construction of the HOR gate will 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. 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 AMM2 *Construction Best Management Practices and Monitoring (*Appendix 3.F *General Avoidance and Minimization Measures)*, to protect listed fish, wildlife, and plant species, 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.

### 4.3.2.4.7.1 Assess Species Exposure

All migrating or rearing salmonids that occur in the project area during construction of the HOR gate will be potentially exposed to the physical alteration of aquatic and channel margin habitat within the footprints of the cofferdams, permanent structures, and dredged areas. Exposure of winter-run Chinook salmon to these habitat conditions will be limited by the low numbers of adults and juveniles that likely occur in this region of the Delta.

### 4.3.2.4.7.2 Assess Species Response

Habitat conditions for anadromous salmonids in Old River in the vicinity of the HOR gate are degraded from historical conditions 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 habitat conditions. During construction, fish passage past the construction site will be maintained by constructing half the structure in one year and the remaining half in the following year. Any winter-run Chinook salmon adults that attempt to pass the site during construction may be temporarily delayed and experience increased energy expenditure 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 reduction is expected in the quality of passage and rearing conditions for juvenile winter-run Chinook salmon 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. These changes will 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 opportunities to ambush juvenile salmonids and other fishes. The constriction of flow and increases in water velocities and turbulence at the interface of the cofferdams and the river may concentrate and disorient juveniles, 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.

**4.3.2.4.7.3 Assess Risk to Individuals**
Changes in physical and hydraulic conditions during construction of the HOR gate are expected to have no effect on migrating adult winter-run Chinook salmon; suitable passage conditions for adults will be maintained throughout the construction period by limiting construction to half the channel width during each year of construction. Although construction of the HOR gate will result in localized reductions in the quality of passage and rearing conditions for juveniles, these changes are unlikely to significantly affect the growth of juvenile winter-run Chinook salmon because of the low quality and minimal use of this habitat by juveniles 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 predator habitat and the vulnerability of juveniles to predators.

### *4.3.2.5 Clifton Court Forebay*

#### *4.3.2.5.1 Overview*

Construction activities at Clifton Court Forebay (CCF) that may potentially affect winter-run Chinook salmon include expansion and dredging of South Clifton Court Forebay (SCCF), construction of divider wall and east/west embankments, dewatering and excavation of North Clifton Court Forebay (NCCF), construction of NCCF outlet canals and siphons, and construction of a SCCF 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 presented in Section 3.2.5 *Clifton Court Forebay*.

In-water construction activities, including pile driving, dredging, riprap placement, and barge operations, will all be conducted within a 5-month work window each year, extending from July 1 to November 30. 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. A total of 4 construction seasons will be required to complete pile driving operations based on the estimated duration of pile installation.

Dredging will be performed with a cutter head dredge, a dragline type dredge, or other acceptable dredging technique. The SCCF will be dredged to an approximate elevation of -10.0 feet. An estimated 1,932 acres of tidal perennial aquatic habitat will be dredged, resulting in the removal of an estimated volume of 7 million cubic yards of material. Dredged material will be disposed of at an approved disposal site or reused for embankment and levee construction if determined to be suitable. Dredging will be performed by two dredges (425 cubic yards capacity each) operating within 200-acre cells enclosed by silt curtains to limit the extent of turbidity and suspended sediment. Dredging of CCF is estimated to require three successive work window seasons.

Permanent impacts on aquatic habitat include the loss of an estimated 258 acres of tidal perennial aquatic habitat in CCF that will be replaced by permanent fill and structures associated with the new Clifton Court Pumping Plant (CCPP), perimeter and divider embankments, outlet canals and siphons, and intake structure and spillway. Estimates of the amount of shallow water habitat potentially affected by construction are not currently available.

#### *4.3.2.5.2 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[22], and riprap placement. Minor increases in turbidity and suspended sediment in CCF and Old River are also expected during construction of the CCPP, outlet canals and siphons, SSCF intake structure, and 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 July 1 to November 30, limiting the duration of these activities to the extent practicable, and implementing the following take minimization measures described in Appendix 3.F *General Avoidance and Minimization Measures*: AMM1 *Worker Awareness Training;* AMM2 *Construction Best Management Practices and Monitoring;* AMM3 *Stormwater Pollution Prevention Plan;* AMM4 *Erosion and Sediment Control Plan;* AMM5 *Spill Prevention, Containment, and Countermeasure Plan;* AMM6 *Disposal and Reuse of Spoils, Reusable Tunnel Material, and Dredged Material Plan;* and AMM14 *Hazardous Material Management*

Dredging of CCF will result in elevated turbidity and suspended 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 take minimization measures listed above, DWR proposes to limit the potential exposure of winter-run Chinook salmon 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 the total surface area of CCF). Dredging will be monitored and regulated through implementation of AMM6 *Disposal and Reuse of Spoils, Reusable Tunnel Material, and Dredged Material Plan* (Appendix 3.F *General Avoidance and Minimization Measures*), which includes preparation of an SAP, 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.

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[22] See Permit Resolution Log item #32 for further information on this point.

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 the timing restrictions on in-water activities and implementation of erosion and sediment control take minimization measures, no adverse water quality effects are anticipated during this period.

###### 4.3.2.5.2.1 Assess Species Exposure

Restriction of in-water construction activities to July 1–November 30 avoids the primary adult migration period and primary juvenile migration and rearing periods of winter-run Chinook salmon in the Delta. Adult winter-run Chinook salmon may enter the lower San Joaquin River in November but are unlikely to occur in the south Delta based on their attraction to Sacramento River water which may be drawn into the San Joaquin River side of the Delta through the DCC (when open), Georgiana Slough, and Three Mile Slough. Juvenile winter-run Chinook salmon which may enter the Delta as early as September, October, or November and be drawn toward the south Delta via the same pathways. Salvage records at the CVP and SWP Fish Collection Facilities indicate that winter-run Chinook salmon juveniles typically do not appear in salvage until November or December.

###### 4.3.2.5.2.2 Assess Species Response

As described in Section 4.3.2.2.2.2 *Assess Species Response*, turbidity levels generated by in-water construction activities in CCF and the adjacent Old River channel are not expected to reach levels that would cause injury to winter-run Chinook salmon. With implementation of the take minimization measures, in-water construction activities will 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. Effects on winter-run Chinook salmon will be limited to behavioral effects in individuals that encounter turbidity plumes. Juveniles, if holding or rearing in the affected areas, are likely to respond by avoiding or moving away from affected areas, disrupting normal activities and possibly increasing their exposure to predators. Such disruptions are expected to be brief and unlikely to affect the growth of individual salmonids.

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 preferred migration and rearing habitat. The potential effects of sedimentation on food production will likely have little effect on juvenile winter-run Chinook salmon growth or survival due to the low quality of existing habitat and implementation of the proposed measures to limit construction effects on turbidity, sedimentation, and other water quality hazards.

###### 4.3.2.5.2.3 Assess Risk to Individuals

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 take minimization measures, the potential for turbidity to result in incidental take of either adult or juvenile winter-run Chinook salmon is extremely small.

#### *4.3.2.5.3 Contaminants*

Dredging, excavation, and expansion of the CCF and construction of new water conveyance facilities presents an exposure risk to winter-run Chinook salmon from potential spills of hazardous materials from construction equipment and from potential re-suspension of contaminated sediment. The risk of accidental spills of contaminants and other potentially hazardous materials will be similar to that described for the NDDs (see Section 4.3.2.2.3 *Contaminants*) due to the proximity of construction activities to the waters of the CCF and neighboring waterways. Implementation of AMM5 *Spill Prevention, Containment, and Countermeasure Plan*, and AMM14 *Hazardous Materials Management* (Appendix 3.F *General Avoidance and Minimization Measures*) will 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., AMM3 *Stormwater Pollution Prevention Plan*), the risk of contaminant spills or discharges to Delta waters from in-water or upland sources will be 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 4.3.2.2.3 *Contaminants*, sediments act as a sink or source of contaminant exposure, and resuspension of contaminated sediments may have adverse effects on fish through direct exposure to contaminants from mobilized sediments or indirect exposure through accumulation of contaminants in the food web. Consequently, dredging, excavation, and expansion of CCF poses a short-term to 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. In view of the proximity of the south Delta waterways to agricultural, industrial, and municipal sources, it is conceivable that a broad range of contaminants that are toxic to fish and other aquatic biota, including metals, 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 have also been found to include heavy metals such as selenium, cadmium, and nickel (G. Fred Lee & Associates 2004). Thus, 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 project 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 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 (Central Valley Water

Board 1998) will be important measures for limiting dispersal of contaminated sediments during dredging and other in-water construction activities.

#### 4.3.2.5.3.1 Assess Species Exposure

The potential for contaminant spills will continue throughout the construction period, with the highest risk occurring during in-water construction activities. Based on the general timing and distribution of winter-run Chinook salmon in the Delta, the potential for direct exposure to contaminants will exist for adults in November and juveniles in October and November. However, adult winter-run Chinook salmon are unlikely to occur in the south Delta based on their attraction to Sacramento River water which may be drawn into the San Joaquin River side of the Delta through the DCC (when open), Georgiana Slough, and Three Mile Slough. Juvenile winter-run Chinook salmon may occur in the south Delta as early as September, October, or November depending on Sacramento flows, Delta inflows, CVP and SWP pumping rates, and operation of the DCC, although salvage records at the CVP and SWP Fish Collection Facilities indicate that winter-run Chinook salmon juveniles typically do not appear in CCF until November or December.

#### 4.3.2.5.3.2 Assess Species Response

As described in 4.3.2.2.3.4 *Assess Species Response*, the discharge of contaminants into the aquatic environment can cause direct or indirect effects on fish, up to and including mortality, depending on the type, concentrations, and fate of contaminants.

#### 4.3.2.5.3.3 Assess Risk to Individuals

Implementation of AMM3 *Stormwater Pollution Prevention Plan*, AMM5 *Spill Prevention, Containment, and Countermeasure Plan*, and AMM14 *Hazardous Material Management*, will minimize the potential for spills or discharges of contaminants into CCF and Old River. Adherence to all preventative, response, and disposal measures in the approved plans is expected to largely eliminate the risk of mortality in winter-run Chinook salmon. 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 will 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 winter-run Chinook salmon 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.

### *4.3.2.5.4 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 sounds (typically, impact pile driving) often reach levels of sufficient intensity to injure or kill fish within a certain radius of the source (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 includes pile placement for the embankments, divider wall, siphon at NCCF outlet, and siphon at Byron Highway (Appendix 3.E *Pile Driving Assumptions for the Proposed Project*). 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 winter-run Chinook salmon. A total of 4 construction seasons will be needed to complete pile driving operations based on the estimated duration of pile installation (Appendix 3.D *Construction Schedule for the Proposed Project*).

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[23]. Typically, such actions include additional physical or operational measures to reduce the intensity and/or duration of underwater noise levels.

### 4.3.2.5.4.1 Assess Species Exposure

Restriction of driving activities to July 1–November 30 avoids the primary adult migration period and primary juvenile migration and rearing periods of winter-run Chinook salmon in the Delta. Based on the general timing and distribution of winter-run Chinook salmon in the Delta, the potential for direct exposure to pile driving noise will exist for adults in November and juveniles in October and November. However, adult winter-run Chinook salmon are unlikely to occur in the south Delta based on their attraction to Sacramento River water which may be drawn into the San Joaquin River side of the Delta through the DCC (when open), Georgiana Slough, and Three Mile Slough. Juvenile winter-run Chinook salmon may occur in the south Delta as early as September, October, or November depending on Sacramento flows, Delta inflows, CVP and SWP pumping rates, and operation of the DCC, although salvage records at the CVP and SWP Fish Collection Facilities indicate that winter-run Chinook salmon juveniles typically do not appear in CCF until November or December.

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[23] See Permit Resolution Log item #33 for further information on this point.

#### 4.3.2.5.4.2 Assess Species Response

As described for the NDDs (see Section 4.3.2.2.4.2 *Assess Species Response*), 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 4.3-1. 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 could 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. Underwater noise generated by other in-water construction activities (e.g., dredging) is not expected to result in direct injury to fish but may temporarily alter behavior of fish within a certain distance from the source.

Table 4.3-5 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 4.3-5. 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 and 183 dB SEL Injury Threshold or Effective Quiet (150 dB SEL) [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) rather than 187 dB and 183 dB cumulative SEL thresholds. Computation assumes that cumulative exposure to single strike SELs <150 dB does not 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 will be limited to areas within 30 feet of the cofferdam sheet piles and 20-46 feet of the NCCF siphon piles (Table 4.3-5). 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).[24] 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).

#### 4.3.2.5.4.3 Assess Risk to Individuals

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 extend 20-46 feet from the source piles, affecting approximately 7-15% of the width (300 feet) of the channel entrance (assuming half-width construction of the NCCF siphon). Thus, salmonids

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[24] In this case, the distance to the injury thresholds are governed by the distance to "effective quiet" (150 dB SEL) rather than the 187 dB and 183 dB cumulative SEL thresholds.

will 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 cumulative SEL thresholds 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 SCCF. Assuming a 5 dB reduction in noise levels can be achieved through dewatering of the cofferdams at the NCCF siphon, the distances to the cumulative SEL thresholds can be approximately halved but noise levels would remain above the cumulative injury thresholds in all waters at the SCCF entrance channel and surrounding waters up to 823 feet away. Pile driving noise exceeding the 150 dB RMS will 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 winter-run Chinook salmon that become entrained into CCF. In general, potentially harmful levels of underwater noise would occur 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, although the risk to winter-run Chinook salmon will be limited to November and possibly October when juveniles may be present in the Delta. The risk of injury or mortality is particularly high in CCF because of limited opportunities to avoid pile driving noise. 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[25]. Typically, such actions include additional physical or operational measures to reduce the intensity and/or duration of underwater noise levels.

### 4.3.2.5.5 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 fish, resulting in direct injury and mortality of fish that become trapped inside the cofferdams or silt curtains. To minimize potential fish stranding losses, DWR proposes to implement AMM8 *Fish Rescue and Salvage Plan* (Appendix 3.F *General Avoidance and Minimization Measures*). This plan will be submitted to the fish and wildlife agencies (NMFS, USFWS, CDFW) for review and approval prior to implementation. The plan will identify appropriate procedures for excluding fish from the construction zones, where feasible, and procedures for collecting, holding, handling, and

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[25] See Permit Resolution Log item #33 for further information on this point.

release for 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.

#### 4.3.2.5.5.1 Assess Species Exposure

Restriction of cofferdam and silt curtain installation to July 1–November 30 avoids the primary adult migration period and primary juvenile migration and rearing periods of winter-run Chinook salmon in the Delta. Based on the general timing and distribution of winter-run Chinook salmon in the Delta, the potential for stranding is greatest for juveniles that may occur in the south Delta as early as September, October, or November depending on Sacramento flows, Delta inflows, CVP and SWP pumping rates, and operation of the DCC.

#### 4.3.2.5.5.2 Assess Species Response

If stranded within cofferdams, juvenile winter-run Chinook salmon would likely be killed by subsequent dewatering and construction within the enclosed structures. The fate of fish that may become stranded within the 200-acre cells surrounded by silt curtains in CCF is less certain but confinement and prolonged exposure (months) to elevated turbidity, suspended sediment, and noise inside the silt curtains is likely to result in incidental take of stranded juveniles.

#### 4.3.2.5.5.3 Assess Risk to Individuals

If present, it is assumed that juvenile winter-run Chinook salmon will be at risk of being stranded within cofferdams or silt curtains that are installed in October or November. Fish rescue and salvage activities using accepted fish collection methods will minimize these losses but some injury or mortality could still occur because of varying degrees of effectiveness of the collection methods and potential stress and injury associated with various capture and handling methods. It will be impractical or infeasible to rescue fish from large, deep areas surrounded by silt curtains in CCF. However, it may be possible to exclude winter-run Chinook salmon and other species from active dredging areas in CCF by deploying silt curtains in a manner that directs fish away from the silt curtains and prevents fish from re-entering these areas during dredging operations. Fish rescue operations at NCCF prior to dewatering will require special considerations given its large surface area, depth, and large numbers of fish that may be present.

### *4.3.2.5.6 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 the following take minimization measures (described in Appendix 3.F *General Avoidance and Minimization Measures*) to minimize the potential for impacts on listed fish species: AMM2 *Worker Awareness Training;* AMM3 *Erosion and Sediment Control Plan;* AMM6 *Disposal and Reuse of Spoils, Reusable Tunnel Material, and Dredged Material;* AMM7 *Barge Operations Plan;* AMM8 *Underwater Sound Control and Abatement Plan; and* AMM9 *Fish Rescue and Salvage Plan.*

#### 4.3.2.5.6.1 Assess Species Exposure

Restriction of in-water construction activities to July 1–November 30 avoids the primary adult migration period and primary juvenile migration and rearing periods of winter-run Chinook salmon in the Delta. Based on the general timing and distribution of winter-run Chinook salmon in the Delta, the potential for injury is greatest for juveniles that may occur in the south Delta as early as September, October, or November depending on Sacramento flows, Delta inflows, CVP and SWP pumping rates, and operation of the DCC.

#### 4.3.2.5.6.2 Assess Species Response

If present during in-water construction activities, adult winter-run Chinook salmon will be capable of readily avoiding or moving away from active construction areas, minimizing their risk of being injured. Juveniles will be at a higher risk because of their limiting swimming abilities and association with nearshore areas.

#### 4.3.2.5.6.3 Assess Risk to Individuals

Based on the potential for exposure and limited ability to avoid active construction areas, winter-run Chinook salmon juveniles that may be present in CCF and the adjacent Old River channel in October and November will be at risk of being injured during dredging, riprap placement, sheetpile installation, and barge operations. DWR proposed several take minimization measures (above) to reduce this risk to winter-run Chinook salmon juveniles.

### *4.3.2.5.7 Loss/Alteration of Habitat*

Dredging, excavation, and expansion of CCF and construction of the new water conveyance facilities will result in temporary and permanent losses or alteration of aquatic habitat in CCF and adjacent Old River channel. 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 impacts on physical habitat associated with construction activities. Dredging, cofferdam installation, levee armoring, and barge operations would affect an estimated 1,932 acres of tidal perennial aquatic habitat through changes in water depths, vegetation, and substrate within CCF and Old River. Permanent impacts on aquatic habitat encompass an estimated 258 acres of tidal perennial aquatic 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.

During construction activities, DWR will implement AMM2 *Construction Best Management Practices and Monitoring* (Appendix 3.F *General Avoidance and Minimization Measures*), to protect listed fish, wildlife, and plant species, their 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. Compensation for unavoidable impacts on aquatic habitat in CCF is not proposed because CCF is not considered suitable habitat for winter-run Chinook salmon.

#### 4.3.2.5.7.1 Assess Species Exposure

All migrating or rearing salmonids that occur in CCF and the adjacent Old River channel during expansion of the CCF and construction of the new water conveyance facilities will be potentially exposed to physical alteration of aquatic and channel margin habitat resulting from changes in water depths, hydraulic conditions, vegetation, substrate, and shoreline structure. All winter-run Chinook salmon that occur in CCF and the adjacent Old River channel during construction activities will be potentially exposed to these changes throughout the construction period.

#### 4.3.2.5.7.2 Assess Species Response

Similar to that described for the HOR gate (see Section 4.3.2.4.7.7 *Assess Species Response*), winter-run Chinook salmon that become entrained into CCF may be adversely affected by changes in 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.

#### 4.3.2.5.7.3 Assess Risk to Individuals

Expansion of CCF and construction of the new water conveyance facilities is expected to reduce 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. Under existing conditions, salmonid migration and rearing habitat in CCF and the adjacent south Delta channels has been degraded by alteration of natural flow patterns, high predator densities, levee clearing and armoring, channel dredging, entrainment, and lost connectivity of migration corridors. Because winter-run Chinook salmon that are entrained into CCF generally suffer high mortality rates (pre-screen losses) (Gingras 1997, Clark et al. 2009), CCF is not considered suitable habitat for winter-run Chinook salmon. Consequently, the projected changes in physical habitat associated with expansion of CCF and construction of the new water conveyance facilities are not expected to significantly affect the survival of individual winter-run Chinook salmon that become entrained into CCF.

## 4.3.3 Effects of Water Facility Maintenance

In-water maintenance of water facilities is not proposed for coverage under this Application (Section 3.1.6 *Take Authorization Requested*), and the only on-land maintenance activity proposed for coverage, transmission line maintenance, has no potential to affect winter-run Chinook salmon. Thus, the following information is provided for context. A separate 2081(b) application will be made to cover take associated with maintenance.

### *4.3.3.1 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, and periodic repairs to prevent mechanical, structural, and electrical failures. 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 suction 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 winter-run Chinook salmon because of the potential for injury or mortality of fish. As described in Section 4.3.2.2 *North Delta Diversions*, restriction of dredging, riprap replacement, and other in-water maintenance activities to the an in-water work window to be approved by CDFW, NMFS, and USFWS will minimize exposure of winter-run Chinook salmon to turbidity and suspended sediment, noise, and other construction-related hazards (e.g., direct physical injury)[26]. Based on the general timing of winter-run Chinook salmon in the project area, potential exposure to these activities will likely be limited to a small proportion of the adults that may be migrating through the project area in June and July, and to juveniles that may arrive in the lower Sacramento River and Delta in September/October.

As described in Section 4.3.2.2 *North Delta Diversion*, dredging and riprap replacement could result in harassment of fish from increases in turbidity, suspended sediment, and noise; injury or mortality of winter-run Chinook salmon from 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 winter-run Chinook salmon is expected to be low based on the location and timing of maintenance activities relative to the primary migration and rearing periods of winter-run Chinook salmon in the project area; the low quality of rearing habitat at the proposed intake locations; and the localized, temporary nature of maintenance activities. Potential adverse effects on winter-run Chinook salmon and aquatic habitat will be further minimized by implementing the following take minimization measures (described in Appendix 3.F *General Avoidance and Minimization Measures*) to limit the extent and duration of potential impacts on aquatic habitat: AMM1 *Worker Awareness Training;* AMM2 *Construction Best Management Practices and Monitoring;* AMM3 *Stormwater Pollution Prevention Plan;* AMM3 *Erosion and Sediment Control Plan;* AMM4 *Spill Prevention, Containment, and Countermeasure Plan;* AMM6

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[26] See Permit Resolution Log items #45 and #47 for further information on this point.

*Disposal and Reuse of Spoils, Reusable Tunnel Material, and Dredged Material;* AMM7 *Barge Operations Plan;* and AMM14 *Hazardous Material Management*.

### *4.3.3.2 Barge Landings*

Maintenance activities at the barge landings will likely include periodic visual inspections, routine maintenance, and perhaps repairs of the docking, loading, and unloading facilities. Maintenance activities also include 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 an in-water work window to be approved by CDFW, NMFS, and USFWS, likely timed from August to October to avoid the adult migration period and the primary juvenile migration and rearing periods of winter-run Chinook salmon in the Delta. Potential adverse effects on winter-run Chinook salmon and aquatic habitat will be further minimized by implementing the following take minimization measures (described in Appendix 3.F *General Avoidance and Minimization Measures*) to limit the extent and duration of potential impacts on aquatic habitat: AMM1 *Worker Awareness Training;* AMM2 *Construction Best Management Practices and Monitoring;* AMM3 *Stormwater Pollution Prevention Plan;* AMM3 *Erosion and Sediment Control Plan;* AMM4 *Spill Prevention, Containment, and Countermeasure Plan;* AMM6 *Disposal and Reuse of Spoils, Reusable Tunnel Material, and Dredged Material;* AMM7 *Barge Operations Plan;* and AMM14 *Hazardous Material Management*[27].

### *4.3.3.3 Head of Old River Gate*

Maintenance of the Head of Old River (HOR) gate, including fishway, boat lock, and navigation structures, 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. 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 necessary 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 sealed clamshell dredge operated from a barge or from the top of the levee. A floating turbidity control curtain would 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 AMM6 *Disposal and Reuse of Spoils, Reusable Tunnel Material, and Dredged Material* (Appendix 3.F *General Avoidance and Minimization Measures*).

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[27] See Permit Resolution Log item #46 for a statement that barge landings would not need maintenance dredging.

Each gate bay will be inspected annually at the end of the wet season for sediment accumulation. Each miter or radial gate bay will 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 AMM8 *Fish Rescue and Salvage Plan* (Appendix 3.F *General Avoidance and Minimization Measures*).

Maintenance activities that have the greatest potential to affect listed species and aquatic habitat at the HOR gate are dredging and cofferdam installation. As described in Section 4.3.2.3 *Barge Landings*, restriction of dredging, cofferdam installation, and other in-water activities to an in-water work window to be approved by CDFW, NMFS, and USFWS (likely in the range from August to October or November) will avoid the primary adult migration period and primary juvenile migration and rearing periods of winter-run Chinook salmon in the Delta. Adult winter-run Chinook salmon may enter the lower San Joaquin River in November but are unlikely to occur as far upstream as the HOR gate based on their attraction to Sacramento River water which may be drawn into the San Joaquin River side of the Delta through the DCC (when open), Georgiana Slough, and Three Mile Slough. Similarly, juvenile winter-run Chinook salmon, which may enter this region of the Delta as early as September/October via these same pathways, are not expected to occur in significant numbers as far upstream as the HOR gate based on the general effects of flow and export pumping on route selection in the Delta.

As described in Section 4.3.2.4 *Head of Old River Gate*, dredging, cofferdam installation, and riprap placement could result in injury or mortality of winter-run Chinook salmon 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 winter-run Chinook salmon from these sources is low due to the location and timing of these activities relative to the primary migration routes of adults and juveniles in the Delta; 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 aquatic 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: AMM1 *Worker Awareness Training;* AMM2 *Construction Best Management Practices and Monitoring;* AMM3 *Stormwater Pollution Prevention Plan;* AMM3 *Erosion and Sediment Control Plan;* AMM4 *Spill Prevention, Containment, and Countermeasure Plan;* AMM6 *Disposal and Reuse of Spoils, Reusable Tunnel Material, and Dredged Material;* AMM7 *Barge Operations Plan;* and AMM14

*Hazardous Material Management* (Appendix 3.F *General Avoidance and Minimization Measures*).

#### *4.3.3.4 Clifton Court Forebay*

Maintenance of CCF and the water conveyance facilities 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 4.3.4.1, *Proposed Delta Exports and Related Hydrodynamics*).

As described in Section 4.3.2.5 *Clifton Court Forebay*, maintenance dredging, embankment repairs, and other in-water activities would be restricted to an proposed in-water work window to be approved by CDFW, NMFS, and USFWS (likely during the period from July to November), thereby avoiding the primary adult migration period and primary juvenile migration and rearing periods of winter-run Chinook salmon in the Delta. Adult winter-run Chinook salmon may enter the lower San Joaquin River in November but are unlikely to occur in the south Delta based on their attraction to Sacramento River water which may be drawn into the San Joaquin River side of the Delta through the DCC (when open), Georgiana Slough, and Three Mile Slough. Juvenile winter-run Chinook salmon which may enter the Delta as early as September, October, or November and be drawn toward the south Delta via the same pathways. Salvage records at the CVP and SWP Fish Collection Facilities indicate that winter-run Chinook salmon juveniles typically do not appear in salvage until November or December.

As described in Section 4.3.2.5 *Clifton Court Forebay*, dredging, levee repairs, and other in-water activities could result in 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 effects on winter-run Chinook salmon from these sources is low due to the location and timing of these activities relative to the primary migration routes of adults and juveniles in the Delta; the low quality of habitat in CCF; and the localized, temporary nature of maintenance activities. Potential adverse effects on winter-run Chinook salmon will be further minimized by implementing a number of take minimization measures (described in Appendix 3.F *General Avoidance and Minimization Measures*) to limit the extent and duration of potential impacts on listed fish species and aquatic habitat: AMM1 *Worker Awareness Training;* AMM2 *Construction Best Management Practices and Monitoring;* AMM3 *Stormwater Pollution Prevention Plan;* AMM3 *Erosion and Sediment Control Plan;* AMM4 *Spill Prevention, Containment, and Countermeasure Plan;* AMM6 *Disposal and Reuse of Spoils, Reusable Tunnel*

*Material, and Dredged Material;* AMM7 *Barge Operations Plan;* and AMM14 *Hazardous Material Management*.

## 4.3.4 Effects of Water Facility Operations

### *4.3.4.1 Proposed Delta Exports and Related Hydrodynamics*

The assessment of the effects of water facility operations in the Delta on winter-run Chinook salmon is divided into two main sections. Section 4.3.4.1.1 *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 PP. Section 4.3.4.1.2 *Assess Species Response to the Proposed Action* examines how the different elements of the PP could affect fish, e.g., through entrainment or changes in river flow.

#### *4.3.4.1.1 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).

##### 4.3.4.1.1.1 Temporal Occurrence

Adult winter-run Chinook salmon first enter the San Francisco Bay Estuary from the Pacific Ocean starting in November (Table 4.3-6). 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).

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[28]. 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).

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

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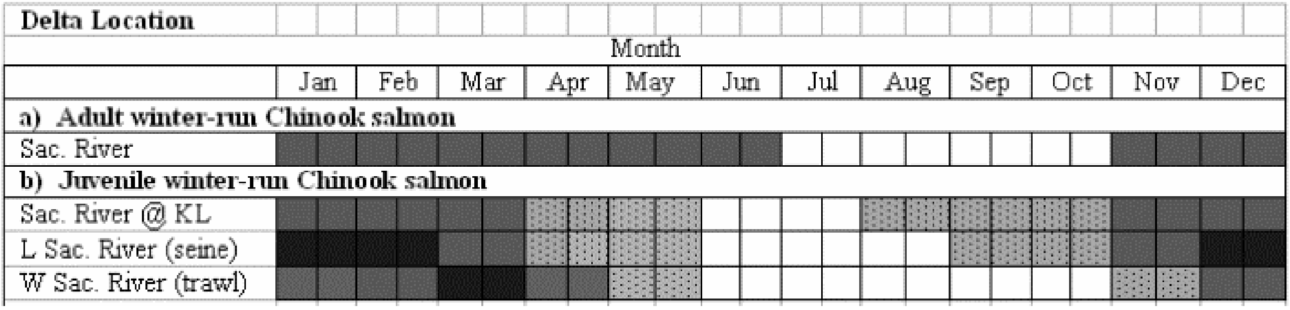
[28] Note that timings discussed in this section are largely based on length-at-date assignments of Chinook salmon race, which have some uncertainty (Harvey et al. 2014).

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 PP 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 4.3-6).

In addition to the seasonal component of juvenile emigration, distinct increases in numbers of 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).

**Table 4.3-6. Temporal Distribution of Winter-Run Chinook Salmon 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) | ▒▒ | ▒▒ | ■■ | ▒▒ | ░░ | | | | | | ░░ | ▒▒ |

*Source: NMFS (2009: 335).*
*Note: KL = Knights Landing. FW = Fremont Weir. Shading denotes relative abundance; high (black), medium (gray), or low (stippled).*

### 4.3.4.1.1.2 Spatial Occurrence

The main adult winter-run Chinook salmon 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 Chinook salmon 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 Chinook salmon 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 Chinook salmon 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 Chinook salmon 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 Chinook salmon 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 Chinook salmon adults and juveniles may occur in other parts of the Delta not described above.

#### 4.3.4.1.1.3 Exposure to North Delta Exports

The potential for exposure of winter-run Chinook salmon to the NDD will be very similar in terms of timing to that described for the Delta Cross Channel by NMFS (2009: 402-403), as discussed in Section 4.3.4.1.2.6, *Exposure to Delta Cross Channel*. However, a greater proportion of Sacramento River basin fish will pass the NDD than the DCC because a portion of fish (~20–40%, based on Perry et al. [2010, 2012]) are expected to enter Sutter/Steamboat Sloughs prior to reaching the DCC. Some fish will enter the Delta from the Yolo Bypass during Fremont Weir overtopping events and via passage through the notch of the modified Fremont Weir[29]. Roberts et al. (2013) utilized proportion of flow as a proxy to estimate percentage of fish that would emigrate through the Yolo Bypass[30]. They estimated that the percentage would range from a mean of ~8% in drier years to ~16% in wetter years for winter-run Chinook salmon (Table 4.3-7).

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

[30] These findings were subsequently published in the peer-reviewed literature (Acierto et al. 2014).

**Table 4.3-7. 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.*

#### 4.3.4.1.1.4 Exposure to South Delta Exports

The potential for exposure to the effects of south Delta exports follows the basic timing outlined in the earlier species-specific discussions and additional information presented for the Delta Cross Channel in Section 4.3.4.1.1.6 *Exposure to Delta Cross Channel*. Hydrodynamic effects of the south Delta export facilities could occur for juvenile winter-run Chinook salmon emigrating from the Sacramento River basin and entering the interior Delta, principally at Georgiana Slough (the DCC will generally 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%[31] (Perry et al. 2010, 2012).

#### 4.3.4.1.1.5 Exposure to Head of Old River Gate Operations

Winter-run Chinook salmon are not expected to be exposed to near-field effects of the HOR gate based on its geographic location. Far-field effects of the HOR gate in terms of flow routing down the San Joaquin River could affect winter-run Chinook salmon if occurring in the interior Delta.

#### 4.3.4.1.1.6 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. The closure of the DCC gates under the NMFS (2009) BiOp's Action 4.1 is described in Section

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[31] 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.

3.3.2.4, *Operational Criteria for the Delta Cross Channel Gates*, and is 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 Chinook salmon will migrate during the main period of DCC closure.

#### 4.3.4.1.1.7 Exposure to Suisun Marsh Facilities

##### *4.3.4.1.1.7.1 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.

##### *4.3.4.1.1.7.2 Roaring River Distribution System*

As described previously for the SMSCG, some winter-run Chinook salmon (juveniles and adults) occur in Montezuma Slough and therefore could be exposed to the RRDS, although the intake is screened.

##### *4.3.4.1.1.7.3 Morrow Island Distribution System*

NMFS (2009: 438) noted that Goodyear Slough is not a migratory corridor for winter-run Chinook salmon, which limits their potential for exposure to the MIDS.

##### *4.3.4.1.1.7.4 Goodyear Slough Outfall*

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

#### 4.3.4.1.1.8 Exposure to North Bay Aqueduct

Winter-run Chinook salmon 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.

#### 4.3.4.1.1.9 Exposure to Other Facilities

##### *4.3.4.1.1.9.1 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 Chinook salmon in the south Delta is from January through March.

###### *4.3.4.1.1.9.2 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 in the Central Valley's Delta region. Migrations of juvenile winter-run Chinook salmon primarily occur outside of the summer period in the Delta. Based on typical water temperatures in the vicinity of the salvage facilities during this period, the temperatures will be incompatible with Chinook salmon life history preferences, generally exceeding 70˚F by mid-June. Mechanical harvesting will occur on an as-needed basis and therefore winter-run Chinook salmon could be exposed to this action, if entrained into the Forebay.

#### *4.3.4.1.2 Assess Species Response to the Proposed Action*

The response of winter-run Chinook salmon to the proposed action and associated take 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.

##### 4.3.4.1.2.1 Near-Field Effects

###### *4.3.4.1.2.1.1 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[32]. 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 described in Chapter 6 *Monitoring Plan*, a number of studies will be conducted to monitor NDD fish screen performance and allow refinement to meet design criteria.

###### *4.3.4.1.2.1.1.1 Entrainment*

Juvenile Chinook salmon at sizes of 30 mm or greater may occur near the NDD structures (National Marine Fisheries Service 1997b). 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 (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 NDDs.

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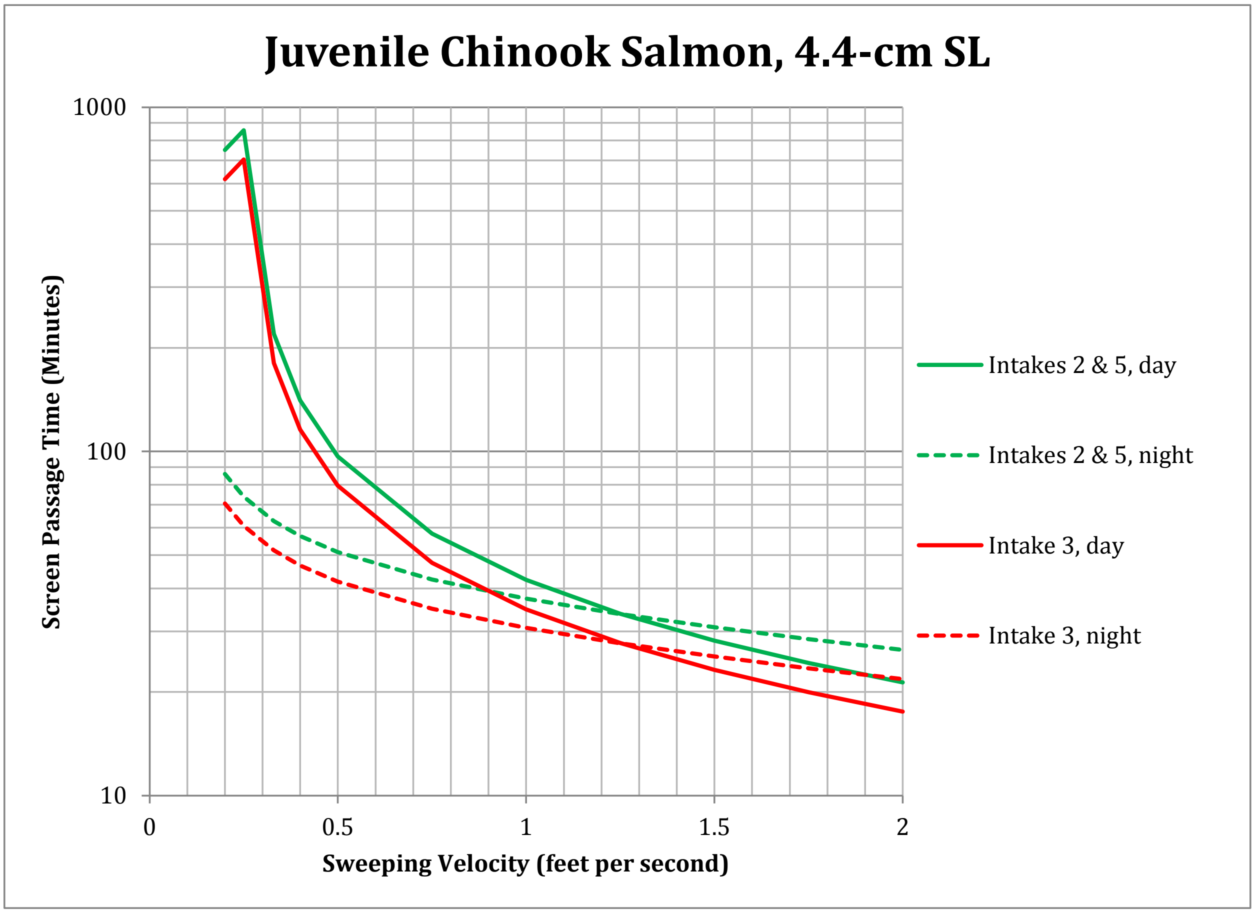
[32] Fish screens will be removed as necessary during maintenance, which could be accompanied by dewatering, for example (see Section 3.3.6.1.1, *Intake Dewatering*, of Chapter 3, *Description of the Proposed Action*). Pumping will not occur in bays with fish screens removed, and therefore there would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

###### *4.3.4.1.2.1.1.2 Impingement, Screen Contact, and Screen Passage Time*

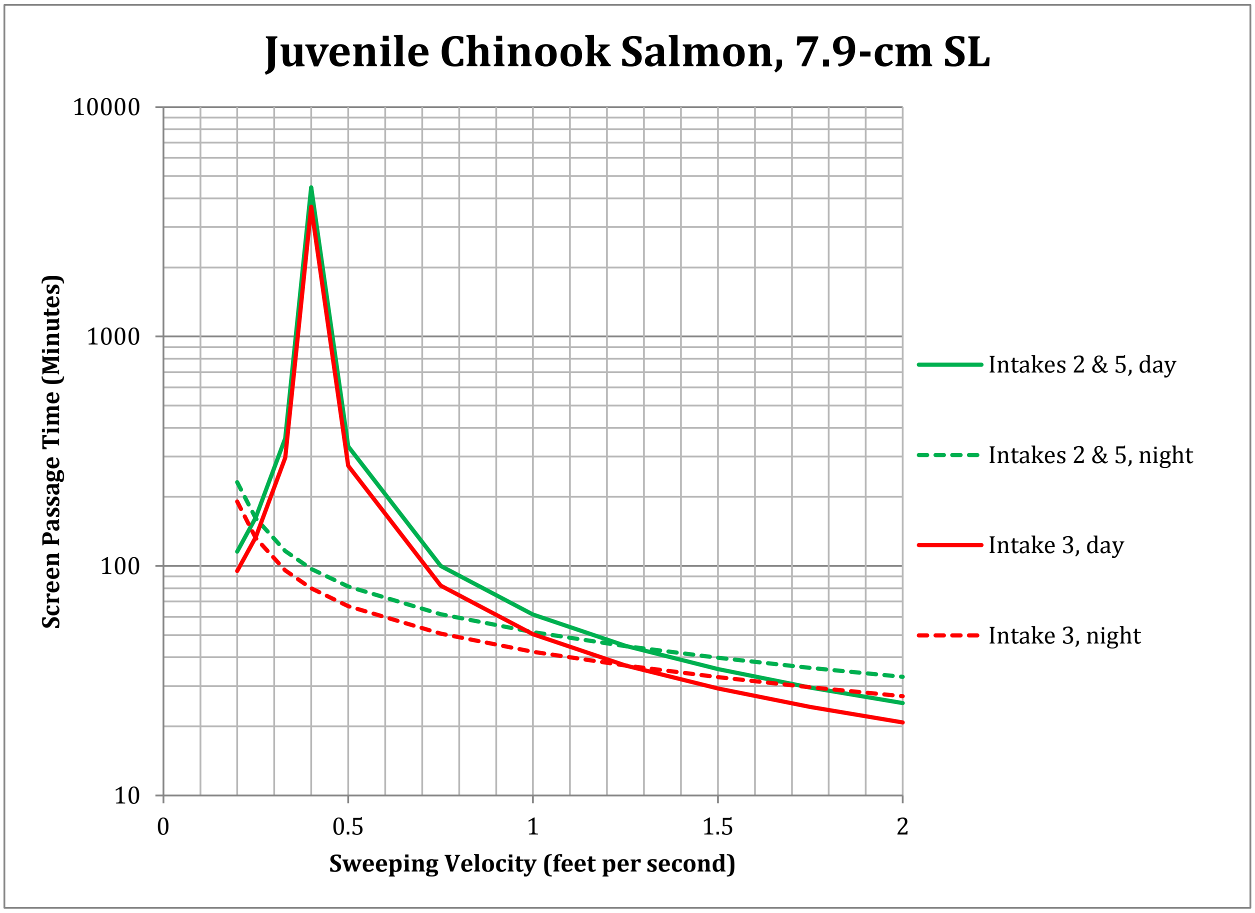
Juvenile winter-run Chinook salmon will have the potential to contact and be impinged on the screens of the NDD. Experimental studies at the UC Davis Fish Treadmill facility found that Chinook salmon experienced frequent contact with the simulated fish screen but were rarely impinged (defined as prolonged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

Although Swanson et al. (2004) 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. (2004) 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 *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* [ICF International 2016, Appendix 5.D]) (Figure 4.3-1 and Figure 4.3-2). It should be noted that the equations of Swanson et al. (2004) 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 4.3-2). 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 4.3-1 and Figure 4.3-2 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 4.3-2) than that of smaller fish (Figure 4.3-1). 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 4.3-1 and Figure 4.3-2). Juvenile winter-run Chinook salmon 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. This uncertainty will be addressed with monitoring and targeted studies examining impingement and passage time along the intakes. Swanson et al. (2004) 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 will be 1,350 feet each; intake 3’s screen length will be 1,110 feet.

**Figure 4.3-1. 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 will be 1,350 feet each; intake 3's screen length will be 1,110 feet.

**Figure 4.3-2. 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**

#### *4.3.4.1.2.1.1.3 Predation*

Predation of juvenile winter-run Chinook salmon 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 the percentage of tagged juvenile Chinook salmon 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 juvenile Chinook salmon providing the estimate of survival in the channel downstream of the screen were released prior to those 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 NDDs will 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 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 PP, there will be three intakes constituting the NDD, compared to only one for the GCID facility, so that the cumulative length of screen will be considerably greater for the PP. 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 (Appendix 5.F *Biological Stressors on Covered Fish*, Section 5.F.3.2.1 in California Department of Water Resources [2013]) suggested that loss along the NDD[33] 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 winter-run Chinook salmon along the NDD, which would constitute take.

###### *4.3.4.1.2.1.2 South Delta Exports*

As described by NMFS (2009: 341-374), direct entrainment of juvenile winter-run Chinook salmon 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%

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[33] 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.

- 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 PP, and a qualitative discussion of potential predation differences between NAA and PP. The above loss percentages are assumed not to differ between NAA and PP, so the differences are attributable to differences in export pumping. Clifton Court Forebay's configuration will change under the PP 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 will 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 pumping at the Banks pumping plant under the PP compared to NAA, which may result in less prescreen loss under the PP 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 PP across Clifton Court Forebay attributable to Banks pumping and the reconfiguration of the Forebay under the PP.

Outside of Clifton Court Forebay, the other major difference in configuration of the SWP south Delta export facility under the PP 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[34]; 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

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[34] 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.

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 PP. This risk cannot be quantified based on available information.

Following completion of PP construction and commencement of PP 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 PP 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 PP loss multipliers and the prevailing multipliers used prior to the commencement of PP operations, and following regulatory agency approval, the new PP 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 levels of incidental take that have been authorized by NMFS and CDFW for the PP in each water year. South Delta export pumping will be managed in real time, as currently occurs, in order to ensure 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, the timing of in-water construction activities (June 1–November 30) will avoid the periods when juvenile winter-run Chinook salmon are most likely to be present in the south Delta. Thus, the interaction of operations with construction is expected to affect only a limited portion of the juvenile winter-run Chinook salmon population, and any effect cannot be quantified because of the lack of specific information for how prescreen loss may 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.

### *4.3.4.1.2.1.2.1 Entrainment*

#### 4.3.4.1.2.1.2.1.1 Salvage-Density Method: Winter-Run Chinook Salmon

The salvage-density method was used to assess differences in south Delta exports and resulting entrainment[35] 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 *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale* (ICF International 2016, Appendix 5.D, Section 5.D.1.1.2, *South Delta Exports*[36]). 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 will be lower under PP than NAA in all water year types for winter-run Chinook salmon (Table 4.3-8). The differences between PP 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 PP at the SWP in critical years to 82% less under PP at the CVP in wet years (Table 4.3-8).

**Table 4.3-8. Estimated Mean Entrainment Index (Number of Fish Lost, Based on Normalized Salvage Data) of Juvenile Winter-Run Chinook Salmon for NAA and PP Scenarios at the CVP/SWP Salvage Facilities, By Water Year Type**

| Water Year Type | State Water Project | | | | Central Valley Project | | |
|---|---|---|---|---|---|---|---|
| | NAA | PP | PP vs. NAA[1] | | NAA | PP | PP 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 (PP) than under the no action alternative (NAA).

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[35] As noted in ICF International (2016, 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. Regardless of the significance of this loss, this effects analysis provides relative differences between the NAA and PP.

[36] See Permit Resolution Log item #118, #119, #120, #121, #122, #123, #134, #135, #136, and #137 for discussion of potential entrainment into the NCCF and subsequent expert through NCCF siphon outlet to pumping plants.

###### 4.3.4.1.2.1.2.1.2 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 winter-run Chinook salmon may take. Zeug and Cavallo (2014) recently demonstrated that 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 PP scenarios (see methods description in *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale* [ICF International 2016, Appendix 5.D], 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 number 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 number of fish 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.

The analysis showed that in wet years salvage of juvenile winter-run Chinook salmon was predicted to be substantially higher under NAA relative to PP (Figure 4.3-3). These differences were particularly apparent in October and November (medians were 82–92% less under PP; although the proportion was very small in October, reflecting very low occurrence in this month; see ICF International [2016], Appendix 5.D, Figure 5.D.42) and again from January through March (medians were 81–95% less under PP). In wet years, median salvage under PP 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 PP 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 PP was also evident in October, November, and January (80–94% lower median salvage under PP), but the differences were less in February–April (4–50% lower median salvage under PP) relative to wetter years (60–96% lower median salvage under PP). 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 PP in December to 63% lower under PP 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 PP and the magnitude of the difference varied considerably between years (Figure 4.3-4 and Figure 4.3-5, Table 4.3-9), 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 PP scenarios overlapped in all years (Figure 4.3-6), 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 PP, although the mean predictions were within the range of those observed in the data used to develop the relationships.

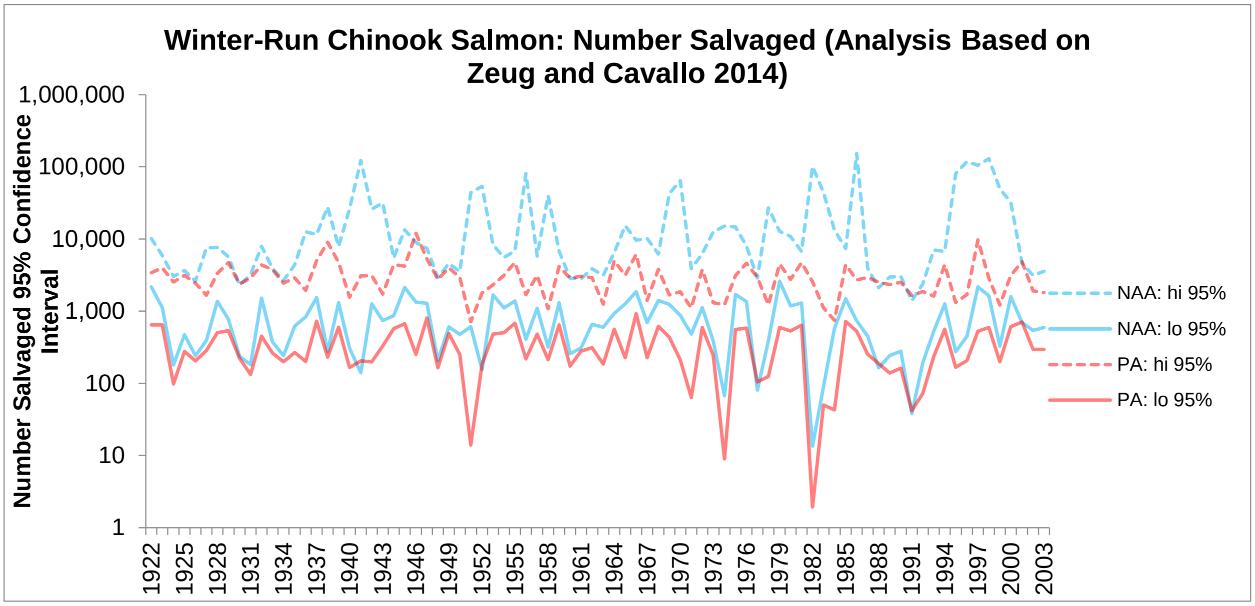

**Figure 4.3-3. 95% Confidence Intervals of Annual Number of Winter-Run Chinook Salmon Salvaged (From 1,000,000 Released), from the Analysis Based on Zeug and Cavallo (2014).**

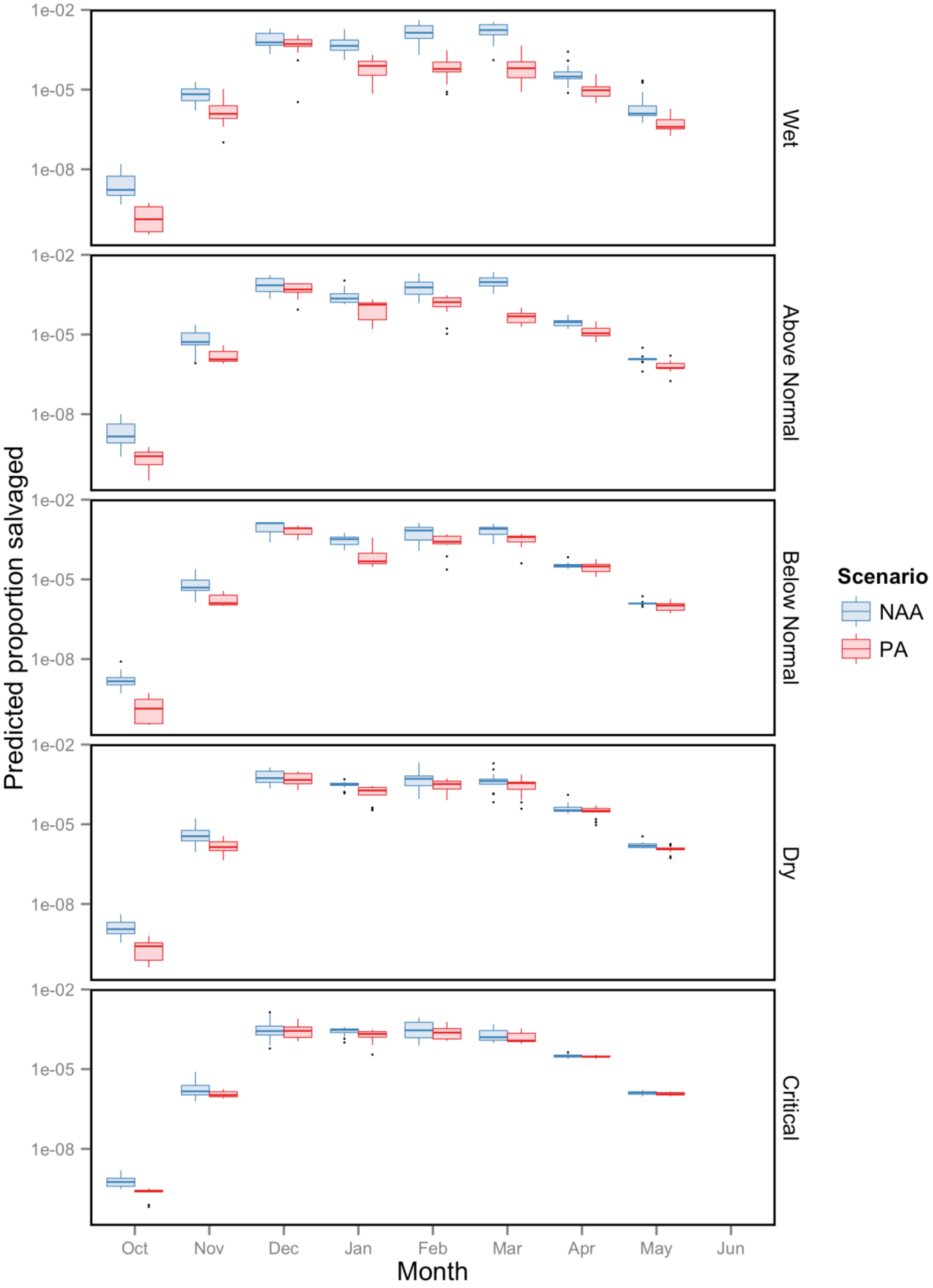
Predicted proportion salvaged
1e-02
1e-05
1e-08
Wet
Above Normal
Below Normal
Dry
Critical
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Month
Scenario
NAA
PA

**Figure 4.3-4. Predicted Proportion of Annual Salvage of Juvenile Winter-Run Chinook Salmon in October-June, from the Analysis Based on Zeug and Cavallo (2014)**[37]

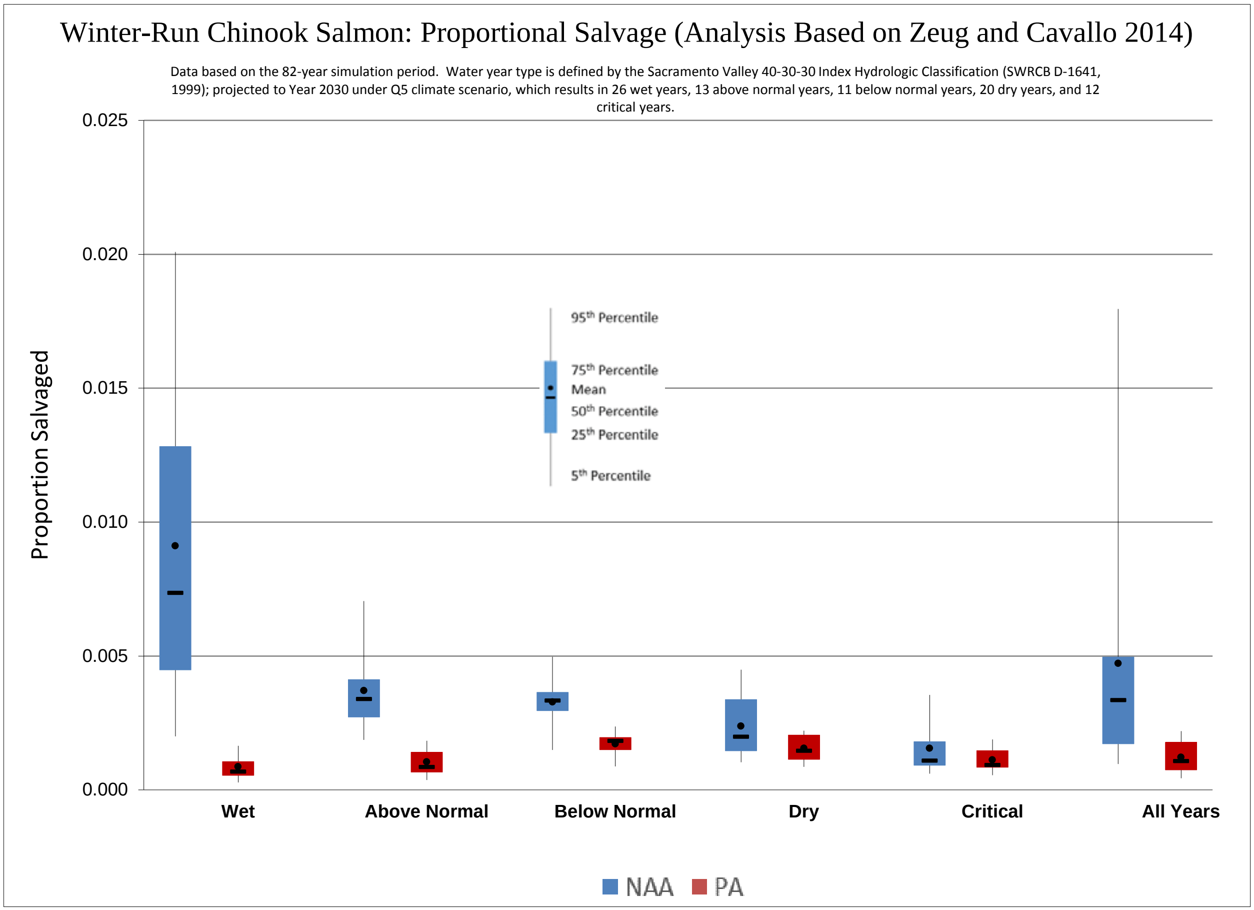

**Figure 4.3-5. Box Plots of Annual Proportion of Juvenile Winter-Run Chinook Salmon Salvaged, Grouped by Water-Year Type, from the Analysis Based on Zeug and Cavallo (2014).**

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[37] The figures presented in this section, as well as those of the other listed fishes, often use the acronym 'PA' when referring to the PP. This reflects material originally developed for the biological assessment (ICF International 2016), which used the term "proposed action" (PA), equivalent to the PP.

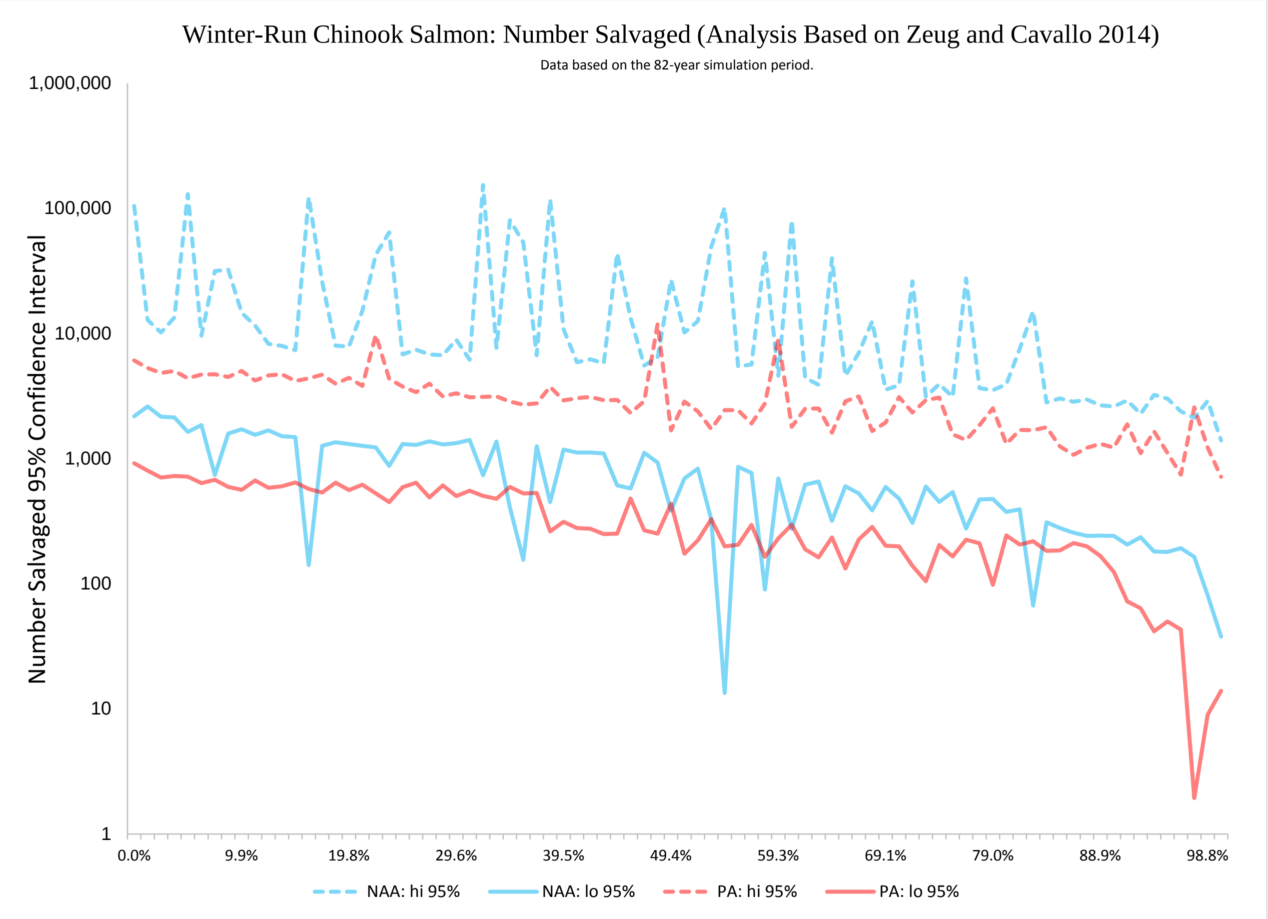

**Figure 4.3-6. Exceedance Plot of Annual Number of Juvenile Winter-Run Chinook Salmon Salvaged, from the Analysis Based on Zeug and Cavallo (2014).**

**Table 4.3-9. 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 | PP | PP 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.

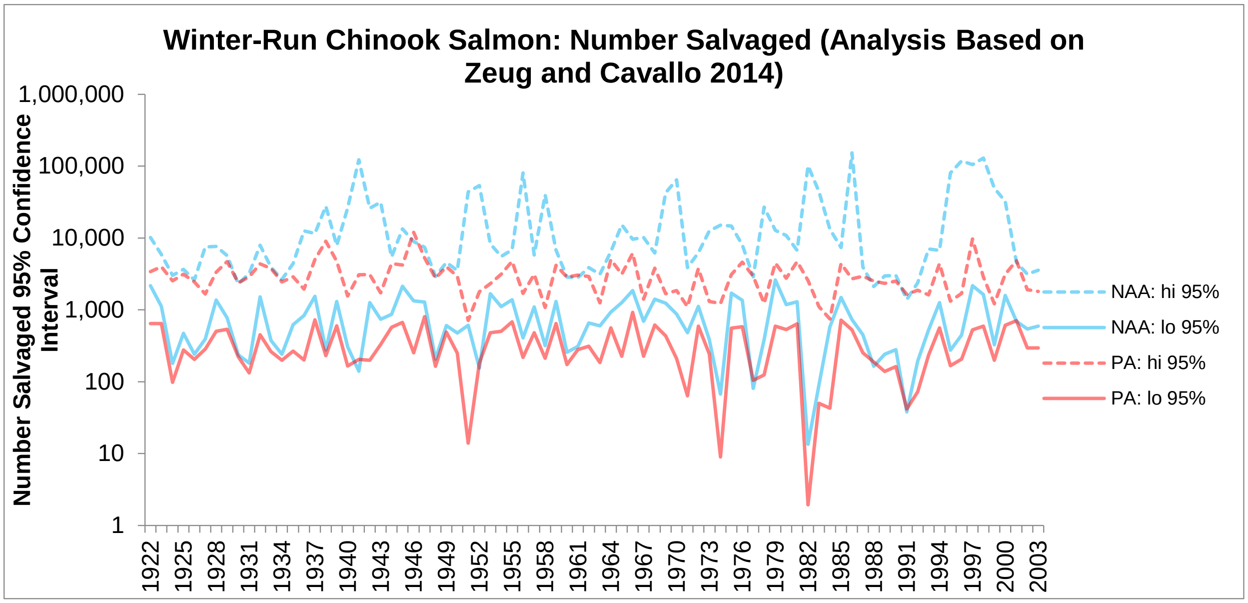

**Figure 4.3-7. 95% Confidence Intervals of Annual Number of Winter-Run Chinook Salmon Salvaged (From 1,000,000 Released), from the Analysis Based on Zeug and Cavallo (2014).**

###### *4.3.4.1.2.1.2.2 Predation*

Appreciable loss 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), is expected to result in less entrainment-related predation loss[38].

##### *4.3.4.1.2.1.3 Head of Old River Gate*

The proposed HOR gate will have the potential to considerably increase the proportion of San Joaquin River basin-origin juvenile salmonids 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 4.3.4.1.3.2.1.1, Channel Velocity (DSM2-HYDRO), and flow routing into channel junctions in Section 4.3.4.1.3.2.1.3, Flow Routing Into Channel Junctions[39].

##### *4.3.4.1.2.1.4 Delta Cross Channel*

The principal effect of the DCC will be to influence the proportion of juvenile winter-run Chinook salmon entering the interior Delta, where survival is lower during downstream migration from the Sacramento River basin. These effects are discussed further in Section 4.3.4.1.3.2.1.2, *Entry into Interior Delta*, in relation to far-field effects.

An additional potential effect of DCC operations is delayed migration of adult winter-run Chinook salmon migrating upstream to the Sacramento River basin. NMFS (2009: 406) noted

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[38] See Permit Resolution Log items #103, #104, #105, #106, #107, #108, #109, #110, #111 for further information predation rates at the south Delta facilities.

[39] See Permit Resolution Log items #138 and #139 for discussion of passage and predation risks at the HOR Gate.

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 Chinook salmon upstream migration, there would be little to no difference in the number of days the gates would be open between NAA and PP (see Table 5.A.6-31 in *CalSim II Modeling and Results* [ICF International 2016, 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 PP (see Table 5.A.6-31 in *CalSim II Modeling and Results* [ICF International 2016, 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 PP to maintain water quality conditions per D-1641 (Rock Slough salinity standard). Given that the differences between NAA and PP in the number of days open generally were not considerable, and adult winter-run Chinook salmon that are migrating to the Sacramento River basin have the ability to drop back and swim around the DCC gates (National Marine Fisheries Service 2009: 406).

The potential for delay of adult winter-run Chinook salmon entering the central Delta and moving up the Mokelumne River system may be dependent on the duration of DCC openings. Assessing the duration of DCC openings in each month for the NAA and PP and the potential effects on upstream-migrating adults 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 PP. Openings commencing in November occurred at a similar frequency under NAA (n = 25 openings over the 82-year CalSim period) and PP (n = 22 openings). Openings tended to be longer under the PP (mean = 14.0 days, median = 8 days, mode = 20 days) than the NAA (mean = 8.6 days, median = 6 days, mode = 3 days) (Figure 4.3-7). 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. A greater frequency of multi-day openings therefore could have some adverse effects on winter-run Chinook salmon 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 winter-run adtuls 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 winter-run Chinook salmon, could be delayed by a greater frequency of multi-day opening and subsequent closure under the PP in some years. Further study is needed to ascertain the extent to which adult winter-run could find an alternative pathway through the Delta, or how long they may hold below the gates until they are reopened.

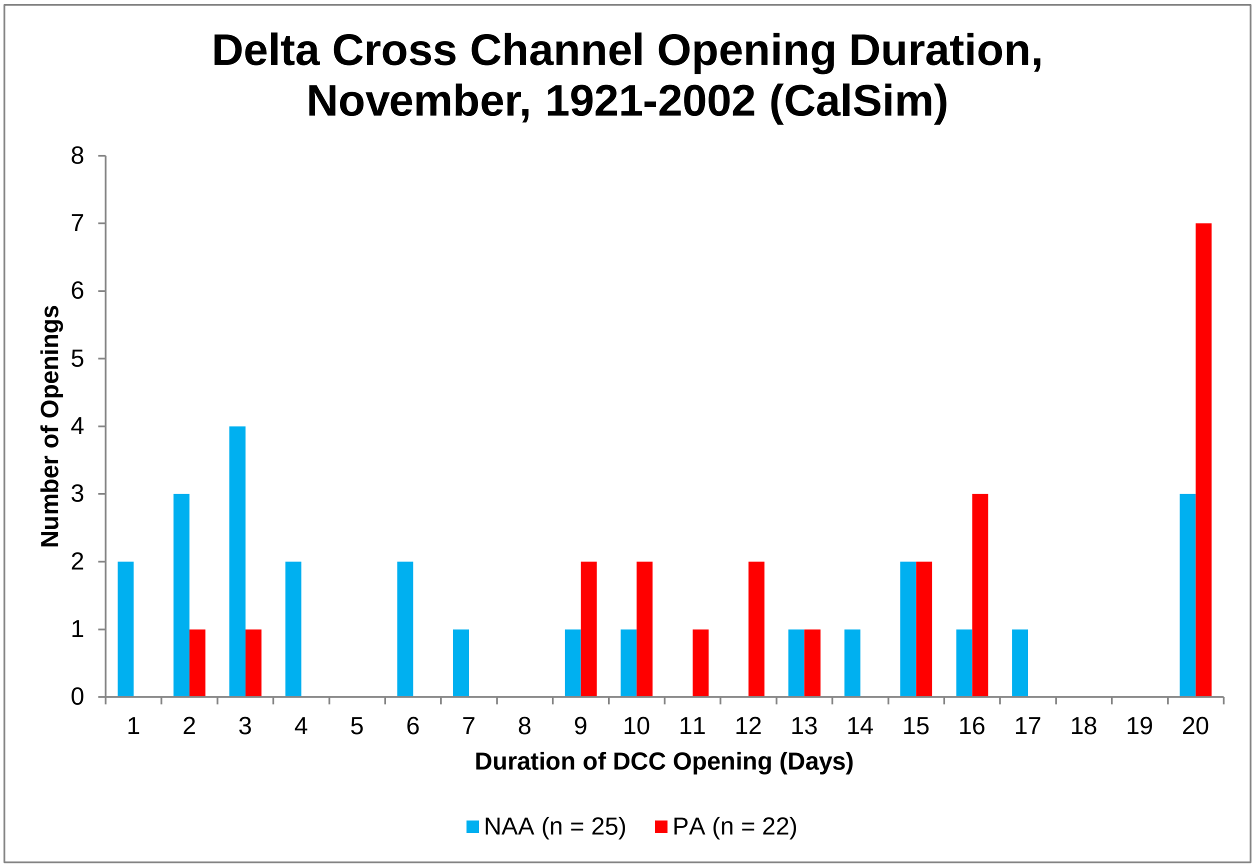

**Figure 4.3-8. Duration of Delta Cross Channel Openings that Began in November, from CalSim Modeling of 1921-2002**

### *4.3.4.1.2.1.5 Suisun Marsh Facilities*

#### *4.3.4.1.2.1.5.1 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 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 winter-run Chinook salmon 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 in natal tributaries is reliant on access provided by short-duration, high-streamflow events, delay in the Delta could affect reproductive viability. This is 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 PP (see Table 5.B.5-29 in

*DSM2 Methods and Results* [ICF International 2016, Appendix 5.B]), indicating that operation of the gates would be similar under NAA and PP.

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 will not change under the PP relative to NAA, and, as previously shown, operations modeling suggested that there will be little difference between NAA and PP in terms of SMSCG opening. Therefore, the potential for adverse near-field effects on downstream-migrating juvenile winter-run Chinook salmon is limited.

###### *4.3.4.1.2.1.5.2 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 are excluded from entrainment. Therefore there is minimal potential for any adverse effect from the RRDS.

###### *4.3.4.1.2.1.5.3 Morrow Island Distribution System*

NMFS (2009: 438) considered it unlikely that juvenile winter-run Chinook salmon are 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 there will be minimal potential for any adverse effect from the MIDS.

###### *4.3.4.1.2.1.5.4 Goodyear Slough Outfall*

NMFS (2009: 438) concluded that it is unlikely for winter-run Chinook salmon to 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.

##### *4.3.4.1.2.1.6 North Bay Aqueduct*

Pumping rates at the North Bay Aqueduct Barker Slough Intake generally would be similar under the NAA and PP (see Table 5.B.5-35 in *DSM2 Methods and Results* [ICF International 2016, Appendix 5.B]). Regardless of differences in the rate of pumping and any resulting differences in exposure to the intake under NAA and PP, 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 will be a minimal potential for the North Bay Aqueduct intake to cause take of juvenile winter-run Chinook salmon.

##### *4.3.4.1.2.1.7 Other Facilities*

###### *4.3.4.1.2.1.7.1 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, 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 occasionally stray into Rock Slough. Modeled pumping suggested that diversions under the PP generally would be similar to NAA, with the exception of April and May, when diversions were modeled to be greater under the PP (see Table 5.B.5-36 in *DSM2 Methods and Results* [ICF International 2016, Appendix 5.B]). 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 PP, suggesting that Rock Slough may have been favored in the modeling of PP for operational reasons, e.g., Old and Middle River flow criteria, for example. Greater use of the Rock Slough intake would increase the potential for adverse effects to juvenile winter-run Chinook salmon under the PP compared to NAA. However, resolution of the aforementioned issues regarding screen effectiveness would be expected to minimize the potential for any adverse effects.

#### *4.3.4.1.2.1.7.2 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 sub-lethal 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 will 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 into Clifton Court Forebay is expected to be less under the PP than NAA in July-August (see Tables 5.D-21, 5.D-22, 5.D-23, 5.D.24, and 5.D-25 in *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale* [ICF International 2016, Appendix 5.D]), which will reduce the exposure of these species to any adverse effects of herbicide treatment compared to the situation under the NAA (although exposure would be minimal under both the NAA and PP scenarios).

Mechanical removal of aquatic weeds in Clifton Court Forebay will occur on an as needed basis and therefore could coincide with occurrence of juvenile winter-run Chinook salmon. In assessing the potential for adverse effects of the 2013-2017 Water Hyacinth Control Program in the Delta, NMFS (2013: 11) concluded that mechanical removal could have negative effects to winter-run Chinook salmon 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 will 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. Potential adverse effects from mechanical removal of water hyacinth or other aquatic weeds (e.g., injury from contact with cutting blades) will 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.

### 4.3.4.1.2.2 Far-Field Effects

### *4.3.4.1.2.2.1 Indirect Mortality Within the Delta*

#### *4.3.4.1.2.2.1.1 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 (ICF International [2016], Appendix 5.D, 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 PP 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 will reduce Sacramento River flows downstream of the NDD, this will allow greater south and central Delta channel flows because of less south Delta exports.

As described in *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale* (ICF International 2016, Appendix 5.D, 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[40]. In addition, the behavior of juvenile salmonids, particularly with respect to selective tidal-stream transport (Delaney et al. 2014) means that

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

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 winter-run Chinook salmon beyond general trends in differences. A comparison of hydrodynamic conditions in important Delta channels for the NAA and PP 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 winter-run Chinook salmon, 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 PP does not account for real-time operations that will occur 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 *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale* (ICF International 2016, Appendix 5.D, 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 PP 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 PP led to differences in channel velocity. Within the south Delta and San Joaquin River, the changes will be beneficial for migrating juvenile salmonids, because channel velocity was generally greater under the PP (Table 4.3-10). 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 1 to 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 PP than NAA. Although the PP 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 (*CalSim II Modeling and Results* [ICF International 2016, Appendix 5.A], 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 differing modeling assumptions for south Delta exports[41], results in Old

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[41] 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

River channel velocity that was slightly lower under PP 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 PP than NAA, reflecting less south Delta exports under the PP (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 1 to June 15.

In the north Delta, less flow in the Sacramento River downstream of the NDD (channel 418) under the PP led to lower median channel velocity under the PP relative to NAA (Table 4.3-10). 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 PP 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 4.3-10), with the latter being farther downstream than the former.

Considering only negative velocity estimates, under the PP 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 4.3-11); 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 PP 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 4.3-12). 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 PP 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 4.3-11).

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 PP 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 PP and NAA (Table 4.3-12).

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criteria in some instances. Additional discussion of the rule curve differences is provided in *CalSim II Modeling and Results* [ICF International 2016, Appendix 5.A], Section 5.A.4.4.

The daily proportion of negative velocity in Old River downstream of the south Delta export facilities under PP 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 a 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 4.3-12). 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 PP 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 Chinook salmon migrating downstream through the north Delta from the Sacramento River basin caused by lower overall velocity, somewhat 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). Winter-run Chinook salmon generally would be expected to benefit from interior Delta channel velocity (e.g., Old River downstream of the south Delta export facilities) that will 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 will occur 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).

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**Table 4.3-10. Median 15-minute Velocity in Important Delta Channels, from DSM2-HYDRO Modeling, with Green Shading Indicating PP is ≥ 5% More than NAA and Red Shading Indicating PP is ≥ 5% Less than NAA.**

| DSM2 Channel | Location | Water Year Type | December | | | January | | | February | | | March | | | April | | | May | | | June | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | NAA | PP | PP vs. NAA | NAA | PP | PP vs. NAA | NAA | PP | PP vs. NAA | NAA | PP | PP vs. NAA | NAA | PP | PP vs. NAA | NAA | PP | PP vs. NAA | NAA | PP | PP 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 (-1%) | 0.010 | 0.010 | 0.000 (1%) | 0.011 | 0.011 | 0.000 (0%) | 0.010 | 0.011 | 0.000 (2%) | 0.010 | 0.010 | 0.000 (0%) | 0.008 | 0.009 | 0.000 (2%) | 0.535 | 0.518 | -0.017 (-3%) |

| DSM2 Channel | Location | Water Year Type | December | | | January | | | February | | | March | | | April | | | May | | | June | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | NAA | PP | PP vs. NAA | NAA | PP | PP vs. NAA | NAA | PP | PP vs. NAA | NAA | PP | PP vs. NAA | NAA | PP | PP vs. NAA | NAA | PP | PP vs. NAA | NAA | PP | PP vs. NAA |
| 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 4.3-11. Median 15-minute Negative Velocity in Important Delta Channels, from DSM2-HYDRO Modeling, with Green Shading Indicating PP is ≥ 5% More than NAA and Red Shading Indicating PP is ≥ 5% Less than NAA.**

| DSM2 Channel | Location | Water Year Type | December | | | January | | | February | | | March | | | April | | | May | | | June | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | NAA | PP | PP vs. NAA | NAA | PP | PP vs. NAA | NAA | PP | PP vs. NAA | NAA | PP | PP vs. NAA | NAA | PP | PP vs. NAA | NAA | PP | PP vs. NAA | NAA | PP | PP 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%) |
| | | 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%) |

| DSM2 Channel | Location | Water Year Type | December | | | January | | | February | | | March | | | April | | | May | | | June | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | NAA | PP | PP vs. NAA | NAA | PP | PP vs. NAA | NAA | PP | PP vs. NAA | NAA | PP | PP vs. NAA | NAA | PP | PP vs. NAA | NAA | PP | PP vs. NAA | NAA | PP | PP vs. NAA |
| 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 (-4%) | -0.438 | -0.444 | -0.006 (-1%) | -0.373 | -0.432 | -0.059 (-16%) | -0.435 | -0.463 | -0.028 (-6%) | -0.460 | -0.472 | -0.012 (-3%) | -0.566 | -0.576 | -0.010 (-2%) | -0.678 | -0.682 | -0.004 (-1%) |

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

**Table 4.3-12. Median Daily Proportion of Negative Velocity in Important Delta Channels, from DSM2-HYDRO Modeling, with Green Shading Indicating PP is ≥ 5% Less than NAA and Red Shading Indicating PP is ≥ 5% More than NAA.**

| DSM2 Channel | Location | Water Year Type | December | | | January | | | February | | | March | | | April | | | May | | | June | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | NAA | PP | PP vs. NAA | NAA | PP | PP vs. NAA | NAA | PP | PP vs. NAA | NAA | PP | PP vs. NAA | NAA | PP | PP vs. NAA | NAA | PP | PP vs. NAA | NAA | PP | PP 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%) | 0.448 | 0.448 | 0.000 (0%) | 0.438 | 0.438 | 0.000 (0%) | 0.438 | 0.438 | 0.000 (0%) | 0.448 | 0.448 | 0.000 (0%) | 0.458 | 0.458 | 0.000 (0%) | 0.031 | 0.063 | 0.031 (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%) |

| DSM2 Channel | Location | Water Year Type | December | | | January | | | February | | | March | | | April | | | May | | | June | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | NAA | PP | PP vs. NAA | NAA | PP | PP vs. NAA | NAA | PP | PP vs. NAA | NAA | PP | PP vs. NAA | NAA | PP | PP vs. NAA | NAA | PP | PP vs. NAA | NAA | PP | PP vs. NAA |
| 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 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%) | 0.281 | 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%) |
| | | 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%) |

### *4.3.4.1.2.2.1.2 Entry into Interior Delta*

Juvenile winter-run Chinook salmon may enter the interior Delta from the mainstem Sacramento River through junctions such as Georgiana Slough/Delta Cross Channel. 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). 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 PP 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 (which 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[42]. Installation of the HOR gate under the PP will greatly reduce entry into Old River from the San Joaquin River. These factors are discussed in this section.

### *4.3.4.1.2.2.1.3 Flow Routing Into Channel Junctions*

Perspective on potential differences in juvenile salmonid entry into the interior Delta between modeled operations of the NAA and PP 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 (*Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale* [ICF International 2016, Appendix 5.D], 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 will occur 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

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[42] 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).

(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 PP, although in one case (December of critical years) the difference in median proportion was 5% less under PP (0.01 absolute difference) (Table 4.3-13). Slightly farther downstream at Steamboat Slough, there were more incidences of median proportion being >5% less under PP (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[43], 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 *DSM2 Methods and Results* [ICF International 2016, Appendix 5.B]). The proportion of flow entering Georgiana Slough under the PP 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 PP, or 0.04 in absolute terms).

For the San Joaquin River, the assumption of 50% closure of the PP's HOR gate from January 1 to June 15, subject to RTO adjustments, led to appreciably less flow (~30–50%) entering Old River under the PP compared to NAA (Table 4.3-13). For Turner Cut, the next downstream junction, the proportion of flow entering the junction generally was greater under PP 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 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 PP, 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 PP were less which, as noted by Cavallo et al. (2015) reflects greater tidal influence; where lower proportions of flow entered the junctions under PP, this probably reflected less south Delta export pumping than NAA.

Overall, the analysis suggested that juvenile winter-run Chinook salmon 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 undertaken to limit potential operational effects, by assessing flow conditions in the context of fish presence.

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[43] 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* for further discussion.

**Table 4.3-13. Median Daily Proportion of Flow Entering Important Delta Channels, from DSM2-HYDRO Modeling, with Green Shading Indicating PP is ≥ 5% Less than NAA and Red Shading Indicating PP 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 | PP | PP vs. NAA | NAA | PP | PP vs. NAA | NAA | PP | PP vs. NAA | NAA | PP | PP vs. NAA | NAA | PP | PP vs. NAA | NAA | PP | PP vs. NAA | NAA | PP | PP 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%) |
| | 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%) |

| Junction | Water Year Type | December | | | January | | | February | | | March | | | April | | | May | | | June | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | NAA | PP | PP vs. NAA | NAA | PP | PP vs. NAA | NAA | PP | PP vs. NAA | NAA | PP | PP vs. NAA | NAA | PP | PP vs. NAA | NAA | PP | PP vs. NAA | NAA | PP | PP vs. NAA |
| 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%) |

#### *4.3.4.1.2.2.1.4 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 Bio Acoustic 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 Chinook salmon. 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) (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 PP, 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% (Table 4.3-13) and some of the results of the through-Delta survival analyses show lower potential survival under the PP because of flow-survival relationships (see Section 4.3.4.1.2.2.1.5, *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 Chinook salmon that would encounter the BAFF. Second, all fish were hatchery-raised, and therefore may have behaved differently than wild fish would in response 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[44] (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 4.3.5.3, *Georgiana Slough Nonphysical Fish Barrier*.

###### *4.3.4.1.2.2.1.5 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 PP. These included the Delta Passage Model, analyses based on Newman (2003) and Perry (2010), and the winter-run Chinook salmon life cycle models, IOS and OBAN. This section describes the principal results of these analyses. The tools were all focused on Chinook salmon.

###### *4.3.4.1.2.2.1.6 Delta Passage Model*

The Delta Passage Model (DPM) integrates operational effects of the NAA and PP that could influence survival of migrating juvenile[45] winter-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 *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale* (ICF International 2016, Appendix 5.D, 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 Collaborative Science and Adaptive Management program and real-time operational adjustments that would occur in relation to fish presence, for example.

For winter-run Chinook salmon, the DPM results suggested that total through-Delta survival would be similar or lower under the PP than the NAA (Figure 4.3-9 and Figure 4.3-10

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[44] 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).

[45] As noted in Section 5.D.1.2.2.1 *Introduction* of Appendix 5.D in ICF International (2016), the DPM is a smolt survival model only, for consideration of effects to actively migrating fish >70 mm, with results based primarily on studies of larger (>140 mm) late fall-run Chinook salmon smolts.

). Mean total through-Delta survival under the PP 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 4.3-14). Mean survival down the mainstem Sacramento River route under the PP 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 PP. As would be expected given that both scenarios assumed a notched Fremont Weir, Yolo Bypass entry was very similar between NAA and PP scenarios, and survival was identical (because the random draws from the route-specific survival distribution [ICF International 2016, Appendix 5.D, Section 5.D.1.2.2.2.5.4 *Route-Specific Survival*] were the same for NAA and PP). A slightly lower (1–2%) proportion of fish entered Sutter and Steamboat Sloughs under the PP compared to NAA (reflecting the flow routing into junctions; see Table 4.3-14), and the difference in mean survival for this route between PP and NAA was similar to that of the mainstem Sacramento River, reflecting the similar flow-survival relationships in the relevant reaches (ICF International 2016, Appendix 5.D, Section 5.D.1.2.2.2.5.5 *Flow-Dependent Survival*). A slightly greater (1–2%[46]) proportion of fish used the interior Delta migration route under the PP compared to NAA (again reflecting the flow routing into junctions; see Table 4.3-13), 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 PP[47].

Seventy-five randomized iterations of the DPM allowed 95% confidence intervals to be calculated for the annual estimates of through-Delta survival (ICF International 2016, Appendix 5.D, Section 5.D.1.2.2.4, *Randomization to Illustrate Uncertainty*); of the 81 years in the simulation, the PP and NAA had non-overlapping confidence intervals in 10 years and all were lower under the PP (Figure 4.3-11). 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 most likely 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[48]; an integrated field study of through-Delta

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[46] 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]).

[47] 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*, in ICF International [2016]), 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.

[48] 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 PP and near the top boundary of the confidence

survival during PP implementation 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)[49] 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 PP (Figure 4.3-12). This corresponds closely with weighted mean flows in below normal years (NAA: 7,826 cfs; PP: 6,687 cfs) and dry years (NAA: 7,116 cfs; PP: 6,048 cfs), which is logical given that these had the greatest differences in survival. 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 (ICF International 2016, Appendix 5.D, Figure 5.D-45). 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 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 so doing, this would limit the potential for take.

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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 PP and NAA, in which case the differences would be more similar to the differences between means.

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

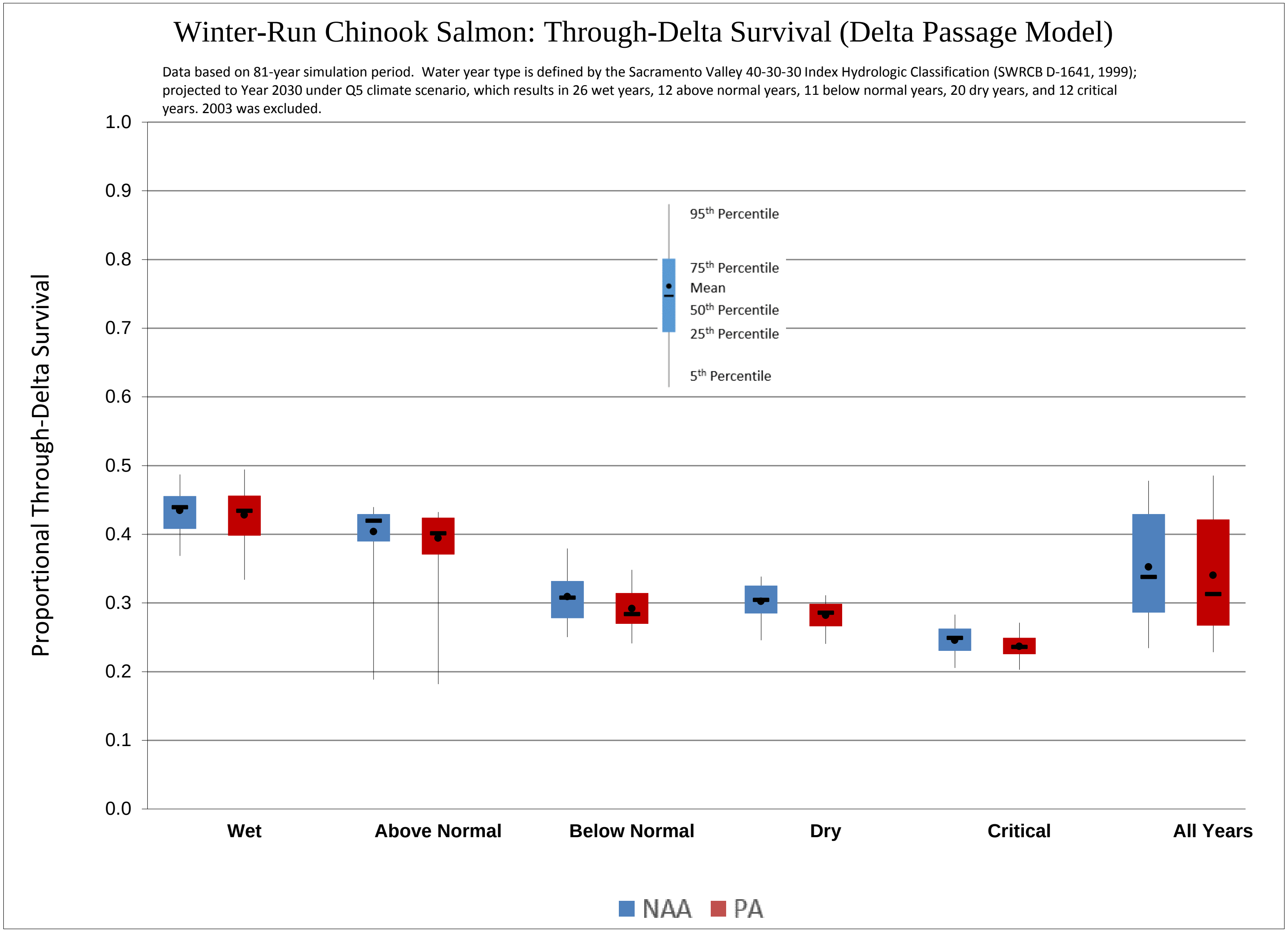

**Figure 4.3-9. Box Plots of Winter-Run Chinook Salmon Annual Through-Delta Survival Estimated from the Delta Passage Model, Grouped by Water Year Type.**

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

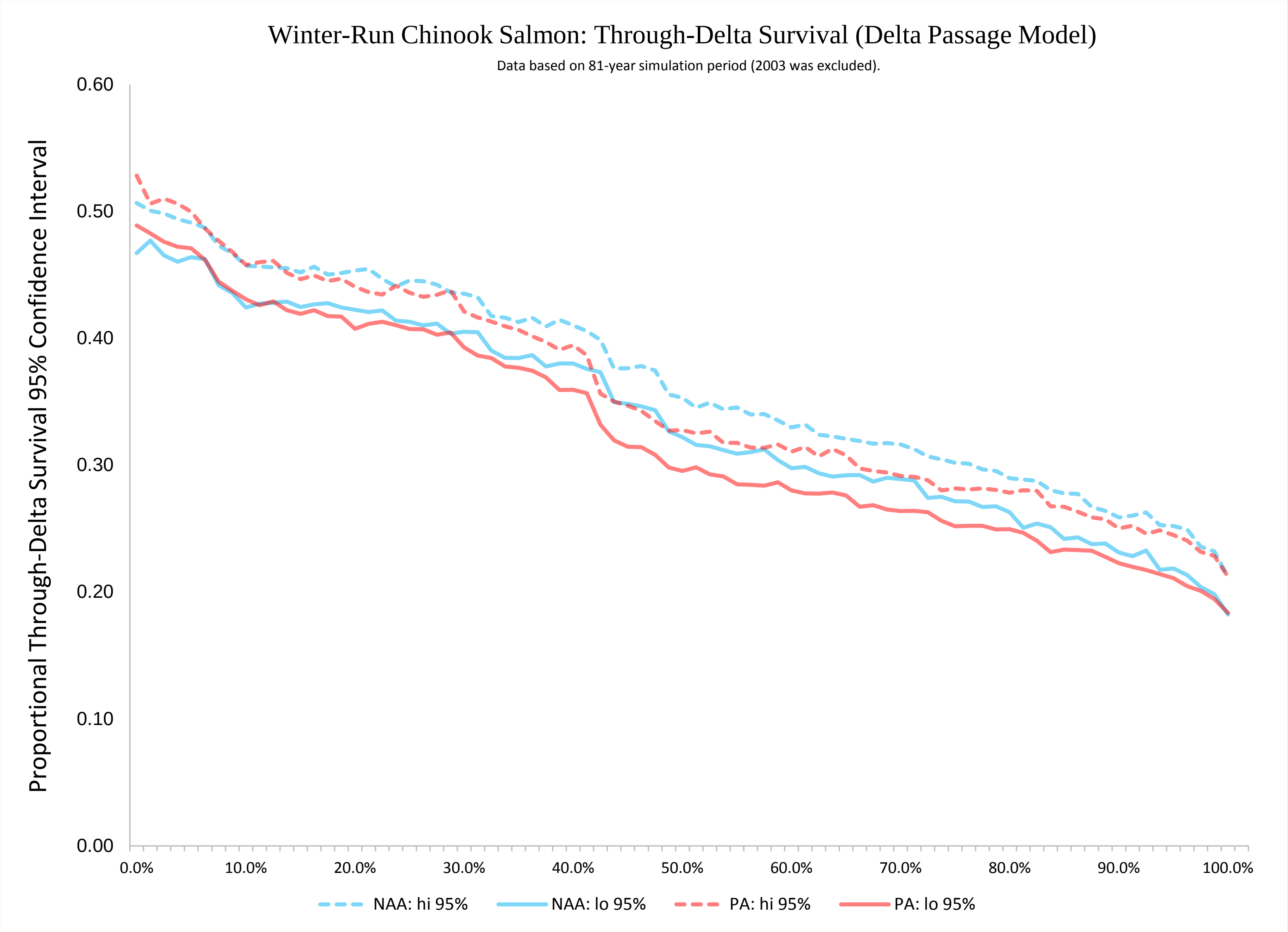

**Figure 4.3-10. Exceedance Plot of Winter-Run Chinook Salmon Annual Through-Delta Survival Estimated from the Delta Passage Model.**

**Table 4.3-14. 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 | PP | PP vs. NAA | NAA | PP | PP vs. NAA | NAA | PP | PP vs. NAA | NAA | PP | PP 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 | PP | PP vs. NAA | NAA | PP | PP vs. NAA | NAA | PP | PP vs. NAA | NAA | PP | PP 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.

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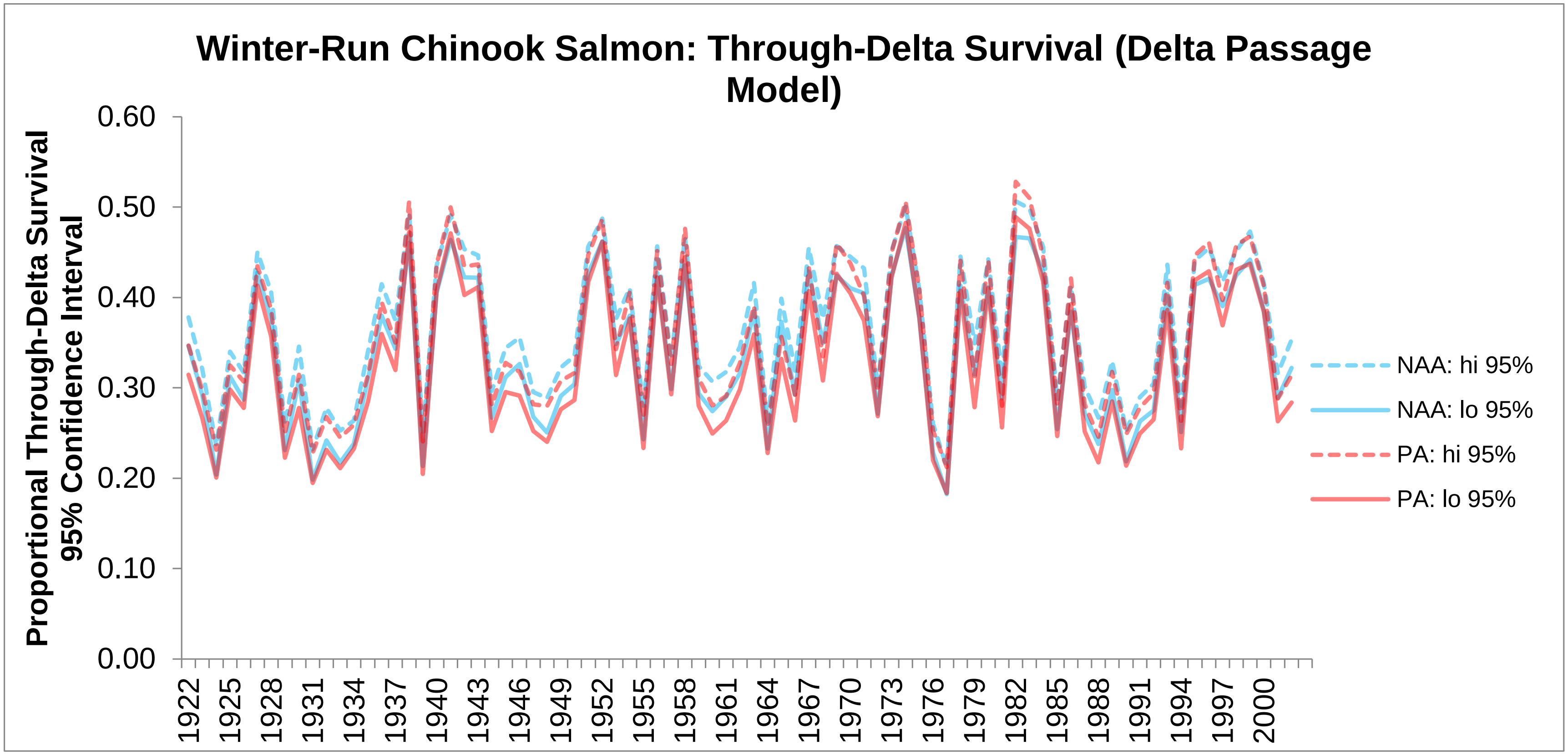
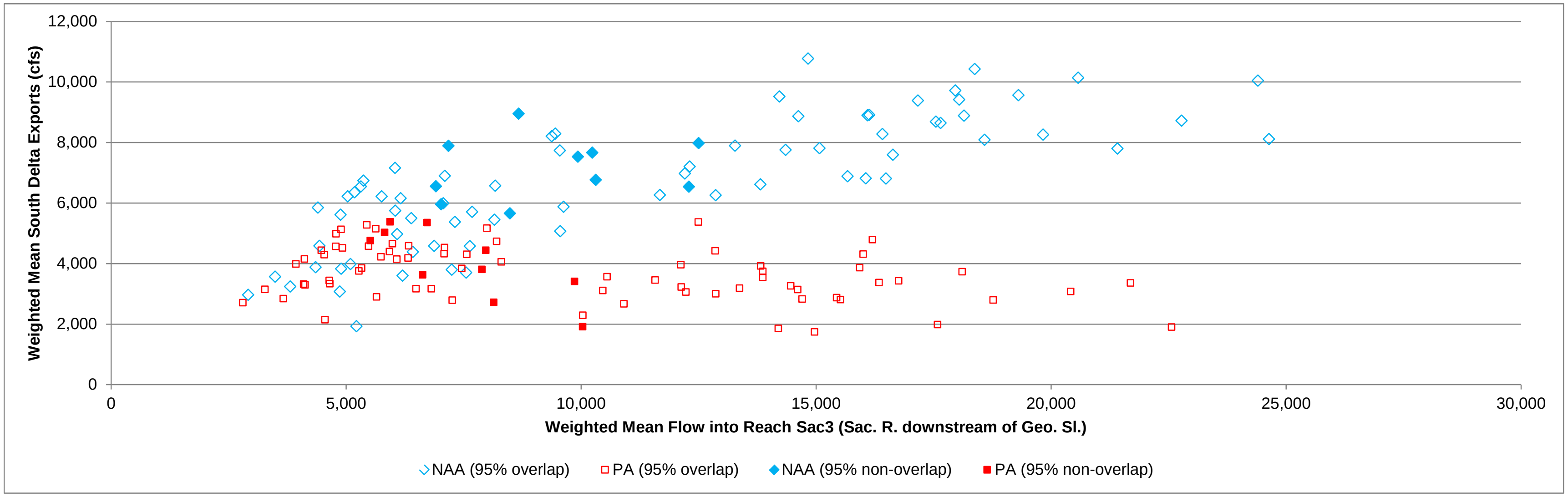


**Figure 4.3-11. Time Series of 95% Confidence Interval Annual Juvenile Winter-Run Chinook Salmon Through-Delta Survival Estimated from the Delta Passage Model**



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

**Figure 4.3-12. 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.**

#### *4.3.4.1.2.2.1.7 Analysis Based on Perry (2010)*

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 PP's proposed NDD on juvenile winter-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 *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale* (ICF International 2016, Appendix 5.D, 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 slightly lower under the PP relative to the NAA for juvenile winter-run Chinook salmon (Figure 4.3-12 and Figure 4.3-13; Table 4.3-15; see also Figure 5.D-71 in Quantitative Methods and Detailed Results for Effects *Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale* [ICF International 2016, Appendix 5.D]). As would be expected, for winter-run Chinook salmon the relative difference between NAA and PP 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 4.3-15). For winter-run Chinook salmon, the greatest differences in overall survival (4–5% less under PP) were in above normal, below normal, and dry years (Table 4.3-16). The relative differences between NAA and PP for through-Delta survival of winter-run Chinook salmon were 2–5% less under the PP.

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) (ICF International 2016, Appendix 5.D, Figure 5.D-65). 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 PP scenarios: for winter-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 PP 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 ICF International [2016], Appendix 5.D). This suggests that although the results discussed above show potentially less survival under the PP relative to the NAA, it might be challenging to statistically detect this small magnitude of difference during PP monitoring, for example.

Given that the analyses described above were for fixed winter-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 5.4.1-17). 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

Chinook salmon: lower survival under the PP relative to NAA (Figure 4.3-13 and Figure 4.3-14; Table 4.3-15), with the relative differences between PP 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 PP scenarios (see Figures 5.D-78 to 5.D-82 in ICF International [2016], Appendix 5.D, Section 5.D.1.2.4.3, *Results*), again suggesting that it might be challenging to statistically detect the small magnitude of the PP effect during monitoring of implementation.

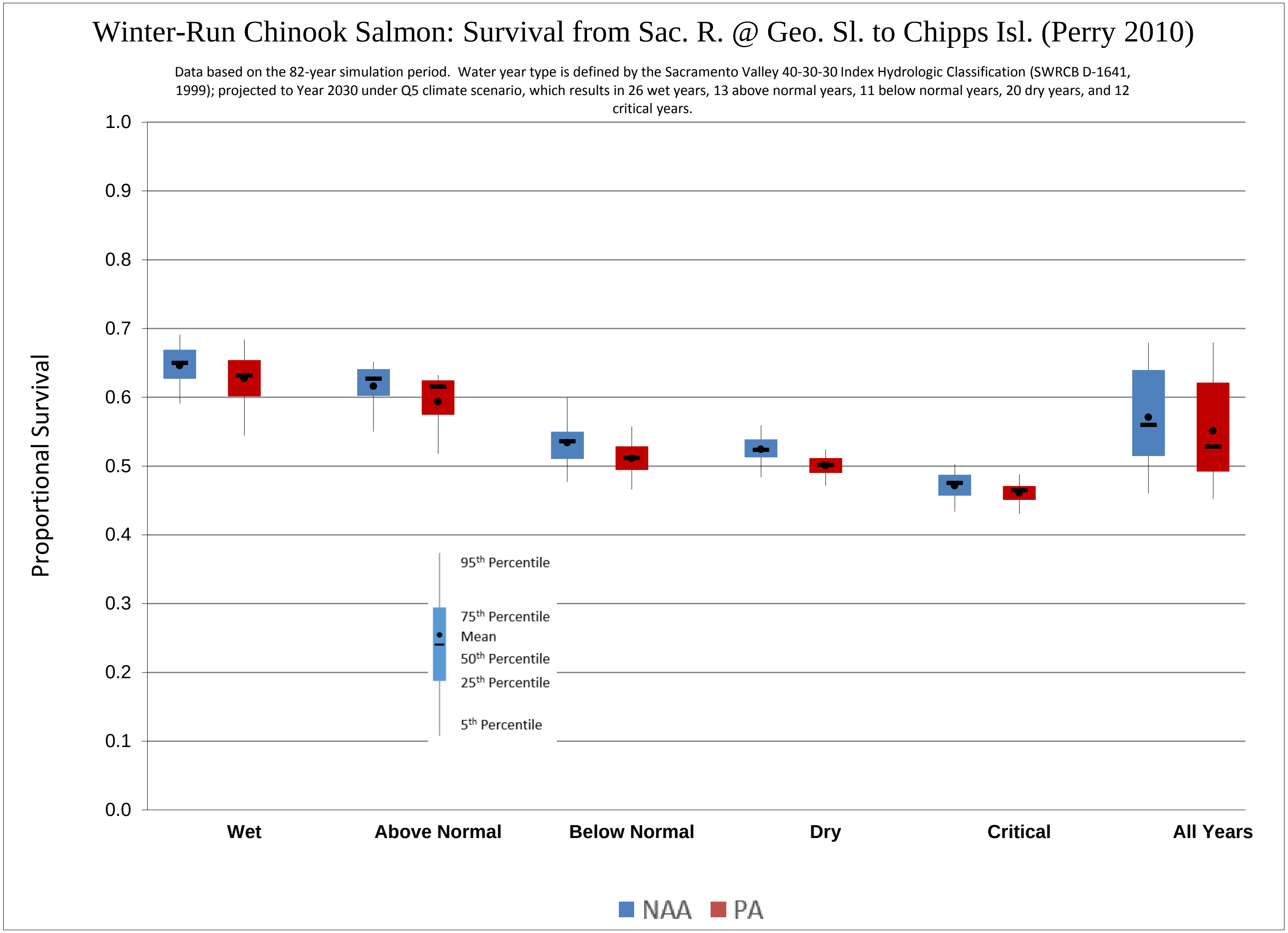


**Figure 4.3-13. Box Plots of Juvenile Winter-Run Chinook Salmon Annual Total Survival from the Sacramento River at Georgiana Slough to Chipps Island, Estimated from the Analysis Based on Perry (2010), Grouped by Water Year Type.**

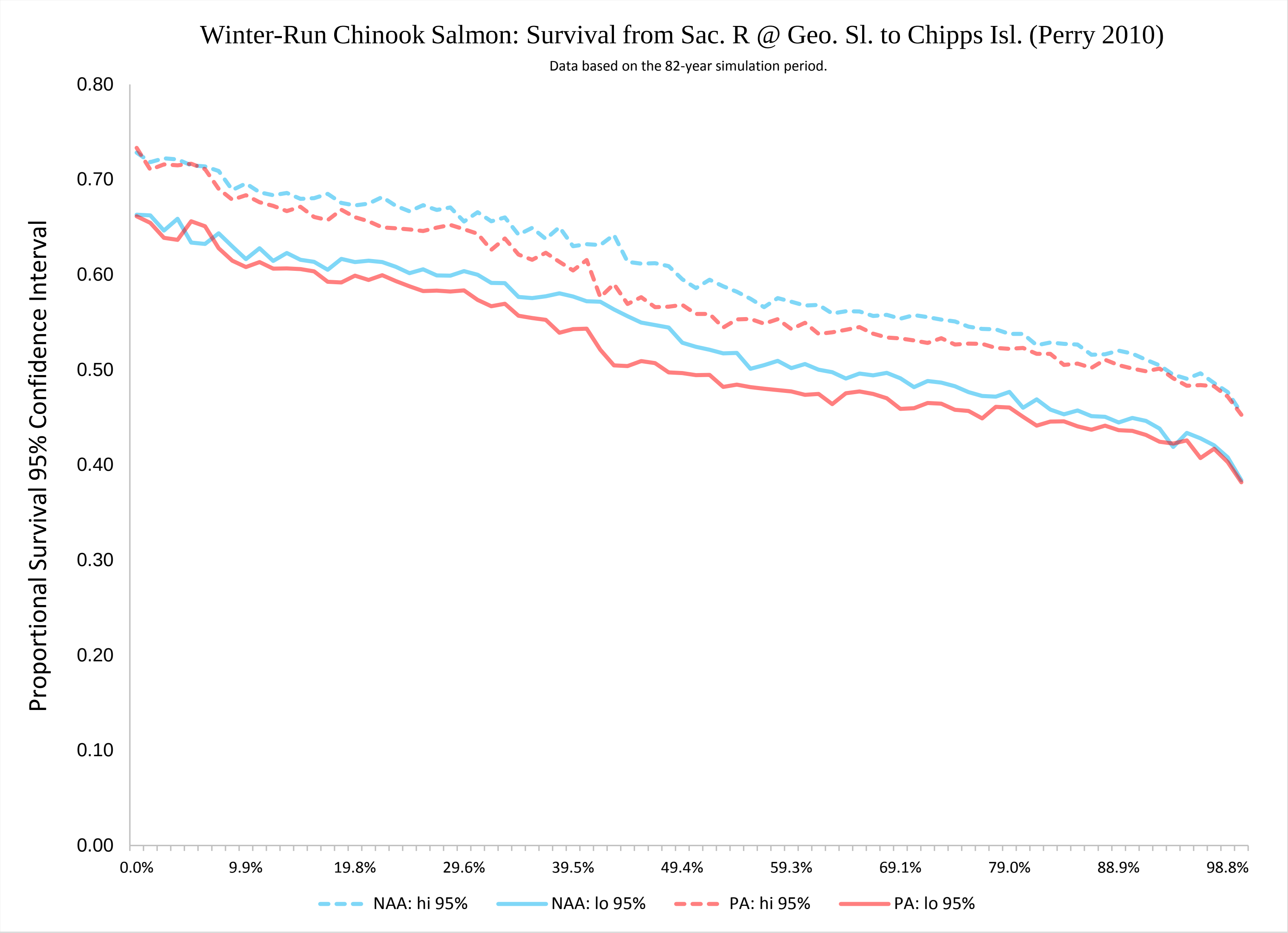


**Figure 4.3-14. Exceedance Plot of Juvenile Winter-Run Chinook Salmon Annual Total Survival from the Sacramento River at Georgiana Slough to Chipps Island, Estimated from the Analysis Based on Perry (2010).**

**Table 4.3-15. 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 | PP | PP vs. NAA | NAA | PP | PP vs. NAA | NAA | PP | PP vs. NAA | NAA | PP | PP vs. NAA | NAA | PP | PP 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.

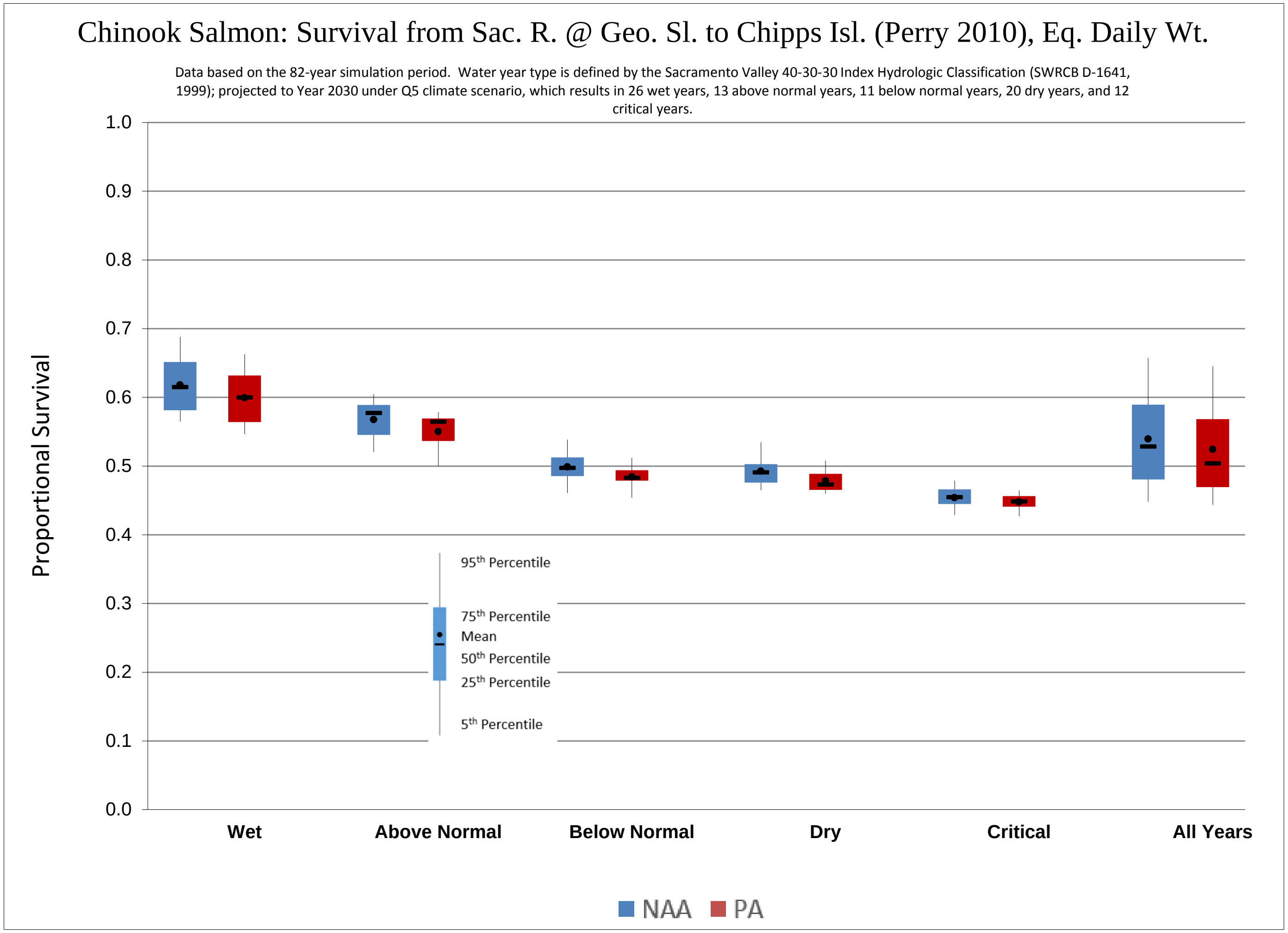


**Figure 4.3-15. Box Plots of Juvenile Chinook Salmon Annual Total Survival from the Sacramento River at Georgiana Slough to Chipps Island, Estimated from the Analysis Based on Perry (2010), Grouped by Water Year Type, Assuming Equal Daily Weighting from December to June.**

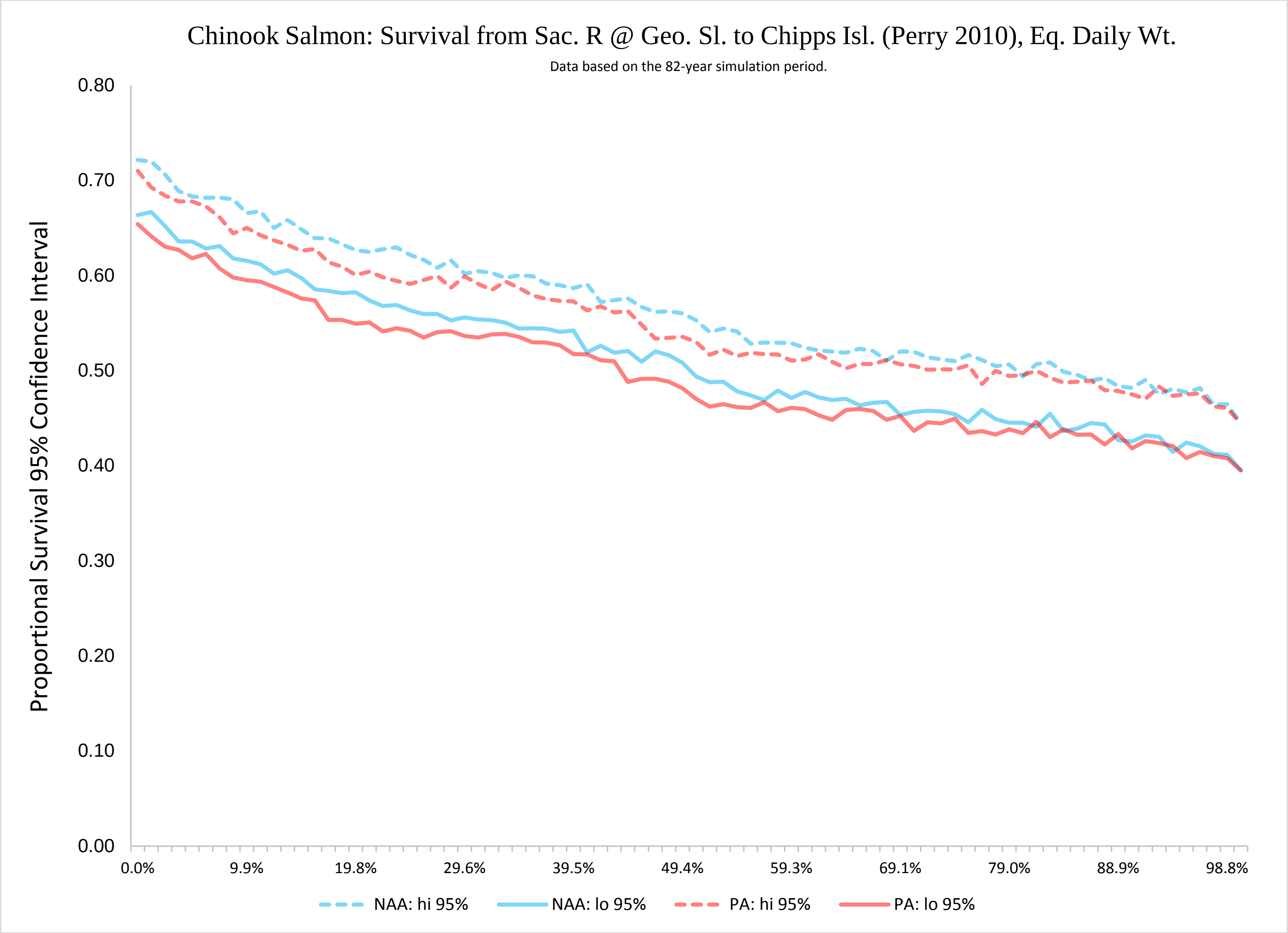


**Figure 4.3-16. Exceedance Plot of Juvenile Chinook Salmon Annual Total Survival from the Sacramento River at Georgiana Slough to Chipps Island, Estimated from the Analysis Based on Perry (2010), Assuming Equal Daily Weighting from December to June.**

**Table 4.3-16. 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 | PP | PP vs. NAA | NAA | PP | PP vs. NAA | NAA | PP | PP vs. NAA | NAA | PP | PP vs. NAA | NAA | PP | PP 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.

#### *4.3.4.1.2.2.1.8 Life Cycle Models (IOS and OBAN)*

The winter-run Chinook salmon life cycle models IOS and OBAN were also run to provide perspective on potential PP effects with respect to both in-Delta and upstream conditions. Methods and results are presented in *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale* (ICF International 2016, Appendix 5.D, Section 5.D.3 *Life Cycle Models*). In both models, ocean conditions were assumed not to differ between the NAA and PP, in order to focus the analysis on potential PP effects.

As described in Section 4.3.4.2, *Upstream Hydrologic Changes*, upstream differences in environmental stressors between the NAA and PP were found to be small, so the main driver of differences in escapement between NAA and PP 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 4.3.4.1.2.2.1.6, *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 (*Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale* [ICF International 2016, Appendix 5.D], 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 PP 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 PP 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. In contrast, OBAN's through-Delta survival component includes Yolo Bypass inundation (which was assumed the same for NAA and PP, based on both scenarios having a notched Fremont Weir) and south Delta exports, which would be appreciably less under the PP 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[50], 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 PP relative to the NAA would be the same as the number of years having less than 50%

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[50] As discussed further in ICF International (2016, 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.

probability of *lower* escapement under the PP relative to the NAA. In simpler terms, 5% additional mortality because of the NDD[51] would cancel out the gains from south Delta export reductions under the PP, 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 PP and NAA escapement estimates, resulting in a median 25% lower escapement for the PP 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 PP and NAA overlapped in all years; in the years with greatest differences in escapement between PP 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 PP scenarios usually were within 90% probability intervals[52]. 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.

#### *4.3.4.1.2.2.2 Habitat Suitability*

##### *4.3.4.1.2.2.2.1 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 juvenile Chinook salmon, 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 (H.T. Harvey & Associates with 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 winter-run Chinook salmon and other species. Wetland benches are at lower elevations where more frequent wetting and inundation may be expected,

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

[52] The exception was one year in which the PP 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.

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.

### *4.3.4.1.2.2.2.2 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 winter-run Chinook salmon. Restored benches in the north Delta could potentially be affected by the PP 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 *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale* (ICF International 2016, Appendix 5.D, 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 PP operations would vary by location and bench type (Table 4.3-17). 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 PP 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 ICF International [2016], Appendix 5.D, 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 4.3-17). Although there were some large *relative* differences in bench inundation indices between NAA and PP (e.g., ~40–90% lower under PP 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 PP 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 judgment, to be a bench inundation index > 0.05[53]) were:

- 29% lower riparian bench inundation index under PP in the Sacramento River from Sutter Steamboat sloughs to Rio Vista in spring of above normal years;

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[53] 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.

- 24% lower riparian bench inundation index under PP in the Sacramento River below the NDD to Sutter/Steamboat sloughs in spring of above normal years
- 19% lower riparian bench inundation index under PP 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.

This analysis does not include an assessment of the potential effects of the PP on channel margin bench habitat in the project area related to future habitat enhancement projects. If these habitat enhancement projects are implemented, there may be effects from reduced flows downstream of the NDD (as discussed in Section 4.4.4.2.2.2.1) and at that time DWR will work with CDFW and NMFS to identify a means of assessing potential adverse effects found to occur at such features, as a result of the PP. As a result of this analysis, additional CESA compliance, in coordination with potential additional ESA compliance, may be required.

**Table 4.3-17. Mean Bench Inundation Index by Location, Bench Type, Water Year Type, and Season, for NAA and PP.**

| Location | Bench Type (Total Length) | Water Year Type | Winter (December-February) | | | | Spring (March-June) | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | NAA | PP | PP vs. NAA | | NAA | PP | PP 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%) |
| 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.

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#### *4.3.4.1.2.2.2.3 Channel Margin Enhancement*

As described above, PP 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 the deficits created by PP 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 4.3.5.1, *Tidal, Channel Margin, and Riparian Habitat Protection and Restoration*.

#### *4.3.4.1.2.2.2.4 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 PP 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 PP, and if so, why. DSM2-QUAL modeling was undertaken to examine water temperature differences between NAA and PP 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 *DSM2 Methods and Results* (ICF International 2016, Appendix 5.B), 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 PP. 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 *DSM2 Methods and Results* [ICF International 2016, Appendix 5.B, Figure 5.B.5.40-1]). This period is may overlap with early (November) occurrence of juvenile winter-run Chinook salmon in the Delta. However, the results suggest differences in mean temperature may be small even when the differences are visually apparent, e.g., in November, the greatest difference between NAA and PP scenarios was at the 20% exceedance level, and was ~0.3°C greater under the PP (ICF International [2016], Appendix 5.B, 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.

In the Delta, there appears to be the potential for a small adverse effect of greater water temperature on juvenile salmon 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 because of the small magnitude of temperature differences between the PP and NAA scenarios and the high frequency of May and June temperatures that exceed the optimal temperature range for both the PP and NAA, indicating temperatures would be above optimal under both scenarios. In any case, winter-run Chinook salmon would be unaffected because they are expected to rarely occur in the Stockton Deep Water Ship Channel, particularly in May or June. 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)

###### *4.3.4.1.2.2.2.5 Selenium*

The increase in the proportion of San Joaquin River water entering the Delta because of less south Delta exports under the PP 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 PP and NAA scenarios in particulate, invertebrate, or whole-body estimates of selenium concentration (see ICF International [2016], Appendix 5.F, *Selenium Analysis*). Therefore, the PP is not likely to increase exposure of salmonids to selenium toxicity.

###### *4.3.4.1.2.2.2.6 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 PP 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 PP than NAA (Table 4.3-18). 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. In any case, the reductions in percentage of Sacramento River water resulting from the PP were consistently less than 20% (absolute value), which, in experiments with adult sockeye salmon, was the lowest level of dilution of homestream water with water from a different stream that the sockeye salmon first detected and behaviorally responded to (Fretwell 1989). Therefore, it is concluded that there would be little effect from changes in olfactory cues for upstream migrating adult salmonids from the Sacramento River basin.

**Table 4.3-18. Mean Percentage of Water at Collinsville Originating in the Sacramento River, from DSM2-QUAL Fingerprinting.**

| Month | Wet | | | | Above Normal | | | | Below Normal | | | | Dry | | | | Critical | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | NAA | PP | PP vs. NAA | | NAA | PP | PP vs. NAA | | NAA | PP | PP vs. NAA | | NAA | PP | PP vs. NAA | | NAA | PP | PP 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%) |

#### *4.3.4.1.2.2.2.7 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 Chinook salmon. *Microcystis* could, however, coincide with the occurrence of upstream-migrating adult salmonids, 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 PP 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 PP, which could give greater potential for *Microcystis* occurrence under the PP, although there has been no detailed study of *Microcystis* occurrence specifically in relation to residence time. Adult salmonids 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 is unlikely that there would be adverse effects to salmonids, particularly those like winter-run Chinook salmon that migrate to the Sacramento River, from changes in *Microcystis* under the PP relative to the NAA.

### *4.3.4.2 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, winter-run Chinook salmon may be affected by implementation of the PP. Therefore, this section assesses potential effects on winter-run Chinook salmon in the Sacramento River upstream of the Delta. The potential effects on winter-run Chinook salmon in the Delta resulting from the PP are described in Section 4.3.4.1 *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 PP and, therefore, no further analyses of effects on winter-run Chinook salmon would be necessary in the waterway.

Results of this preliminary analysis indicated that there would be no effect of the PP on operations in the Trinity, San Joaquin, and Stanislaus Rivers and on Clear Creek (*Upstream Water Temperature Methods and Results* [ICF International 2016, Appendix 5.C]). Accordingly, it was concluded that these areas are not part of the project area (ICF International 2016, Chapter 4 *Action Area and Environmental Baseline*). This preliminary analysis indicated that there is the potential for changes in reservoir operations, instream flows, and water temperatures in the Sacramento River and American River. Winter-run Chinook salmon, however, do not occur in the American River. Therefore, the analysis of potential effects is described here for the Sacramento River, only.

### *4.3.4.2.1 Sacramento River*

The PP 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 PP 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-run Chinook salmon.

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). ICF International (2016, Appendix 5.D *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale*) provides detail on the methods used to evaluate flow effects of the PP.

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 Sacramento River and can lead to sublethal impairments that include reduced growth, inhibited smoltification, altered migration, disease, and ultimately death. ICF International (2016, Appendix 5.D) provides detail on the methods used to evaluate water temperature effects of the PP.

#### 4.3.4.2.1.1 Assess Species Exposure

Implementation of the PP 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 4.3-19 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 4.3-19. 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 1997a, 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 4.3-20).

**Table 4.3-20. 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 4.3-19.

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[54].

### 4.3.4.2.1.2 Assess Species Response to the Proposed Action

### *4.3.4.2.1.2.1 Spawning, Egg Incubation, and Alevins*

#### *4.3.4.2.1.2.1.1 Flow-Related Effects*

Estimated mean monthly flow rates and reservoir storage volumes were examined for the PP 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 4.3-19). 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 PP would be similar (less than 5% difference) to storage under NAA for all water year types (ICF International 2016, Appendix 5.A, Table 5.A.6-3). During the majority of months and water year types of the winter-run spawning period, the PP would result in insignificant changes (less than 5% difference) in mean flow in the Sacramento River at the Keswick Dam to Red Bluff locations (ICF International 2016, Appendix 5.A, Table 5.A.6-10 and Table 5.A.6-35). However, at both locations, flows under the PP 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 PP 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 PP 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 4.3.4.2.2 *Summary of Upstream Effects*.

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[54] See http://resources.ca.gov/docs/ecorestore/projects/Wallace_Weir_Modification.pdf.

#### *4.3.4.2.1.2.1.2 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 (ICF International [2016], 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 4.3-20), 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 PP, 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 PP and the NAA during the winter-run spawning and egg incubation period. Further information on the WUA analysis methods is provided in *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale* (ICF International 2016, Appendix 5.D, Section 5.D.2.2 *Spawning Flows Methods*).

Differences in winter-run spawning WUA under the PP 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 PP generally match those of the NAA for all water year types in all three segments (Figure 4.3-15–Figure 4.3-33).

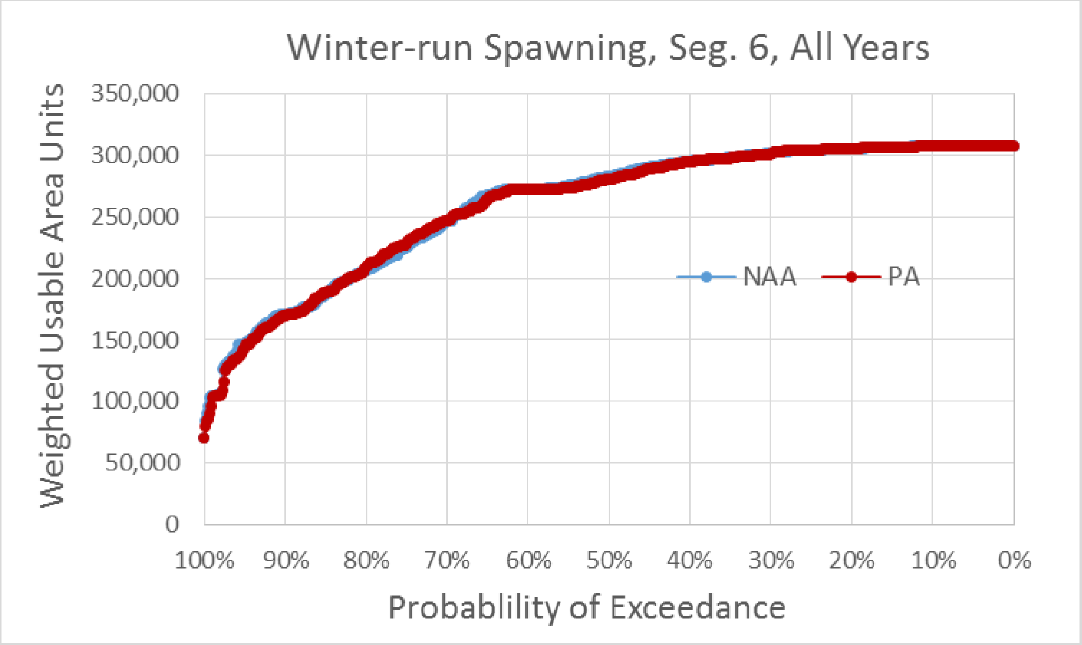

**Figure 4.3-17. Exceedance Plot of Winter-Run Chinook Salmon Spawning Weighted Usable Area (WUA) for NAA and PP Model Scenarios in River Segment 6, All Water Years**

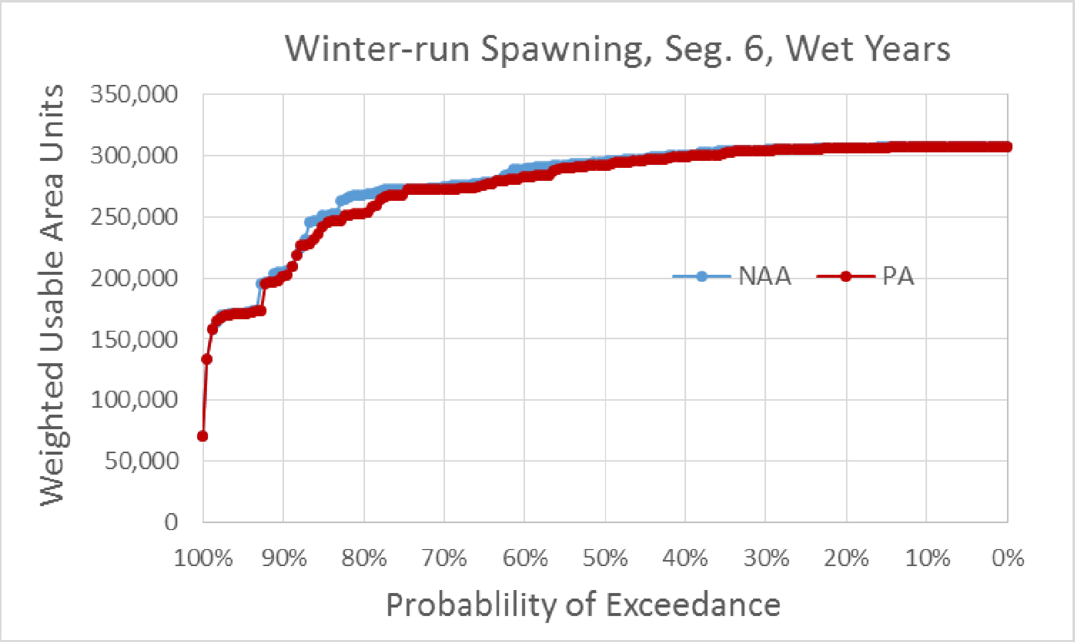

**Figure 4.3-18. Exceedance Plot of Winter-Run Chinook Salmon Spawning Weighted Usable Area (WUA) for NAA and PP Model Scenarios in River Segment 6, Wet Water Years**

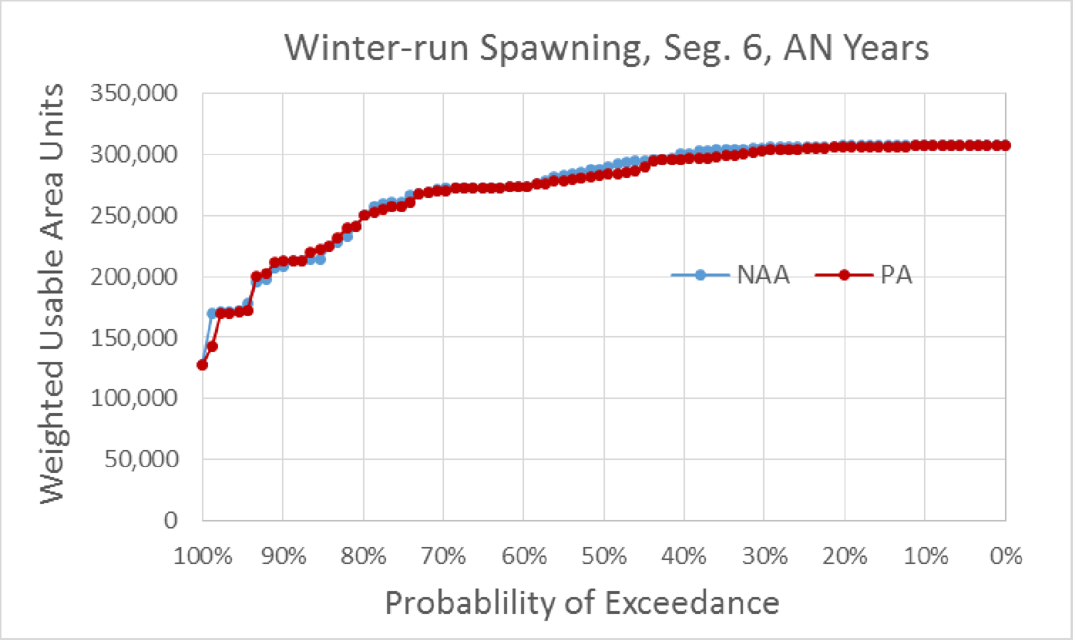

**Figure 4.3-19. Exceedance Plot of Winter-Run Chinook Salmon Spawning Weighted Usable Area (WUA) for NAA and PP Model Scenarios in River Segment 6, Above Normal Water Years**

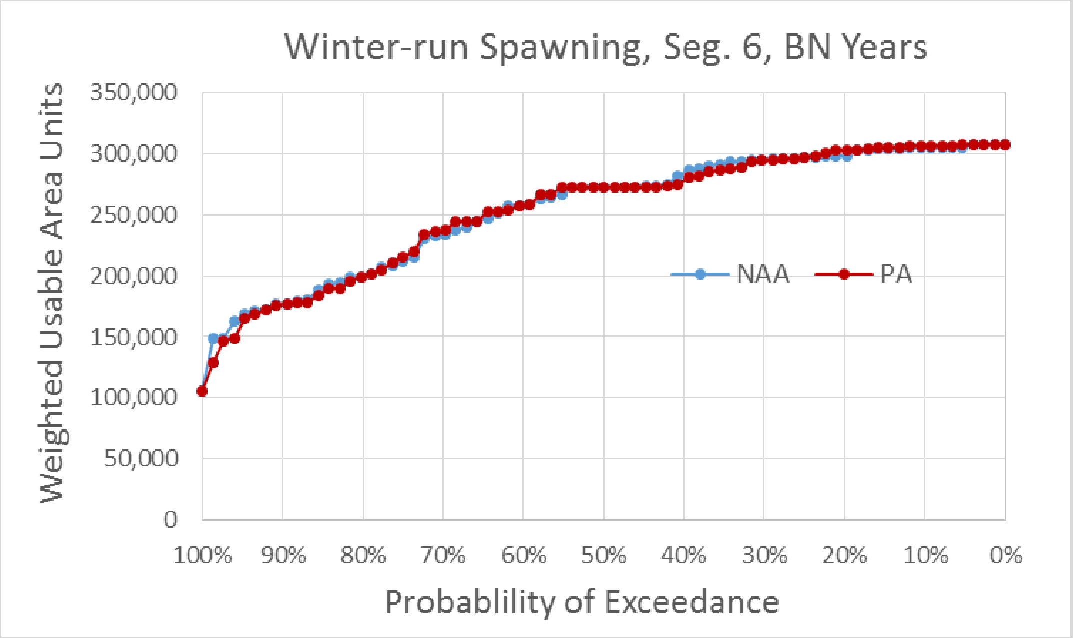

**Figure 4.3-20. Exceedance Plot of Winter-Run Chinook Salmon Spawning Weighted Usable Area (WUA) for NAA and PP Model Scenarios in River Segment 6, Below Normal Water Years**

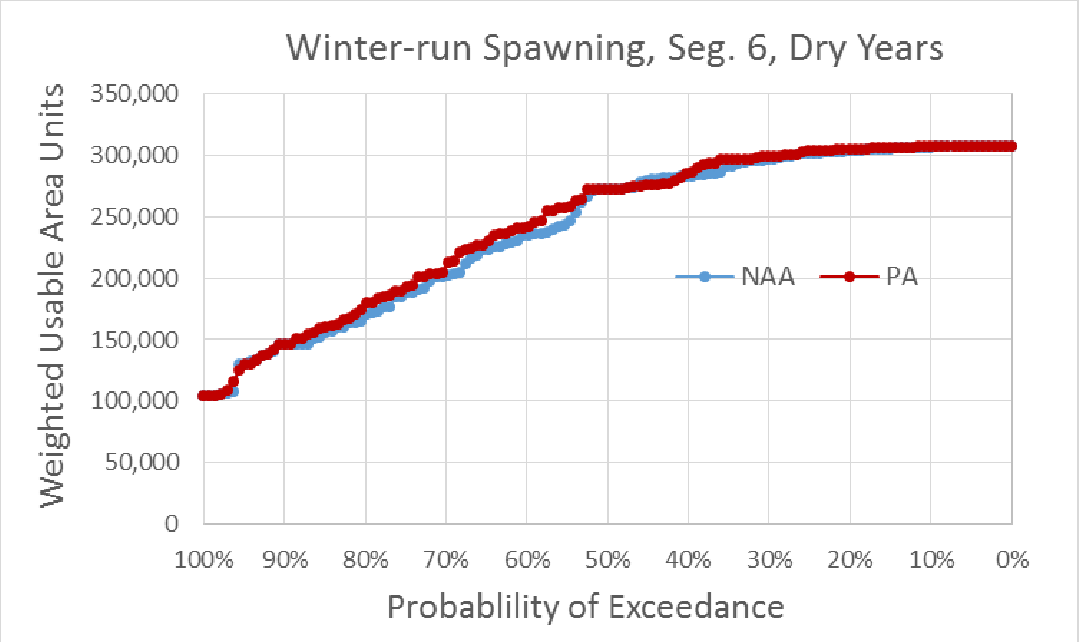

**Figure 4.3-21. Exceedance Plot of Winter-Run Chinook Salmon Spawning Weighted Usable Area (WUA) for NAA and PP Model Scenarios in River Segment 6, Dry Water Years**

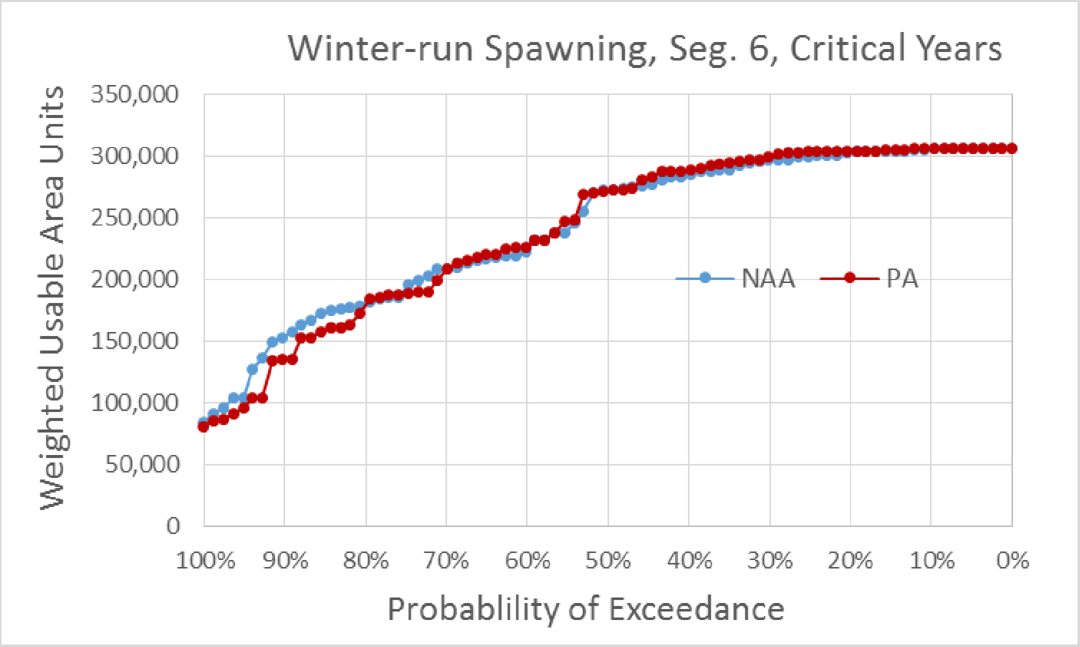

**Figure 4.3-22. Exceedance Plot of Winter-Run Chinook Salmon Spawning Weighted Usable Area (WUA) for NAA and PP Model Scenarios in River Segment 6, Critical Water Years**

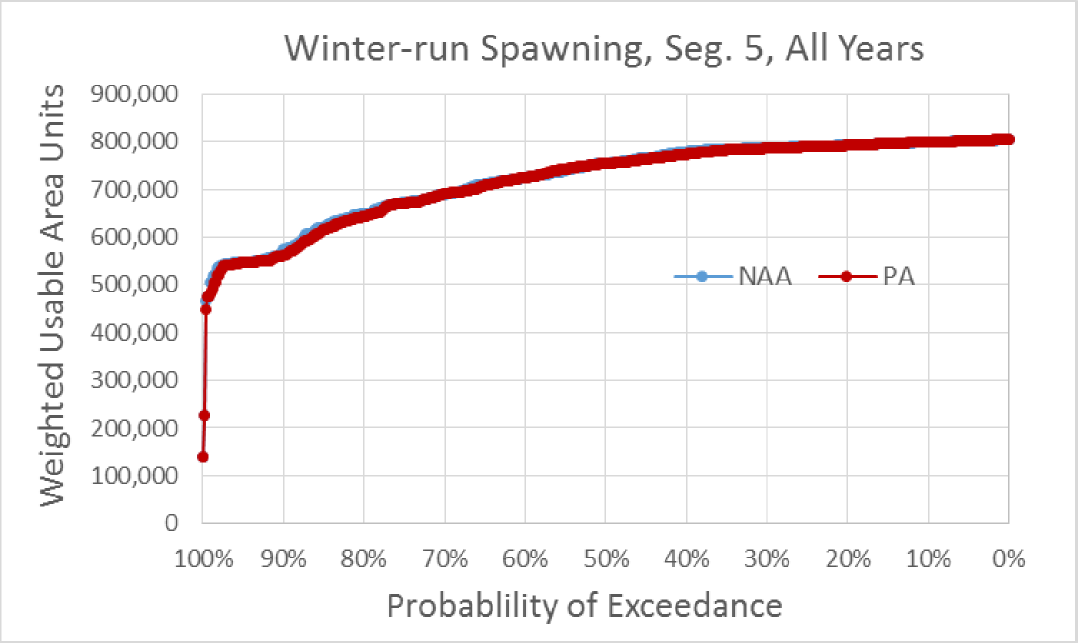

**Figure 4.3-23. Exceedance Plot of Winter-Run Chinook Salmon Spawning Weighted Usable Area (WUA) for NAA and PP Model Scenarios in River Segment 5, All Water Years**

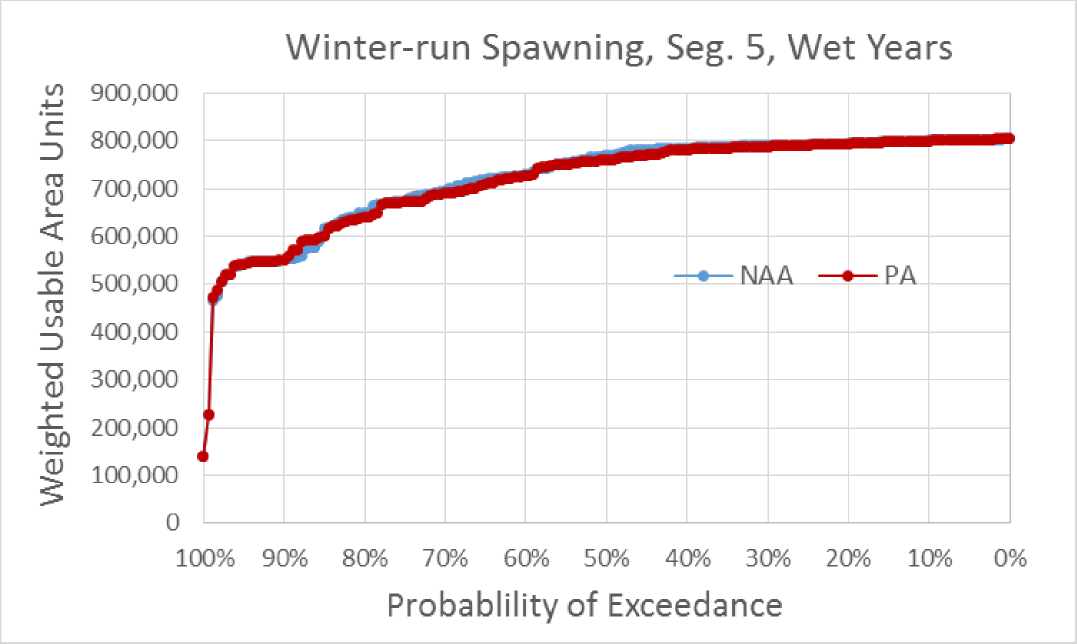

**Figure 4.3-24. Exceedance Plot of Winter-Run Chinook Salmon Spawning Weighted Usable Area (WUA) for NAA and PP Model Scenarios in River Segment 5, Wet Water Years**

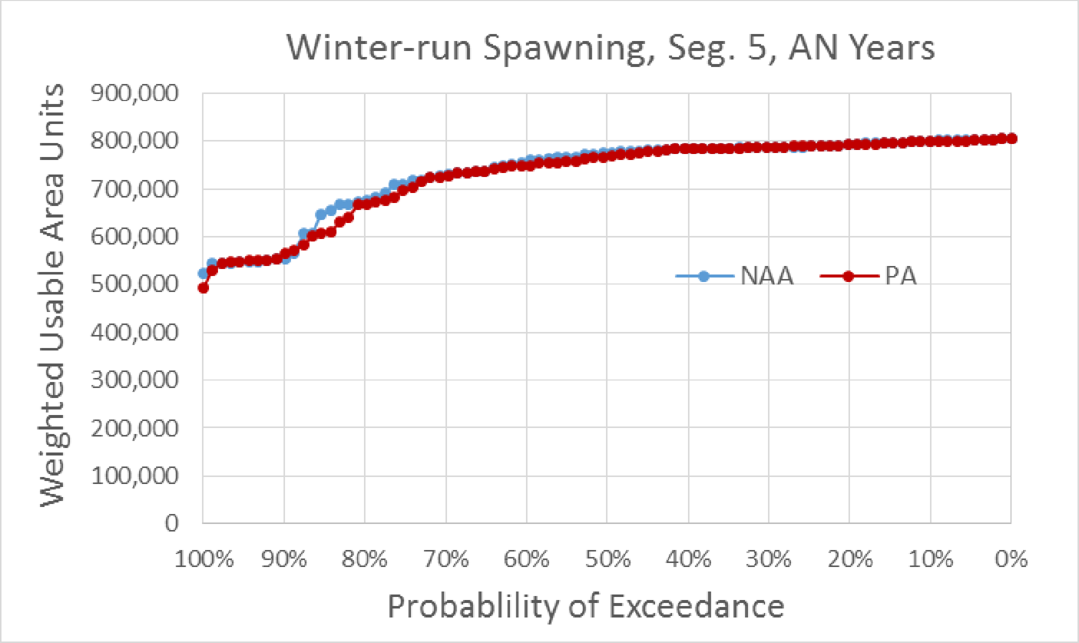

**Figure 4.3-25. Exceedance Plot of Winter-Run Chinook Salmon Spawning Weighted Usable Area (WUA) for NAA and PP Model Scenarios in River Segment 5, Above Normal Water Years**

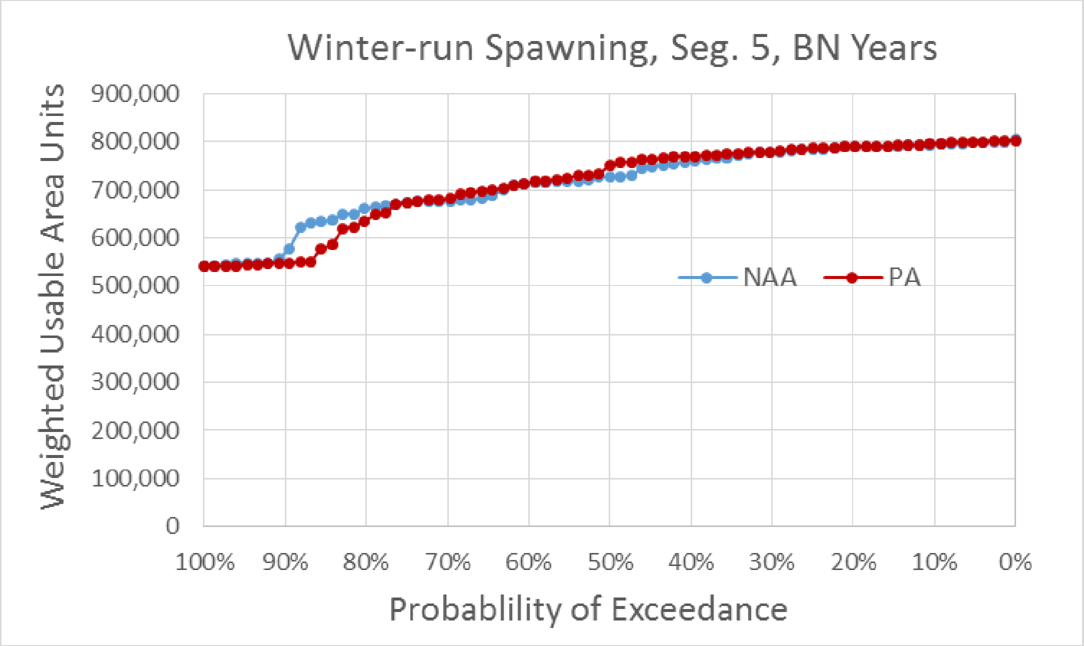

**Figure 4.3-26. Exceedance Plot of Winter-Run Chinook Salmon Spawning Weighted Usable Area (WUA) for NAA and PP Model Scenarios in River Segment 5, Below Normal Water Years**

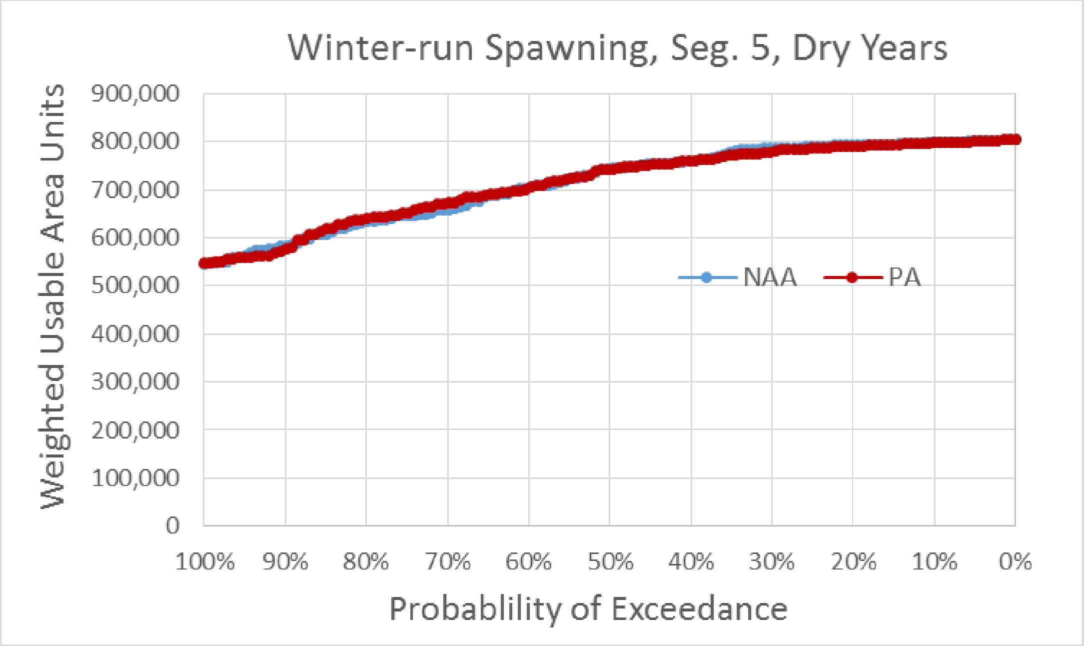

**Figure 4.3-27. Exceedance Plot of Winter-Run Chinook Salmon Spawning Weighted Usable Area (WUA) for NAA and PP Model Scenarios in River Segment 5, Dry Water Years**

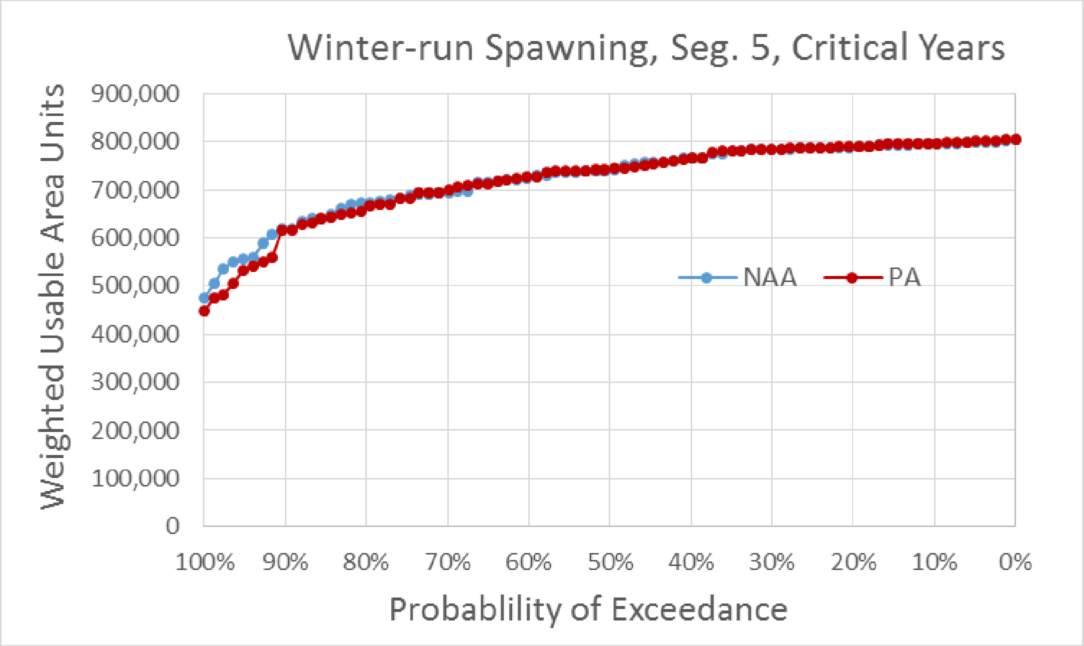

Figure 4.3-28. Exceedance Plot of Winter-Run Chinook Salmon Spawning Weighted Usable Area (WUA) for NAA and PP Model Scenarios in River Segment 5, Critical Water Years

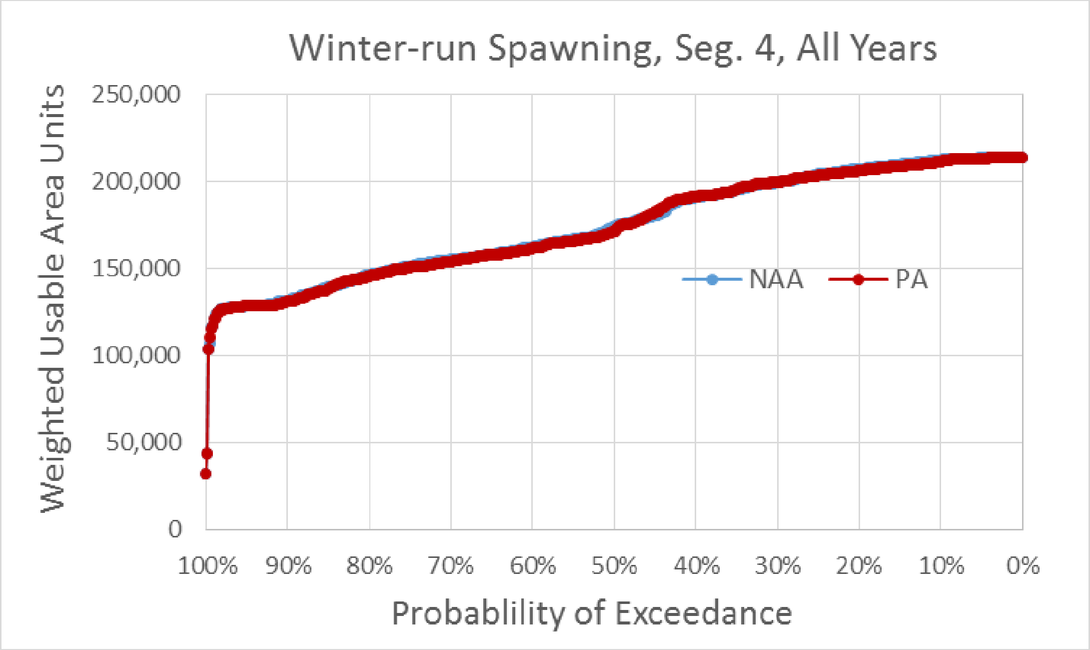

Figure 4.3-29. Exceedance Plot of Winter-Run Chinook Salmon Spawning Weighted Usable Area (WUA) for NAA and PP Model Scenarios in River Segment 4, All Water Years

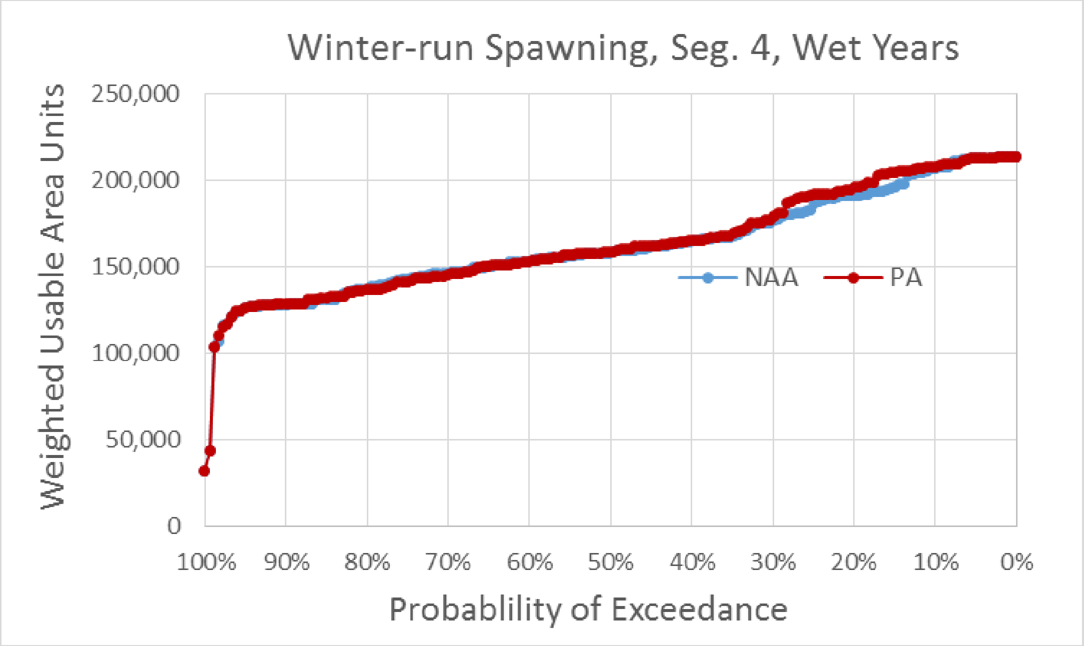

**Figure 4.3-30. Exceedance Plot of Winter-Run Chinook Salmon Spawning Weighted Usable Area (WUA) for NAA and PP Model Scenarios in River Segment 4, Wet Water Years**

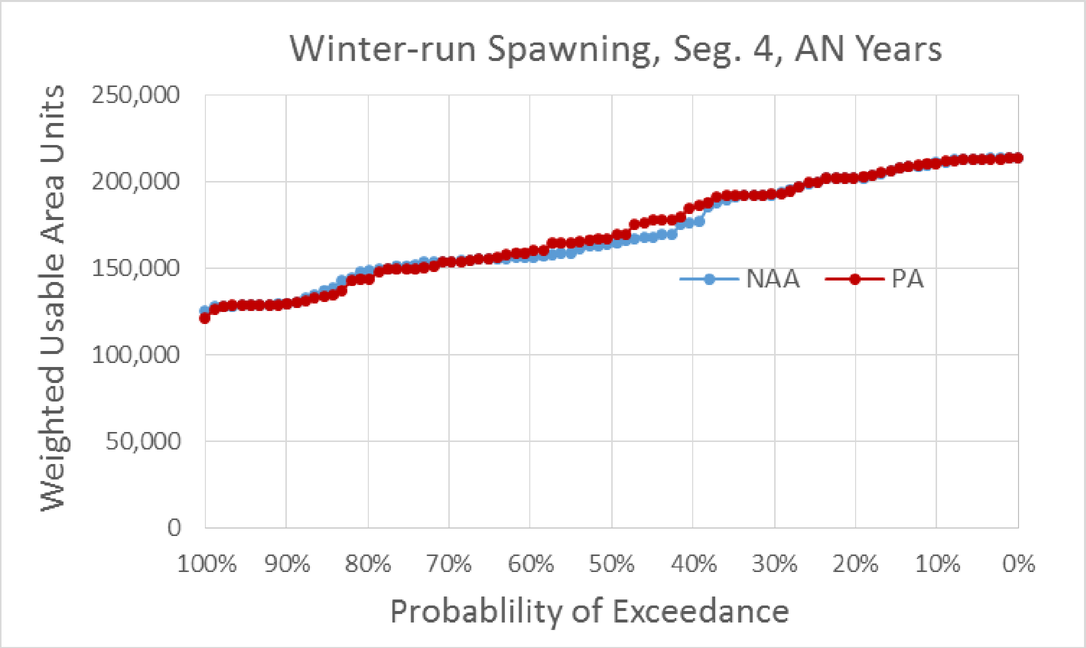

**Figure 4.3-31. Exceedance Plot of Winter-Run Chinook Salmon Spawning Weighted Usable Area (WUA) for NAA and PP Model Scenarios in River Segment 4, Above Normal Water Years**

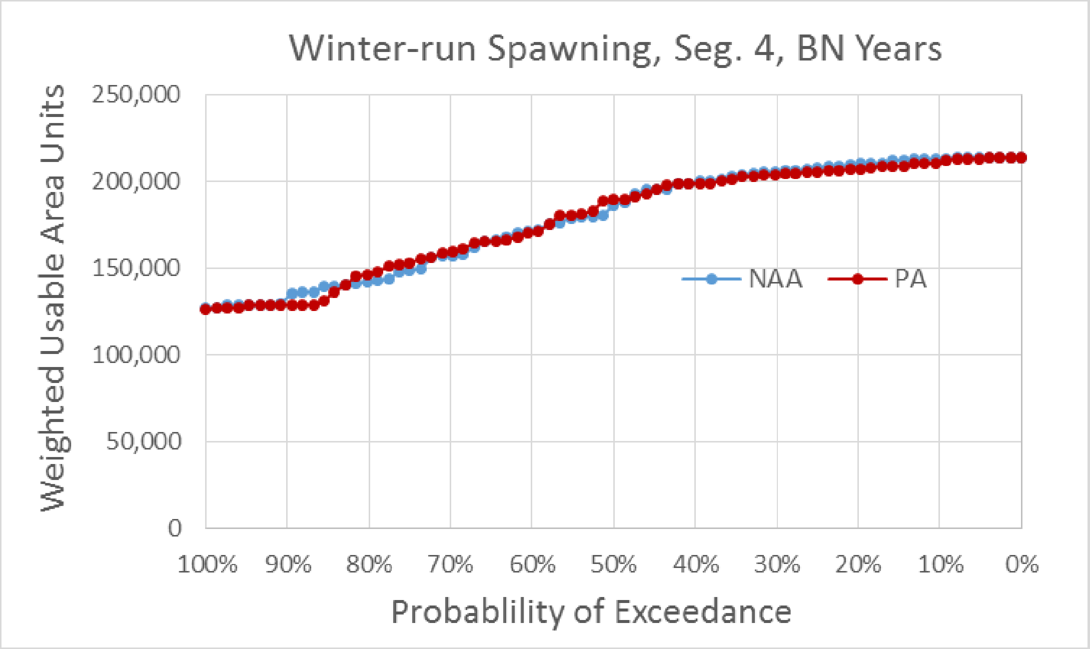

**Figure 4.3-32. Exceedance Plot of Winter-Run Chinook Salmon Spawning Weighted Usable Area (WUA) for NAA and PP Model Scenarios in River Segment 4, Below Normal Water Years**

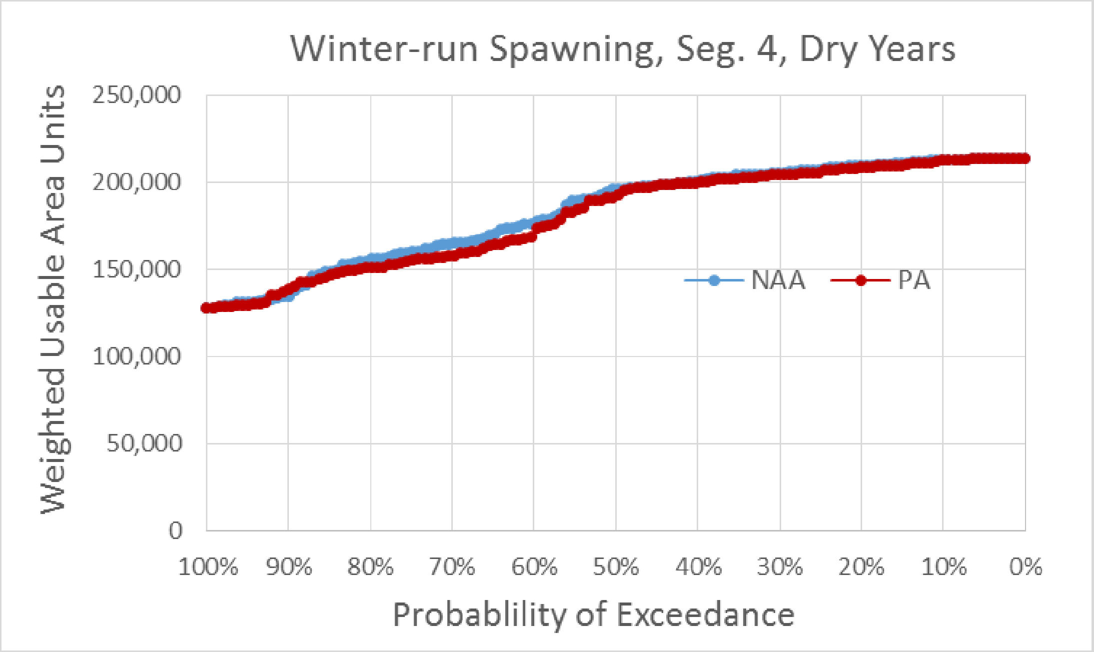

**Figure 4.3-33. Exceedance Plot of Winter-Run Chinook Salmon Spawning Weighted Usable Area (WUA) for NAA and PP Model Scenarios in River Segment 4, Dry Water Years**

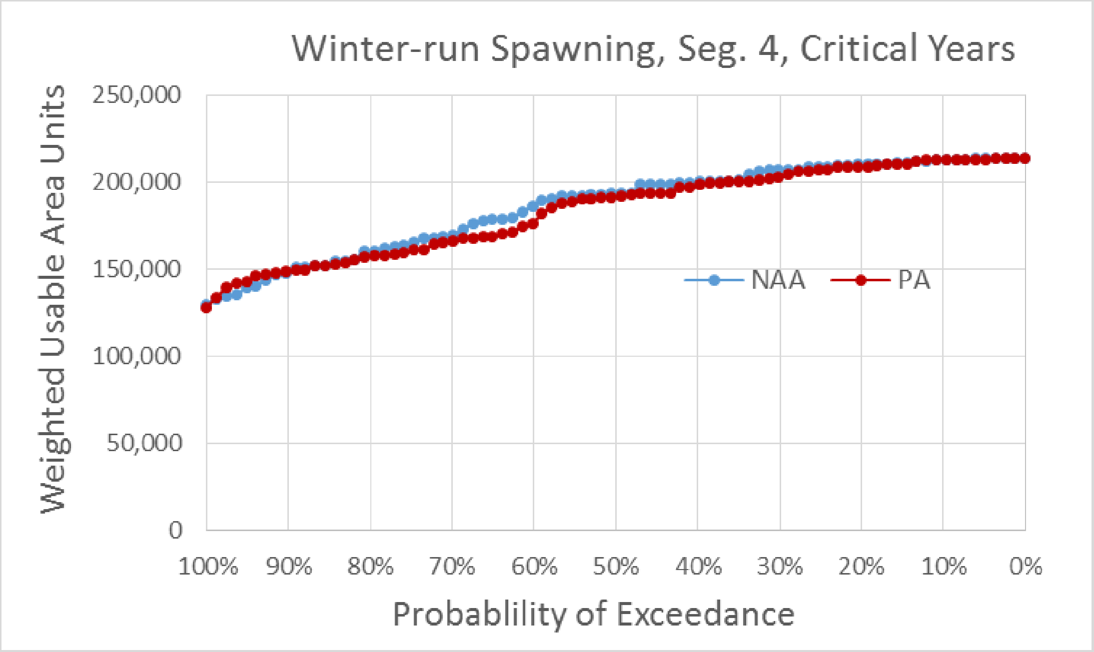

**Figure 4.3-34. Exceedance Plot of Winter-Run Chinook Salmon Spawning Weighted Usable Area (WUA) for NAA and PP Model Scenarios in River Segment 4, Critical Water Years**

Differences in spawning WUA in each segment under the PP 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 4.3-21 to Table 4.3-23). The means differed by less than 5% for most months and water year types, but mean WUA in Segment 6 under the PP 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 PP and NAA were 6%, except for an 8% higher WUA for the PP 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 4.3.4.2.2 *Summary of Upstream Effects*.

**Table 4.3-21. Winter-Run Chinook Salmon Spawning Weighted Usable Area (WUA) and Differences (Percent Differences) in River Segment 6 between Model Scenarios (green indicates PP is at least 5% higher [raw difference] than NAA; red indicates PP is at least 5% lower)**

| Month | WYT | NAA | PP | PP 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%) |
| 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 4.3-22. Winter-Run Chinook Salmon Spawning Weighted Usable Area (WUA) and Differences (Percent Differences) in River Segment 5 between Model Scenarios (green indicates PP is at least 5% higher [raw difference] than NAA; red indicates PP is at least 5% lower)**

| Month | WYT | NAA | PP | PP 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%) |
| | 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 4.3-23. Winter-Run Chinook Salmon Spawning Weighted Usable Area (WUA) and Differences (Percent Differences) in River Segment 4 between Model Scenarios (green indicates PP is at least 5% higher [raw difference value] than NAA; red indicates PP is at least 5% lower)**

| Month | WYT | NAA | PP | PP 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%) |
| | 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%) |

### *4.3.4.2.1.2.1.3 Redd scour*

The probability of flows occurring under the PP 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 (ICF International 2016, 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 PP and the NAA are for the Keswick Dam and Red Bluff locations. As discussed in *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale* (ICF International 2016, 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 PP 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 *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale* (ICF International 2016, Appendix 5.D, Section 5.D.2.2 *Spawning Flows Methods*).

Table 4.3-24 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 4.3-25), and several water years and months with mean monthly flow greater than 21,800 cfs were predicted at Red Bluff (Table 4.3-26) under both the NAA and PP. For winter-run Chinook salmon, there would be no differences between the PP and the NAA in the percentage of scouring flows at either location.

**Table 4.3-24. 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**

| Species/Race | Keswick Dam | | | Red Bluff | | |
|---|---|---|---|---|---|---|
| | NAA | PP | PP vs. NAA | NAA | PP | PP vs. NAA |
| Winter-run Chinook salmon | 0.2 | 0.2 | 0 (0%) | 0.7 | 0.7 | 0 (0%) |

**Table 4.3-25. Water Year and Month with Mean Flow > 27,300 cfs at Keswick Dam during the Winter-run Chinook Salmon Spawning and Incubation Period**

| Water Year | Month | WYT | Flow (cfs) | |
|---|---|---|---|---|
| | | | NAA | PP |
| 1963 | April | Wet | 30,893 | 30,893 |

**Table 4.3-26. Water Years and Months with Mean Flow > 21,800 cfs at Red Bluff during the Winter-run Chinook Salmon Spawning and Incubation Period**

| Water Year | Month | WYT | Flow (cfs) | |
|---|---|---|---|---|
| | | | NAA | PP |
| 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 4.3-28 below for these results.

###### *4.3.4.2.1.2.1.4 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 (ICF International 2016, 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 4.3.4.2.1.2.1.2 *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 PP 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 (ICF International 2016, 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 *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale* (ICF International [2016], Appendix 5.D, Section 5.D.2.2 *Spawning Flows Methods*).

Differences in winter-run redd dewatering under the PP 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 PP 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 4.3-34 to Figure 4.3-39). 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 PP (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 PP. Further discussion regarding flow-related effects during the June through November period is provided in Section 4.3.4.2.2 *Summary of Upstream Effects*.

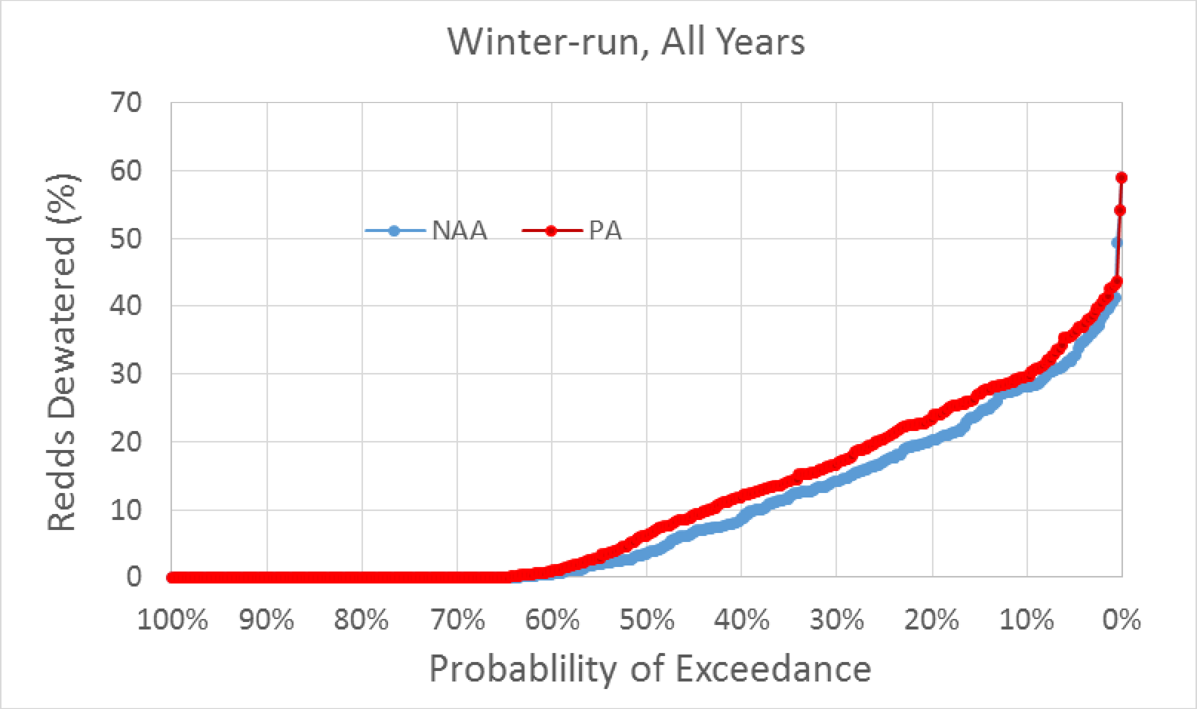

**Figure 4.3-35. Exceedance Plot of Winter-Run Chinook Salmon Percent of Redds Dewatered for NAA and PP Model Scenarios, All Water Years**

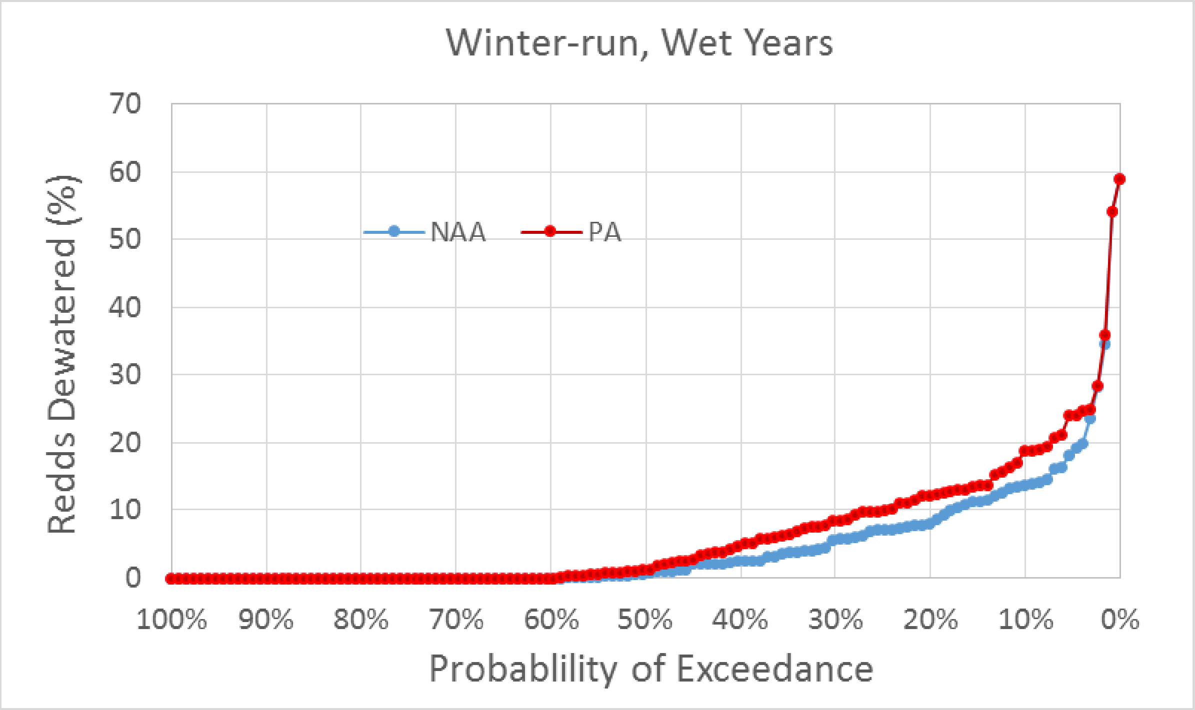

Figure 4.3-36. Exceedance Plot of Winter-Run Chinook Salmon Percent of Redds Dewatered for NAA and PP Model Scenarios, Wet Water Years

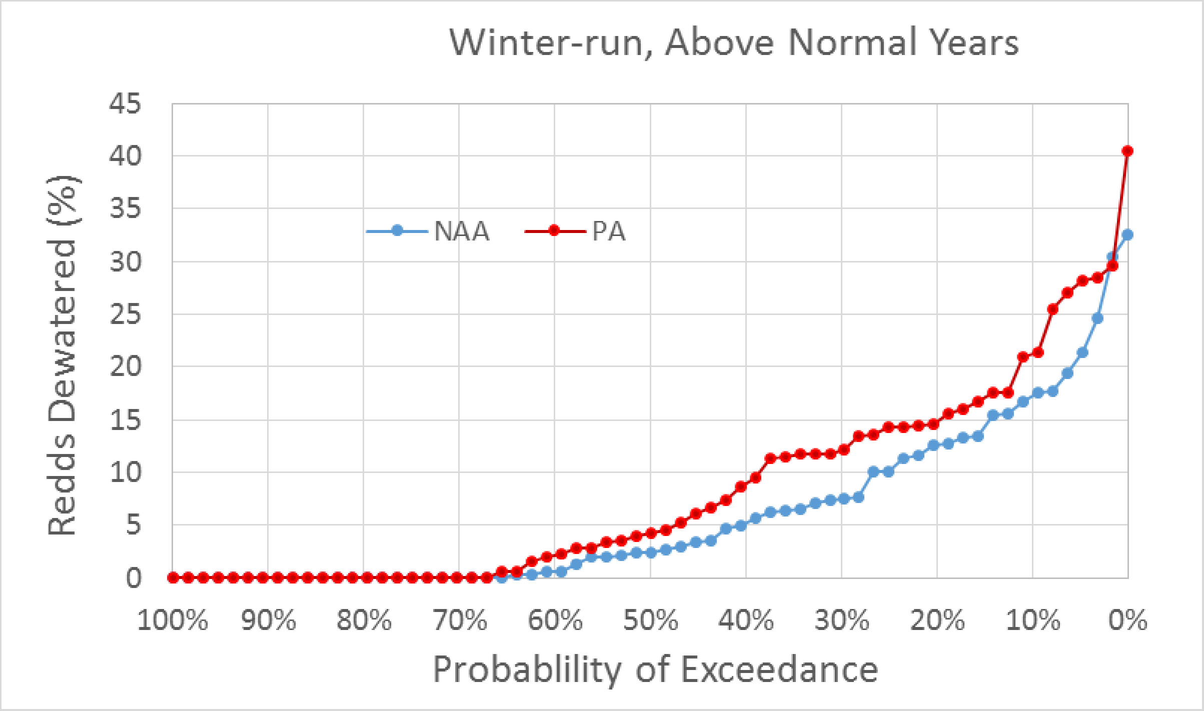

Figure 4.3-37. Exceedance Plot of Winter-Run Chinook Salmon Percent of Redds Dewatered for NAA and PP Model Scenarios, Above Normal Water Years

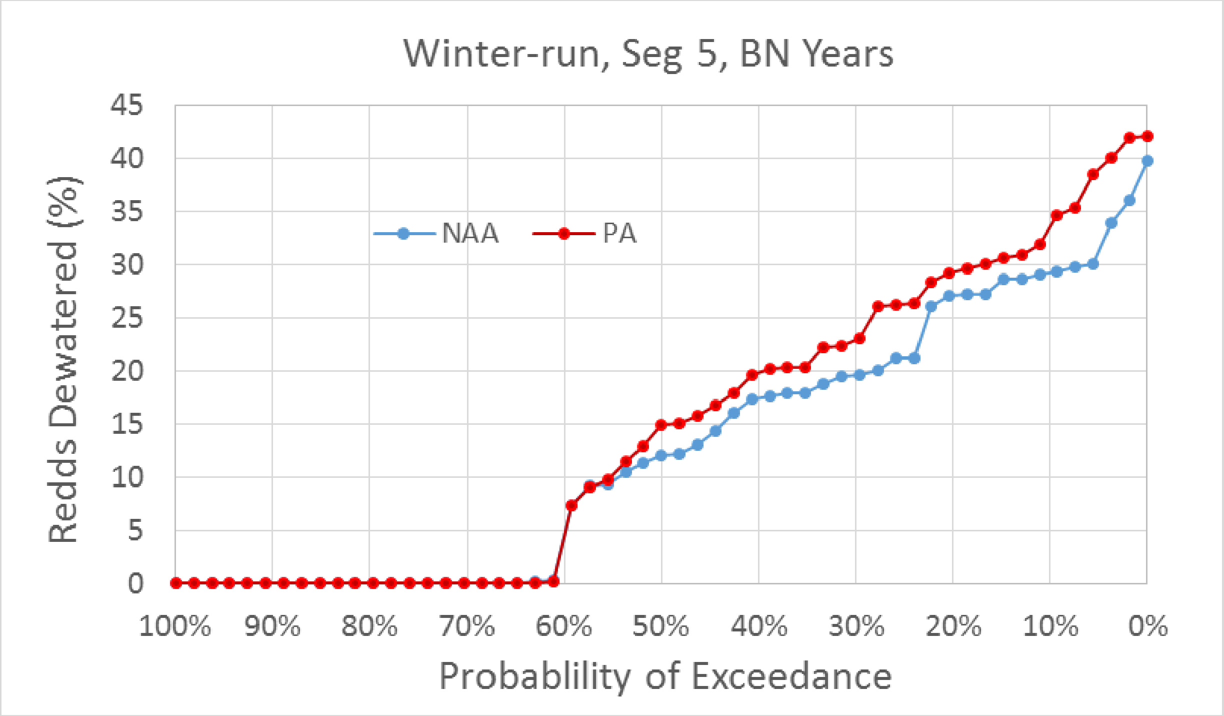

Figure 4.3-38. Exceedance Plot of Winter-Run Chinook Salmon Percent of Redds Dewatered for NAA and PP Model Scenarios, Below Normal Water Years

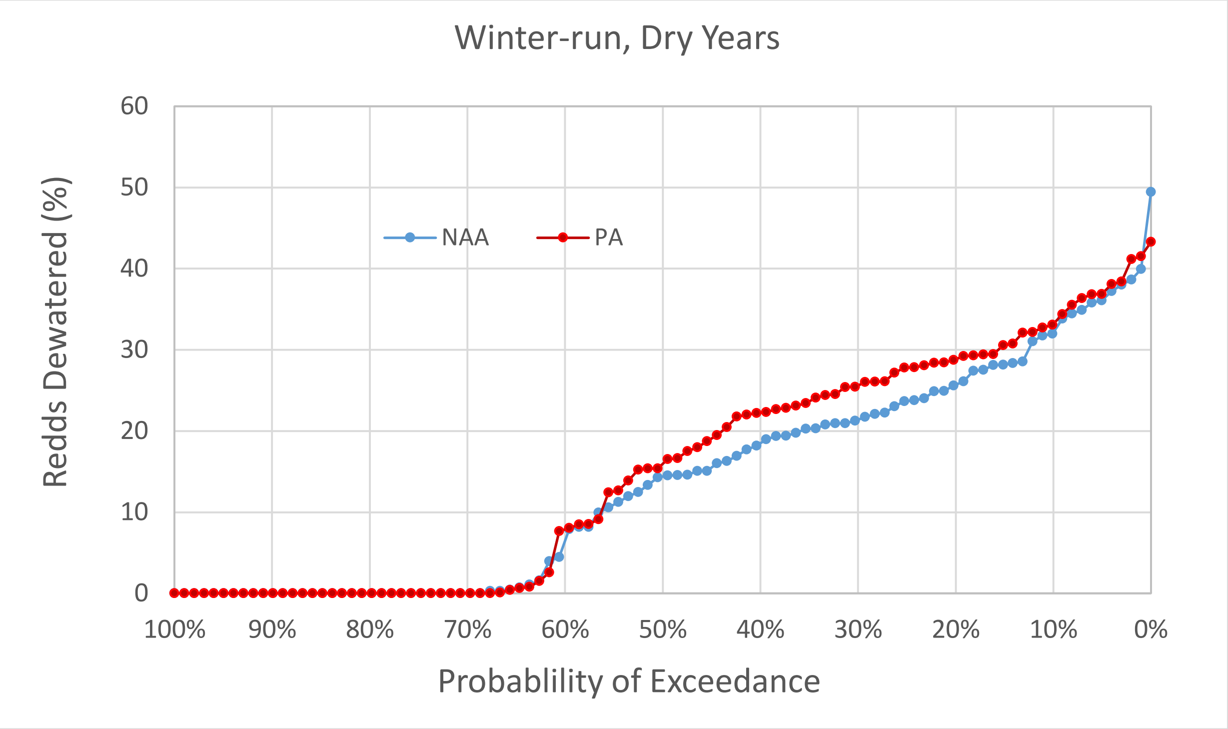

Figure 4.3-39. Exceedance Plot of Winter-Run Chinook Salmon Percent of Redds Dewatered for NAA and PP Model Scenarios, Dry Water Years

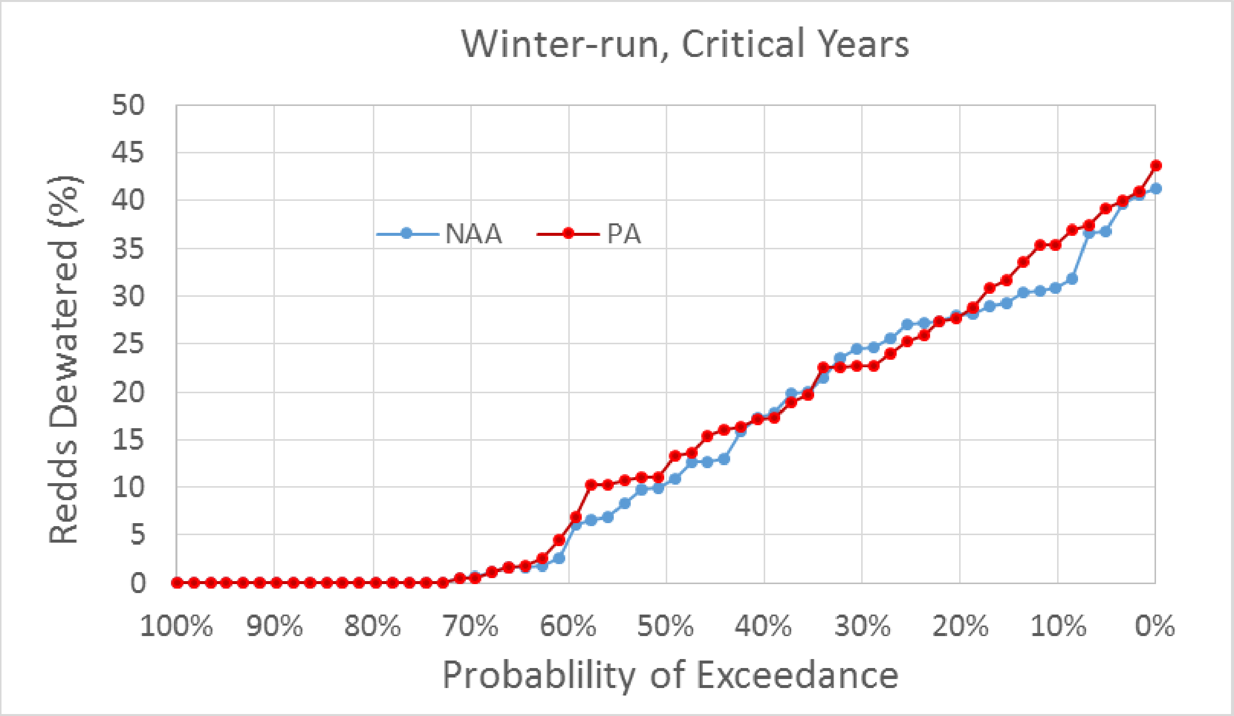

**Figure 4.3-40. Exceedance Plot of Winter-Run Chinook Salmon Percent of Redds Dewatered for NAA and PP Model Scenarios, Critical Water Years**

Differences in redd dewatering between the PP 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 4.3-27). The mean percent redds dewatered under the PP 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 PP 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 PP and NAA. Further discussion regarding flow-related effects during the June through November period is provided in Section 4.3.4.2.2 *Summary of Upstream Effects*.

**Table 4.3-27. Winter-Run Chinook Salmon Percent of Redds Dewatered (Percent of Total Redds) and Differences (Percent Differences) between Model Scenarios (green indicates PP is at least 5% lower [raw difference] than NAA; red indicates PP is at least 5% higher)**

| Month | WYT | NAA | PP | PP 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%) |

#### *4.3.4.2.1.2.1.5 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 ICF International [2016], Appendix 5.D, Attachment 5.D.2 *SALMOD Model* for a full description). The SALMOD results for this type of mortality are presented in Table 4.3-28, 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 4.3-41. 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 PP 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 PP 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 4.3-28). 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 4.3-28 comprise redd dewatering and redd scour (ICF International 2016, Appendix 5.D, Attachment 5.D.2 *SALMOD Model*). Redd scour, as described in Section 4.3.4.2.1.2.1.3 *Redd Scour*, is expected to have little effect on winter-run Chinook salmon under either project scenario, but redd dewatering (Section 4.3.4.2.1.2.1.4 *Redd Dewatering*) is predicted to increase under the PP for June and August egg cohorts of some water year types (Table 4.3-27). 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 4.3.4.2.2 *Summary of Upstream Effects*.

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**Table 4.3-28. 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 |
| PP | 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 |
| PP | 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 |
| PP | 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 |
| PP | 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 |
| PP | 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 |
| PP | 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.

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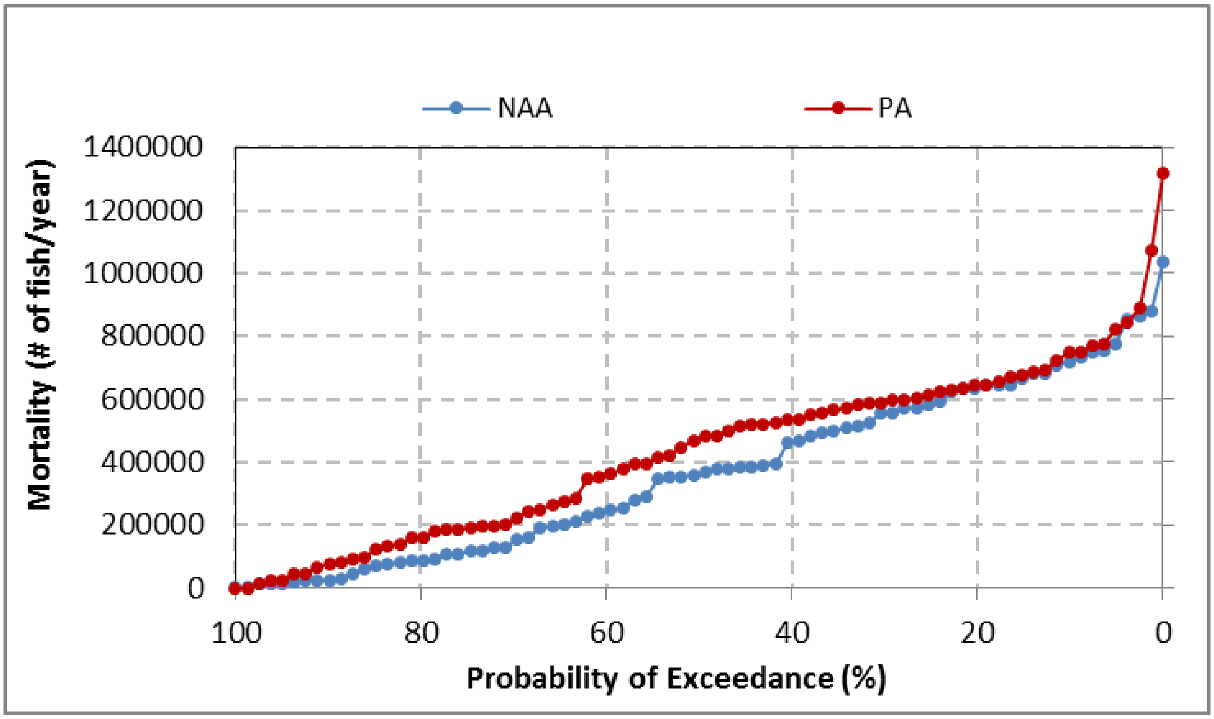

**Figure 4.3-41. Exceedance Plot of Annual Flow-Based Mortality (#of Fish/Year) of Winter-Run Chinook Salmon Spawning, Egg Incubation, and Alevins**

###### *4.3.4.2.1.2.1.6 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 4.3-19) are presented in *Upstream Water Temperature Methods and Results* (ICF International [2016], Appendix 5.C, 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, and Table 5.C.7-8). Overall, the PP 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 PP 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 (ICF International [2016], Appendix 5.C, 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, and Figure 5.C.7.8-7). The values for the PP in these exceedance plots generally overlap those of the NAA. Further examination of above normal water years during August (Figure 4.3-41) and September (Figure 4.3-42) at Red Bluff, below normal years during September at Red Bluff (Figure 4.3-43), and in below normal years during September at Bend Bridge (Figure 4.3-44), where the largest increases in mean monthly water temperatures were modeled, reveals that there is a general trend towards marginally higher temperatures under the PP.

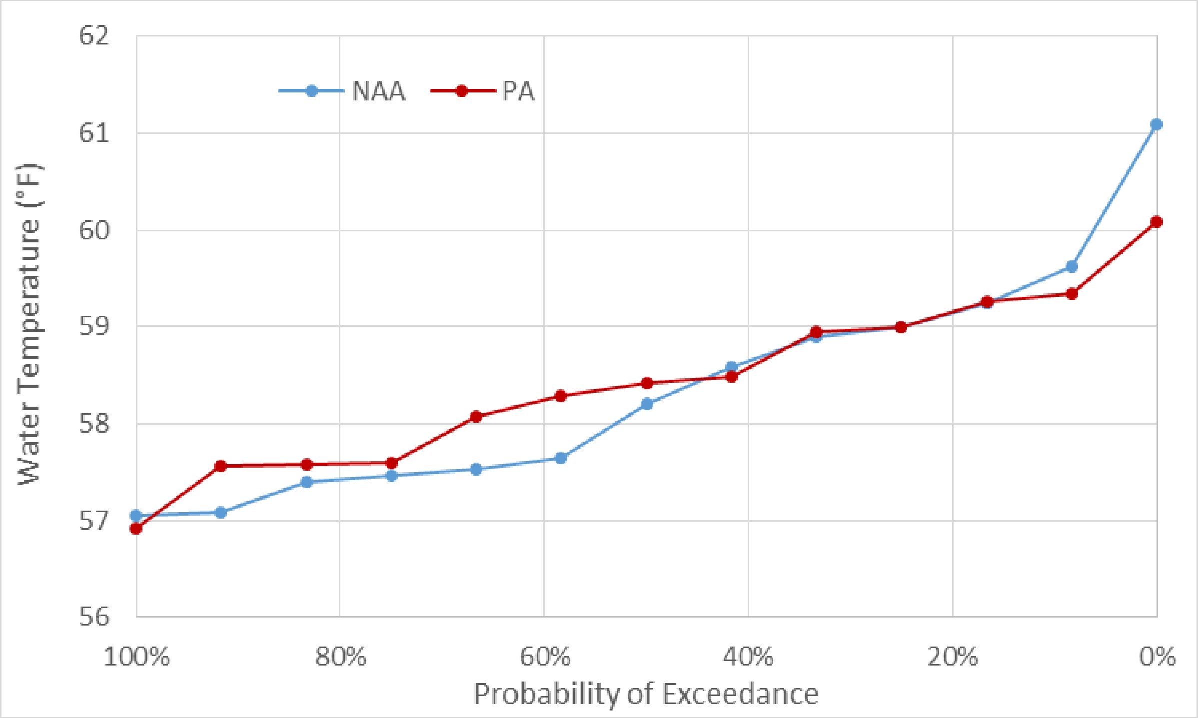

**Figure 4.3-42. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the Sacramento River at Red Bluff in August of Above Normal Water Years**

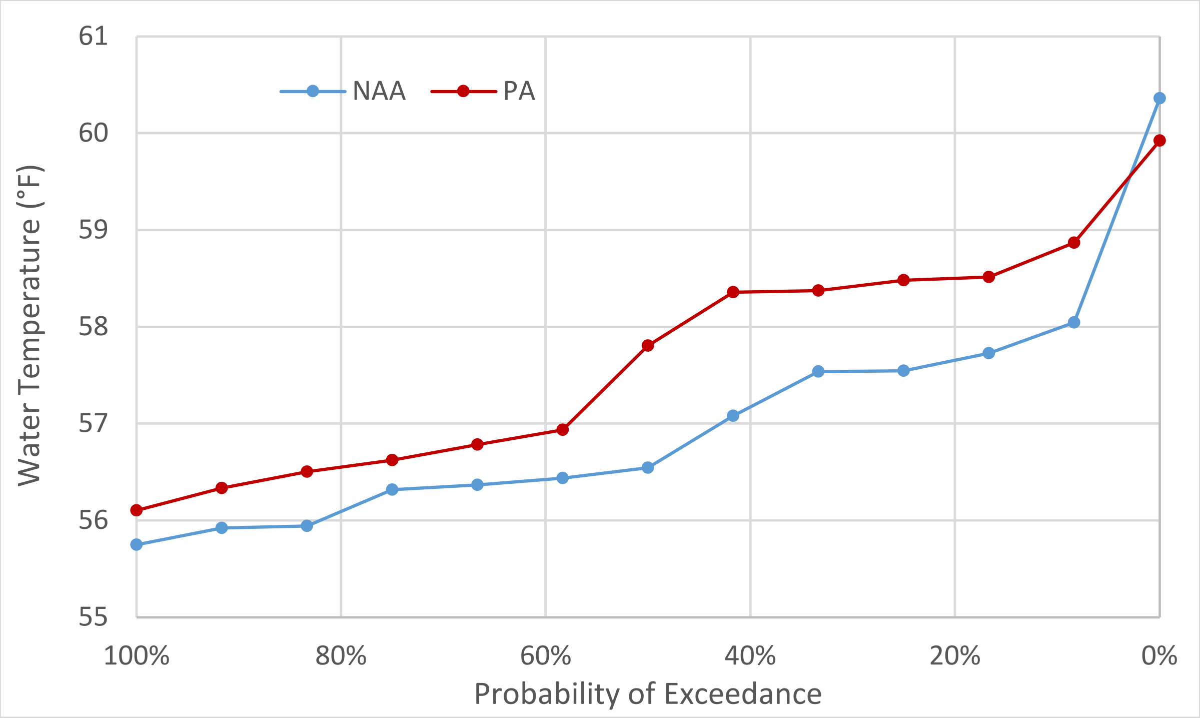

**Figure 4.3-43. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the Sacramento River at Red Bluff in September of Above Normal Water Years**

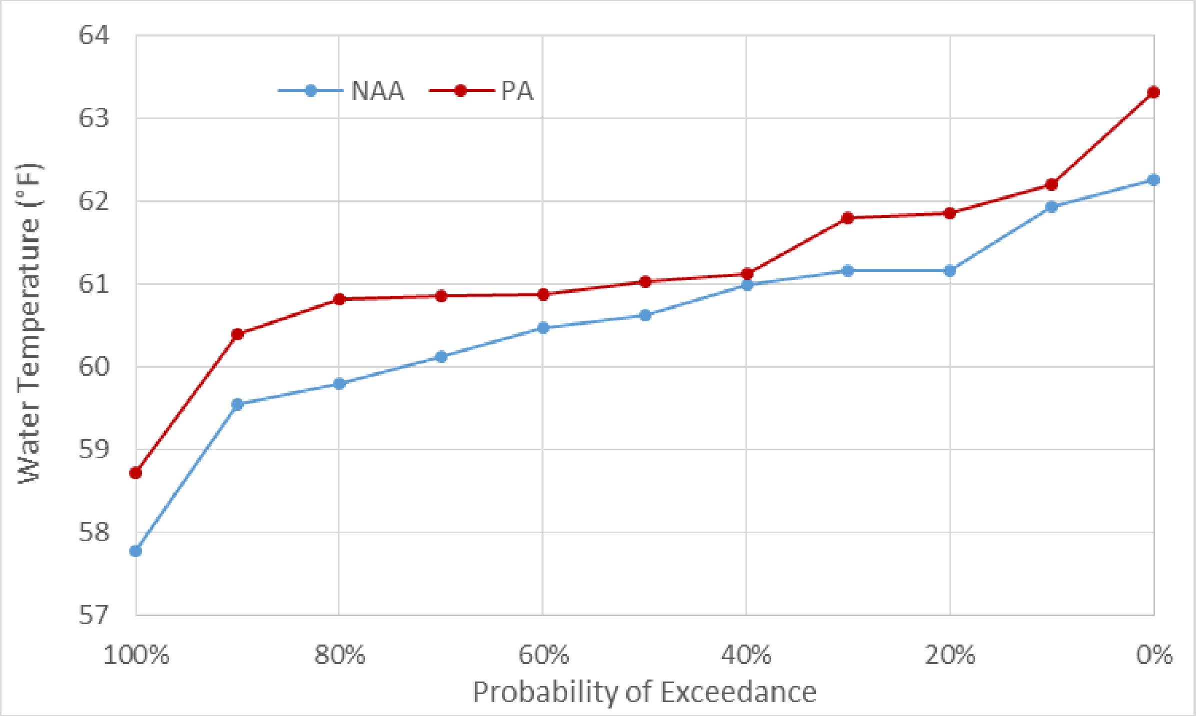

**Figure 4.3-44. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the Sacramento River at Red Bluff in September of Below Normal Water Years**

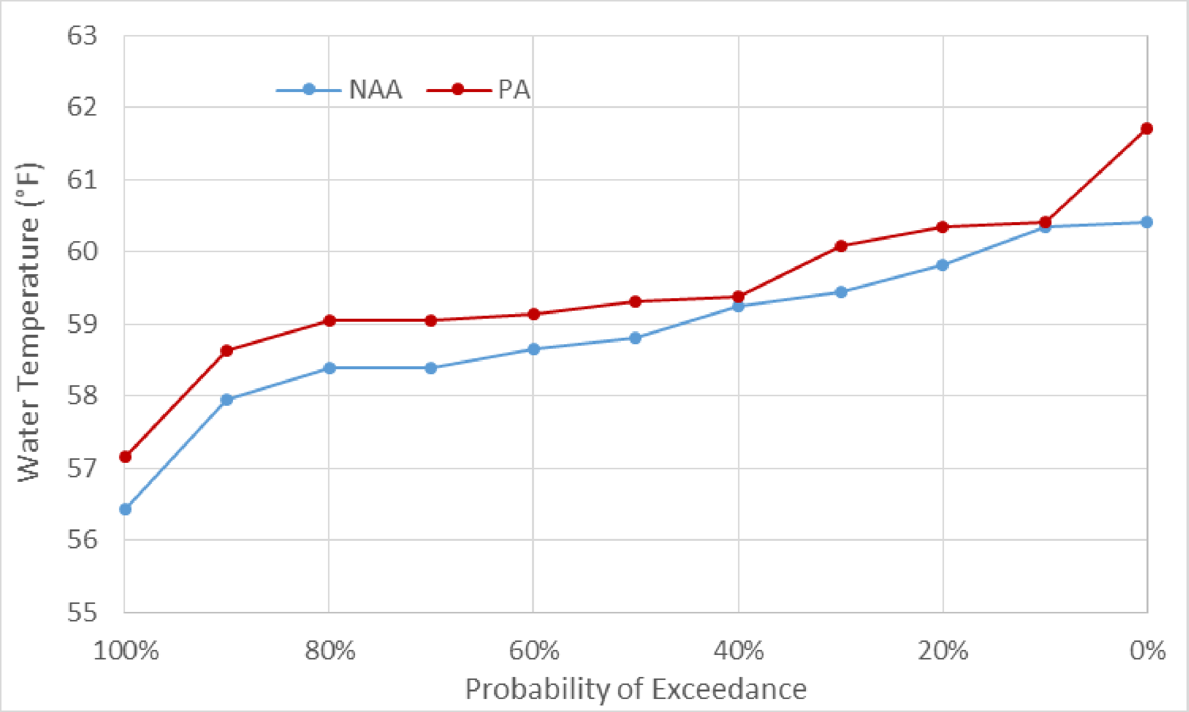

**Figure 4.3-45. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the Sacramento River at Bend Bridge in September of Below Normal Water Years**

The exceedance of temperature thresholds in the Sacramento River presented in *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale* (ICF International [2016], 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 *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale* (ICF International [2016], Appendix 5.D, 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 PP in frequency of exceedance of the threshold was greater than 5%, and (2) the difference between NAA and PP 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 (ICF International [2016], 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 *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale* (ICF International 2016, 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 PP 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 (ICF International 2016, 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 PP 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 PP 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 *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale* (ICF International [2016], 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 4.3-45) 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 PP would be different from those under the NAA in this 1 year. Therefore, it was concluded that this result is due to modeling limitations.

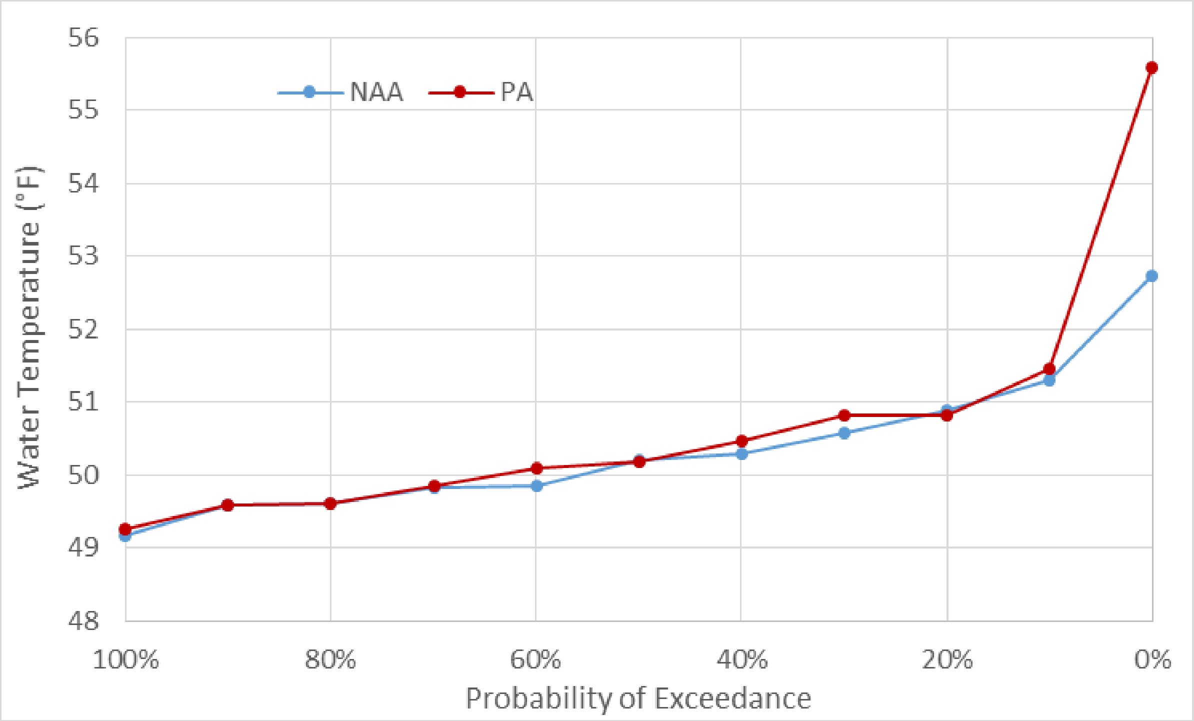

**Figure 4.3-46. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the Sacramento River above Clear Creek in May of Below Normal Water Years**

At Balls Ferry, the percent of days exceeding the 55.4°F 7DADM threshold under the PP 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 (ICF International [2016], 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 4.3-46) reveals that this effect is due entirely to 1 year (1923) during which temperatures would be much higher.

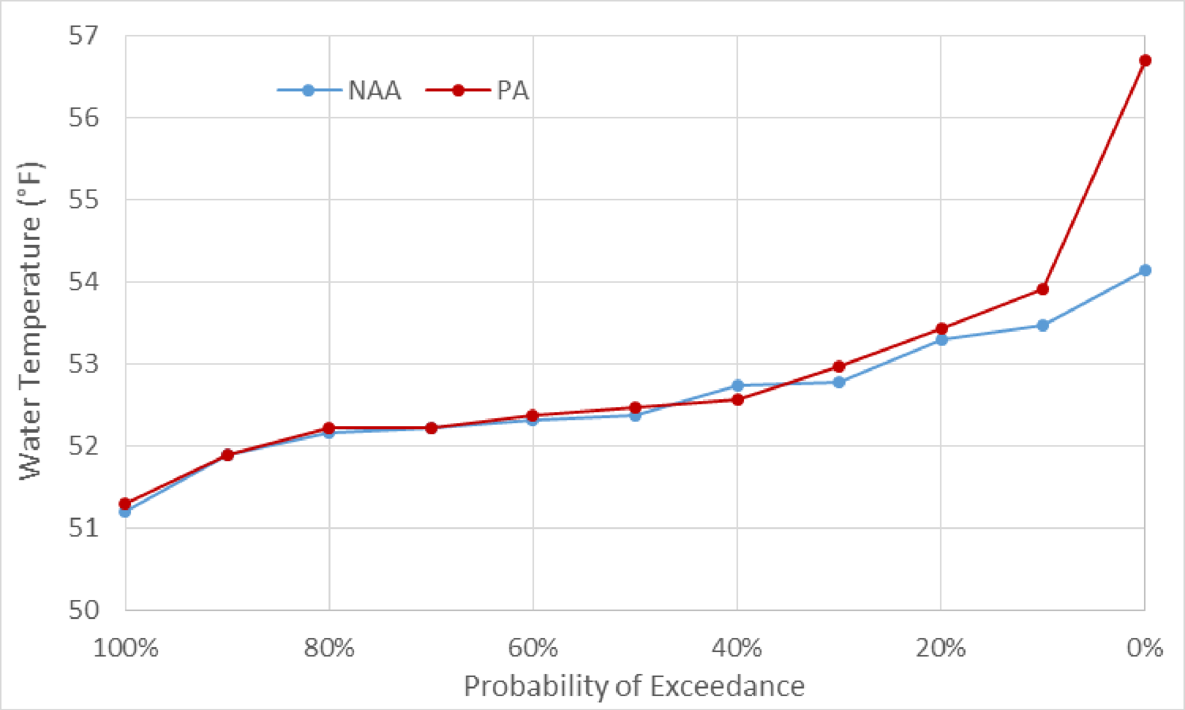

**Figure 4.3-47. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the Sacramento River at Balls Ferry in May of Below Normal Water Years**

At Bend Bridge, the percent of days exceeding the 55.4°F 7DADM threshold under the PP 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 PP would be more than 5% lower than under the NAA during June of above normal years (ICF International [2016], 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 PP 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 (ICF International [2016], 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 PP 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 *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale* (ICF International [2016], Appendix 5.D, Section 5.D.2.1.2.2 *Water Temperature Threshold Analysis*). The two cases where modeled water temperatures under the PP 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 PP 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 ICF International [2016], Appendix 5.D, Attachment 1 *Reclamation Egg Mortality Model*, for full model description). As noted in *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale* (ICF International [2016], 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 PP and NAA was considered a biologically meaningful effect (see ICF International [2016], Appendix 5.D, Section 5.D.2.1.2.3 *Reclamation Egg Mortality Model*, for details). Results of the model are presented in Table 4.3-29 and Figure 4.3-47 through Figure 4.3-52.

These results indicate that there would be no biologically meaningful increases in egg mortality under the PP 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 very small (less than 1% difference) (Table 4.3-29). Also, the difference between means in below normal water years is driven by a single year (1923), as indicated in Figure 4.3-50, 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 PP 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 4.3-29. Winter-Run Chinook Salmon Egg Mortality (Percent of Total Individuals) and Differences (Percent Differences) between Model Scenarios, Reclamation Egg Mortality Model**

| WYT | NAA | PP | PP 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%) |

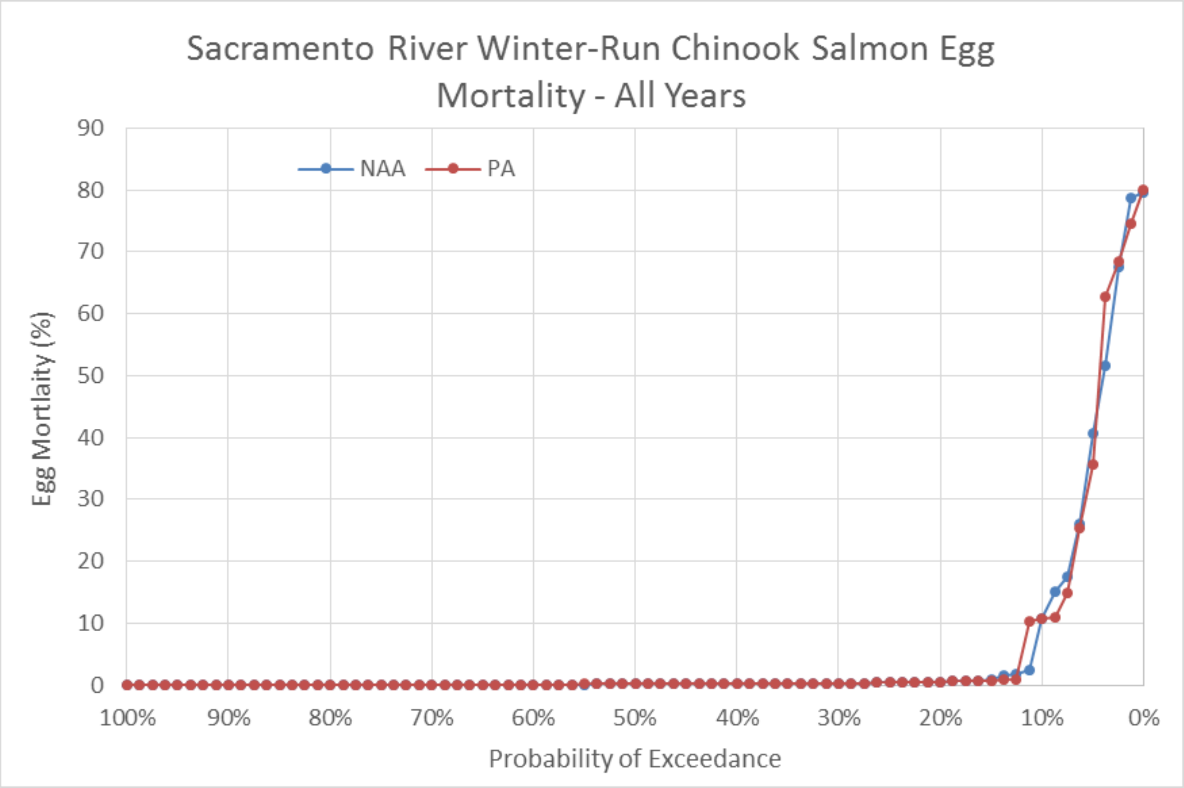

**Figure 4.3-48. Exceedance Plot of Winter-Run Chinook Salmon Egg Mortality for NAA and PP Model Scenarios, Reclamation Egg Mortality Model, All Water Years**

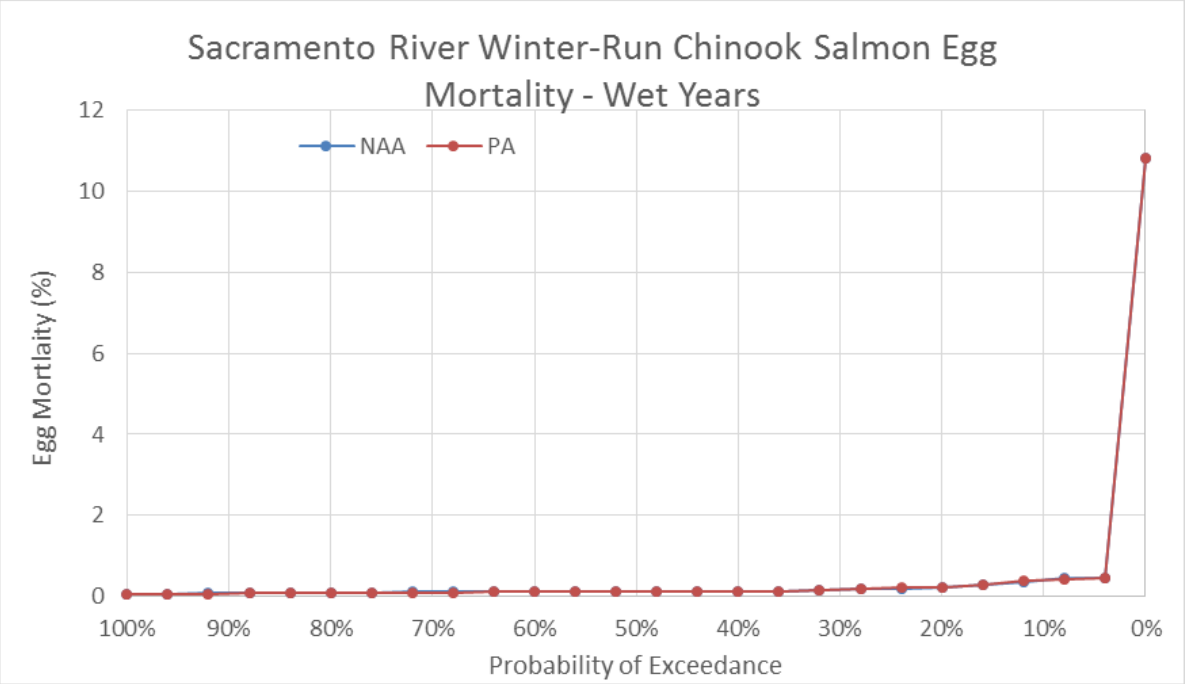

**Figure 4.3-49. Exceedance Plot of Winter-Run Chinook Salmon Egg Mortality for NAA and PP Model Scenarios, Reclamation Egg Mortality Model, Wet Water Years**

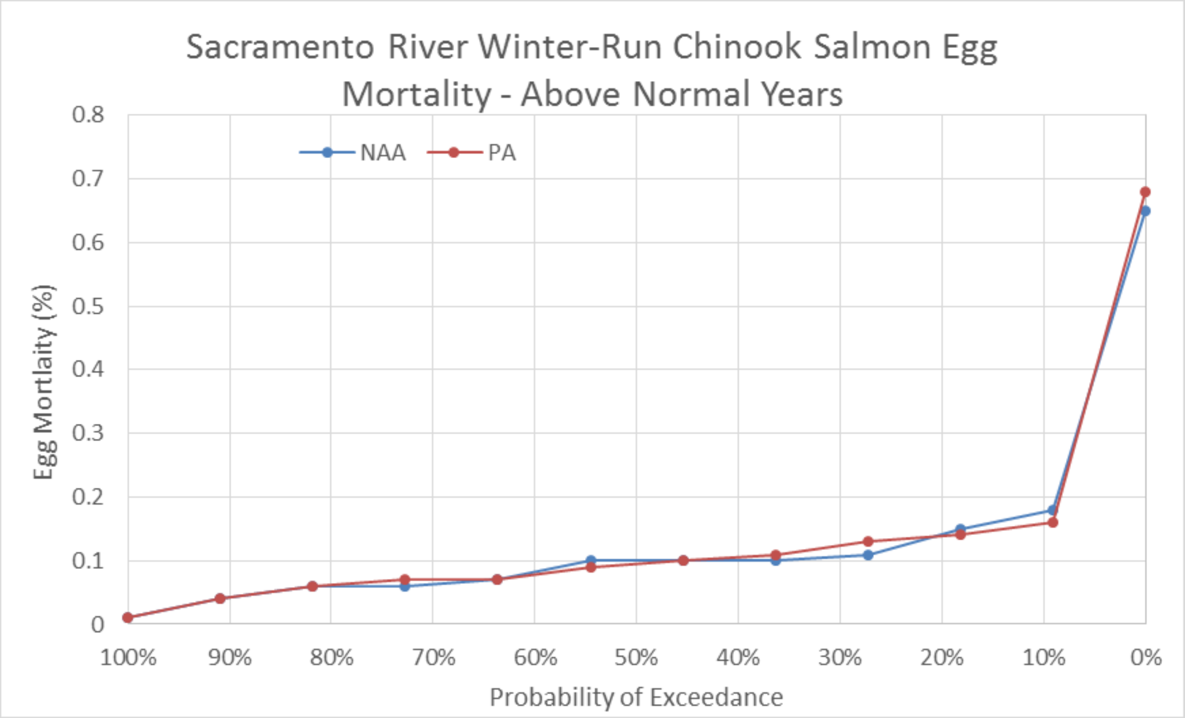

**Figure 4.3-50. Exceedance Plot of Winter-Run Chinook Salmon Egg Mortality for NAA and PP Model Scenarios, Reclamation Egg Mortality Model, Above Normal Water Years**

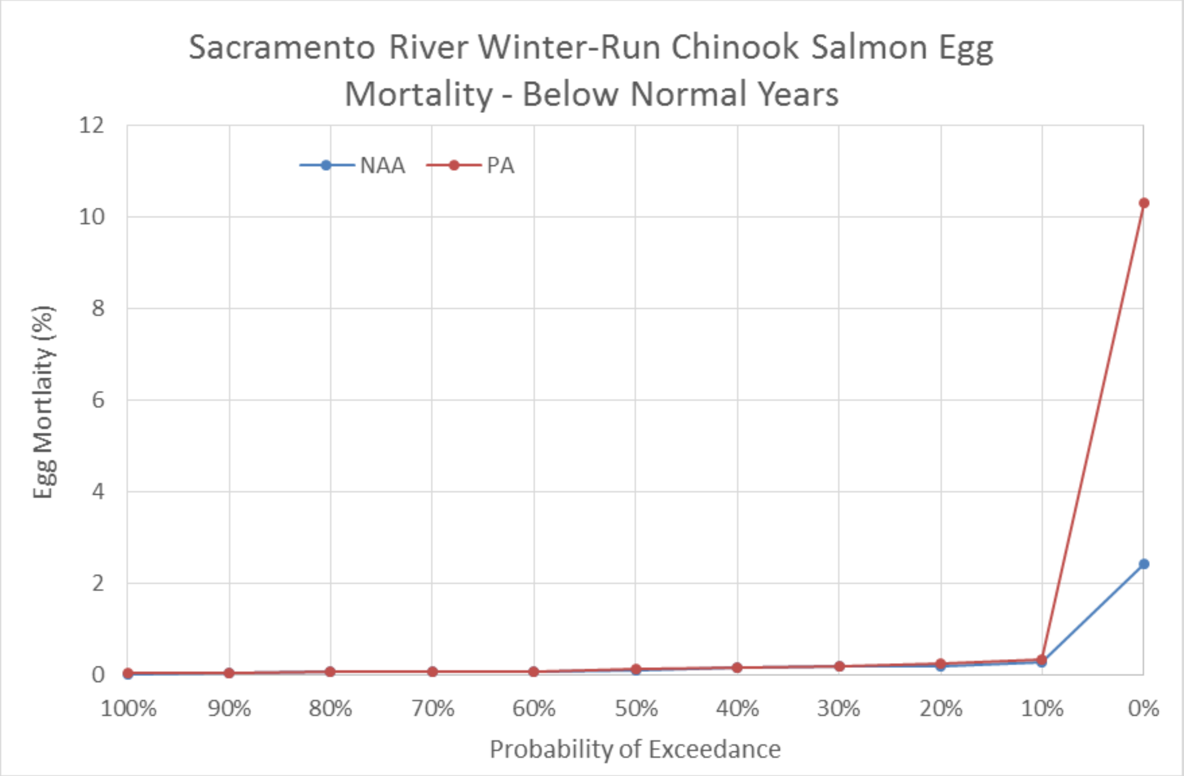

Figure 4.3-51. Exceedance Plot of Winter-Run Chinook Salmon Egg Mortality for NAA and PP Model Scenarios, Reclamation Egg Mortality Model, Below Normal Water Years

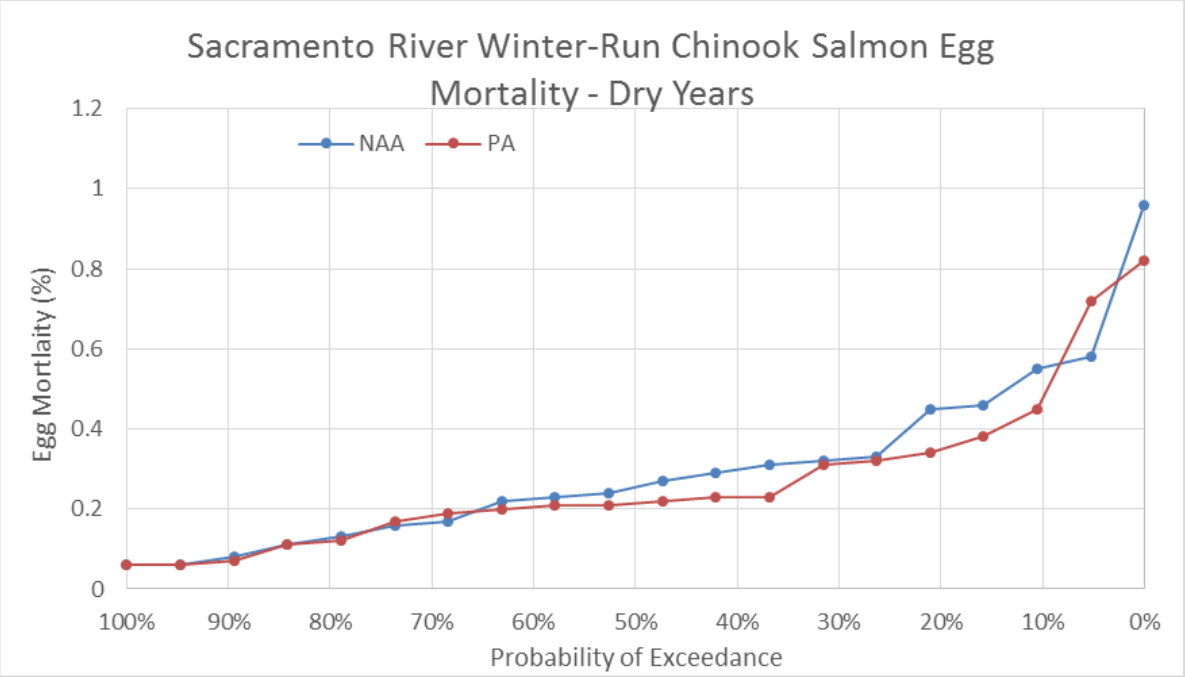

Figure 4.3-52. Exceedance Plot of Winter-Run Chinook Salmon Egg Mortality for NAA and PP Model Scenarios, Reclamation Egg Mortality Model, Dry Water Years

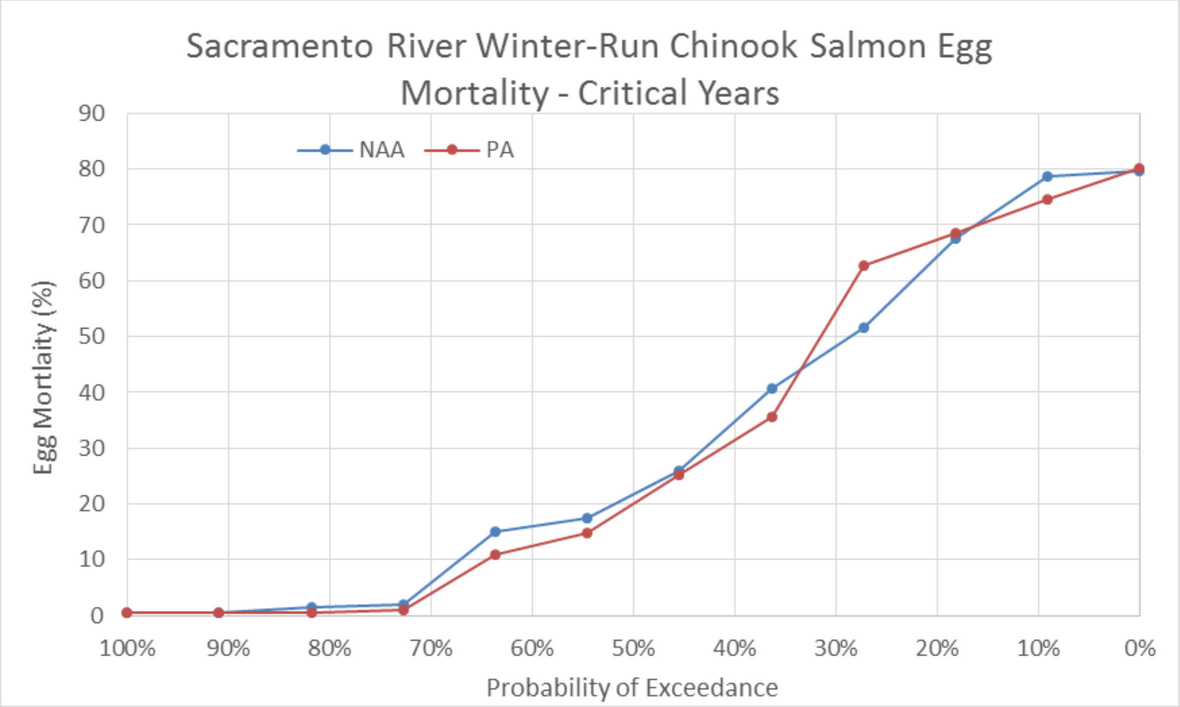

**Figure 4.3-53. Exceedance Plot of Winter-Run Chinook Salmon Egg Mortality for NAA and PP Model Scenarios, Reclamation Egg Mortality Model, Critical Water Years**

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 ICF International [2016], Appendix 5.D, Attachment 5.D.2 *SALMOD Model*, for a full description). Table 4.3-28 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 4.3-53. 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 PP relative to the NAA and, in fact, average annual mortality would decrease by 31,755 fish, or 7% under the PP. 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 PP relative to the NAA. Almost all of the mortality (>99%) in both the NAA and PP would occur while the eggs are in the gravel and not in vivo (pre-spawn).

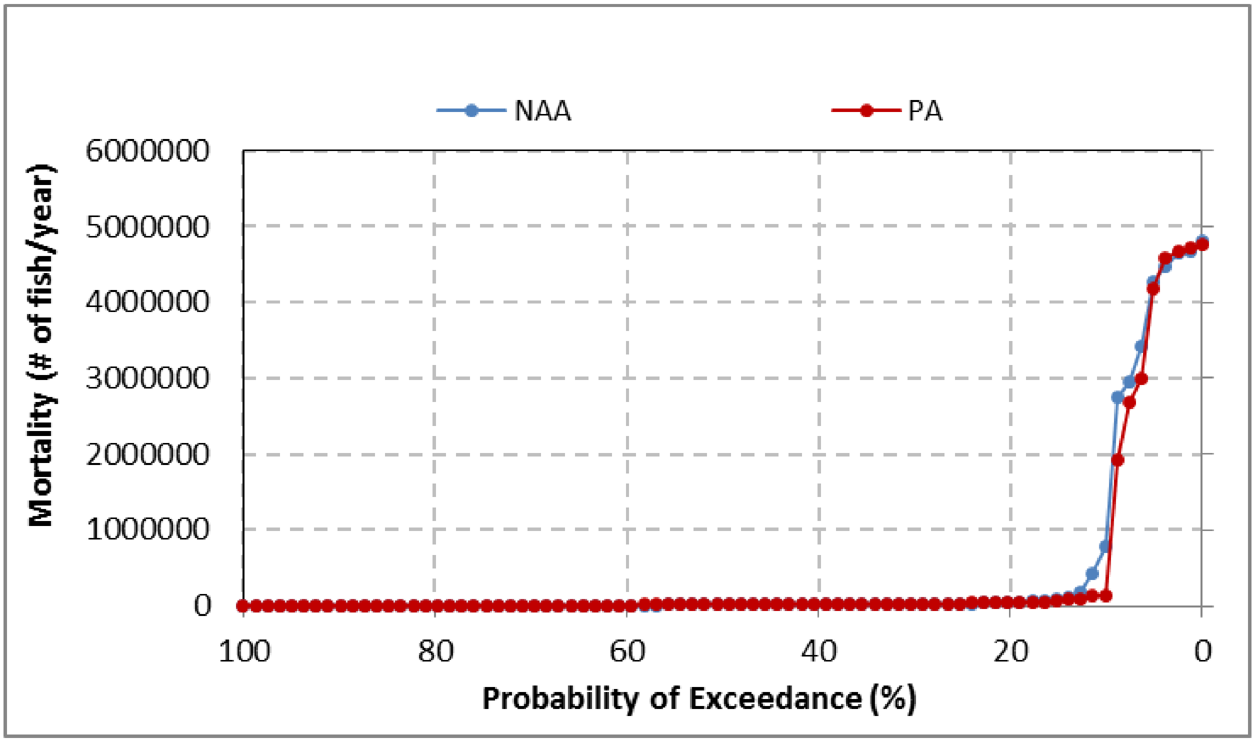

**Figure 4.3-54. Exceedance Plot of Annual Water Temperature-Based Mortality (#of Fish/Year) of Winter-Run Chinook Salmon Spawning, Egg Incubation, and Alevins.**

### *4.3.4.2.1.2.2 Fry and Juvenile Rearing*

#### *4.3.4.2.1.2.2.1 Flow-Related Effects*

As discussed in *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale* (ICF International [2016], 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 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, 2015, Cramer Fish Sciences 2014, National Marine Fisheries Service 2009, U.S. 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, U.S. 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 *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale* (ICF International 2016, 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 PP, and, therefore, it is expected that the juvenile stranding risk would be similar for the PP and the NAA.

Estimated mean monthly flow rates and reservoir storage volumes were examined for the PP 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 4.3-19; ICF International [2016], Appendix 5.A *CalSim II Modeling and Results,* Table 5.A.6-10 and Table 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 PP would be similar (less than 5% difference) to storage under the NAA for all water year types (ICF International [2016], Appendix 5.A *CalSim II Modeling and Results,* Table 5.A.6-3). Mean Shasta September storage under the PP 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 PP.

During most months and water year types of the rearing period, mean flow under the PP 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 PP than under the NAA during November of all water year types except critical water years, with 26% lower flows under the PP than under the NAA for wet and above normal water year types at Keswick Dam and 21% lower flows at Red Bluff (ICF International [2016], Appendix 5.A *CalSim II Modeling and Results*, Table 5.A.6-10 and Table 5.A.6-35). Flows under the PP 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 PP 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 PP 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 4.3.4.2.2 *Summary of Upstream Effects*.

Rearing weighted usable area (WUA) provides an index of rearing habitat availability that takes into consideration 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 (ICF International [2016], 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 PP 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 PP and the NAA for the midpoint of each segment during each month of the winter-run fry and juvenile rearing periods (ICF International [2016], 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 *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale* (ICF International [2016], Appendix 5.D, Section 5.D.2.3 *Rearing Flows Methods*).

Differences between the PP 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 4.3-54–Figure 4.3-71) and juvenile (Figure 4.3-72–Figure 4.3-89) rearing periods in each of the river segments for each water year type and all water year types combined. The PP 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 4.3-54, Figure 4.3-60, Figure 4.3-66, Figure 4.3-72, and Figure 4.3-78), but for Segment 4, the juvenile exceedance curve for the PP is slightly higher than the NAA curve (Figure 4.3-84). With the curves broken out by water year type, reductions in fry rearing WUA under the PP are evident in Segment 6 during critical water years (Figure 4.3-59) and Segment 5 during below normal years (Figure 4.3-63), while reductions in juvenile rearing WUA under the PP are seen in Segment 6 in above normal years (Figure 4.3-74). Increases in juvenile rearing WUA under the PP are evident in Segment 4 during wet and above normal years (Figure 4.3-85 and Figure 4.3-86) and both increases and reductions in juvenile rearing WUA can be seen in Segment 5 during below normal years (Figure 4.3-81). The WUA modeling indicates that the PP 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 4.3.4.2.2, *Summary of Upstream Effects*.

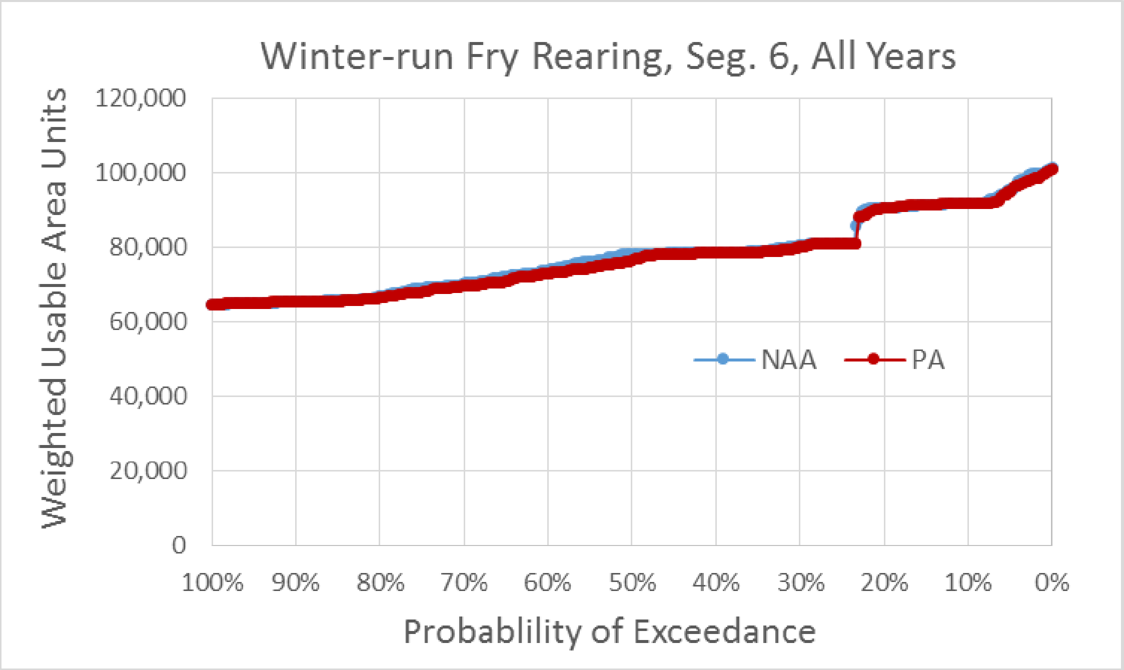

**Figure 4.3-55. Exceedance Plot of Winter-Run Chinook Salmon Fry Rearing Weighted Usable Area (WUA) for NAA and PP Model Scenarios in River Segment 6, All Water Years**

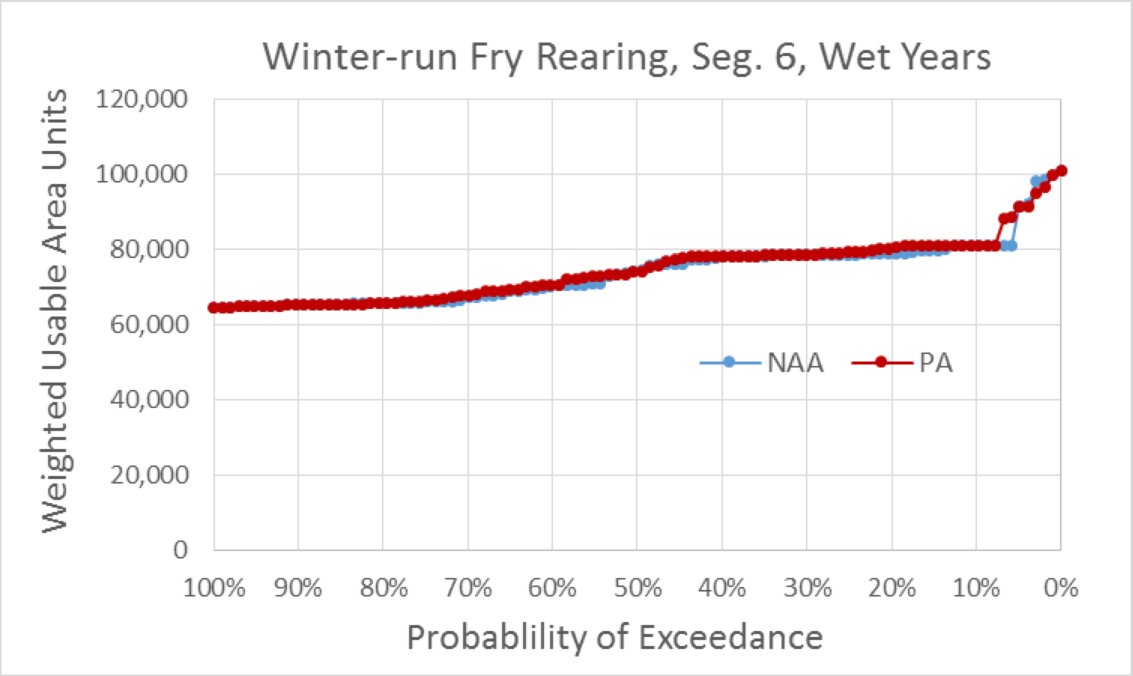

**Figure 4.3-56. Exceedance Plot of Winter-Run Chinook Salmon Fry Rearing Weighted Usable Area (WUA) for NAA and PP Model Scenarios in River Segment 6, Wet Water Years**

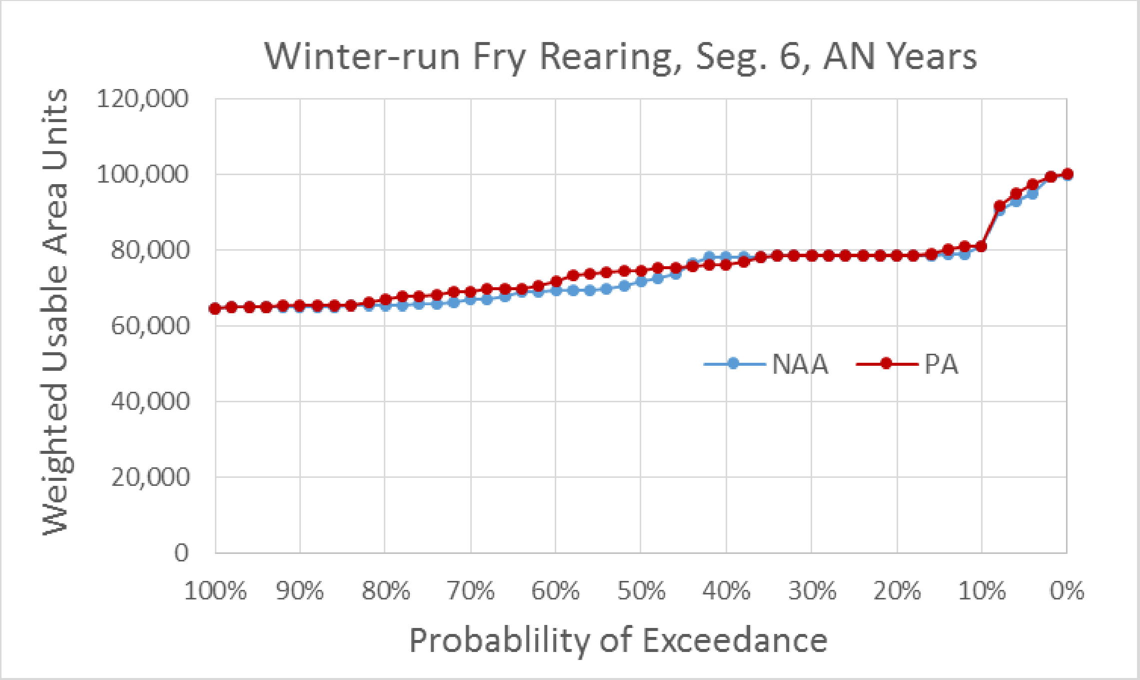

**Figure 4.3-57. Exceedance Plot of Winter-Run Chinook Salmon Fry Rearing Weighted Usable Area (WUA) for NAA and PP Model Scenarios in River Segment 6, Above Normal Water Years**

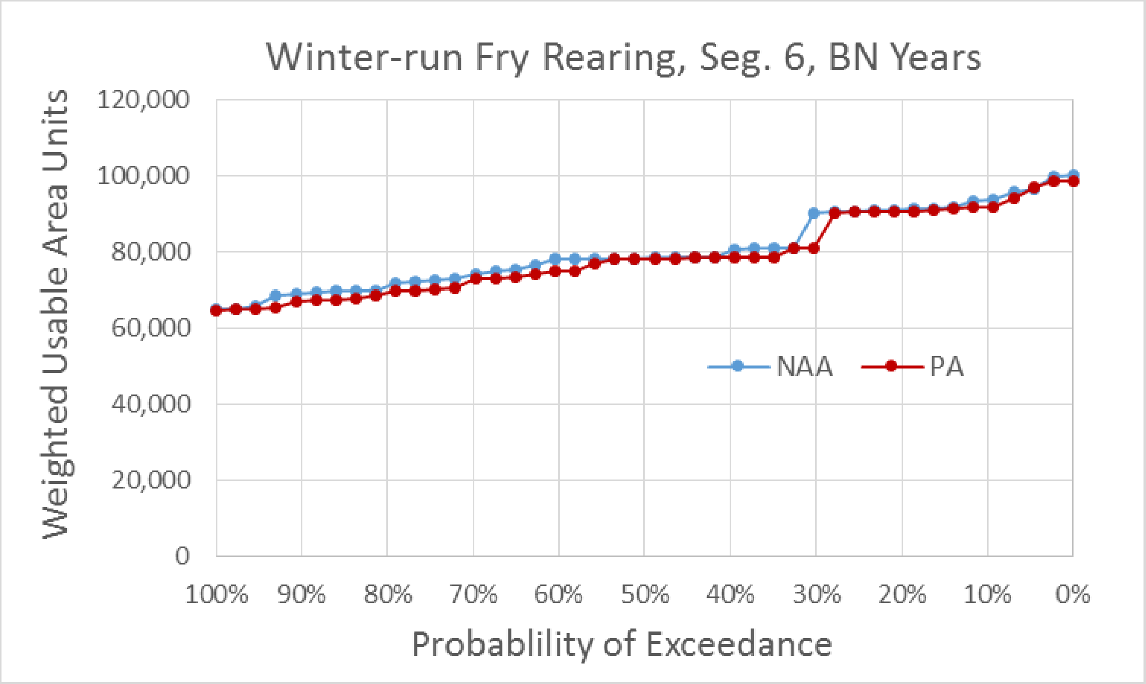

**Figure 4.3-58. Exceedance Plot of Winter-Run Chinook Salmon Fry Rearing Weighted Usable Area (WUA) for NAA and PP Model Scenarios in River Segment 6, Below Normal Water Years**

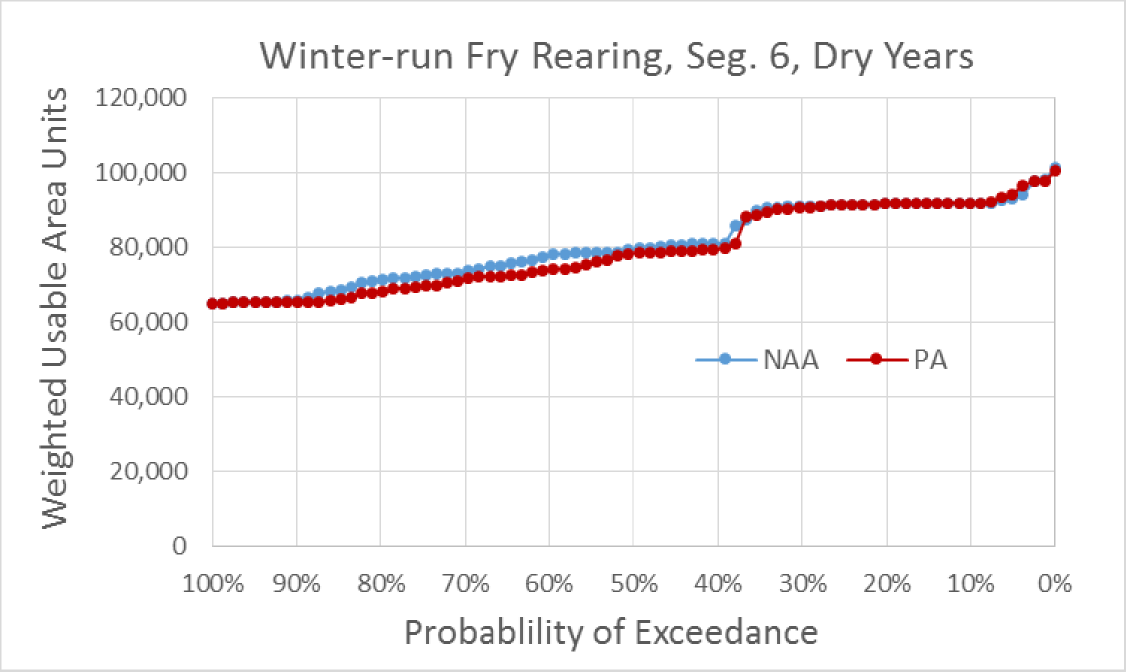

Figure 4.3-59.Exceedance Plot of Winter-Run Chinook Salmon Fry Rearing Weighted Usable Area (WUA) for NAA and PP Model Scenarios in River Segment 6, Dry Water Years

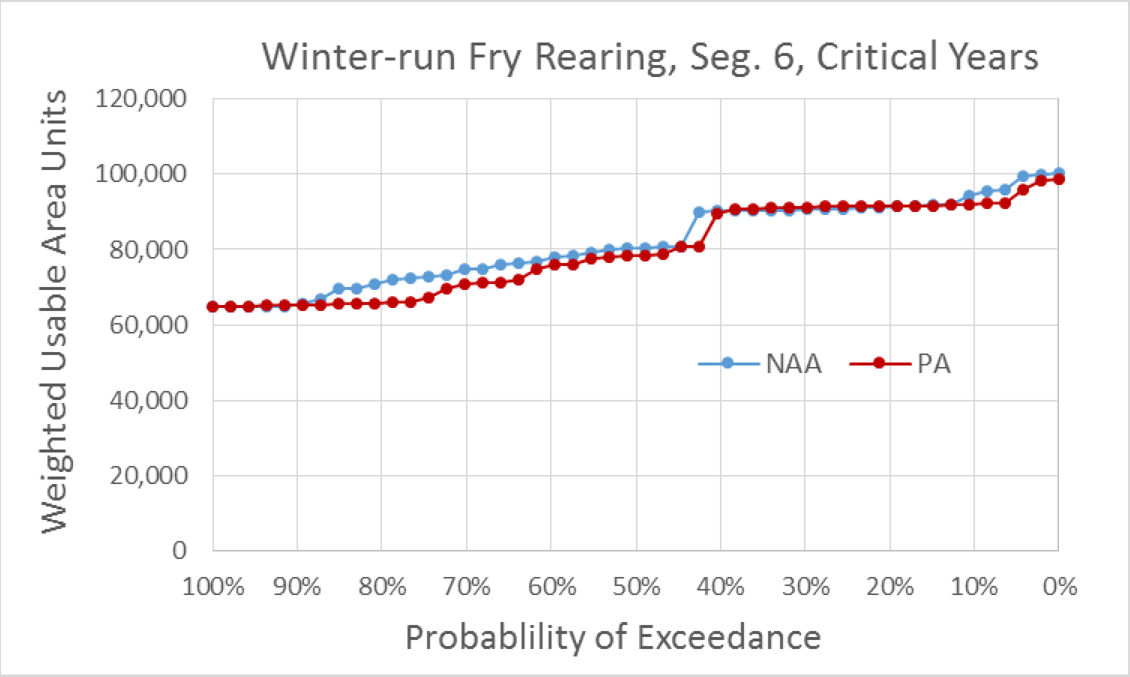

Figure 4.3-60. Exceedance Plot of Winter-Run Chinook Salmon Fry Rearing Weighted Usable Area (WUA) for NAA and PP Model Scenarios in River Segment 6, Critical Water Years

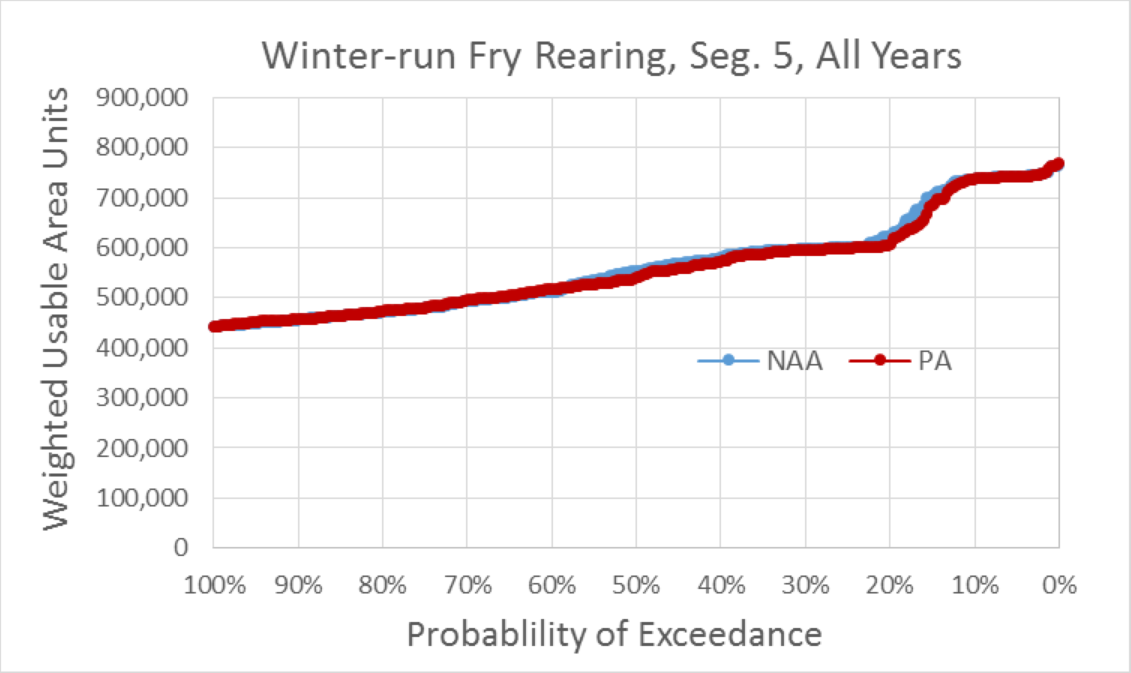

Figure 4.3-61. Exceedance Plot of Winter-Run Chinook Salmon Fry Rearing Weighted Usable Area (WUA) for NAA and PP Model Scenarios in River Segment 5, All Water Years

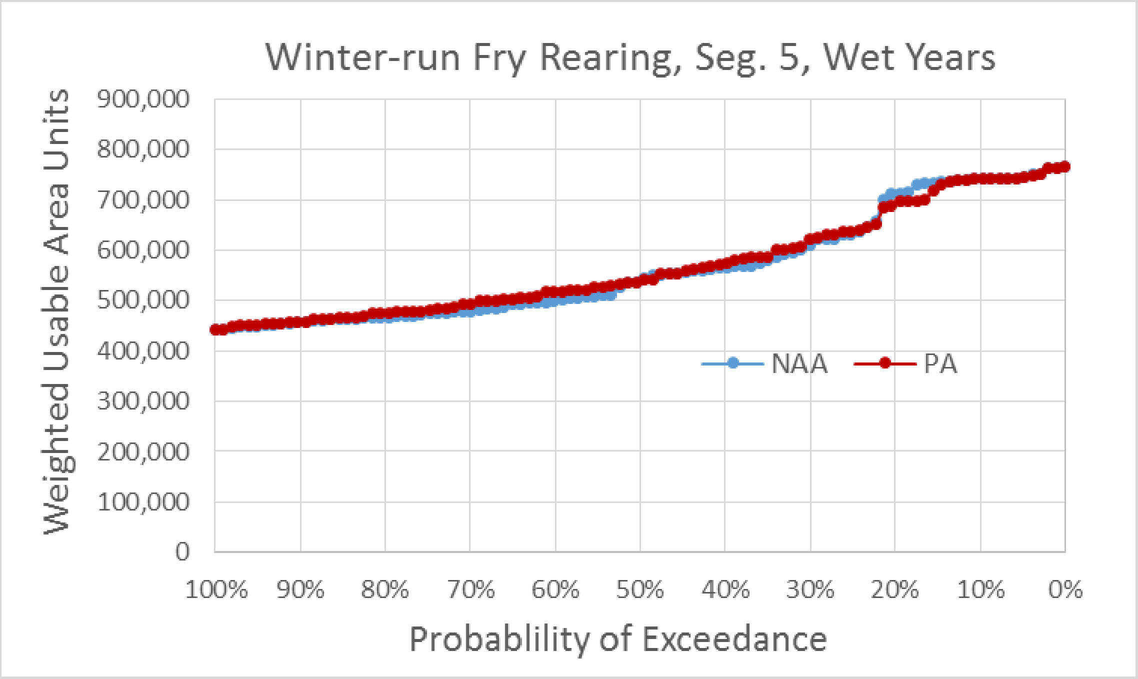

Figure 4.3-62. Exceedance Plot of Winter-Run Chinook Salmon Fry Rearing Weighted Usable Area (WUA) for NAA and PP Model Scenarios in River Segment 5, Wet Water Years.

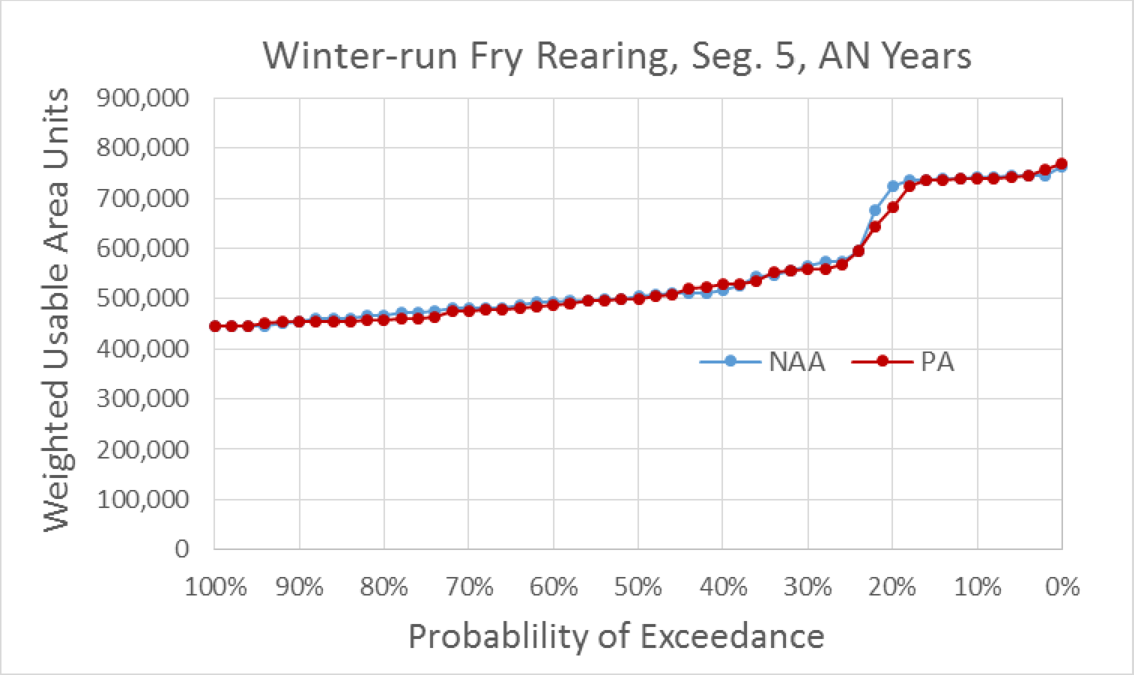

Figure 4.3-63.Exceedance Plot of Winter-Run Chinook Salmon Fry Rearing Weighted Usable Area (WUA) for NAA and PP Model Scenarios in River Segment 5, Above Normal Water Years

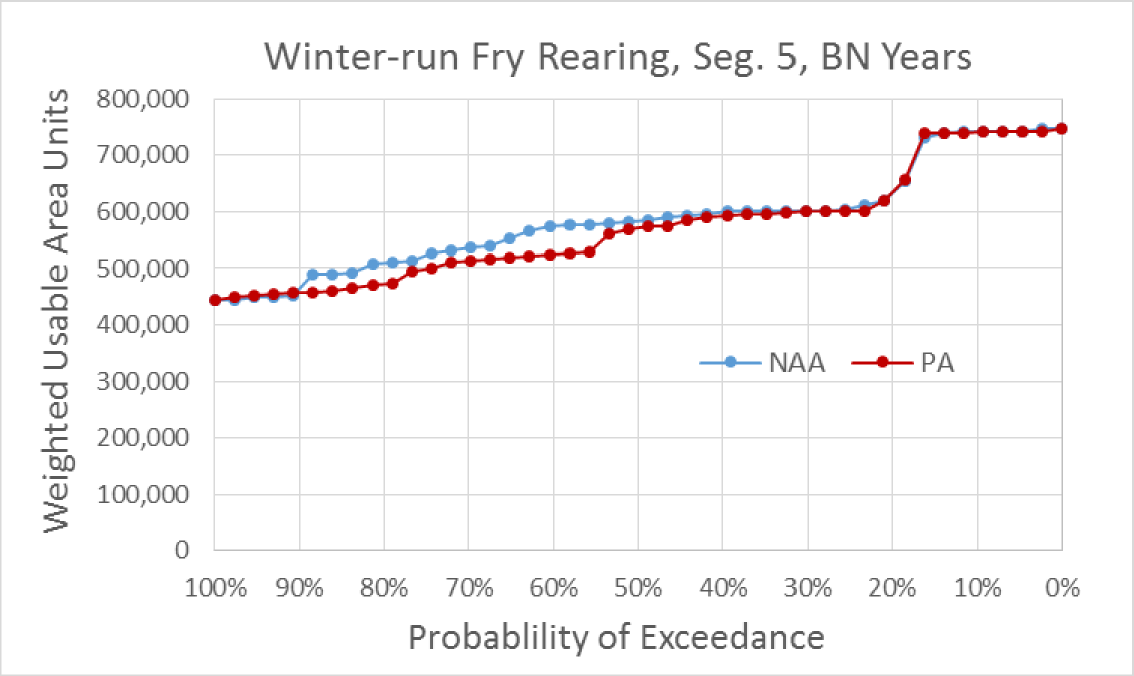

Figure 4.3-64. Exceedance Plot of Winter-Run Chinook Salmon Fry Rearing Weighted Usable Area (WUA) for NAA and PP Model Scenarios in River Segment 5, Below Normal Water Years

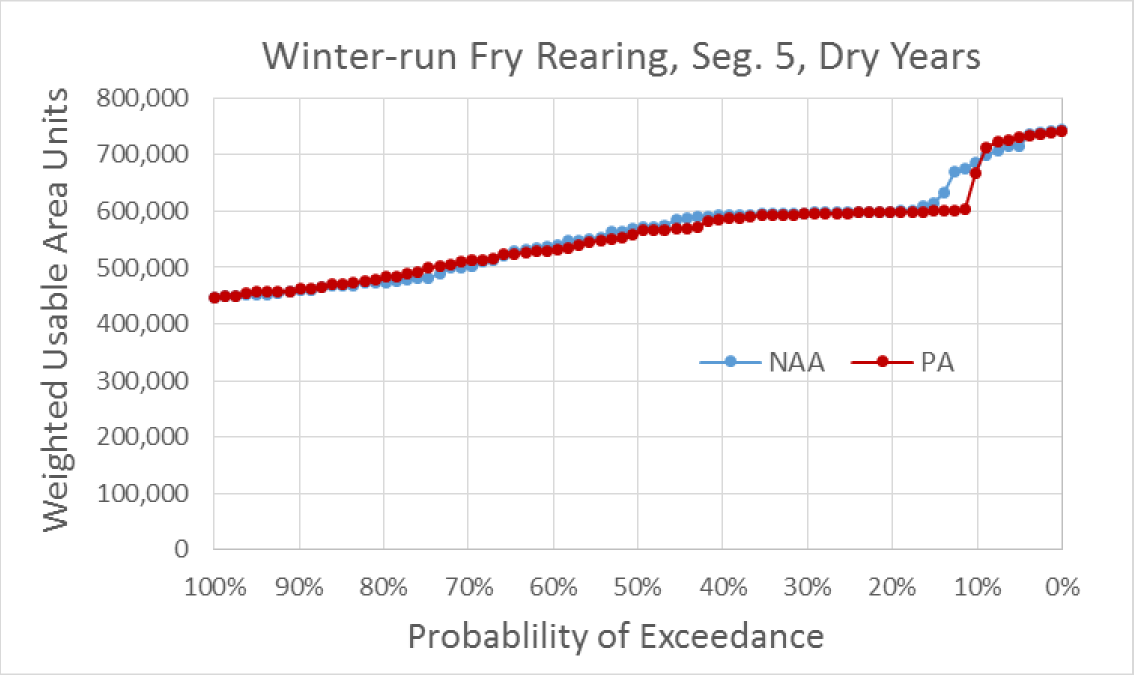

**Figure 4.3-65. Exceedance Plot of Winter-Run Chinook Salmon Fry Rearing Weighted Usable Area (WUA) for NAA and PP Model Scenarios in River Segment 5, Dry Water Years**

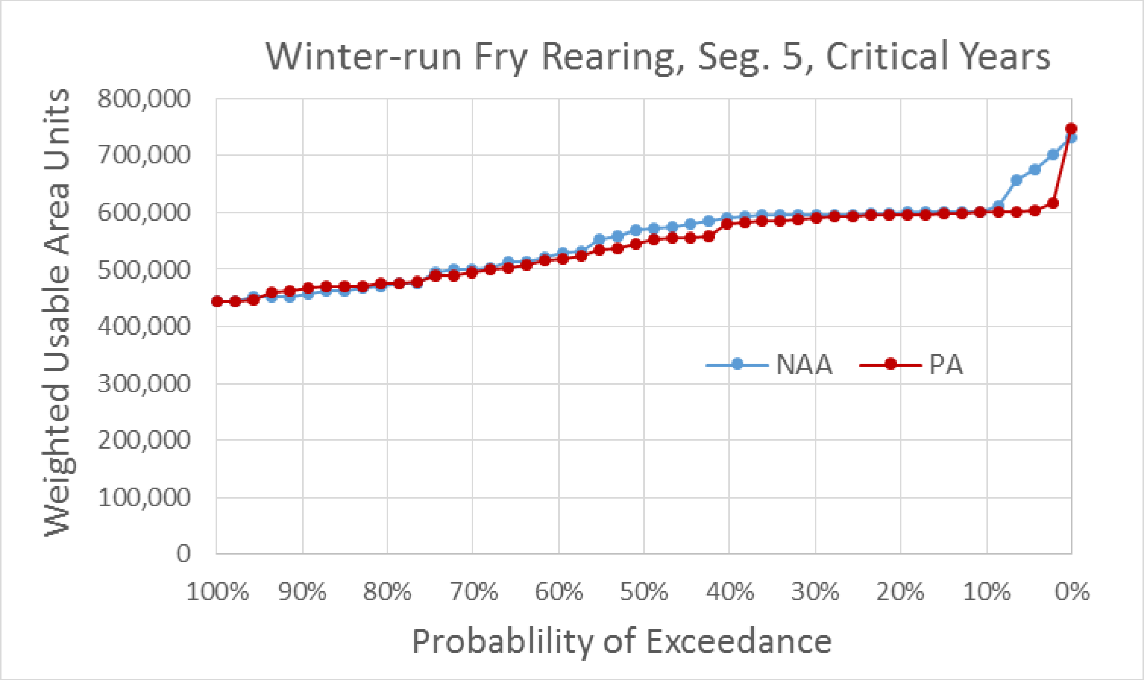

**Figure 4.3-66. Exceedance Plot of Winter-Run Chinook Salmon Fry Rearing Weighted Usable Area (WUA) for NAA and PP Model Scenarios in River Segment 5, Critical Water Years**

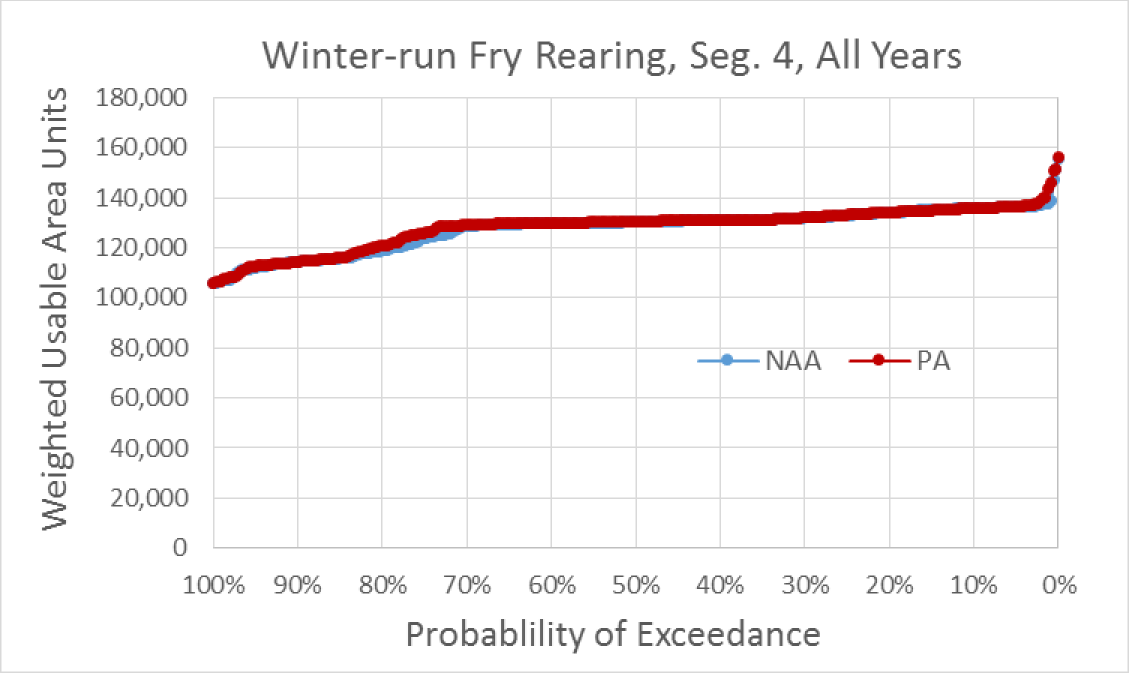

Figure 4.3-67. Exceedance Plot of Winter-Run Chinook Salmon Fry Rearing Weighted Usable Area (WUA) for NAA and PP Model Scenarios in River Segment 4, All Water Years

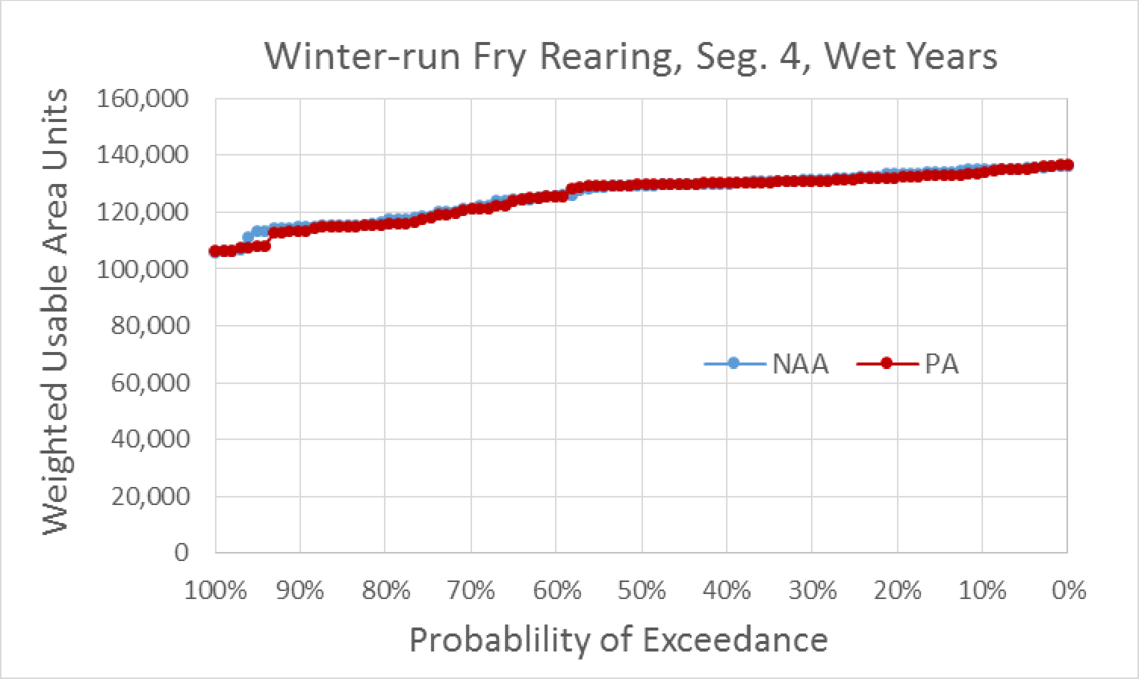

Figure 4.3-68. Exceedance Plot of Winter-Run Chinook Salmon Fry Rearing Weighted Usable Area (WUA) for NAA and PP Model Scenarios in River Segment 4, Wet Water Years

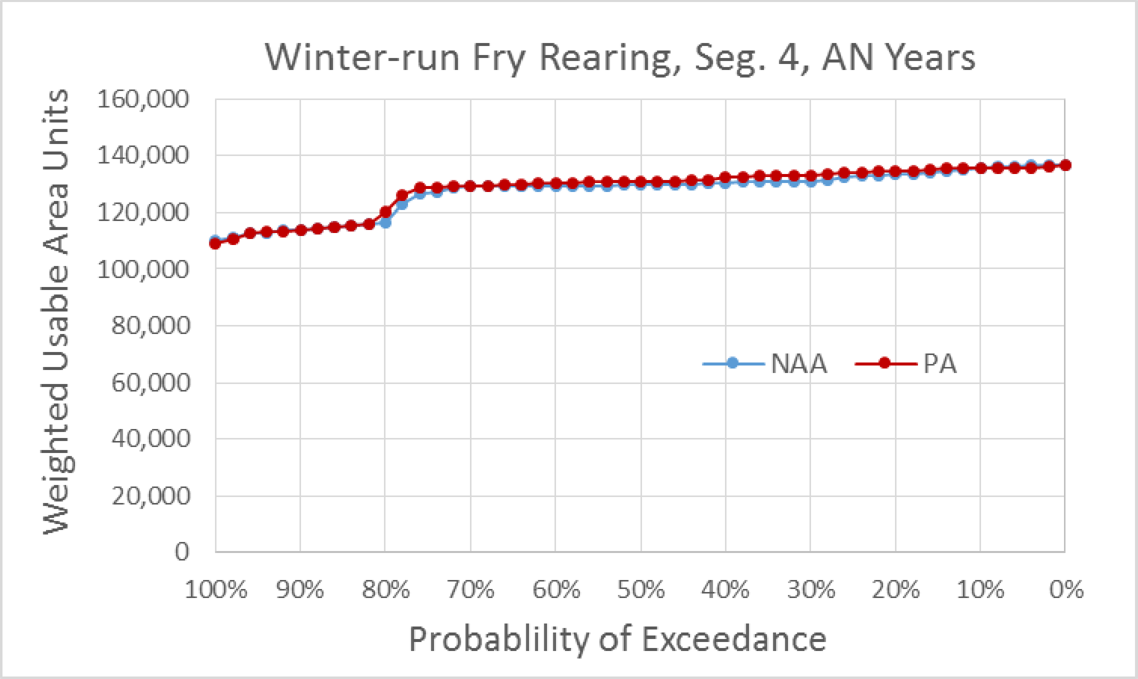

**Figure 4.3-69. Exceedance Plot of Winter-Run Chinook Salmon Fry Rearing Weighted Usable Area (WUA) for NAA and PP Model Scenarios in River Segment 4, Above Normal Water Years**

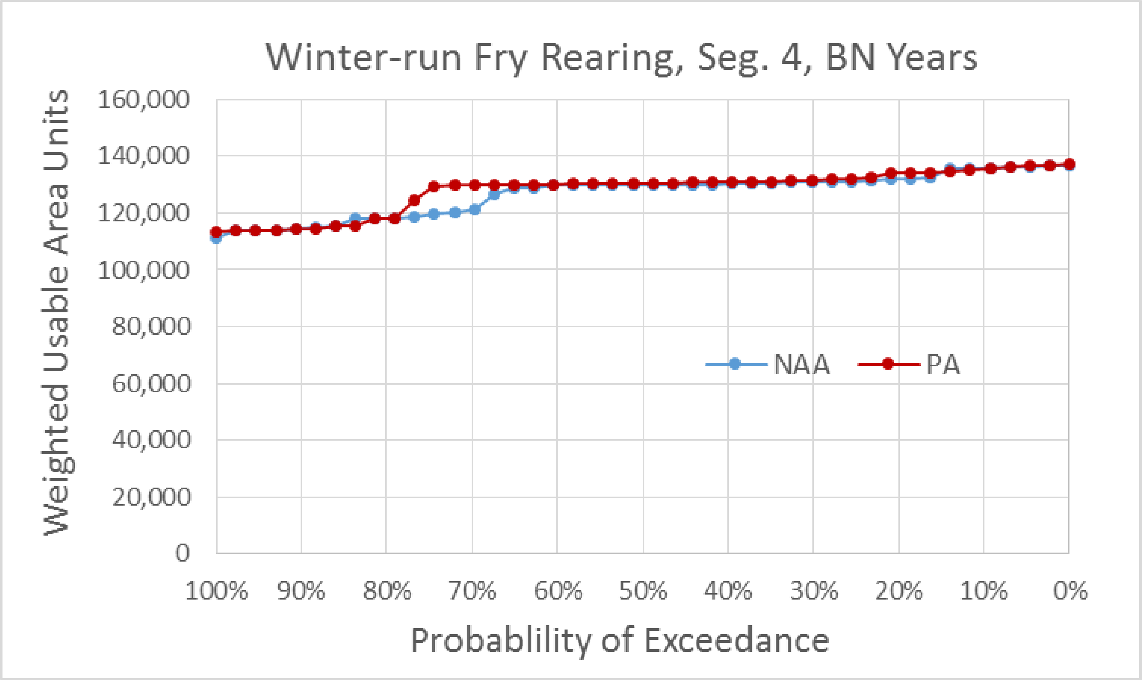

**Figure 4.3-70. Exceedance Plot of Winter-Run Chinook Salmon Fry Rearing Weighted Usable Area (WUA) for NAA and PP Model Scenarios in River Segment 4, Below Normal Water Years**

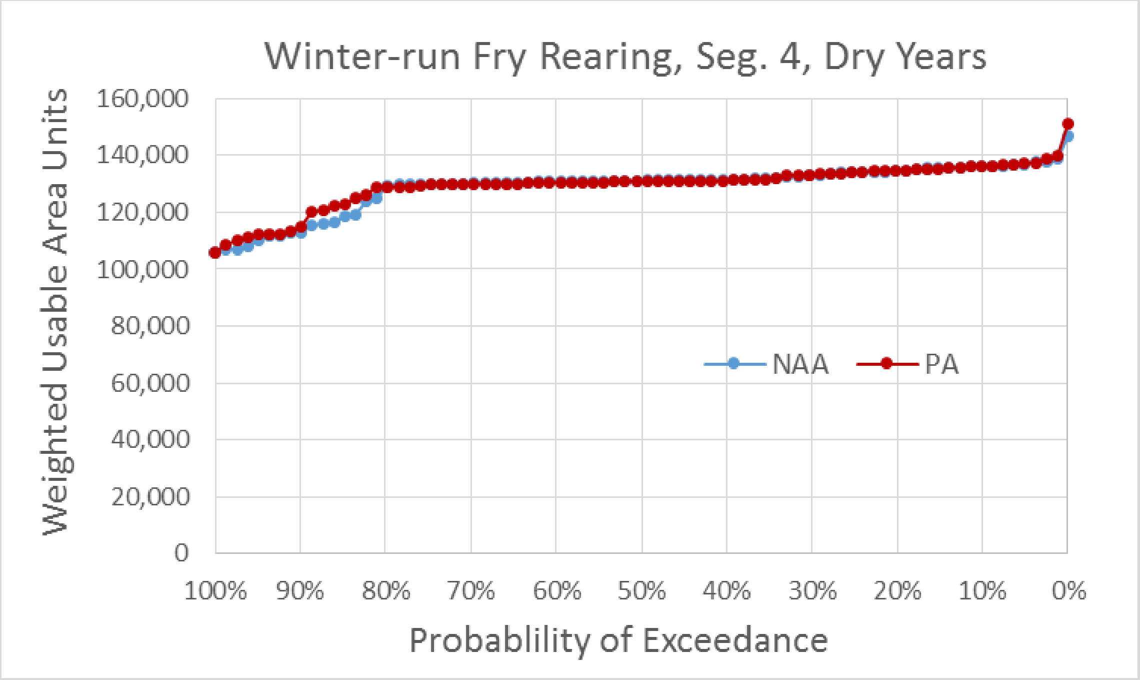

**Figure 4.3-71. Exceedance Plot of Winter-Run Chinook Salmon Fry Rearing Weighted Usable Area (WUA) for NAA and PP Model Scenarios in River Segment 4, Dry Water Years**

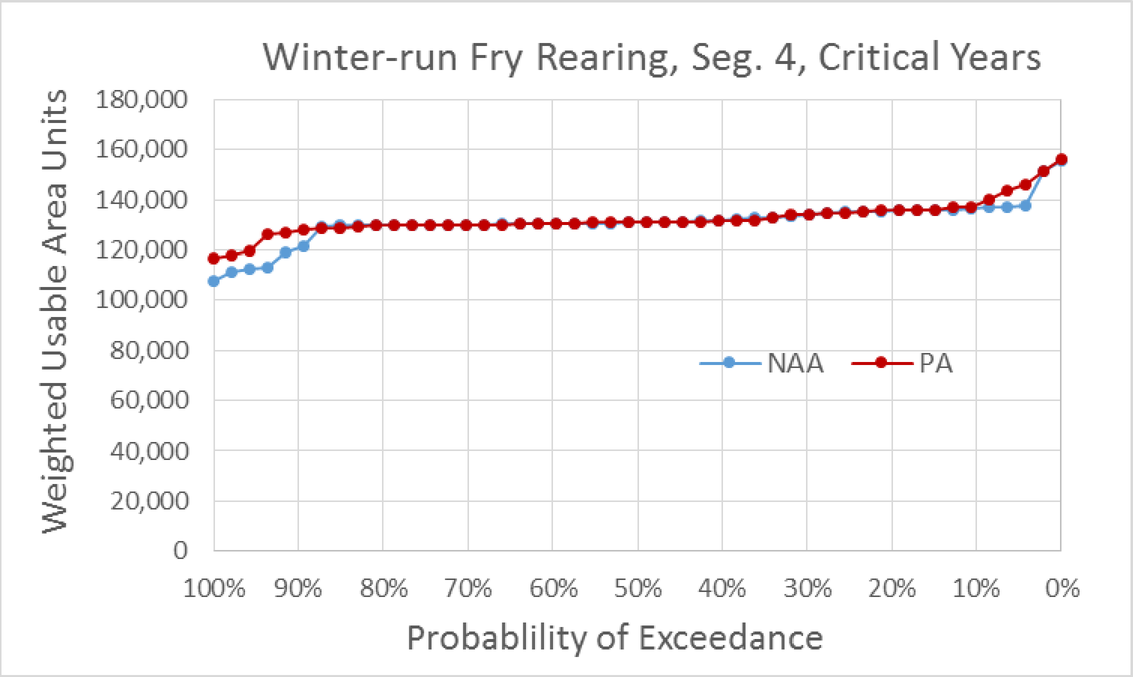

**Figure 4.3-72. Exceedance Plot of Winter-Run Chinook Salmon Fry Rearing Weighted Usable Area (WUA) for NAA and PP Model Scenarios in River Segment 4, Critical Water Years**

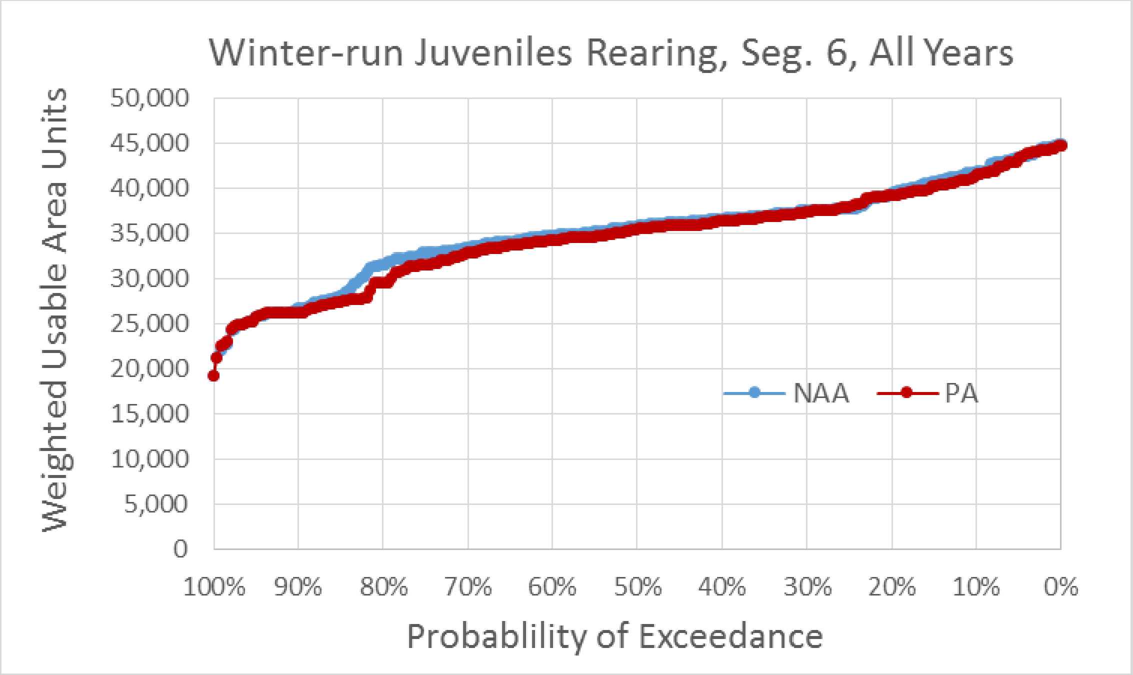

Figure 4.3-73. Exceedance Plot of Winter-Run Chinook Salmon Juvenile Rearing Weighted Usable Area (WUA) for NAA and PP Model Scenarios in River Segment 6, All Water Years

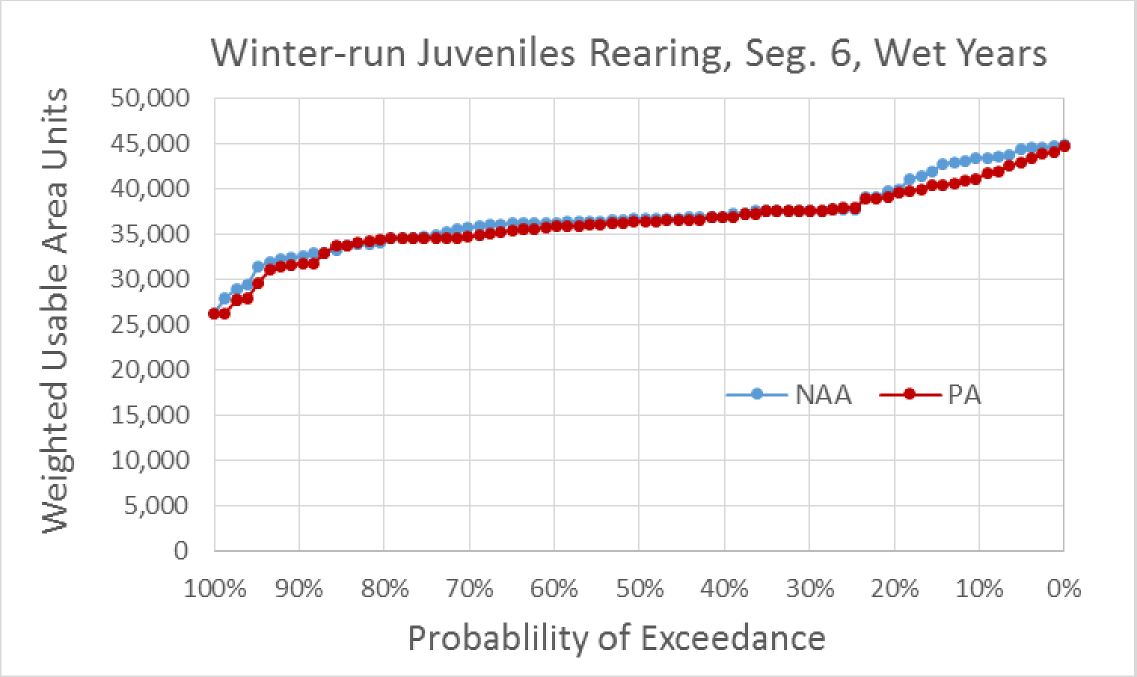

Figure 4.3-74. Exceedance Plot of Winter-Run Chinook Salmon Juvenile Rearing Weighted Usable Area (WUA) for NAA and PP Model Scenarios in River Segment 6, Wet Water Years

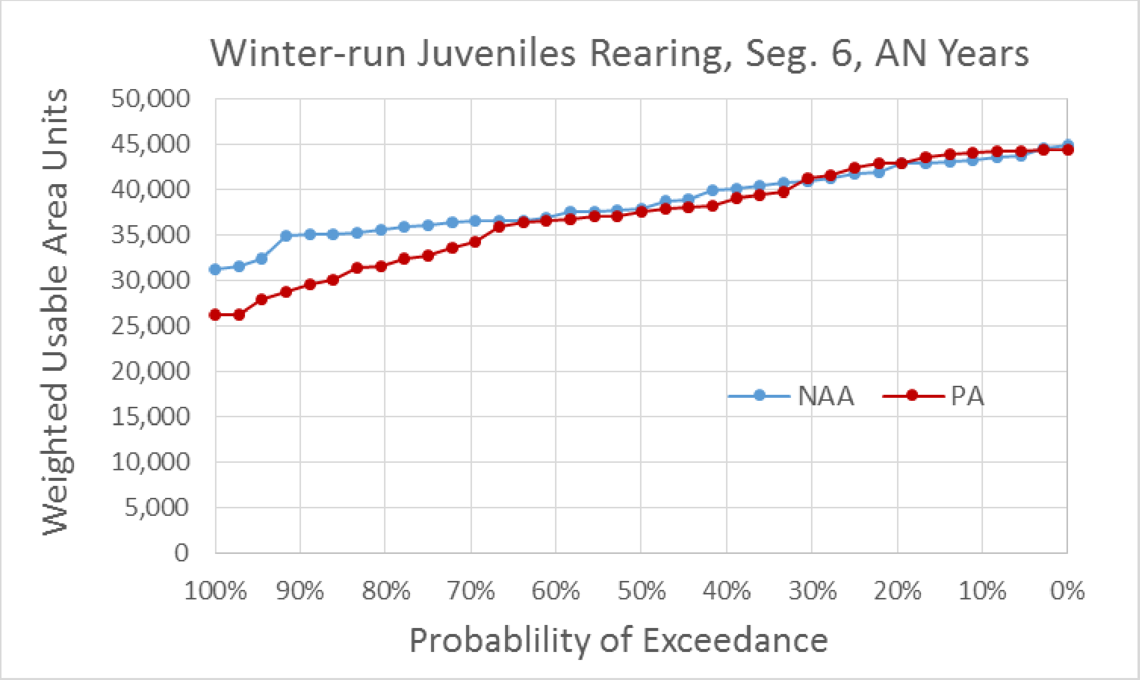

**Figure 4.3-75. Exceedance Plot of Winter-Run Chinook Salmon Juvenile Rearing Weighted Usable Area (WUA) for NAA and PP Model Scenarios in River Segment 6, Above Normal Water Years**

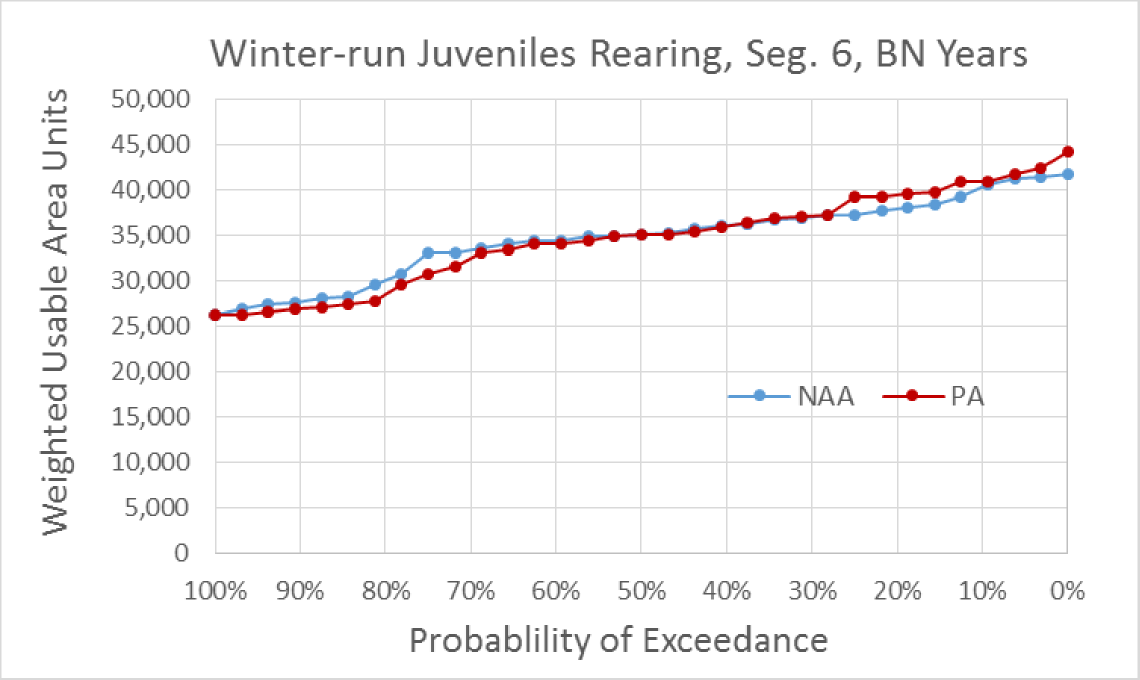

**Figure 4.3-76. Exceedance Plot of Winter-Run Chinook Salmon Juvenile Rearing Weighted Usable Area (WUA) for NAA and PP Model Scenarios in River Segment 6, Below Normal Water Years**

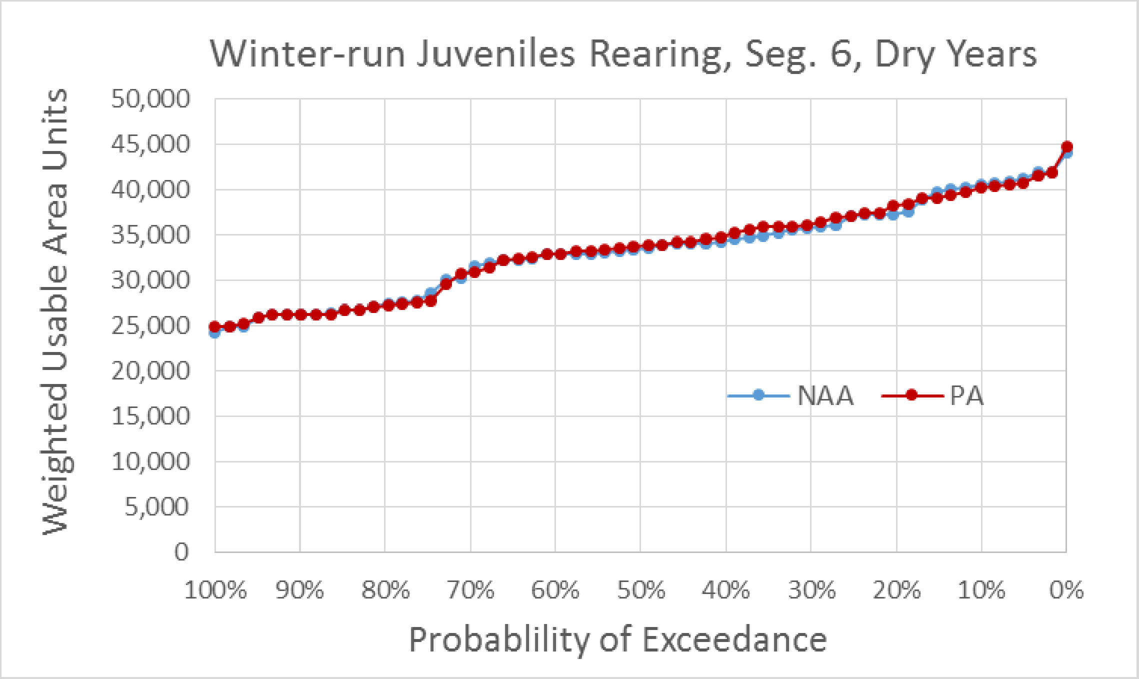

**Figure 4.3-77. Exceedance Plot of Winter-Run Chinook Salmon Juvenile Rearing Weighted Usable Area (WUA) for NAA and PP Model Scenarios in River Segment 6, Dry Water Years**

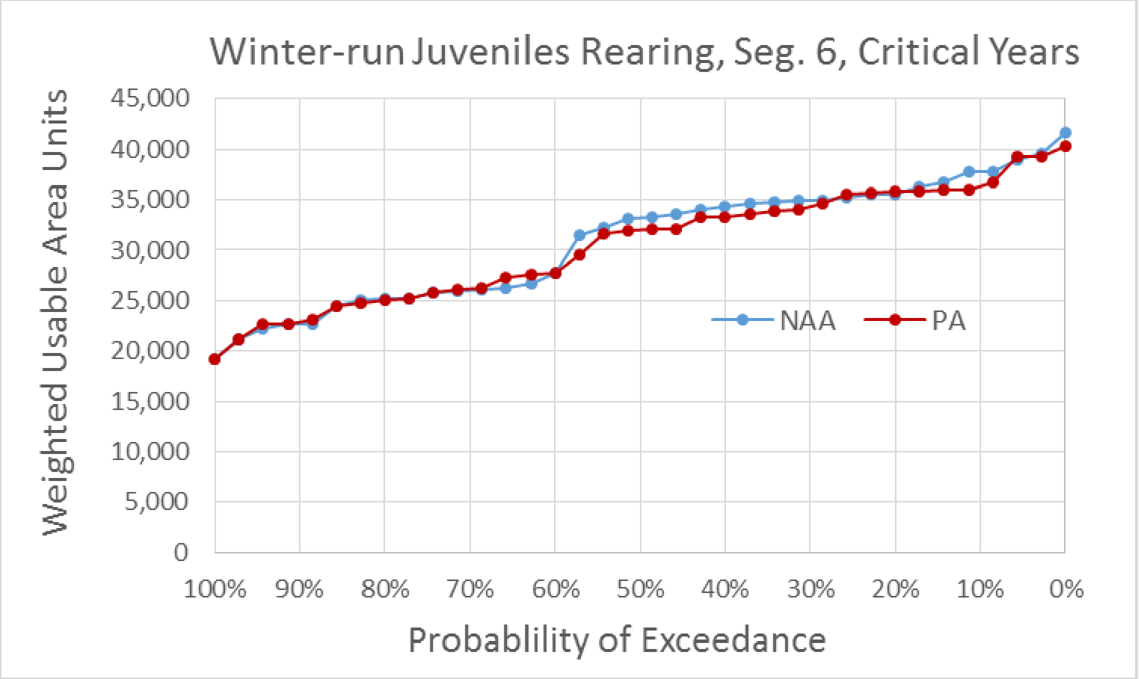

**Figure 4.3-78. Exceedance Plot of Winter-Run Chinook Salmon Juvenile Rearing Weighted Usable Area (WUA) for NAA and PP Model Scenarios in River Segment 6, Critical Water Years**

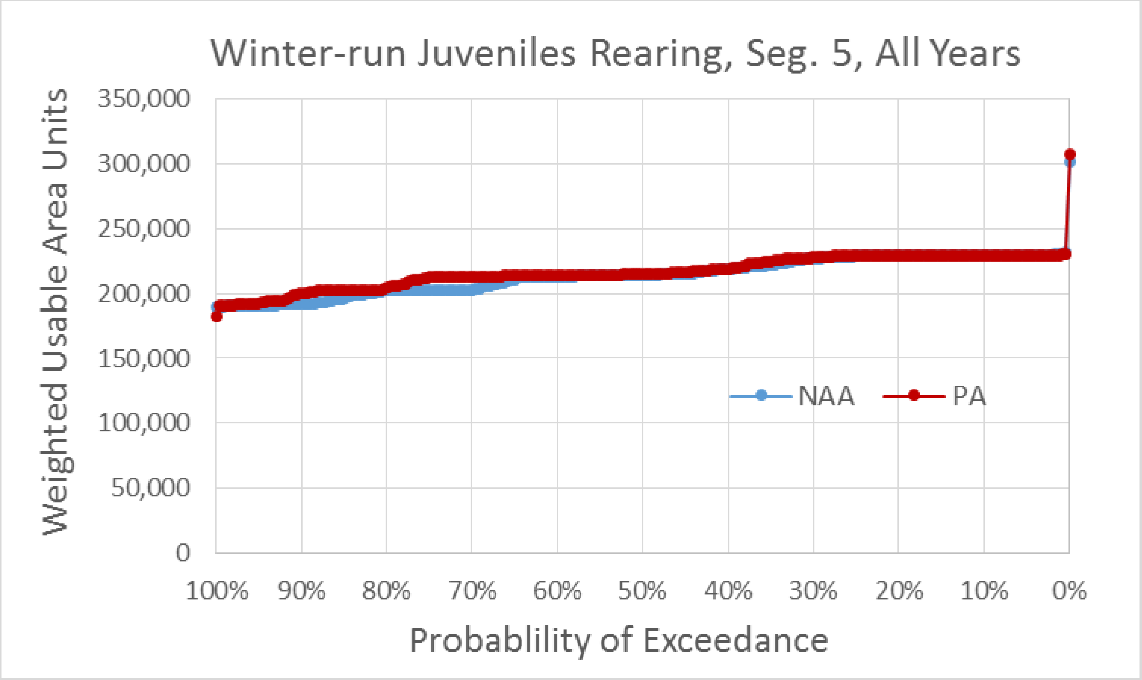

**Figure 4.3-79. Exceedance Plot of Winter-Run Chinook Salmon Juvenile Rearing Weighted Usable Area (WUA) for NAA and PP Model Scenarios in River Segment 5, All Water Years**

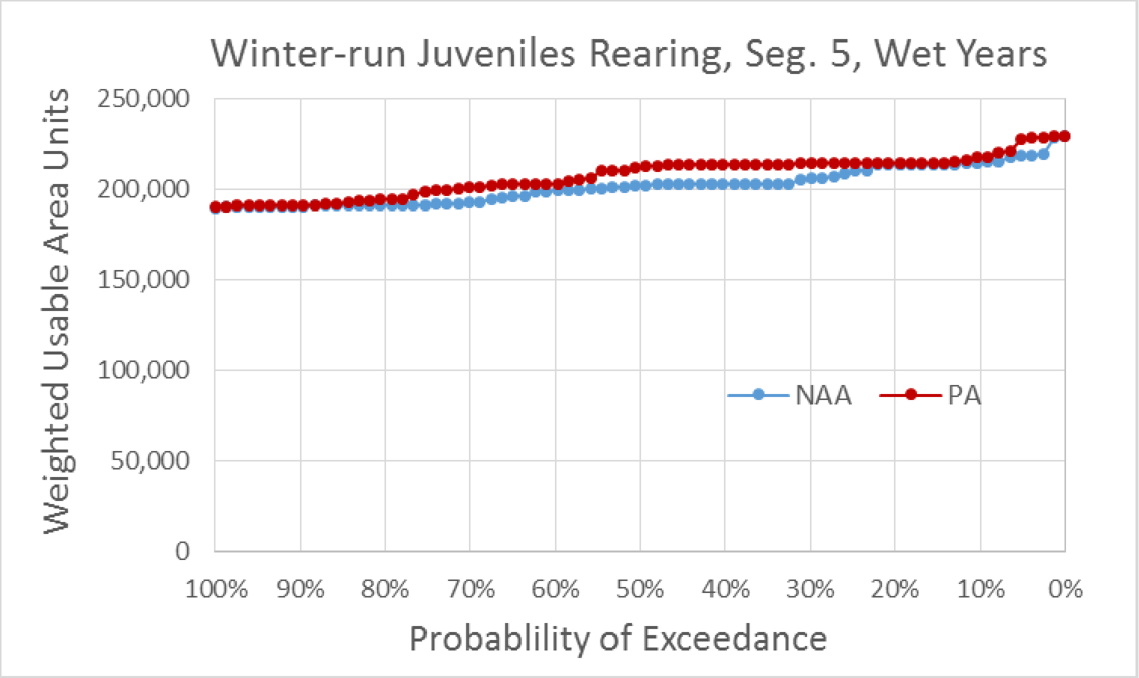

**Figure 4.3-80. Exceedance Plot of Winter-Run Chinook Salmon Juvenile Rearing Weighted Usable Area (WUA) for NAA and PP Model Scenarios in River Segment 5, Wet Water Years**

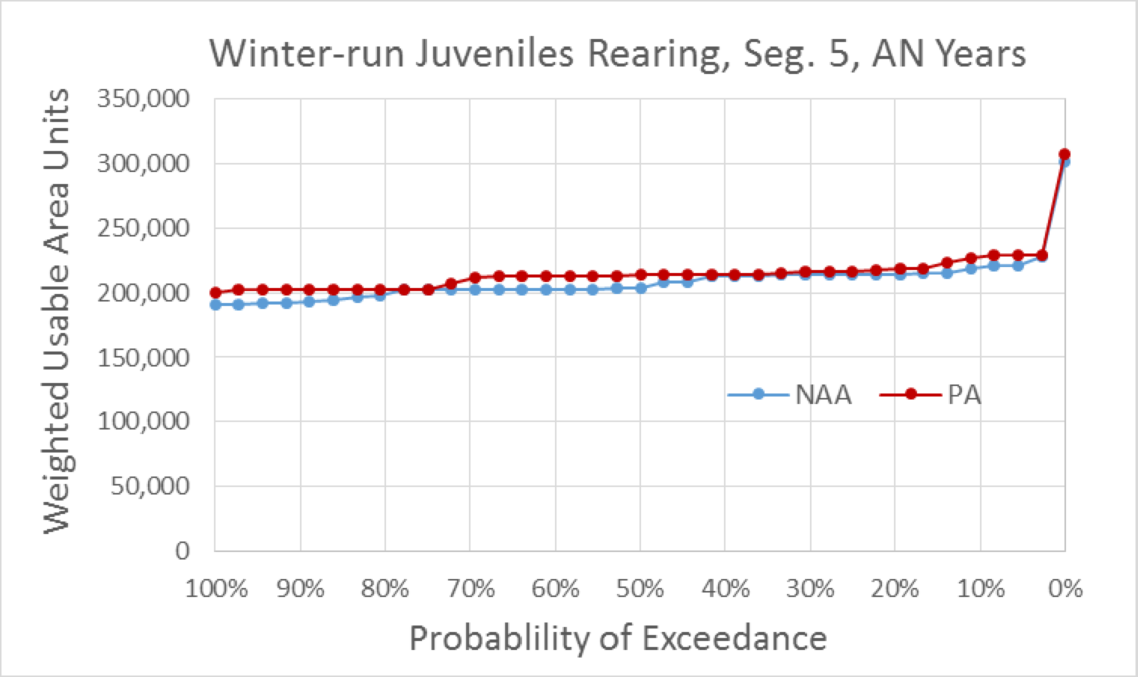

Figure 4.3-81. Exceedance Plot of Winter-Run Chinook Salmon Juvenile Rearing Weighted Usable Area (WUA) for NAA and PP Model Scenarios in River Segment 5, Above Normal Water Years

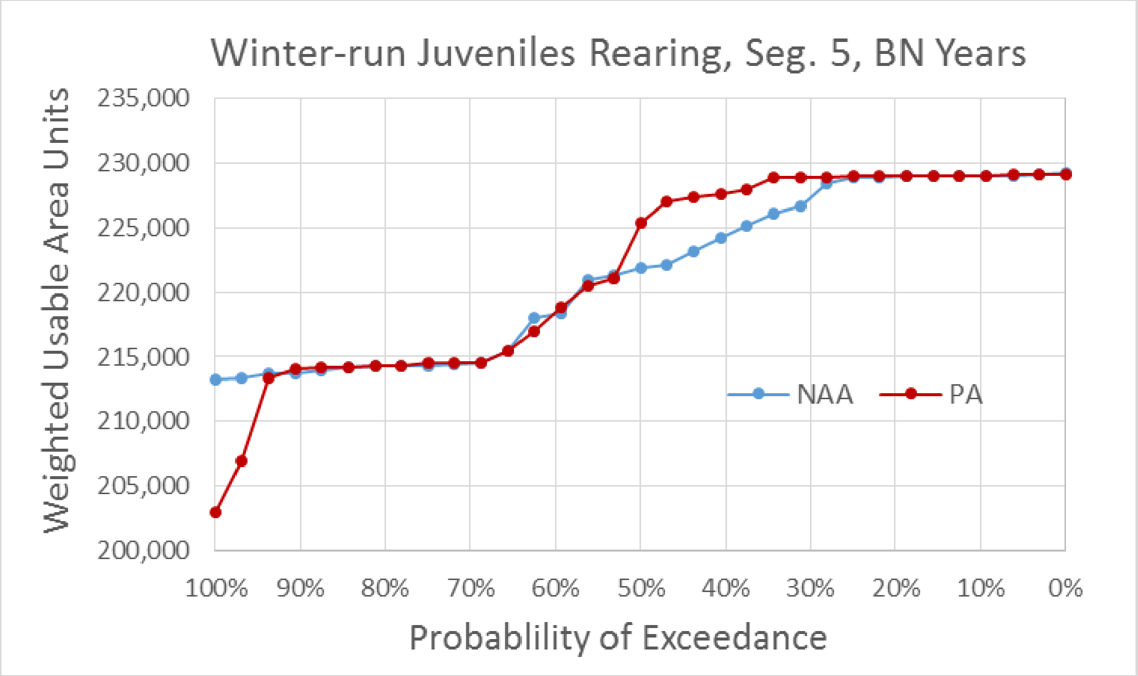

Figure 4.3-82.Exceedance Plot of Winter-Run Chinook Salmon Juvenile Rearing Weighted Usable Area (WUA) for NAA and PP Model Scenarios in River Segment 5, Below Normal Water Years

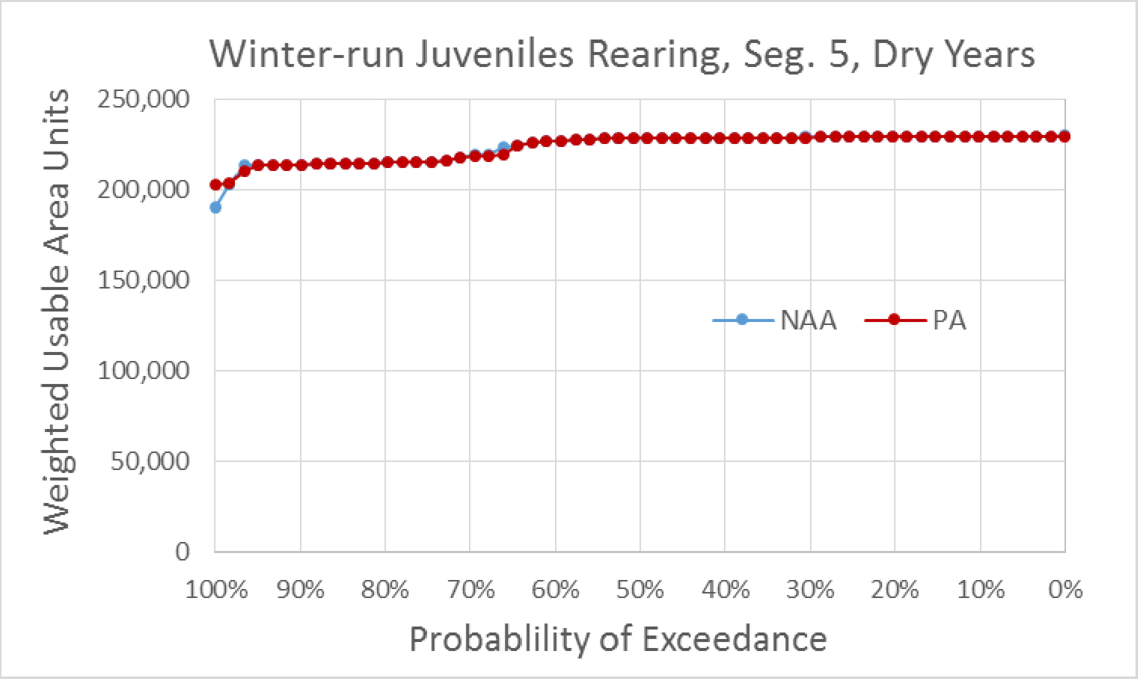

Figure 4.3-83.Exceedance Plot of Winter-Run Chinook Salmon Juvenile Rearing Weighted Usable Area (WUA) for NAA and PP Model Scenarios in River Segment 5, Dry Water Years

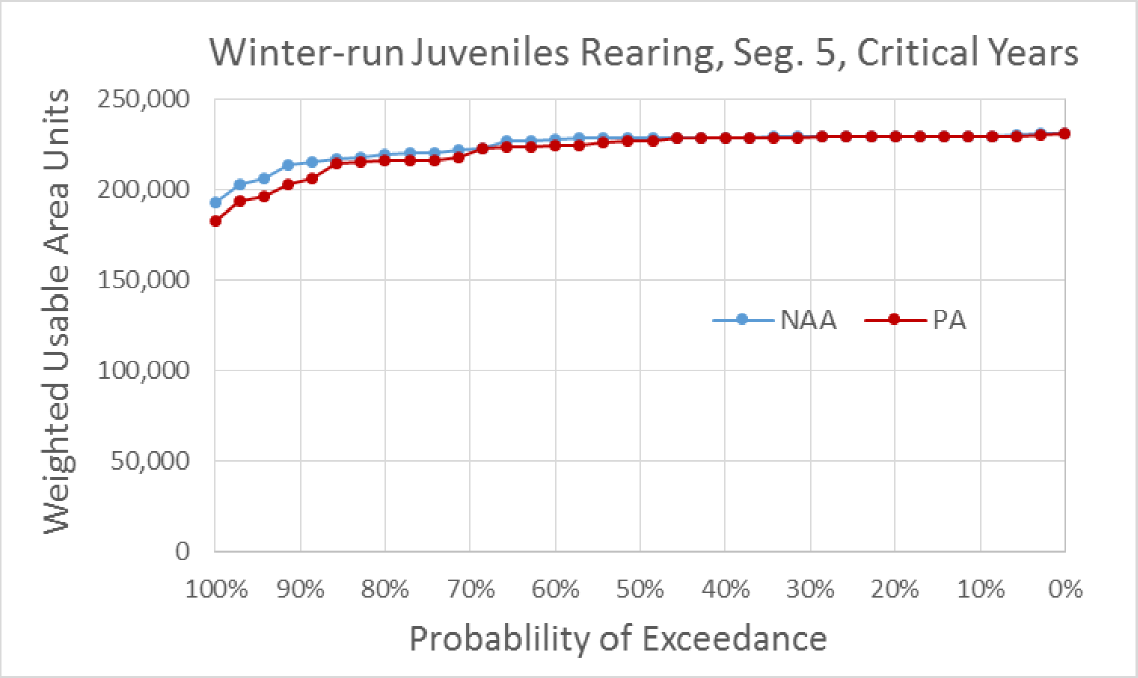

Figure 4.3-84. Exceedance Plot of Winter-Run Chinook Salmon Juvenile Rearing Weighted Usable Area (WUA) for NAA and PP Model Scenarios in River Segment 5, Critical Water Years

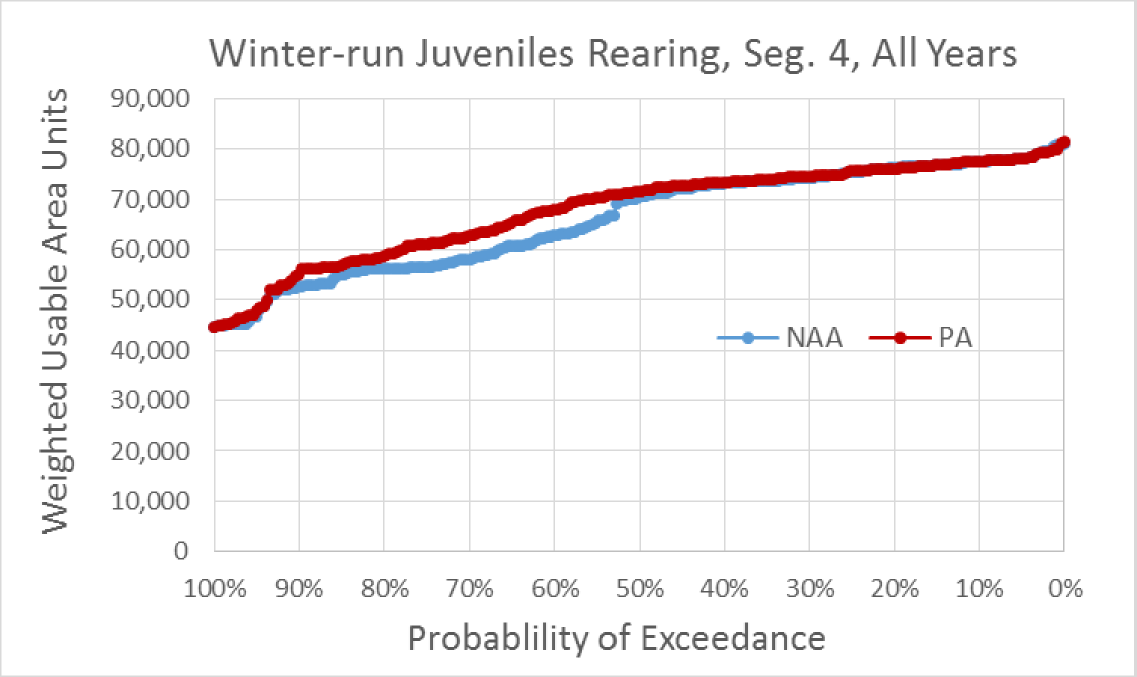

Figure 4.3-85. Exceedance Plot of Winter-Run Chinook Salmon Juvenile Rearing Weighted Usable Area (WUA) for NAA and PP Model Scenarios in River Segment 4, All Water Years

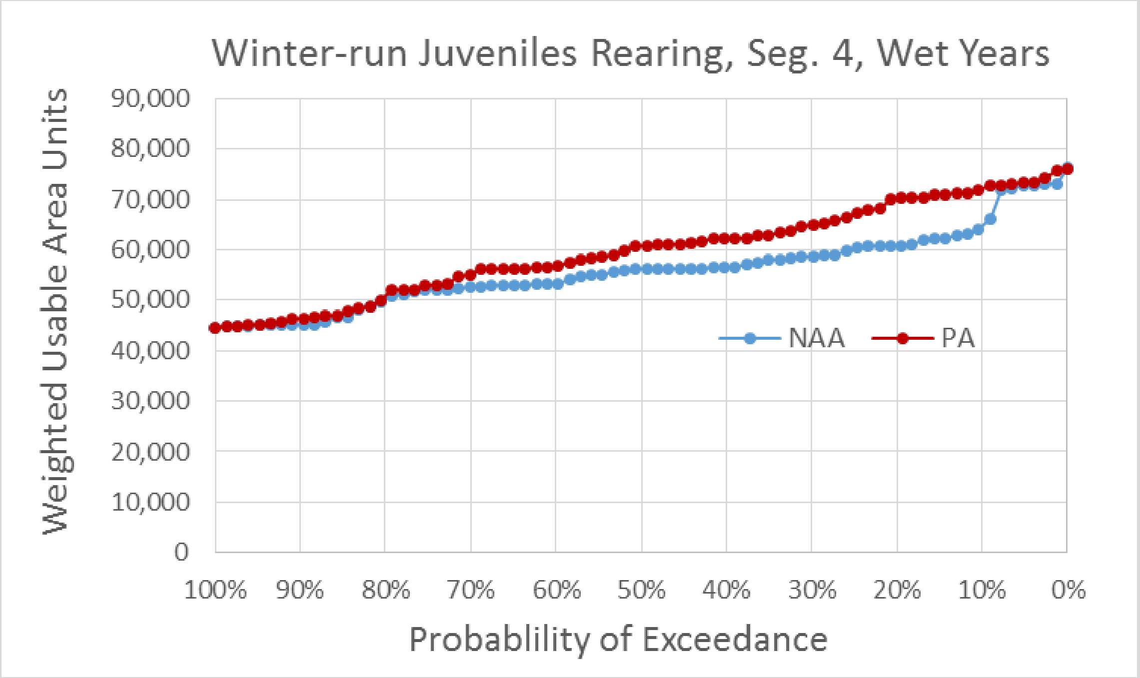

Figure 4.3-86. Exceedance Plot of Winter-Run Chinook Salmon Juvenile Rearing Weighted Usable Area (WUA) for NAA and PP Model Scenarios in River Segment 4, Wet Water Years

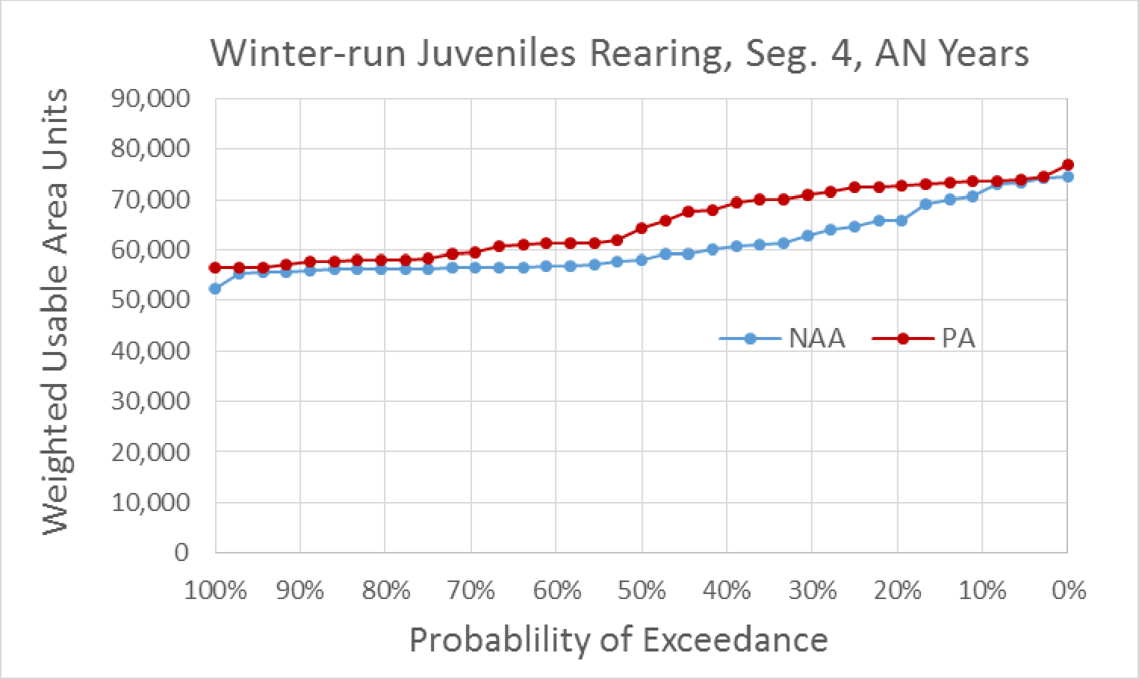

Figure 4.3-87. Exceedance Plot of Winter-Run Chinook Salmon Juvenile Rearing Weighted Usable Area (WUA) for NAA and PP Model Scenarios in River Segment 4, Above Normal Water Years

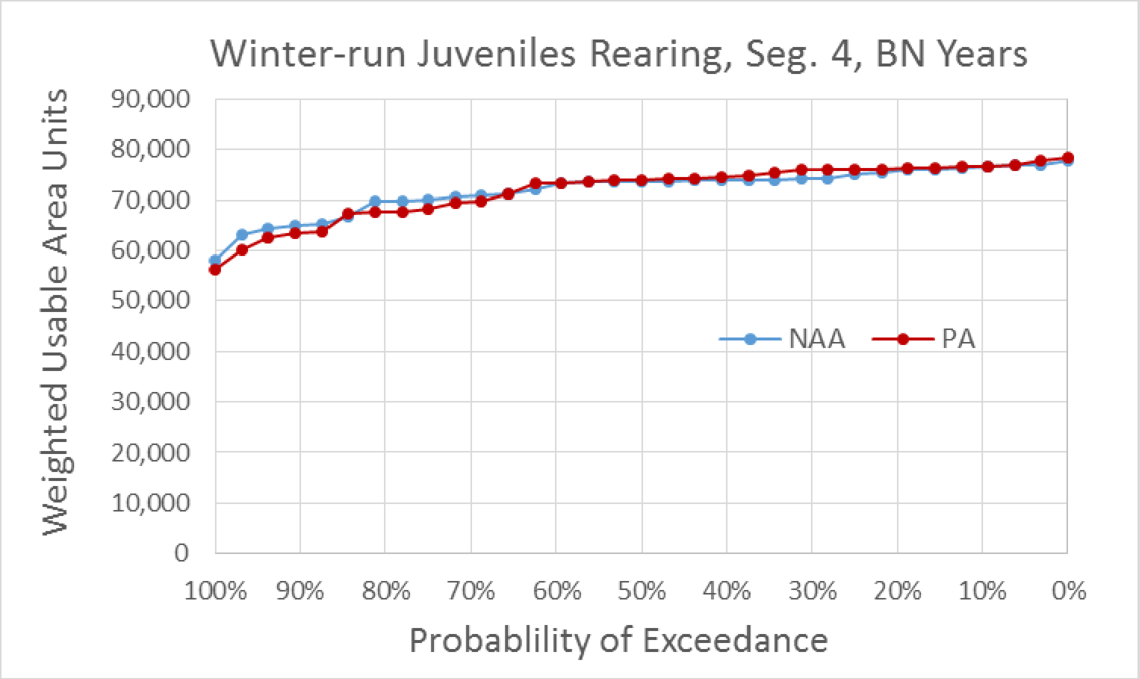

Figure 4.3-88. Exceedance Plot of Winter-Run Chinook Salmon Juvenile Rearing Weighted Usable Area (WUA) for NAA and PP Model Scenarios in River Segment 4, Below Normal Water Years

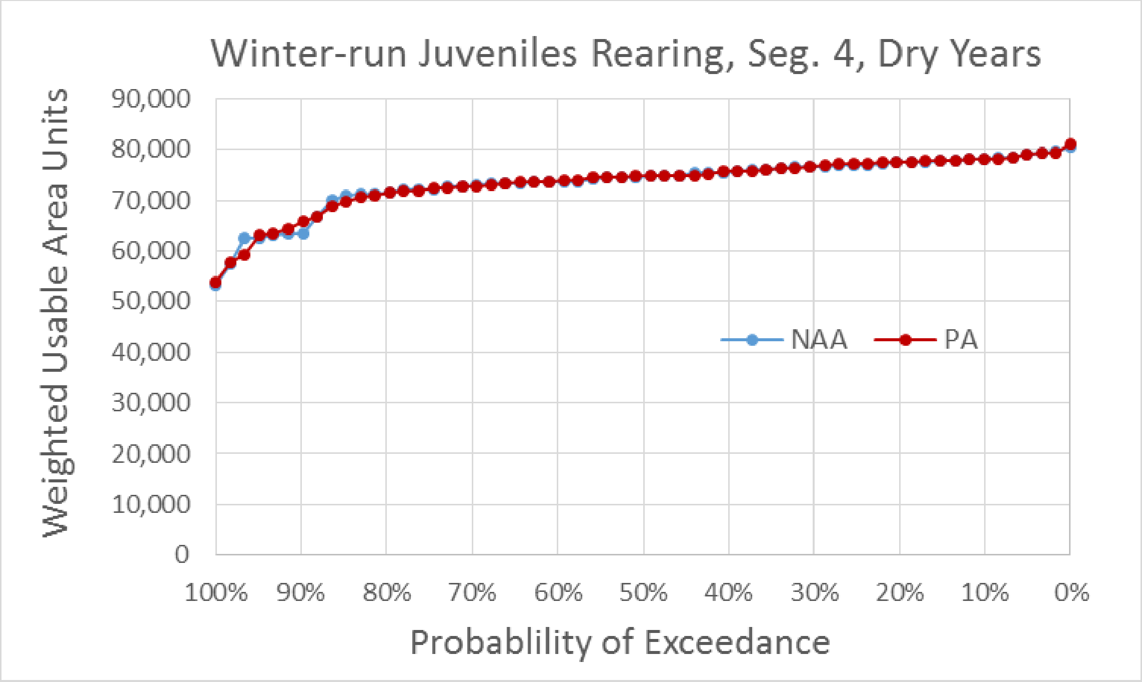

**Figure 4.3-89. Exceedance Plot of Winter-Run Chinook Salmon Juvenile Rearing Weighted Usable Area (WUA) for NAA and PP Model Scenarios in River Segment 4, Dry Water Years**

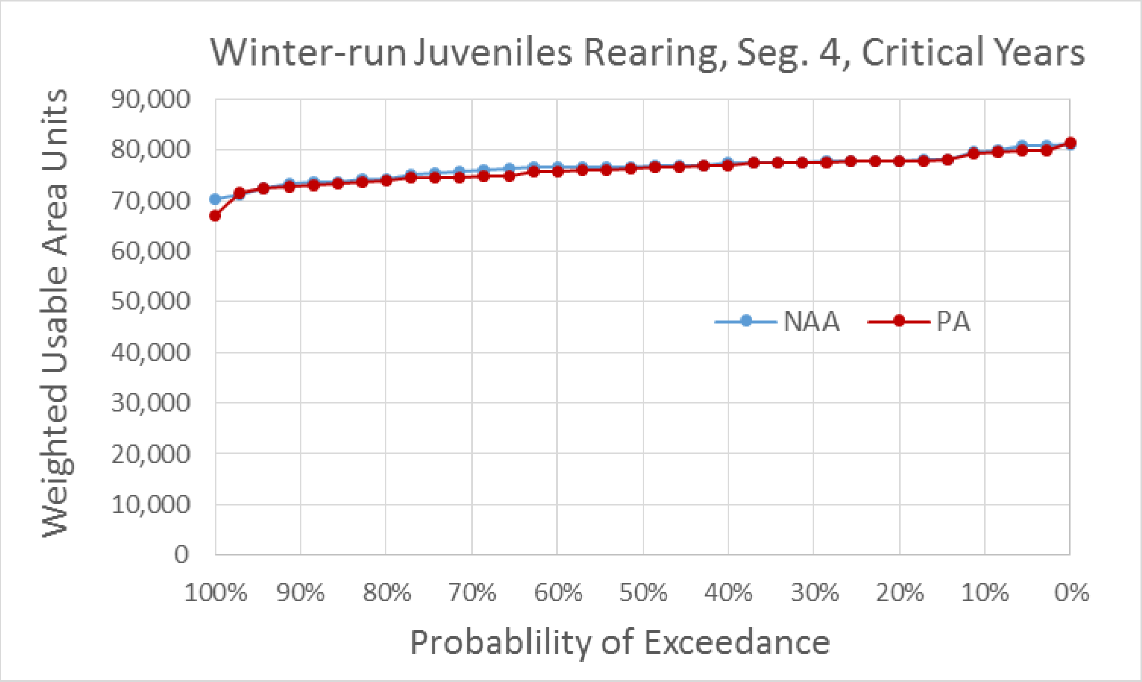

**Figure 4.3-90. Exceedance Plot of Winter-Run Chinook Salmon Juvenile Rearing Weighted Usable Area (WUA) for NAA and PP Model Scenarios in River Segment 4, Critical Water Years**

Differences in winter-run Chinook salmon fry and juvenile rearing WUA in each segment under the PP 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 4.3-30 to Table 4.3-35). 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 PP was up to 9% lower than that under the NAA (August and October of below normal years) (Table 4.3-30 and Table 4.3-31). 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 PP during above normal years in Segment 6 (Table 4.3-33) and 13% and 18% increases under the PP during wet and above normal years, respectively, in Segment 4 (Table 4.3-35). Mean WUA for juvenile rearing under the PP 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 PP 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 4.3-30. Winter-Run Chinook Salmon Fry Rearing Weighted Usable Areas (WUA) and Differences (Percent Differences) between Model Scenarios in River Segment 6 (green indicates PP is at least 5% higher [raw difference] than NAA; red indicates PP is at least 5% lower)**

| Month | Water Year Type | NAA | PP | PP 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%) |
| 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 4.3-31. Winter-Run Chinook Salmon Fry Rearing Weighted Usable Areas (WUA) and Differences (Percent Differences) between Model Scenarios in River Segment 5 (green indicates PP is at least 5% higher [raw difference] than NAA; red indicates PP is at least 5% lower)**

| Month | Water Year Type | NAA | PP | PP 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 4.3-32. Winter-Run Chinook Salmon Fry Rearing Weighted Usable Areas (WUA) and Differences (Percent Differences) between Model Scenarios in River Segment 4 (green indicates PP is at least 5% higher [raw difference] than NAA; red indicates PP is at least 5% lower)**

| Month | Water Year Type | NAA | PP | PP 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 4.3-33. Winter-Run Chinook Salmon Juvenile Rearing Weighted Usable Areas (WUA) and Differences (Percent Differences) between Model Scenarios in River Segment 6 (green indicates PP is at least 5% higher [raw difference] than NAA; red indicates PP is at least 5% lower)**

| Month | Water Year Type | NAA | PP | PP 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%) |
| | 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 4.3-34. Winter-Run Chinook Salmon Juvenile Rearing Weighted Usable Areas (WUA) and Differences (Percent Differences) between Model Scenarios in River Segment 5 (green indicates PP is at least 5% higher [raw difference] than NAA; red indicates PP is at least 5% lower)**

| Month | Water Year Type | NAA | PP | PP 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 4.3-35. Winter-Run Chinook Salmon Juvenile Rearing Weighted Usable Areas (WUA) and Differences (Percent Differences) between Model Scenarios in River Segment 4 (green indicates PP is at least 5% higher [raw difference] than NAA; red indicates PP is at least 5% lower)**

| Month | Water Year Type | NAA | PP | PP 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%) |

###### *4.3.4.2.1.2.2.2 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 ICF International [2016], Appendix 5.D, Attachment 5.D.2 *SALMOD Model*, for a full description). Results for flow-related mortality of these life stages are presented in Table 4.3-28 and the annual exceedance plot for all water year types combined is presented in Figure 4.3-90. These results indicate that flow-related mortality of winter-run Chinook salmon fry would increase moderately under the PP 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 PP. The flow-related mortality of winter-run Chinook salmon pre-smolts would be moderately lower under the PP 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 PP. 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 4.3-28). Accordingly, these results indicate that the PP 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[55] 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.

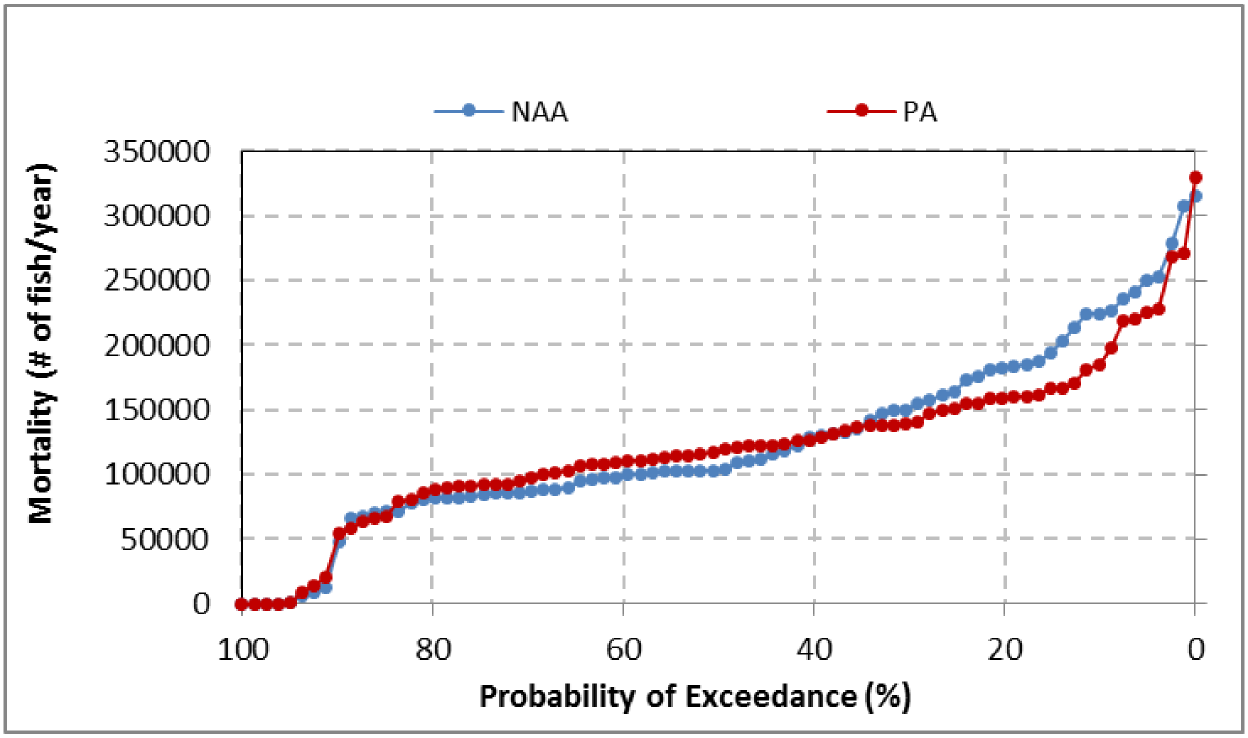

**Figure 4.3-91. Exceedance Plot of Annual Flow-Based Mortality (# of Fish/Year) of Winter-Run Chinook Salmon Fry and Juveniles**

### *4.3.4.2.1.2.2.3 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 4.3-19) are presented in *Upstream Water Temperature Methods and Results* (ICF International 2016, Appendix 5.C), 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[56]. Overall, the PP 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 PP 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] "Negligible" is defined as a difference between the NAA and PA of <5%.

[56] 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 juvenile rearing period (*Upstream Water Temperature Methods and Results* [ICF International 2016, Appendix 5.C], 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[57]). The values for the PP 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 PP 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 4.3-91). 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 PP, 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 PP.

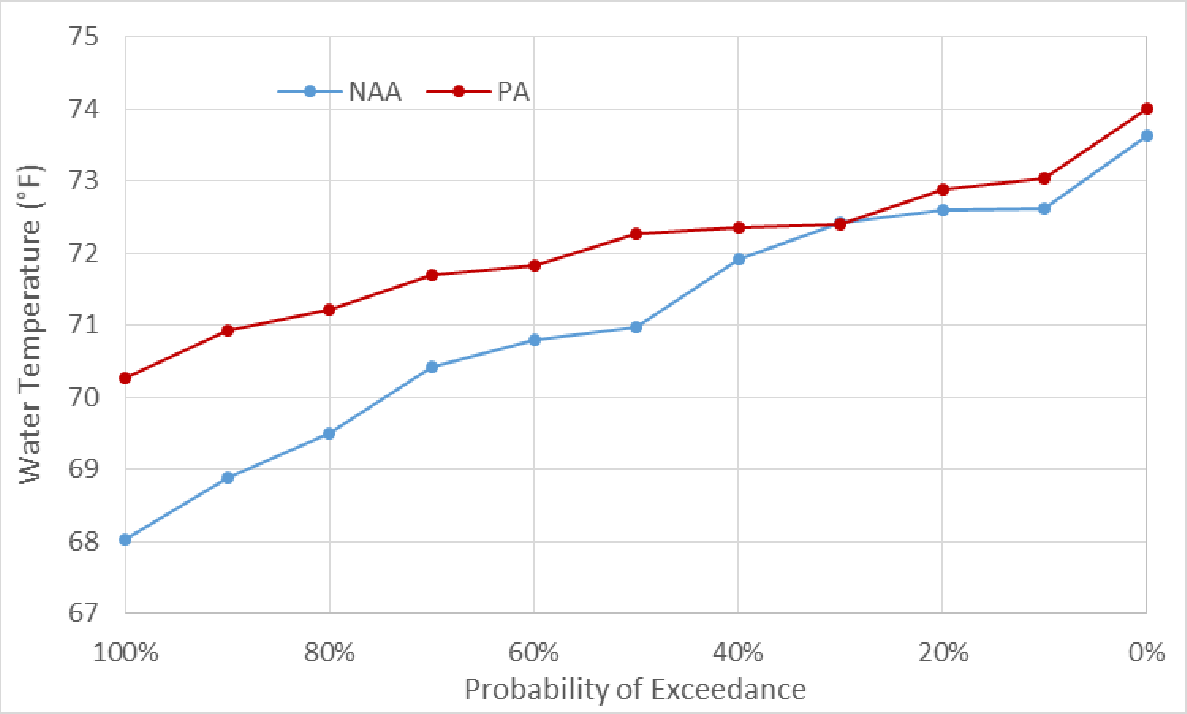

**Figure 4.3-92. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the Sacramento River at Wilkins Slough/Knights Landing in August of Below Normal Water Years[58]**

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

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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.

from Keswick Dam to Red Bluff and 64°F for the non-core juvenile rearing reach at Knights Landing (ICF International [2016], 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 (ICF International [2016], 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 *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale* (ICF International 2016, 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 PP 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 (ICF International [2016], 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 PP 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 (ICF International [2016], 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 PP 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 PP, 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 PP 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 (ICF International [2016], 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 PP 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 PP, but exceedances would be higher on average.

At Bend Bridge, the percent of days exceeding the 61°F 7DADM threshold under the PP 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%) (ICF International [2016], 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 PP 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 PP 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 PP 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 (ICF International [2016], 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 PP would be more than 5% higher than under the NAA during October of wet water years (6.9%) (ICF International [2016], 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 PP

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 ICF International [2016], Appendix 5.D, Attachment 5.D.2 *SALMOD Model*, for a full description). Results for water temperature-related mortality of these life stages are presented in Table 4.3-28 and the annual exceedance plot for all water year types combined is presented in Figure 4.3-93. These results indicate that differences under the PP 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 PP and there would be insignificant differences between scenarios in mortality (759 fish, or 1% lower under the PP). Accordingly, these results indicate that the PP would not increase water temperature-related mortality of fry and juvenile winter-run Chinook salmon relative to the NAA.

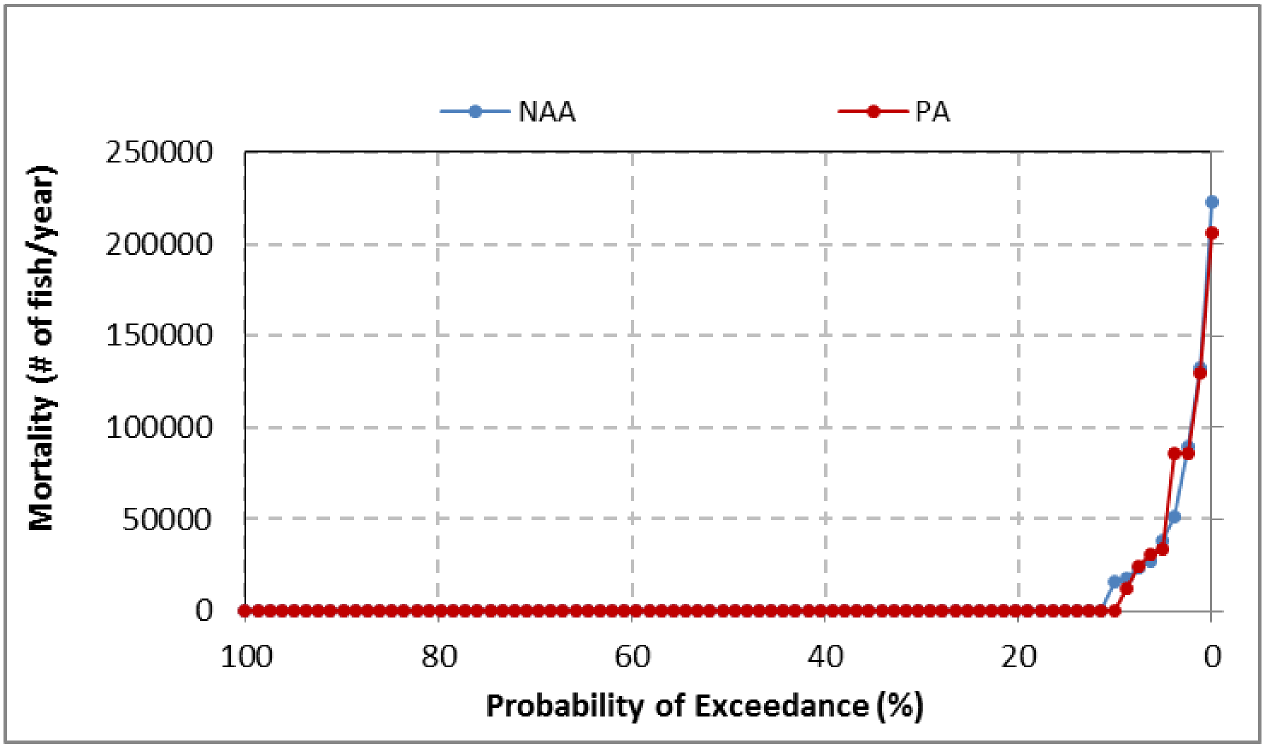

**Figure 4.3-93. Exceedance Plot of Annual Water Temperature-Based Mortality (# of Fish/Year) of Winter-Run Chinook Salmon Fry and Juveniles**

### *4.3.4.2.1.2.3 Juvenile Emigration*

#### *4.3.4.2.1.2.3.1 Flow-Related Effects*

Mean monthly flows were evaluated in the Sacramento River at four locations along the downstream migration corridor of juvenile 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 4.3-19). 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 *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale* (ICF International 2016, 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 PP.

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 PP would be similar (less than 5% difference) to storage under NAA for all water year types. Mean Shasta September storage under the PP 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 PP (ICF International [2016], Appendix 5.A *CalSim II Modeling and Results*, Table 5.A.6-3).

In general, mean flow under the PP 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 (ICF International [2016], Appendix 5.A *CalSim II Modeling and Results*, Table 5.A.6-10, Table 5.A.6-14, Table 5.A.6-35, and Table 5.A.6-36). During July, mean flow in critical water years under the PP 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 PP 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 PP 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 PP 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 PP 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 PP; 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 PP compared with the NAA at all the locations, except Verona. During March, flow under the PP 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 PP 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 4.3.4.2.2 *Summary of Upstream Effects*.

###### *4.3.4.2.1.2.3.2 Water Temperature-Related Effects*

Modeled mean monthly water temperatures in the Sacramento River in the reach from Keswick Dam to Knights Landing during the July through March juvenile emigration period for winter-run Chinook salmon, with a peak during September and October (Table 4.3-19) are presented in *Upstream Water Temperature Methods and Results* (ICF International 2016, Appendix 5.C, 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, and Table 5.C.7-10)[59]. Overall, the PP 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 PP 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 (ICF International [2016], Appendix 5.C, 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[53]). The curves for PP generally match those of the NAA, except in below normal water years in August at Knights Landing, during which water temperatures under the PP 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 4.3-90). 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 PP, 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 PP.

Please see the discussion of water temperature thresholds for juvenile winter-run Chinook salmon emigration in Section 4.3.4.2.1.3.1.2, *Fry and Juvenile Rearing*, which concludes that there would be more exceedances (5% or greater) in certain months and water year types under the PP. 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 4.3.4.2.2 *Summary of Upstream Effects*, below.

### *4.3.4.2.1.2.4 Adult Immigration*

#### *4.3.4.2.1.2.4.1 Flow-Related Effects*

Mean monthly flows were evaluated in the Sacramento River at four locations along the upstream migration corridor of adult 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 4.3-19). 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 *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon,*

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[59] Water temperature results for Wilkins Slough were used to represent Knights Landing for this analysis.

*Central Valley Steelhead, Green Sturgeon, and Killer Whale* (ICF International 2016, 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 PP (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 PP 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 PP. Mean Shasta May storage under the PP would also be similar (less than 5% difference) to storage under NAA for all water year types (ICF International [2016], Appendix 5.A, 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 PP and the NAA or would be greater under the PP. During January, mean flow under the PP 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 PP; at the other two locations, all differences in January flow would be less than 5% (ICF International [2016], Appendix 5.A *CalSim II Modeling and Results,* Table 5.A.6-10, Table 5.A.6-14, Table 5.A.6-35, and Table 5.A.6-36). During February, mean flow would be lower (up to 13% lower at Keswick) under the PP compared with the NAA at all the locations, except Verona. During March, flow under the PP 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 PP would be greater (up to 8% greater at Wilkins Slough) at all the locations, except Verona. During June, flow under the PP 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 PP 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 PP would be greater (up to 10% greater) at Wilkins Slough and Verona.

The CALSIM modeling results given here indicate that the PP 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 4.3.4.2.2 *Summary of Upstream Effects*.

As described in *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale* (ICF International 2016, 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 adult immigration conditions in the Sacramento River. The effect of the PP on the frequency of flows below this threshold was evaluated by comparing CALSIM flows between the PP 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.

###### *4.3.4.2.1.2.4.2 Water Temperature-Related Effects*

Modeled mean monthly water temperatures in the Sacramento River at Keswick Dam, Bend Bridge, and Red Bluff during the December through August adult immigration period for winter-run Chinook salmon (Table 4.3-19) are presented in *Upstream Water Temperature Methods and Results* (ICF International [2016], Appendix 5.C, Section 5.C.7 *Upstream Water Temperature Modeling Results,* Table 5.C.7-3, Table 5.C.7-7, and Table 5.C.7-8). Overall, the PP 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 PP 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 immigration period (ICF International 2016, 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, and Figure 5.C.7.8-7). The values for the PP 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 PP curve is consistently higher than the NAA curve by approximately 0.5°F (Figure 4.3-93). 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 PP and, therefore, there would be no biologically meaningful effect on winter-run Chinook salmon adult immigrants moving through the Red Bluff area.

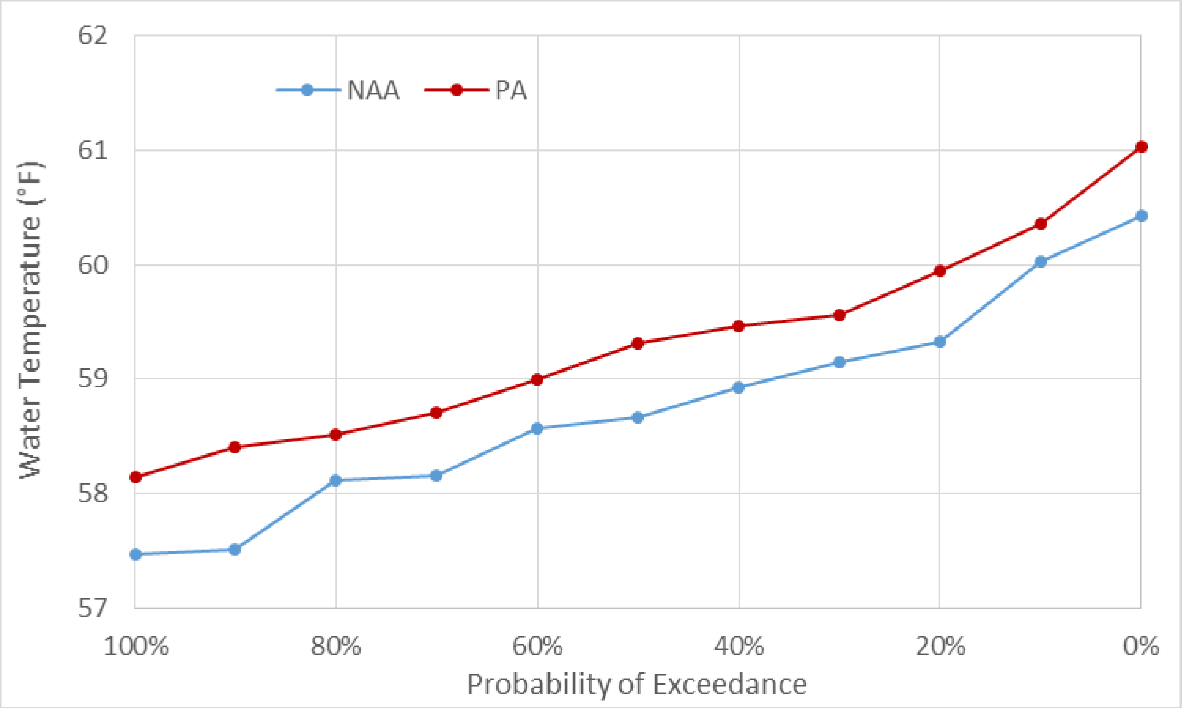

**Figure 4.3-94. Exceedance Plot of Mean Monthly Water Temperatures (°F) in the Sacramento River at Red Bluff in August of Below Normal Water Years**

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 (ICF International [2016], 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 (ICF International [2016], 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 *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale* (ICF International 2016, 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 PP 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 PP would be more than 5% higher than under the NAA: August in critical years (5.1% higher under the PP) (ICF International 2016, 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 PP, 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 4.3.4.2.2 *Summary of Upstream Effects*.

### *4.3.4.2.1.2.5 Adult Holding*

#### *4.3.4.2.1.2.5.1 Flow-Related Effects*

Mean monthly flow rates and reservoir storage volumes were examined for the PP 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 4.3-19). 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 PP would be similar (less than 5% difference) to storage under NAA for all water year types (ICF International [2016], Appendix 5.A *CalSim II Modeling and Results*, Table 5.A.6-3). During the majority of months and water year types of the winter-run holding period, the PP would result in minor changes (less than 5% difference) in mean flow in the Sacramento River at the Keswick Dam and Red Bluff locations (ICF International [2016], Appendix 5.A *CalSim II Modeling and Results*, Table 5.A.6-10 and Table 5.A.6-35). However, at both locations flows under the PP 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 PP would be up to 18% higher than flow under the NAA; during February of critical years flow under the PP would be up to 13% lower; and during August of below normal years flow would be 10% lower under the PP (ICF International [2016], Appendix 5.A *CalSim II Modeling and Results*, Table 5.A.6-10 and 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 PP during the peak holding period, and increases and decreases in flow would, on balance, be similar during the rest of the holding period, the PP is predicted to have a small positive effect on flow conditions for winter-run holding habitat.

#### *4.3.4.2.1.2.5.2 Water Temperature-Related Effects*

Modeled mean monthly water temperatures in the Sacramento River at Keswick Dam, Balls Ferry, and Red Bluff during the January through August adult holding period for winter-run Chinook salmon (Table 4.3-19) are presented in *Upstream Water Temperature Methods and Results* (ICF International [2016], Appendix 5.C, Section 5.C.7 *Upstream Water Temperature Modeling Results,* Table 5.C.7-3, Table 5.C.7-5, and Table 5.C.7-8). Overall, the PP 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 PP 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 (ICF International [2016], 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, and Figure 5.C.7.8-7). The curves for PP 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 PP curve is consistently higher than the NAA curve by approximately 0.5°F (Figure 4.3-93).

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 (U.S. Environmental Protection Agency 2003). The threshold was converted to function with daily model outputs for each month separately (ICF International [2016], 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 *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale* (ICF International [2016], Appendix 5.D, Section 5.D.2.5 *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-77 through Table 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 PP 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 (ICF International [2016], 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 PP would not differ by more than 5% in any month or water year type (ICF International [2016], Appendix 5.D, Section 5.D.2.5 *Detailed Water Temperature Threshold Analysis Results*, Table 5.D-78). The average daily exceedance under the PP 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 PP 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%) (ICF International [2016], 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 PP, 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 4.3.4.2.2 *Summary of Upstream Effects*.

#### *4.3.4.2.1.2.6 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: ICF International (2016), 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 *IOS.*

- OBAN: ICF International (2016), 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 *OBAN.*

- SALMOD: ICF International (2016), Appendix 5.D *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale,* Attachment 5.D.2 *SALMOD Model.*

##### *4.3.4.2.1.2.6.1 IOS*

Results of the IOS model are presented in *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale* (ICF International [2016], Appendix 5.D, Section 5.D.3.1, *IOS*). The model predicts that upstream effects of the PP would be insignificant. Median egg survival under the PP (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 PP (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 PP relative to the NAA, but this is largely an effect of in-Delta survival resulting from lower flows downstream of the NDD facilities. Median through-Delta survival under the PP 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 PP shifts temporally during the 80-year time series (ICF International [2016], Appendix 5.D, Section 5.D.3.1 *IOS*). In the late 1920s to early 1930s, egg and fry survival under the PP was lower than survival under the NAA. In the late 1980s and early 1990s, egg and fry survival under the PP was higher than survival under the NAA. Despite this pattern, the escapement results are primarily result from reduced in-Delta survival under the PP.

###### *4.3.4.2.1.2.6.2 OBAN*

Results of the OBAN model are presented in *Quantitative Methods and Detailed Results for Effects Analysis of Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale* (ICF International 2016, Appendix 5.D, Section 5.D.3.2 *OBAN*). The model predicts temporal variability in escapement, with insignificant differences between the NAA and PP. 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 PP such that there is no overall difference in median escapement.

###### *4.3.4.2.1.2.6.3 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 (ICF International [2016], Appendix 5.D, 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 4.3-36 and an exceedance plot is provided in Figure 4.3-94. Overall, these results indicate that changes in winter-run Chinook salmon annual potential production under the PP 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 PP 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. In addition, 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. 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 4.3-36. 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 |
| PP | 1,797,449 |
| Difference | -12,961 |
| Percent Difference[2] | -1 |
| **Water Year Types[3]** | |
| Wet (32.5%) | |
| NAA | 1,983,169 |
| PP | 1,963,584 |
| Difference | -19,584 |
| Percent Difference | -1 |
| Above Normal (12.5%) | |
| NAA | 1,639,594 |
| PP | 1,633,821 |
| Difference | -5,773 |
| Percent Difference | 0 |
| Below Normal (17.5%) | |
| NAA | 2,069,244 |
| PP | 2,019,856 |
| Difference | -49,389 |
| Percent Difference | -2 |
| Dry (22.5%) | |
| NAA | 1,801,338 |
| PP | 1,775,288 |
| Difference | -26,050 |
| Percent Difference | -1 |
| Critical (15%) | |
| NAA | 1,399,166 |
| PP | 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.

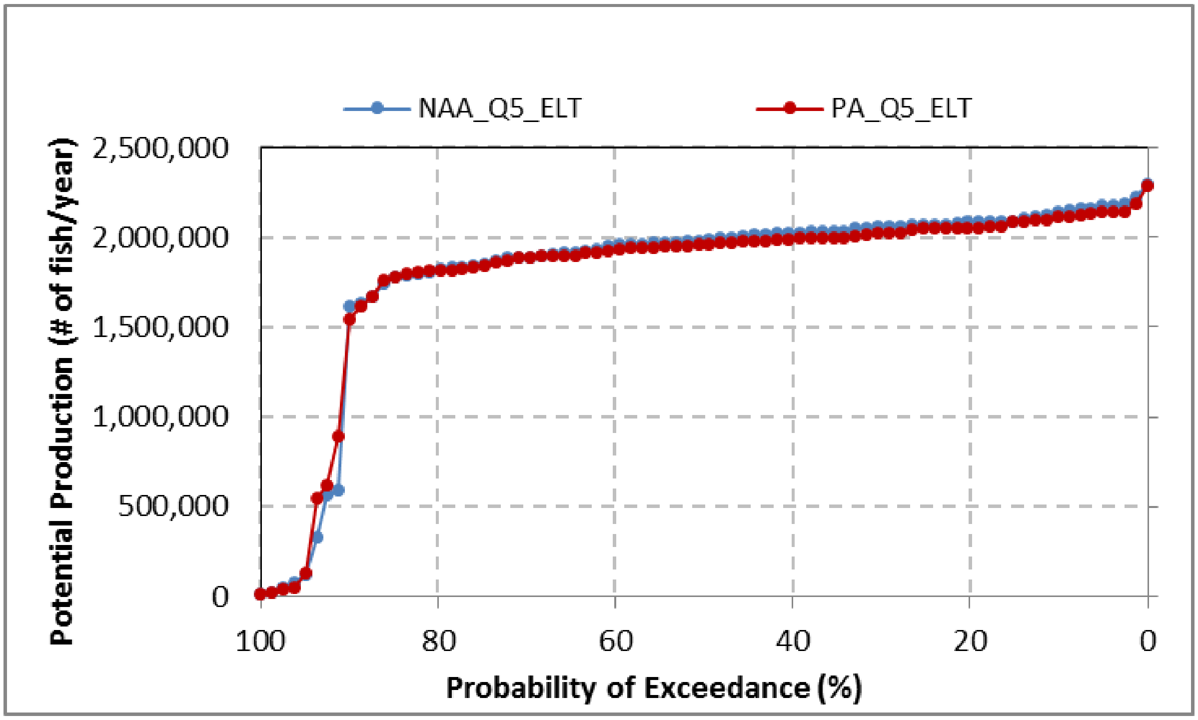

**Figure 4.3-95. Exceedance Plot for Annual Potential Production (# of Fish/Year) of Winter-Run Chinook Salmon, SALMOD**

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 ICF International [2016], Appendix 5.D, Attachment 5.D.2 *SALMOD Model* for details). The initial egg value was 5,913,000 for both NAA and PP 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 4.3-37. There would be 5 years during which production would be below the 5% (295,650 fish) threshold under both the NAA and PP. There would be 1 year fewer (14% lower) under the PP compared to the NAA during which production would be below the 10% (591,300 fish) threshold. Therefore, the PP would have insignificant effects on the frequency of worst-case scenario years for winter-run Chinook salmon.

**Table 4.3-37. 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) | PP (# of Years) | PP 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%) |

### 4.3.4.2.1.3 Assess Risk to Individuals

Based on the responses of winter-run Chinook salmon exposed to the PP described in Section 4.3.4.2.1.2 *Assess Species Response to the Proposed Action*, above, the risk to individuals would be small to negligible in the Sacramento River, 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 be largely similar between the NAA and PP. There are few instances in which there would be small effects to individuals resulting from changes in reservoir operations under the PP. Winter-run Chinook salmon may experience small reductions in survival of egg, alevin, fry, and juvenile life stages 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 instream flows. See Section 4.3.4.2.2 *Summary of Upstream Effects* for a description of how actual operations of the PP may reduce the likelihood that these effects would occur.

#### *4.3.4.2.2 Summary of Upstream Effects*

The results presented in Section 4.3.4.2.1 *Sacramento River* indicate that, overall, upstream effects of the PP on winter-run Chinook salmon are expected to be predominantly small to negligible. There are a few particular upstream changes described here that are noteworthy because physical conditions under the PP 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 PP 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 PP 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 PP as modeled can be avoided during actual PP operations is also provided.

1. **Increased frequency of exceedance of water temperature thresholds for rearing winter-run Chinook salmon during September from Keswick to Red Bluff, especially in below normal water years, under the PP 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 PP's operational modeling. Modeling of the coldwater pool volume, which is more indicative of temperature management suggests PP end-of-September (EOS) storage similar to that of the NAA (ICF International [2016], Appendix 5.C, Table 5.C.7.21-1 *Shasta Cold Water Pool Volume*). If real-time cold water pool management efforts under the PP use similar decision making tools and criteria as currently utilized (i.e., NAA), then releases from Shasta Lake under the PP would actually be sustained at similar levels as the NAA during September. Thus, it is likely that the PP would not experience higher water temperatures relative to the NAA during September, as was modeled in this analysis.

2. **Increased frequency of exceedance of water temperature thresholds for spawning winter-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 PP 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 PP relative to the NAA. Given that winter-run Chinook salmon spawning is limited to the Sacramento River upstream of Clear Creek (see Section 4.3.4.2.1.2 *Assess Species Exposure*), and the temperatures within this reach under the PP are similar to the NAA, it is likely that there would be minimal, if any, effects on the spawning winter-run Chinook salmon under the PP relative to the NAA. In addition, for all water year types during these months in which there is a biologically meaningful increase of 5% in the frequency of exceedance under the PP relative to the NAA, the actual difference in mean magnitude of exceedance would not be biologically meaningful (<0.5°F) (Section 4.3.4.2.1.2.1.6 *Water Temperature-Related Effects*). Therefore, although there are more exceedances under the PP during these months, the magnitude would not be biologically meaningful. 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 PP and the NAA, the PP is likely to result in similar conditions as the NAA (ICF International [2016], Appendix 5.C, Table 5.C.7.21-1 *Shasta Cold Water Pool Volume*). Thus, it is likely that the PP would not experience higher water temperatures relative to the NAA during August and September, as was modeled in this analysis.

3. **Increased risk of redd dewatering for June and August cohorts of winter-run Chinook salmon in the Sacramento River from Keswick to Battle Creek under the PP relative to the NAA.** This increase risk is a result of the lower Shasta releases in September and November under the PP 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. **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 Chinook salmon in the Sacramento River under the PP relative to the NAA.** These reduced 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 PP and the NAA, actual differences in September Shasta Reservoir releases between the PP and the NAA would be minor 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 ICF International [2016], 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 PP

5. **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 in the Sacramento River.** These reduced flows are the result of lower releases from Shasta Reservoir. As noted above, there is a low certainty in the assumed positive linear relationship between flow and migration success (see ICF International [2016], 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 PP.

In summary, these CalSim II results show that the upstream storage conditions under the PP would generally be similar to the NAA. With the increased flexibility offered by the proposed north Delta diversion under the PP, 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 PP. Thus typically model results show lower river flows in the fall months (primarily in September and November) under the PP compared to the NAA. The September flow reductions modeled under PP 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 PP, 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. ICF International (2016, Appendix 5.A *CALSIM Methods and Results*), provides a detailed description of the CalSim II model, assumptions used to model the NAA and the PP 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 Collaborative Science and 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 PP (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*), which will allow for minimization of modeled effects identified above to listed species under future operations of the PP.

## 4.3.5 Effects of Construction and Maintenance of Mitigation

### *4.3.5.1 Tidal, Channel Margin, and Riparian Habitat Protection and Restoration*

#### *4.3.5.1.1 Overview*

As summarized in Table 5.4-1 in Chapter 5 *Take Minimization and Mitigation Measures*, 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 5.4.1 *Delta Smelt*. 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 fill. Channel margin habitat would also be restored as discussed in Section 5.4.3 *Sacramento River Winter-Run Chinook Salmon.* 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.

#### *4.3.5.1.2 Assess Species Exposure*

Construction at habitat restoration sites will be undertaken during the in-water work window and therefore most winter-run Chinook salmon are unlikely to be exposed. Once constructed, Chinook salmon would have access to the restoration sites during their periods of occurrence within the Delta.

#### *4.3.5.1.3 Assess Fish Species Response*

As previously noted, restoration construction effects are expected to be limited given the proposed timing of in-water work. For any Chinook salmon individuals that are present, the types of construction effects at restoration sites are likely to be similar to those described in Section 4.3.2 *Effects of Water Facility Construction* for construction of the NDD, although the magnitude of these effects will be substantially less given the reduced amount of in-water work necessary. These effects may include turbidity, exposure to contaminants, and direct physical injury; effects from pile driving and stranding are not expected. Construction of restoration sites will require very little in-water work, and will be performed in accordance with take minimization measures described in Section 5.3 *Take Minimization Measures* (Section 5.3.3 *Sacramento River Winter-Run Chinook Salmon*).

To the extent that individual migrating Chinook salmon 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, 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 5.4-1 in Chapter 5 *Take Minimization and Mitigation Measures*). Potential adverse effects to Chinook salmon 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.

### *4.3.5.2 Georgiana Slough Nonphysical Fish Barrier*

#### *4.3.5.2.1 Overview*

As described in Section 5.3.3.2.1 *Nonphysical Fish Barrier at Georgiana Slough*, 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. 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 PP, 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).

#### *4.3.5.2.2 Assess Species Exposure*

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 Chinook salmon migrating upstream to natal tributaries in the Sacramento River watershed will be exposed to NPB operations, but will be unlikely to overlap the construction or removal period.

#### *4.3.5.2.3 Assess Fish Species Response*

Any pile driving for NPB construction will be done with a vibratory hammer during times when presence of listed salmonids will not 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 2014).

The potential effectiveness of the NPB for deterring juvenile salmonids from entry into Georgiana Slough was discussed in the context of operations in Section 4.3.4.1.2.2.1.4 *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 (California Department of Water Resources 2012, 2015a). Indeed, the 2011 and 2012 BAFF pilot studies provided evidence that predatory fish were deterred by the BAFF being turned on,[60] 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[61], passage will be available under/around the FFGS, or under the BAFF. An FFGS 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

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[60] The BAFF was switched on and off every ~25 hours in order to test its effectiveness in deterring migrating juvenile salmonids.

[61] 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.

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 salmonids 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).

### 4.3.6 Effects of Monitoring Activities

As described in Chapter 6 *Monitoring Plan*, effectiveness monitoring for fish would consist of a combination of continuation of existing monitoring authorized under the 2008/2009 BiOps and the 2009 Incidental Take Permit (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 6.2 in Chapter 6 *Monitoring Plan*); 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 PP will be unlikely to affect winter-run Chinook salmon and are not discussed here. Existing monitoring activities that will inform operations of the PP (e.g., trawl and seines surveys by DFW and USFWS) are not part of the PP. 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.

As discussed in Section 4.3.4.1.3.1.1.1, *Entrainment*, for the NDD, the NDD fish screens will exclude juvenile salmonids from entrainment, so there will be no effect from entrainment monitoring at the NDD. If impingement monitoring were to consist of visual observation by diver survey, there will 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 will be no effect if conducting observations with an acoustic imaging camera. At the south Delta export facilities, salvage of juvenile salmonids will occur the same way under NAA and PP. Some juvenile salmonids collected during sampling of salvaged fish will die; however, as shown in Section 4.3.4.1.3.1.1.2, *Impingement, Screen Contact, and Screen Passage Time*, entrainment at the south Delta export facilities is expected to be lower under the PP than NAA, therefore any effects to juvenile salmonids from salvage monitoring will also be lower under the PP than NAA. Given that monitoring informs adjustments to operations to protect migrating juvenile salmonids, the ultimate net effect of monitoring will be beneficial at a population level.

### 4.3.7 Take Analysis

Take estimation for the purposes of the direct effects, cumulative effects, and climate change assessments is based upon the likelihood of physical injury or mortality to individuals of winter-run Chinook salmon. It is not possible to predict the number of individuals that would be subject to such take; in general, that would be a density-dependent phenomenon, e.g., with more fish subject to take in years when a relatively large run passed through the project area. Instead, the risk of take is assessed through proxies such as the area of habitat affected, the duration of impact pile driving, or the probability of a contaminant release. Each foregoing section of the take analysis has identified the mechanisms by which take could occur and the probability that take would occur. If that probability is substantial, so that some individuals are likely to suffer mortality, then factors influencing the magnitude of take have been detailed, including take minimization measures (more fully described in Chapter 5 *Mitigation*), as well as the take proxies mentioned above. Mitigation is described (in Chapter 5 *Mitigation*) that is proportionate to the take, so as to show full mitigation for the take. The following take analysis considers mechanisms of take for which authorization is needed (such as, conveyance facility construction and operations), as well as mechanisms of take for which authorization is not here requested (such as, maintenance activities or construction of mitigation sites) or is not needed (such as, CVP operations, cumulative effects, or climate change), because all such mechanisms are considered in determining whether the PP is likely to jeopardize winter-run Chinook salmon.

#### 4.3.7.1 Upstream Take

Potential take of winter-run Chinook salmon by the PP that occurs upstream of the Delta is not evaluated in this Take Analysis because all such take is attributable to the operation of facilities that: 1) are federally owned and operated or 2) in the case of the Oroville Complex, is evaluated in a separate and ongoing NMFS consultation related to FERC licensing. Effects of the operations of Shasta Dam, which is under USBR jurisdiction, on winter-run Chinook salmon in the Sacramento River are analyzed in the Effects Analysis in Section 4.3.4.2 *Upstream Hydrologic Changes*. Effects of Folsom Dam, which is also under USBR jurisdiction, are not evaluated in this application because winter-run Chinook salmon do not occur in the American River. All construction related activities of the PP will occur in the Delta.

#### 4.3.7.2 Delta Take

A full analysis of potential take of winter-run Chinook salmon by the PP that occurs in the Delta is included in following sections of the Effects Analysis: Section 4.3.2 *Effects of Water Facility Construction,* Section 4.3.3, *Effects of Water Facility Maintenance;* and Section 4.3.4, *Effects of Water Facility Operations.* A summary of the results of those analyses is provided below.

##### 4.3.7.2.1 Effects of Water Facility Construction

The PP facilities where construction has the greatest potential to result in take of Chinook salmon include the NDDs, the temporary barge landings, the Head of Old River gate, and the Clifton Court Forebay modifications. Winter-run Chinook salmon are rarely present in the vicinity of the HOR gate, so construction of this facility has substantially less potential to result in take of winter-run Chinook salmon, compared to the other facilities named. Construction activities will include cofferdam installation, levee clearing and grading[62], riprap placement, dredging, and barge operations and may cause turbidity and sedimentation, contaminant spills, underwater noise, fish stranding, direct contact with construction equipment, and loss or alteration of habitat. A detailed discussion of underwater noise effects and mitigation measures is given in Section 4.3.2.2.4 *Underwater Noise*.

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[62] See Permit Resolution Log item #32 for further information on this point.

Take associated with construction activities will be minimized by restricting construction to in-water work windows when few winter-run Chinook salmon are present in the Delta[63]. All life stages of winter-run Chinook salmon are largely absent from the Delta during these periods.

In addition to restricting construction to periods when winter-run Chinook salmon are largely absent from the Delta, take associated with the construction activities will be minimized by using the take minimization measures specified in Section 4.3.2 *Effects of Water Facility Construction*: AMM1 *Worker Awareness Training;* AMM2 *Construction Best Management Practices and Monitoring;* AMM3 *Stormwater Pollution Prevention Plan (SWPPP);* AMM4 *Erosion and Sediment Control Plan;* AMM5 *Spill Prevention, Containment, and Countermeasure Plan;* AMM6 *Disposal and Reuse of Spoils, Reusable Tunnel Material, and Dredged Material;* AMM7 *Barge Operations Plan;* and AMM14 *Hazardous Material Management* (Appendix 3.F *General Avoidance and Minimization Measures*).

Expected effects on winter-run Chinook salmon habitat include both temporary and permanent effects. Construction of the NDDs, for instance, is expected to impact 26.7 acres of tidal perennial aquatic habitat and 1.02 linear miles of channel margin habitat, of which 6.6 acres tidal perennial aquatic habitat and 1.02 linear miles of channel margin habitat would be permanently lost (Table 5.4-1 in Chapter 5 *Take Minimization and Mitigation Measures*). Much of the habitat affected, especially at the barge landing, HOR gate, and CCF locations, is currently in a degraded condition, so alteration and loss of this habitat is expected to have little effect on the habitat's potential for food production, as related to growth of the fish. However, the creation of new predator habitat at the facilities is expected to lead to an increase in predation mortality of winter-run Chinook salmon juveniles.

Take resulting from construction activities and from habitat loss and alteration will be mitigated by tidal wetland and channel margin habitat restoration at a 3:1 mitigation ratio as shown in Table 5.4-1 in Chapter 5 *Take Minimization and Mitigation Measures.*

Overall, the impact of take on winter-run Chinook salmon resulting from the construction activities will not be substantial because of the work windows used to avoid periods of winter-run presence in the Delta, the take minimization measures that will be implemented, and habitat restoration will fully offset losses of suitable habitat.

#### *4.3.7.2.2 Effects of Water Facility Maintenance*

Water facility maintenance is not proposed for coverage under this Application (Section 3.1.6 *Take Authorization Requested*), and the following information is provided for context.

Regular and unscheduled maintenance will be needed for each of the four principal PP facilities. The maintenance activities with the most potential to result in take of winter-run Chinook salmon are dredging and levee maintenance. These activities will be scheduled for the same work

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[63] Proposed in-water work windows vary within the Delta: June 1 to October 31 at the NDDs, July 1 to November 30 at the CCF, and August 1 to October 31 at both the HOR Gate and the barge landings.

windows as those used for construction. Potential adverse effects will be further minimized by implementing take minimization measures to limit the extent and duration of activities. With implementation of the work windows and take minimization measures, take resulting from water facility maintenance activities is expected to be negligible.

### *4.3.7.2.3 Effects of Water Facility Operations in the Delta*

Potential take of winter-run Chinook salmon resulting from effects of the PP is discussed in this section, with 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 intake screens or CCF. Far-field effects are those occurring over a broader area, e.g., effects on through-Delta survival caused by reduced river flow downstream of the NDD.

#### 4.3.7.2.3.1 Near-field Effects

**North Delta Diversions.** The fish screens on the NDDs are expected to excude most salmonids, resulting in neglible take by entrainment. The potential for impingement is uncertain and will be addressed with monitoring and targeted studies following construction of the intakes. There is potential for predation of juvenile salmonids along the NDDs, which would constitute take.Operational effects of the PP will be monitored for North Delta intake reach salmonid survivorship (see Table 6.2 in Chapter 6 *Monitoring Plan*) to assess compliance with the performance standard (i.e., to maintain listed juvenile salmonid survival rates through the reach containing the NDD [0.25 mile upstream of the upstream-most intake to 0.25 mile downstream of the downstream-most intake] of 95% or more of the existing survival rate in this reach).

**South Delta Exports.** Entrainment loss at the south Delta export facilities will be reduced under PP operations in all water year types for winter-run Chinook salmon (see results presented in Section 4.3.4.1.2.1.2.1 *Entrainment*). The reduction will be substantial in wet years, as a result of much lower south Delta export pumping facilitated by operation of the NDD, and will be smaller in critical water years. Lower south Delta exports will also result in less impingement injury and mortality and lower predation mortality in CCF and other parts of the pumping facilities.

**Head of Old River Gate.** Near field effects of the HOR gate are not evaluated for this take analysis because winter-run Chinook salmon almost never occur in the vicinity of the head of Old River (see Section 4.3.4.1.1.5, *Exposure to Head of Old River Gate Operations*).

**Delta Cross Channel.** DCC gate operations have the potential to delay upstream migration to the Sacramento River of adult salmonids from the Mokelumne River system. However, the PP is expected to result in little to no difference in the number of days that the DCC gates are closed, and adult salmonids that are migrating to the Sacramento River have the ability to drop back and swim around the DCC gates, so DCC operations under the PP are expected to result in no change in the level of take of winter-run Chinook salmon. Juvenile migrants entering the Delta at this time would also be more susceptible to entry into the low-survival interior Delta; such effects are captured in the analysis based on the DPM.

**Suisun Marsh Facilities.** Operations of the Suisun March Salinity Control Gates will change little with the PP, so no change in take of winter-run Chinook salmon is expected.

**Other Facilities and Programs**. The Clifton Court Forebay Aquatic Weed Control Program uses copper-based herbicides in CCF, which could result in injury and mortality of winter-run Chinook salmon if they were exposed. However, the herbicide is used during July and August, when winter-run Chinook salmon are rarely present in CCF. Mechanical removal of aquatic weeds may overlap with the occurrence of these fish in CCF, potentially resulting in injury, but any take resulting from mechanical weed removal will be offset by a reduction in abundance of predatory fishes that inhabit the weed mats. The removal of weeds also reduces mortality resulting from smothering of the fish during salvage operations, thereby further offsetting the take.

#### 4.3.7.2.3.2 Far-field Effects

**Channel Velocity Effects.** Exports by the NDD will result in reduced flow velocities in the Sacramento River and other north Delta channels downstream of the NDD, particularly during wetter water years. Potentially adverse effects on winter-run Chinook salmon from reduced flow velocity include delayed migration of emigrating juveniles, leading to greater risk of predation and other sources of mortality and injury, and greater risk of entry into migration routes with greater mortality, such as Georgiana Slough. Interior Delta channel velocity (i.e., channels off the main stem San Joaquin River such as Old River downstream of the south Delta export facilities) is expected to increase with the PP, resulting in somewhat more positive and less frequently negative flow (see Table 4.3-11, for example). This will reduce mortality of emigrating winter-run juveniles diverted into the central and south Delta. Because winter-run juveniles migrate primarily through the north Delta, the reduction in flow velocities downstream of the NDD is expected to have a greater impact on the species than the increase of flow velocities in the central and south Delta, resulting on balance in some incidental take. This assessment of the potential for take, as well as the assessments for other far-field effects, does not account for the results of the coordinated monitoring and research under the Collaborative Science and Adaptive Management Program, including real-time operations that will be performed to limit potential operational effects 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.

**Entry into Interior Delta.** The channel junctions with the most potential to affect entry of winter-run juveniles into the interior Delta are the Georgiana Slough and DCC junctions and the junctions of Sutter and Steamboat Sloughs with the Sacramento River. The proportion of flow entering a junction generally is a reasonable proxy for the proportion of fish entering the junction (Cavallo et al. 2015). Risk of entry into the interior Delta, where mortality rates of juvenile salmonids are relatively high, is expected to increase with the PP because reduced net flow downstream of the NDD would result in greater tidal influence and, therefore, more reversing flood flow entering the Sacramento River junction with the DCC and Georgiana Slough. Installation of the proposed nonphysical barrier at the Georgiana Slough junction is expected to reduce the take level, although results of nonphysical barrier trials, while promising, are uncertain because of factors such as being based on larger late fall-run Chinook salmon smolts (see Section 4.3.4.1.2.2.1.4 *Nonphysical Fish Barrier at Georgiana Slough*). Entry of juveniles from the Sacramento River to Sutter and Steamboat Sloughs is expected to reduce take because survival in the sloughs is generally relatively high and the sloughs allow the juveniles to bypass the junction with Georgiana Slough (Perry et al. 2010, 2012). The PP is expected to result in little change in flow entering these sloughs, except during winter and early spring months when the DCC gates will be closed, therby eliminating any risk of juveniles entering the interior Delta through the DCC channel.

**Through Delta Survival.** Several different analytical tools were used to estimate through-Delta survival of emigrating winter-run Chinook salmon juveniles (Section 4.3.4.1.2.2.1.6, *Delta Passage Mode*l; Section 4.3.4.1.2.2.1.8, *Analysis Based on Perry (2010)*; Section 4.3.4.1.2.2.1.9, *Life Cycle Models (IOS and OBAN)*). For the PP, the Delta Passage Model predicted 2% to 7% (relative scale) lower total survival of winter-run Chinook salmon smolts (the model does not include effects on Chinook salmon fry, for which an analysis of effects on rearing habitat as channel margin benches; see further discussion below), depending on water year type. The model predicted the largest reduction for dry water year types. The analysis based on Perry (2010) predicted slight reduction of total survival with the PP for winter-run Chinook salmon (2% to 5% lower, relative scale). As with the Delta Passage Model, the greatest reduction in survival was for dry water year types. OBAN predicted that the benefits of lower south Delta exports could offset additional mortality from the NDD up to ~5% NDD mortality, which would result in no net effect of the PP on through-Delta survival. Consistent with the Delta Passage Model, IOS predicted lower through-Delta survival. An important reason that OBAN and IOS differ in their results with respect to potential NDD effects is that OBAN has a relatively strong relationship between through-Delta survival and south Delta exports (see Section 4.3.1.1.1.1.1.1 *Life Cycle Models (IOS and OBAN)*). However, results of both models had high uncertainty because of overlapping confidence intervals between the PP and baseline conditions. Overall, the analyses of through-Delta survival predicted that the PP would result in little change or a small reduction in survival of winter-run Chinook salmon juveniles through the Delta.

**Channel Margin Habitat Suitability.** Channel margins in the Sacramento River and in Sutter and Steamboat Sloughs provide critical rearing and downstream migration holding habitat for winter-run juveniles. This habitat has been restored in recent years with the installation of wetland and riparian benches (Sections 4.3.4.1.2.2.2, *Habitat Suitability*). The habitat value of wetland and riparian benches along channel margins in the Delta is strongly affected by water level, which in turn depends on levels of flow and, depending on location, tidal influences. An analysis using an inundation index (see ICF International [2016], 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* for details) showed that the wetland benches, which are at lower elevations than the riparian benches, would be little affected by flow changes resulting from the PP. For riparian benches, however, there were important reductions in inundation index values with the PP in the spring of wetter years (Table 4.3-17 *Mean Bench Inundation Index by Location, Bench Type, Water Year Type, and Season, for NAA and PP*). Large reductions in the riparian bench inundation index also occurred in drier years, but this effect was discounted because the riparian benches would have little habitat value in such years under either PP or baseline conditions. Channel margin enhancement would be implemented as mitigation to offset the reduced habitat value of riparian benches, so take of winter-run Chinook salmon associated with this reduction would be fully mitigated (Section 4.3.4.1.2.2.2.3, *Channel Margin Enhancement*).

**Water Temperature.** DSM2-QUAL modeling indicates that implementation of the PP will result in increases in water temperatures in the Delta; the magnitude of the change, however, is too small or at the wrong time of year to affect winter-run Chinook salmon.

**Selenium.** Reductions in south Delta exports under the PP will result in higher proportions of San Joaquin River water in the Delta and increased concentrations of selenium. However, analyses indicate that these increases would have no effect on selenium uptake by winter-run Chinook salmon.

**Olfactory Cues for Upstream Migration.** The proportion water at Collinsville (the Sacramento - San Joaquin River confluence) that originates from the Sacramento River, as estimated using DSM2-QUAL fingerprinting analysis, would be consistently lower under the PP than under baseline conditions (Table 4.3-18 *Mean Percentage of Water at Collinsville Originating in the Sacramento River, from DSM2-QUAL Fingerprinting*), potentially reducing olfactory cues needed for successful upstream migration of winter-run Chinook salmon. This reduction results from the reduced flow downstream of the NDD (due to NDD exports) and increased flow in the lower San Joaquin River (due to reduced south Delta exports). However, during the months when winter-run Chinook salmon adults migrate through the Delta (Table 4.3-6 *Temporal Distribution of Winter-Run Chinook Salmon within the Delta*), Sacramento River water would form the major portion of the water in the confluence area. In any case, the reductions in percentage of Sacramento River water resulting from the PP were consistently less than 20% (absolute value), which, in experiments with adult sockeye salmon, was the lowest level of dilution of homestream water with water from a different stream that the sockeye salmon first detected and behaviorally responded to (Fretwell 1989). Therefore, it is concluded that there would be little effect from changes in olfactory cues for upstream migrating adult winter-run Chinook salmon, resulting in no take.

**Microcystis.** *Microcystis* is a toxic blue-green alga known to have negative effects on the aquatic foodweb of the Delta (Brooks et al. 2012). Streamflow, which determines residence time, is probably important in determining which Delta channels experience *Microcystis* blooms because the algal cells require time to grow into blooms. It is uncertain if the PP would, on balance, change residence time in channels used by winter-run Chinook salmon. In any case, however, *Microcystis* blooms primarily occur from June to October, when winter-run Chinook salmon are largely absent from the Delta, so the blooms are not expected to affect these fish.

### 4.3.8 Analysis of Potential for Jeopardy

The capability of winter-run Chinook salmon to survive and reproduce is based on the availability of suitable aquatic habitat and supportable levels of mortality from natural and human-induced sources. Information on population trends and known threats to the species are presented in ICF International (2016, Appendix 4.A *Status of the Species and Critical Habitat Accounts*, Section 4.A.1 *Chinook Salmon, Sacramento River Winter-Run (*Oncorhynchus tshawytscha)). These sources have been used to develop the cumulative effects and jeopardy analyses provided below.

#### *4.3.8.1 Cumulative Effects*

The projects and programs that have been considered as part of the cumulative analysis have been drawn primarily from BDCP Draft EIR/EIS Appendix 3D *Defining Existing Conditions, No Action Alternative, No Project Alternative, and Cumulative Impact Conditions* (California Department of Water Resources, U.S. Bureau of Reclamation, U.S. Fish and Wildlife Service, and National Marine Fisheries Service 2013). Those projects and programs that could impact listed fishes in the project area are presented in Appendix 4.C *Information to Support Cumulative Effects Analysis*. The list of past, present and reasonably foreseeable future projects and programs has been evaluated to determine which of these activities may affect winter-run Chinook salmon. Most of the local, state and federal land use and land management programs that are affecting or will affect the project area are designed to manage the resources of the area for multiple uses, including agriculture, recreation, fish and wildlife habitat, flood protection and water management.

#### *4.3.8.1.1 Habitat Restoration and Enhancement*

Many of these projects and programs have a conservation or restoration component and thus could ultimately be beneficial to winter-run Chinook salmon. Principal among these is California EcoRestore, which was launched by the California Natural Resources Agency in 2015 and includes advancing (i.e., completing, or breaking ground on) 30,000 acres of fish and wildlife habitat projects by 2020; of this, 25,000 acres is associated with existing mandates for habitat restoration, pursuant to federal biological opinions, and 5,000 acres is habitat enhancements funded by Proposition 1 grants to local governments, non-profit organizations, and other entities. California EcoRestore has the potential to increase available habitat for occupancy by winter-run Chinook salmon, as well as enhancing the lower levels of the food web by restoring tidal natural community functioning.

The California Water Action Plan 2016 Update describes other state and federal programs in the early stages of implementation that are likely to benefit winter-run Chinook salmon, including a program to repair and install fish screens at diversions along the migration routes of juvenile Chinook salmon and steelhead in the Sacramento and San Joaquin River Basins, including the Delta; and a plan to investigate the feasibility of providing salmon and steelhead access to their historical spawning and rearing habitat upstream of major reservoirs, including Lake Shasta. The upstream habitat access plan, as well as a number of other actions that are expected to benefit listed anadromous fish in the Central Valley, are mandated by the RPA in the NMFS (2009) Biological Opinion for Long-term Operations of the Central Valley Project and State Water Project, and listed in the NMFS (2014) *Recovery Plan for Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, and California Central Valley steelhead*.

#### *4.3.8.1.2 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 winter-run Chinook salmon.

### *4.3.8.1.3 Agricultural Practices*

Agricultural practices occur throughout the Central Valley adjacent to waterways used by Chinook salmon. 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 project area, including the Sacramento River and Delta. Agricultural practices may also introduce nitrogen, ammonia, and other nutrients into the watershed, 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 reproductive success and survival rates (Dubrovsky et al. 1998; Kuivila and Moon 2004; Scholz et al.2012). Discharges occurring outside the Project Area but that flow downstream into the Project Area also contribute to cumulative effects.

### *4.3.8.1.4 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 4.3-38 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 4.3-38. 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 4.3-39 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 4.3-39. 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% |

| Community | 2000 | 2010 | Average Annual Growth Rate 2000–2010 |
|---|---|---|---|
| **Small or Unincorporated Communities** | | | |
| Clarksburg | 681 | 418 | -3.9% |
| Sources: U.S. Census Bureau 2000; U.S. Census Bureau 2011.<br>[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.

Adverse effects on Chinook and their habitat may result from urbanization-induced point and non-point source chemical contaminant discharges within the project 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 are recreational boating and fishing. Boating activities may result in increased wave action and propeller wash in waterways. This potentially could degrade riparian and wetland habitat by eroding channel banks and mid-channel islands. In shallow water, wakes and propeller wash can also churn up benthic sediments thereby potentially resuspending contaminated sediments and degrading areas of submerged vegetation. This, in turn, can reduce habitat quality for the invertebrate forage base required for the survival of juvenile salmonids moving through the system. Increased recreational boat operation in the Delta may also result in more contamination from the operation of gasoline and diesel powered engines on watercraft entering the water bodies of the Delta.

#### *4.3.8.1.5 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. 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).

###### *4.3.8.1.6 Activities within the Nearshore Pacific Ocean*

Future tribal, state and local government actions will likely take 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 management 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 winter-run Chinook salmon 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.

###### *4.3.8.1.7 Other Activities*

Other future actions within the project area that are likely to occur and may adversely affect Chinook salmon and their 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 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 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 at temperatures as high as 100°F into the project area. This 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).

#### *4.3.8.2 Climate Change*

Climate change and associated water temperature and streamflow effects have potential to negatively affect winter-run Chinook salmon. These runs are vulnerable because their egg and alevin life stages coincide with the warmest months of the year (Table 4.3-19).

Some global climate models (GCMs) predict that summer water temperatures in the Sacramento River and its tributaries may increase by 3°C to 6°C by the end of this century, which would result in a greater frequency in exceedance of lethal water temperature thresholds (Dimacali 2013; Thompson et al. 2012; Cloern et al. 2011; PRBO Conservation Science 2011; Yates et al. 2008). The GCMs also predict potential reductions in streamflow by the end of the century (Thompson et al. 2012; Cloern et al. 2011), although are subject to moderation by reservoir releases (PRBO Conservation Science 2011; Yates et al. 2008). Predicted reductions in reservoir cold water pool storage volume would diminish the capacity of managers to counter water temperature increases (Dimacali 2013; Cloern et al. 2011; Yates et al. 2008).

GCMs consistently predict much smaller effects on water temperature and streamflow over the first several decades of this century, which include the time period of the PP starting operations (i.e., up to the completion of construction in 2029). Predictions for water temperature increases and streamflow reduction by about 2030 are generally small (<1.5°C and <1%, respectively) (Brown et al. 2016; Dimacali 2013; Cloern et al. 2011). Cloern et al. (2011), using 16°C as the lethal water temperature threshold for winter-run Chinook salmon spawning, egg incubation, and alevin life stage in the upper Sacramento River, predicted an increase of up to 22 percent in the frequency of months with exceedances of the threshold for the end of the century, but about a one percent increase for the decade from 2025 to 2035. Similarly, Thompson et al. (2012), in a study of climate change effects on spring-run Chinook salmon in Butte Creek, predicted large reductions in survival of adults during the summer holding period during the second half of this century, but little change before about 2030. However, modeling undertaken for the BDCP/CWF EIR/S does suggests potential effects of climate change in relation to existing climate; see Impact AQUA-40. These impacts would occur regardless of the PP, for the effects are not evident when compared to the NAA.

#### *4.3.8.3 Potential to Jeopardize Continued Existence of the Species*

The following discussion considers the potential for the PP, when considered in conjunction with cumulative effects and the effects of climate change, to jeopardize the continued existence of Sacramento River winter-run Chinook salmon.

*Level of Take* – Incidental take of Sacramento River winter-run Chinook salmon will occur as a result of implementing the PP, as described in Section 4.3.7 *Take Analysis*. Due to the inherent biological characteristics of winter-run Chinook salmon, the large size and variability of the river systems, and the complex interactions of many of the effects of the PP facilities and their operations, it is generally not possible to quantify numbers of individuals that may be taken incidental to the many components of the proposed project. However, the overall potential for take is low. The covered activities, facilities, and changes in operations associated with the new facilities have a low likelihood of resulting in persistent changes in mortality of individuals. Habitat losses would be relatively small—~50 acres as a result of construction and 0.42 acres as a result of operational effects on channel margin benches (Table 5.4-1 in Chapter 5 *Take Minimization and Mitigation Measures*)—and are not expected to have a population-level effect.

Take Minimization Measures – The proposed take minimization measures described in Section 5.3.3 *Sacramento River Winter-Run Chinook Salmon* of Chapter 5 *Take Minimization and Mitigation Measures* greatly reduce the potential for mortality of individuals, which makes it unlikely that activities will affect reproductive rates of the population or survivorship of individuals.

As described in Section 4.2.7.2.2 *Effect of Take Minimization Measures* for longfin smelt, DWR and DFW have collaborated to propose spring Delta outflow criteria to fully mitigate potential adverse effects to longfin smelt (see also Section 5.3.2 *Longfin Smelt* in Chapter 5 *Take Minimization and Mitigation Measures*). This has been achieved through curtailment of exports at certain times. As such there would be essentially no difference in upstream operations between PP with longfin smelt spring outflow criteria and PP without such criteria for which the detailed analysis of upstream effects was presented in Section 4.3.4.2 *Upstream Hydrologic Changes*. This is reflected in little difference in May and September Shasta reservoir storage between these scenarios (Table 4.D-1 in Appendix 4.D *Comparison of Key Hydrological Variables for Proposed Project with Longfin Smelt Spring Outflow Criteria to No Action Alternative and Proposed Project Scenarios*). Within the Delta, reduction in south Delta exports to achieve longfin smelt spring outflow criteria would result in more positive Old and Middle River flows in March of below normal and dry water years in particular (Table 4.D-5 in Appendix 4.D), possibly providing a benefit to winter-run Chinook salmon in terms of improved south Delta hydrodynamics (although generally the effects would be expected to be similar to those described in Section 4.3.4.1 *Proposed Delta Exports and Related Hydrodynamics*). Per the longfin smelt spring outflow criteria (Section 5.3.2 *Longfin Smelt* in Chapter 5 *Take Minimization and Mitigation Measures*), the upper limit of the Delta outflow criteria of 44,500 cfs resulted in CalSim modeling giving somewhat greater north Delta exports in wet years for the PP with longfin smelt spring outflow criteria compared to PP, with the result that mean April flows in wet years below the NDD were around 1,600 cfs (5%) less under PP with longfin smelt spring outflow criteria compared to PP and therefore 12% less than NAA (Table 4.D-4 in Appendix 4.D). Given the very high flows at which the longfin smelt outflow criteria would level off, the leveling-off in through-Delta survival observed at high flows (Figure 5.D-45 in Appendix 5.D of ICF International [2016]; Figure 5 of Perry et al. [2016]) and the previously described take minimization measures of operational constraints, real-time operations, and Georgiana Slough nonphysical fish barrier, no additional effects are expected.

*Mitigation* – Mitigation is expected to fully offset habitat loss and any loss of individuals because high-quality, larger-scale, intact habitat will be acquired, enhanced, and managed in perpetuity; see Section 5.4.3 *Sacramento River Winter-Run Chinook Salmon* of Chapter 5 *Take Minimization and Mitigation Measures*. Thus the PP fully mitigates for the potential incidental take of winter-run Chinook salmon.

While the winter-run Chinook salmon populations are in decline (ICF International (2016, Appendix 4.A *Status of the Species and Critical Habitat Accounts*, Section 4.A.1 *Chinook Salmon, Sacramento River Winter-Run (*Oncorhynchus tshawytscha)), the PP will not exacerbate this decline and is not expected to result in significant losses of individuals of the species or its habitat. The applicant’s take minimization measures will ensure impacts on habitat and individuals are minimized, and the mitigation will ensure an appropriate extent of habitat is protected.

The most immediate primary threat to winter-run Chinook salmon’s survival is that it has only one population, which spawns outside of its historical range in artificially maintained habitat that is vulnerable to drought. It is conceivable that a single catastrophe, such as a very prolonged drought, could cause extinction of the species or extirpation of an entire year-class. The primary long-term threat to winter-run Chinook salmon is increased water temperature associated with global climate change. Other major threats include elevated water temperatures in spawning, rearing, and migration habitats, persistent reductions in streamflow, degraded habitat in the Sacramento River and the Delta, exposure to toxins, predation and competition from exotic species, overfishing, reduced genetic diversity and integrity, and entrainment in large and small diversions (see discussion in ICF International (2016, Appendix 4.A *Status of the Species and Critical Habitat Accounts*, Section 4.A.1 *Chinook Salmon, Sacramento River Winter-Run (*Oncorhynchus tshawytscha)).

The PP will not threaten the survival of winter-run Chinook salmon because the covered activities will not result in significant losses of individuals of the species or habitat. 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 be largely similar between the PP and baseline conditions. There are a few instances in which there would be small effects to individuals resulting from changes in reservoir operations under the PP, as summarized in the following paragraph.

Upstream of the Delta, winter-run Chinook salmon may experience small reductions in survival of egg, alevin, fry, and juvenile life stages due to increased water temperatures in the Sacramento River during August and September and increased risk of redd dewatering for June and August cohorts. Winter-run juveniles may experience reduced survival and growth during emigration in September and November due to reduced instream flows. If real-time cold water pool management efforts under the PP use similar decision-making tools and criteria as currently utilized (i.e., baseline conditions), then releases from Shasta Lake under the PP would actually be sustained at similar levels as the baseline during September. Thus, it is likely that the PP would not experience higher water temperatures relative to the baseline during September, as was modeled in this analysis. 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, further minimizes the likelihood that the PP might result in adverse changes to upstream temperatures.

In the Delta, the PP is expected to result in slightly reduced survival of winter-run Chinook salmon juveniles in the lower Sacramento River and Sutter and Steamboat Sloughs, and slightly reduced quality of channel margin habitat, as a result of reduced flow downstream of the NDD.

However, these effects to some extent would be offset by reduced direct and indirect mortality resulting from lower exports at the south Delta export facilities and higher flows in south Delta channels; the remaining take would be avoided, minimized, or mitigated as described above.

Considering the potential for take relative to these factors, the take minimization measures, and that the loss of habitat will be fully mitigated, the PP will not adversely affect the reproduction and survival of winter-run Chinook salmon, and the issuance of the ITP will not jeopardize the continued existence of the species.

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