6 Effects Analysis for Delta Smelt and Terrestrial Species

6.1 Effects on Delta Smelt

The potential effects of the proposed action (PA) on Delta Smelt are evaluated in this section for Water Facility Construction; Water Facility Maintenance; Water Facility Operations; Conservation Measures; Monitoring Activities; and Cumulative Effects.

Within each of the subsections, effects are evaluated for five life stages: migrating adults (December–March), spawning adults (February–June), eggs/embryos (spring: ~March–June), larvae/young juveniles (spring: ~March–June), and juveniles (~July–December). As previously described, for each life stage, individual-level effects are considered (*i.e.*, the effects to individual fish), as well as population-level effects (*i.e.*, the proportion of the population that could be affected by the individual-level effects).

The ability to estimate population-level effects has uncertainty, and by necessity is qualitative. In recent years, there have been several modeling efforts to determine factors driving long-term species abundance trends, but the results have been disparate, suggesting multiple factors. The population-level analysis in this document does not quantitatively evaluate the magnitude of change in Delta Smelt abundance that a predicted change in the analyzed factors could cause, which would require the use of a population/life cycle model (e.g., Maunder and Deriso 2011; Rose *et al.* 2013a,b; Newman *et al.* in preparation) incorporating the factors of importance for which predictions of values for NAA and PA could be made.

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

Each subsection also includes analysis of effects to critical habitat, with specific reference to the primary constituent elements, which USFWS has defined as follows[1]:

- Primary Constituent Element 1: “Physical habitat” is defined as the structural components of habitat. Because Delta Smelt is a pelagic fish, spawning substrate is the only known important structural component of habitat. It is possible that depth variation is an important structural characteristic of pelagic habitat that helps fish maintain position within the estuary’s low-salinity zone (LSZ) (Bennett *et al.* 2002; Hobbs *et al.* 2006).

- Primary Constituent Element 2: “Water” is defined as water of suitable quality to support various Delta Smelt life stages with the abiotic elements that allow for survival and reproduction. Delta Smelt inhabit open waters of the Delta and Suisun Bay. Certain conditions of temperature, turbidity, and food availability characterize suitable pelagic habitat for Delta Smelt. Factors such as high entrainment risk and contaminant exposure

[1] This text is adapted from the USFWS Biological Opinion on the 2014 Georgiana Slough Floating Fish Guidance Structure Project.

can degrade this PCE even when the basic water quality is consistent with suitable habitat.

- Primary Constituent Element 3: "River flow" is defined as transport flow to facilitate spawning migrations and transport of offspring to LSZ rearing habitats. River flow includes both inflow to and outflow from the Delta, both of which influence the movement of migrating adult, larval, and juvenile Delta Smelt. Inflow, outflow, and Old and Middle Rivers flow influence the vulnerability of Delta Smelt larvae, juveniles, and adults to entrainment at Banks and Jones River flow interacts with the fourth primary constituent element, salinity, by influencing the extent and location of the highly productive LSZ where Delta Smelt rear.

- Primary Constituent Element 4: "Salinity" is defined as the LSZ nursery habitat. The LSZ is where freshwater transitions into brackish water; the LSZ is defined as 0.5–6.0 psu (Kimmerer 2004). The 2 psu isohaline is a specific point within the LSZ where the average daily salinity at the bottom of the water is 2 psu (Jassby *et al.* 1995). By local convention the location of the LSZ is described in terms of the distance from the 2 psu isohaline to the Golden Gate Bridge (X2); X2 is an indicator of habitat suitability for many San Francisco Estuary organisms and is associated with variance in abundance of diverse components of the ecosystem (Jassby *et al.* 1995; Kimmerer 2002). The LSZ expands and moves downstream when river flows into the estuary are high. Similarly, it contracts and moves upstream when river flows are low. During the past 40 years, monthly average X2 has varied from as far downstream as San Pablo Bay (45 km) to as far upstream as Rio Vista on the Sacramento River (95 km). In general, Delta Smelt habitat quality and surface area are greater when X2 is located in Suisun Bay. Both habitat quality and quantity diminish the more frequently and further the LSZ moves upstream, toward the confluence.

Although the analysis focuses on these definitions of critical habitat, it is acknowledged that important aspects of habitat occur outside these definitions. For example, as noted by the IEP MAST Team (2015: 106), although some researchers describe the low salinity zone as the center of distribution for juvenile Delta Smelt, Delta Smelt occur in relatively high abundance in the Cache Slough complex, which can also be considered as nursery habitat. In addition, recent laboratory studies suggest that Delta Smelt acclimate easily to LSZ salinity and above (up to 10 ppt), which points to other factors such as food, turbidity, or temperature playing a greater role in survival (Kammerer *et al.* 2015).

6.1.1 Effects of Water Facility Construction on Delta Smelt

6.1.1.1 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 Delta Smelt and its designated critical habitat. Approximately 100 over-water borings are currently proposed to collect geotechnical data at the proposed locations of the north Delta intakes, barge landings, tunnel alignment crossings, HOR gate, and CCF facilities (Table 3-4). Site-specific studies will investigate several geotechnical properties of these sites, including the stability of canal embankments and levees,

liquefaction of soils, seepage through coarse-grained soils, settlement of embankments and structures, subsidence, and soil-bearing capacity. Specific field activities will include drilling of sample soil borings, cone penetration, and other *in situ* tests (slug tests, aquifer/pumping tests, and test pits) to evaluate subsurface conditions. In-water borings will be conducted using a mud rotary method in which a conductor casing will be pushed into the sediment to isolate the drilling area, drilling fluids (bentonite), and cuttings from the surrounding water. Drilling fluids and cuttings will be contained within the conductor casing and returned to a recirculation tank on the drill ship or barge where they will be transferred to drums for storage and disposal.

DWR plans to restrict in-water drilling to the approved in-water work window (August 1 to October 31) between the hours of sunrise and sunset. The duration of drilling at each location will vary depending on the number and depth of the holes, drill rate, and weather conditions, but activities are not expected to exceed 60 days at any one location. Overwater borings for the intake structures and river crossings for tunnels will be carried out by a drill ship and barge-mounted drill rigs. A number of AMMs are proposed to avoid or minimize potential turbidity, suspended sediment, and other water quality impacts (e.g., bentonite or contaminant spills) on listed species and aquatic habitat during geotechnical activities: 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;* AMM14 *Hazardous Material Management Plan;* AMM6 *Disposal and Reuse of Spoils, Reusable Tunnel Material, and Dredged Material;* and AMM7 *Barge Operations Plan* (Appendix 3.F, *General Avoidance and Minimization Measures*) (Appendix 3.F, *General Avoidance and Minimization Measures*).

Restricting in-water drilling to August 1 to October 31 will effectively avoid the periods when Delta Smelt may be present in the action areas of the proposed geotechnical activities. Therefore, no direct effects on Delta Smelt are anticipated. Geotechnical activities in open water may affect the designated critical habitat of Delta Smelt through suspension and deposition of sediment (resulting in burial of potential spawning substrate) or direct disturbance of spawning substrate or shallow water habitat. However, these effects are expected to be negligible based on the small areas and nature of disturbance resulting from installation and removal of the casings, and the general lack of physical features at the propose sites that are thought to be preferred by Delta Smelt for spawning (see 6.1.1.3, North Delta Intakes. 6.1.1.4, Barge Landings, 6.1.1.5, Head of Old River Gate, and 6.1.1.6, Clifton Court Forebay). Consequently, with implementation of the proposed in-water work window and AMMs, geotechnical exploration is not likely to adversely affect Delta Smelt or its designated critical habitat.

6.1.1.2 North Delta Intakes

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 can divert a maximum of 3,000 cfs of river water. Each intake consists of an intake structure fitted with on-bank fish screens; gravity collector box conduits extending through the levee to convey flow to the sedimentation system; a sedimentation system consisting of sedimentation basins to capture sand-sized sediment and drying lagoons for sediment drying and consolidation; a sedimentation afterbay providing the transition from the sedimentation basins to a shaft that will discharge into a tunnel leading to an

IF; 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, *Description of the Proposed Action*.

Construction activities that could potentially affect Delta Smelt include the following in-water activities: cofferdam installation and removal, levee clearing and grubbing, riprap placement, dredging, and barge operations. In-water construction or work activities are defined here as activities occurring within the active channel of the river, which would be part of, or immediately adjacent to, the river (e.g., at waterline, in water column, on riverbed, or along river shoreline). All other sediment-disturbing activities associated with construction of the north Delta intakes and associated facilities, including construction of the sedimentation basins, will be isolated from the Sacramento River and will use appropriate BMPs and AMMs to prevent the discharge of sediment to the river.

Construction of the three intakes is expected to take 5 years, with the construction of each facility beginning in different years (Intake 5 in year 1, Intake 3 in year 2, and Intake 2 in year 3) and requiring 3 years to complete. Construction of each intake structure will involve the installation of a sheetpile cofferdam in the Sacramento River during the first construction season, which will isolate the majority of work area from the river during the remaining years of construction. Some clearing and grubbing at the construction site may be required prior to cofferdam installation depending on site conditions (e.g., presence of vegetation). Once the cofferdam is installed, the area within the perimeter of the cofferdam will be dewatered to the extent possible. Dewatering of the cofferdam will be performed using a screened intake to prevent entrainment of fish. Before dewatering is complete, fish rescue and salvage activities will be performed to collect any stranded fish and return them to the river. Water pumped from within the cofferdams will be discharged to settling basins or Baker tanks to remove the sediment before being returned to the river via pumping or gravity flow. After the cofferdams have been dewatered, dredging, foundation pile driving, and other construction activities will proceed within the perimeter of the cofferdams.

It is assumed that once the intakes are completed and the cofferdams are removed, the area in front of each intake will be dredged to provide appropriate water depths and hydraulic conditions at each intake. If dredging is required, it will occur within the in-water construction window (June 1 through October 31) when listed fish species are least likely to occur in the action area. It is also assumed that periodic maintenance dredging will be needed to maintain appropriate flow conditions and would occur only during the approved in-water work window.

During the in-water construction period, a total of approximately 13.1 acres of shallow water habitat will be permanently[2] affected by construction activities. These impacts include 9.9 acres that will be altered by dredging and barge operations through changes in channel depths, benthic habitat, cover, and temporary in-water and overwater structure (barges, spud piles) within active work areas adjacent to the proposed intake structure and levee slope. The footprints of proposed intake structures, transition walls, and bank protection will result in the permanent loss of

[2] All impacts to Delta Smelt habitat are assumed to be permanent because they would occur over multiple years, which could affect multiple generations of Delta Smelt, given that the species generally lives for ~1 year.

approximately 3.2 acres of shallow water habitat. Permanent modifications of nearshore habitat due to the presence of these structures will encompass a total of 5,367 feet of shoreline. At each intake, between 1.6 and 3.1 acres of river area will be located within the cofferdams during construction.

6.1.1.2.1 Turbidity and Suspended Sediment

Construction activities that disturb the riverbed and banks within the footprints of the north Delta intake facilities may temporarily increase turbidity and suspended sediment levels in the Sacramento River. These activities include cofferdam installation and removal, levee clearing and grading, riprap placement, dredging, and barge operations. These activities will be restricted to the in-water construction window (June 1 through October 31) when listed fish species are least likely to occur in the action area. In addition to limiting activities to the in-water work window, AMMs are proposed to avoid or minimize impacts due to increases in turbidity and suspended sediment levels on water quality and direct and indirect affects to listed fish species resulting from sediment-disturbing activities. AMMs include the following: 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;* AMM14 *Hazardous Material Management Plan;* AMM6 *Disposal and Reuse of Spoils, Reusable Tunnel Material, and Dredged Material;* and AMM7 *Barge Operations Plan* (Appendix 3.F, *General Avoidance and Minimization Measures*). (

All other sediment-disturbing activities associated with construction of the north Delta intake facilities, including construction of the sedimentation basins, will be isolated from the Sacramento River and will not result in the discharge of sediment to the river with implementation of the proposed avoidance and minimization measures and best management practices related to off-bank (land-based) construction activities.

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 the proposed erosion and sediment control AMMs, no adverse water quality effects are anticipated during this period.

6.1.1.2.1.1 Migrating Adults (December-March)

6.1.1.2.1.1.1 Individual-Level Effects

The timing of in-water construction activities (June 1–October 31) will avoid the Delta Smelt adult migration season. Therefore, there would be no effect on migrating adults from temporary increases in turbidity and suspended sediment.

6.1.1.2.1.1.2 Population-Level Effects

No population-level effect would occur.

6.1.1.2.1.2 Spawning Adults (February-June)

6.1.1.2.1.2.1 Individual-Level Effects

During cofferdam installation, levee clearing and grubbing, riprap placement, 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. Increases in turbidity and suspended sediment levels associated with these activities will be temporary and localized, and unlikely to reach levels causing direct injury or mortality to Delta Smelt.

Little is known about the spawning requirements of Delta Smelt or the sensitivity of spawning adults to turbidity and suspended sediment. In general, Delta Smelt are adapted to turbid waters where they presumably benefit from increased feeding efficiency and avoidance of sight-feeding predators. In laboratory experiments, the feeding rates of Delta Smelt generally were found to be highest at turbidities less than or equal to 12 NTU, relatively persistent over a broad range of turbidities (12-120 NTU), and showed a strong decline at 250 NTU (Hasenbein *et al.* 2013). This finding is consistent with monitoring data which shows that Delta Smelt are often captured in turbidities between 10 and 50 NTU (Feyrer *et al.* 2007).

During in-water construction activities at the proposed intake sites, 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 (2008) 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. These levels would not be expected to adversely affect Delta Smelt based on the general association and feeding responses of Delta Smelt to turbidity (Hasenbein *et al.* 2013).

Increases in suspended sediment during in-water construction activities may result in localized sediment deposition in the vicinity of the proposed intakes, degrading potential spawning habitat of Delta Smelt through burial of suitable substrates. However, the Sacramento River in the vicinity of the proposed intake sites do not likely support significant spawning of Delta Smelt because of the low quality of spawning habitat in the action area. There appears to be little or no habitat thought to be preferred by Delta Smelt for spawning in this reach, which is dominated by steep levee slopes, existing riprap, and low quantities of riparian and aquatic vegetation.

6.1.1.2.1.2.2 Population-Level Effects

Spawning adults may be present in the vicinity of the intakes during February through June. Thus, the timing of in-water construction activities (June 1–October 31) will avoid most of the spawning season (January through June, with peak numbers during February through May). In addition, historical survey data indicate that most of the Delta Smelt population is distributed downstream of the proposed intake sites. Adults and larvae have been reported to occur in the north Delta and farther upstream (Vincik and Julienne 2012) but the results from various surveys and general life history information suggest that the proportion of the population occupying the action area is low and most likely to occur during the primary winter and spring migration and spawning periods. For example, the mean densities of Delta Smelt larvae collected in the vicinity of the proposed intakes during the 1991-1994 egg and larval surveys was 4-6% of the mean densities collected downstream of these locations during April and May (Section 6.1.3, *Effects of Water Facility Operations on Delta Smelt*). The low proportion of migrating adults that would be expected to occur near the proposed intake sites during construction and operation of these

facilities is also supported by the results of the DSM2-PTM analysis described in Section 6.A.2.1, *Migrating Adult Movement Upstream (DSM2-PTM)*, of Appendix 6.A, *Quantitative Methods for Biological Assessment of Delta Smelt*. Thus, the potential effects of increased turbidity and suspended sediment would be limited to a small proportion of the population that may be present in the action area in June. The low quality of spawning habitat and expected low utilization of the intake sites by spawning adults further reduces the likelihood of population-level effects.

6.1.1.2.1.3 Eggs/Embryos (Spring: ~March-June)

6.1.1.2.1.3.1 Individual-Level Effects

Delta Smelt eggs and embryos are demersal and adhesive, attaching to substrates with an adhesive stalk formed by the outer layer of the egg (Bennett 2005). Although the potential for exposure is low, individual eggs would be subject to burial by the deposition of suspended sediment generated by in-water construction activities.

6.1.1.2.1.3.2 Population-Level Effects

No population-level effects are anticipated because of the timing of in-water construction activities, the low proportion of the population utilizing the action area, and the low quality of spawning habitat in the affected reaches.

6.1.1.2.1.4 Larvae/Young Juveniles (Spring: ~March-June)

6.1.1.2.1.4.1 Individual-Level Effects

Based on the general discussion of effects above (see *Spawning Adults*), Delta Smelt larvae and early juveniles are not likely to adversely affected by the levels of turbidity and suspended sediment generated by in-water construction activities at the north Delta intake sites.

6.1.1.2.1.4.2 Population-Level Effects

No population-level effects are anticipated because of the timing of in-water construction activities, the low proportion of the population utilizing the action area, and general association and feeding responses of Delta Smelt to turbidity within the range generated by in-water activities.

6.1.1.2.1.5 Juveniles (Summer/Fall: ~July-December)

6.1.1.2.1.5.1 Individual-Level Effects

Juvenile Delta Smelt rear downstream of the proposed intake locations in the summer and fall and therefore would be unaffected by increased turbidity and suspended sediment during in-water construction activities.

6.1.1.2.1.5.2 Population-Level Effects

No population-level effect would occur.

6.1.1.2.2 Contaminants

Construction of the north Delta intakes could result in accidental spills of contaminants, including oil, fuel, hydraulic fluids, concrete, paint, and other construction-related materials, resulting in localized water quality degradation and potential adverse effects on Delta Smelt and other listed fish species. The risk of such effects is highest during in-water construction activities because of the proximity of construction activities 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 the following AMMs (Appendix 3.F, *General Avoidance and Minimization Measures*) is expected to minimize the potential for introduction of contaminants to surface waters and guide rapid and effective response in the case of inadvertent spills of hazardous materials*:* AMM1 *Worker Awareness Training;* AMM2 *Construction Best Management Practices and Monitoring;* AMM3 *Stormwater Pollution Prevention Plan;* AMM4 *Erosion and Sediment Control Plan;* AMM14 *Hazardous Materials Management Plan;* AMM5 *Spill Prevention, Containment, and Countermeasure Plan;* AMM6 *Disposal of Spoils, Reusable Tunnel Material, and Dredged Material; and Barge Operations Plan*).

Contaminants may also enter the aquatic environment through the disturbance, resuspension, or discharge of contaminated soil and sediments from construction sites. The proposed intake sites are located downstream of major urban and agricultural regions where sediments have been affected by discharges from these sources for many decades. No information on sediment contaminants at these sites is currently available. Metals, PCBs, hydrocarbons (typically oil and grease), and ammonia 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.

The potential for introduction of contaminants from disturbed sediments will be addressed through the development and implementation of an HMMP with specific measures to address the containment, handling, storage, and disposal of contaminated sediments. Because the potential mobilization of contaminants is closely linked to sediment disturbance and associated increases in turbidity and suspended sediment, implementation of the erosion and sediment control AMMs would further minimize this risk.

6.1.1.2.2.1 Migrating Adults (December-March)

6.1.1.2.2.1.1 Individual-Level Effects

The timing of in-water construction activities (June 1–October 31) will avoid the Delta Smelt adult migration season. Some risk would also exist outside the in-water construction period. However, with the implementation of proposed pollution prevention and erosion and sediment control AMMs, there is little or no risk of exposure of migrating adults to contaminants.

6.1.1.2.2.1.2 Population-Level Effects

No population-level effects would occur.

6.1.1.2.2.2 Spawning Adults (February-June)

6.1.1.2.2.2.1 Individual-Level Effects

Exposure of fish to contaminants as a result of spills or sediment disturbance can cause effects that range from physiological stress, potentially resulting in delayed effects on growth, survival,

and reproductive success, to direct mortality (acute toxicity) depending on the on the concentration, toxicity, solubility, bioavailability, and duration of exposure, as well as the sensitivity of the exposed organisms. For example, Delta Smelt are highly sensitive to sublethal levels of pyrethrin which causes neurological damage and results in impaired swimming ability and potential effects on chemosensory abilities (Connon *et al.* 2009). Such impairments may affect the ability of Delta Smelt to swim against tides or water currents, increasing their susceptibility to predation and lowering their ability to find food (Connon *et al.* 2009). Chemosensory impairment may also affect the ability of Delta Smelt to detect pheromones and find mates (Connon *et al.* 2009). In addition, contaminants can enter the aquatic food web and accumulate in fish through their diet, leading to adverse effects on behavior, tissues and organs, reproduction, growth, and immune system (Connon *et al.* 2009).

Based on the timing of in-water construction activities (June 1–October 31), spawning adults in the vicinity of the intake sites would be subject to direct exposure to contaminant spills or sediment-borne contaminants (i.e., through exposure to turbidity plumes) in June. However, implementation of the proposed pollution prevention and erosion and sediment control AMMs would effectively minimize this risk.

6.1.1.2.2.2.2 Population-Level Effects

No population-level effects are anticipated because of the timing of in-water construction activities, distribution of spawning adults, low quality of spawning habitat in the vicinity of the intake sites, and implementation of the proposed pollution control and erosion and sediment control AMMs.

6.1.1.2.2.3 Eggs/Embryos (Spring: ~March-June)

6.1.1.2.2.3.1 Individual-Level Effects

Delta Smelt eggs and embryos are demersal and adhesive, attaching to substrates with an adhesive stalk formed by the outer layer of the egg (Bennett 2005). Although exposure of eggs or embryos is expected to be minimal, individual eggs could suffer adverse effects if directly exposed to contaminant spills or sediment-borne contaminants during construction. Implementation of the proposed pollution prevention and erosion and sediment control AMMs would effectively minimize this risk throughout the construction period.

6.1.1.2.2.3.2 Population-Level Effects

No population-level effects are anticipated because of the timing of in-water construction activities, low proportion of spawning adults in the action area, low quality of spawning habitat, and implementation of the proposed pollution control and erosion and sediment control AMMs.

6.1.1.2.2.4 Larvae/Young Juveniles (Spring: ~March-June)

6.1.1.2.2.4.1 Individual-Level Effects

Based on the general discussion of effects above (see *Spawning Adults*), individual larvae and early juveniles, if present, may be adversely affected by direct exposure to contaminant spills or sediment-borne contaminants during construction of the intakes. However, implementation of the proposed pollution prevention and erosion and sediment control AMMs would effectively minimize this risk throughout the construction period.

6.1.1.2.2.4.2 Population-Level Effects

No population-level effects are anticipated because of the timing of in-water construction activities, low proportion of the population utilizing the action area, and implementation of the proposed pollution control and erosion and sediment control AMMs.

6.1.1.2.2.5 Juveniles (Summer/Fall: ~July-December)

6.1.1.2.2.5.1 Individual-Level Effects

Juvenile Delta Smelt rear downstream of the proposed intake locations in the summer and fall and therefore are unlikely to be affected by contaminant spills or sediment-borne contaminants during construction of the intakes.

6.1.1.2.2.5.2 Population-Level Effects

No population-level effects would occur.

6.1.1.2.3 Underwater Noise

Pile driving conducted in or near open water can produce underwater noise of sufficient intensity to injure or kill fish. During construction of the north Delta intakes, potentially harmful underwater noise levels could occur during installation of temporary sheet piles (cofferdams), permanent foundation piles for the intake facilities, and permanent bridge piers for the Highway 160 bridge.

Restriction of pile driving activities in or near open water in the Sacramento River to June 1 through October 31 will minimize the exposure of Delta Smelt to potentially harmful underwater noise. In addition, DWR will develop and implement an underwater sound control and abatement plan outlining specific measures that can be employed to further minimize potential impacts on Delta Smelt (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) that are not expected to produce noise levels high enough to cause injury. However, the degree to which vibratory and non-impact driving methods can be performed is unknown at this time due to uncertain geologic conditions at the proposed intake sites. 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 Delta Smelt and other listed fish species may be present. Coordination, implementation, and monitoring of these measures will 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 that will be taken should the thresholds be exceeded.

6.1.1.2.3.1 Migrating Adults (December-March)

6.1.1.2.3.1.1 Individual-Level Effects

The timing of in-water construction activities (June 1–October 31) will avoid the Delta Smelt adult migration season. There would be no risk of exposure of migrating adults to impact pile driving noise.

6.1.1.2.3.1.2 Population-Level Effects

No population-level effects would occur.

6.1.1.2.3.2 Spawning Adults (February-June)

6.1.1.2.3.2.1 Individual-Level Effects

Restricting impact pile to June 1–October 31 would avoid most of the Delta Smelt spawning season, although some potential for exposure of spawning adults would occur in June. In general, the effects of pile driving noise on fish may include behavioral responses, physiological stress, temporary and permanent hearing loss, tissue damage (auditory and non-auditory), and mortality. Factors that 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. In Delta Smelt and most other teleost fish, the presence of a swim bladder to maintain buoyancy increases their vulnerability to underwater noise (Hastings and Popper 2005). Sublethal effects of elevated noise include damage to hearing organs that may temporarily affect swimming ability and hearing sensitivity, which may reduce the ability of fish to detect predators or prey. Non-injurious levels of 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), potentially increasing an individual's vulnerability to predation or reducing growth or spawning success.

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 6.1-1). 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 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 6.1-1. Interim Criteria for Injury to Fish from Pile Driving Activities.

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

Fish smaller than 2 grams are more sensitive to underwater noise than larger individuals, and may experience injury at 183 dB (Fisheries Hydroacoustic Working Group 2008). Larval and juvenile delta smelt are generally smaller than 2 grams while adults average 2 to 3 grams (Foott and Bigelow 2010]). Because some adult delta smelt are less than the 2 grams, the lower injury threshold (183 dB) applies to this life stage as well. The interim criteria were set to be conservatively protective of fish.

In the following effects analysis, the potential for physical injury of fish from exposure to pile driving sounds was evaluated using a spreadsheet model developed by NMFS to calculate the distances from a 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.

Other sources of in-water noise include generator and engine vibration transmitted through the hulls of work barges and associated vessels, and dredge equipment. Noise levels produced by these sources typically are less than those associated with vibratory pile driving and are likely to be comparable to ambient noise conditions in the vicinity of the intakes caused by traffic, boats, water skiers, etc. For routine vessel traffic, these noise levels typically range from peak levels of 160 to 190 dB at a range of 10 meters, depending on vessel size (Thomsen et al. 2009). Dredge equipment noise will vary depending on equipment type. For example, a hydraulic cutterhead dredge working in the Stockton Deepwater Ship Channel produced noise levels of around 152 to 157 dB at 1 meter from the source (Reine and Dickerson 2014). Removal of pilings or other underwater structures could involve use of vibratory methods. This could generate sounds that could cause avoidance behavior of any fish present. However, the noise levels generated by vibratory driving do not approach the peak or cumulative sound criteria outlined above.

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

Table 6.1-2 presents the extent, timing, and duration of pile driving noise levels predicted to exceed the interim injury and behavioral thresholds based on application of the NMFS spreadsheet model and the assumptions presented in Appendix 3.E, *Pile Driving Assumptions for the Proposed Action*. This analysis considers only those pile driving activities that could generate noise levels sufficient to exceed the interim injury thresholds in the Sacramento River or other waters potentially supporting listed fish species. These activities include impact pile driving in open water, in cofferdams adjacent to open water, or on land within 200 feet of open water. Because the extent to which impact driving will be required is unknown at this time, the following analysis presents underwater noise impacts based on the worst-case scenario in which all piles are driven with an impact driver with no attenuation (no dewatering or attenuation devices). In addition, the 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 6.1-2. 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 183 dB SEL Injury Threshold[1, 2] (feet)	Distance to 150 dB RMS Behavioral Threshold[2] (feet)	Number of Construction Seasons	Timing of Pile Driving	Duration of Pile Driving (days)
Intake 2						
Cofferdam	33	2,814	13,058	1	Jun-Oct	42
Foundation	46	3,280	32,800	1	Jun-Oct	8
SR-160 Bridge	33	1,522	7,065	1	Jun-Oct	5
Intake 3						
Cofferdam	33	2,814	13,058	1	Jun-Oct	42
Foundation	46	3,280	32,800	1	Jun-Oct	8
SR-160 Bridge	33	1,522	7,065	1	Jun-Oct	5
Intake 5						
Cofferdam	33	2,814	13,058	1	Jun-Oct	42
Foundation	46	3,280	32,800	1	Jun-Oct	8
SR-160 Bridge	33	1,522	7,065	1	Jun-Oct	5

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

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

Sound monitoring data collected during similar types of pile driving operations indicate that single-strike peak SPLs exceeding the interim injury thresholds are expected to be limited to areas within 33–46 feet of the source piles (Table 6.1-2). Based on cumulative (daily) exposures of fish to pile driving noise, the risk of injury may extend 2,814 feet during installation of the cofferdams, 3,280 feet during installation of the foundation piles, and 1,522 feet during installation of the SR-160 bridge piers assuming worst-case conditions. Based on a threshold of 150 dB RMS, the potential for behavioral effects would extend 13,058, 32,800, and 7,065 feet, respectively. However, the extent of noise levels exceeding the injury and behavioral thresholds would be constrained to varying degrees by major channel bends that range from approximately 2,300 to 10,700 feet away from each intake facility. The potential for effects would occur over periods of 42 days during cofferdam installation, 8 days during foundation pile installation, and 5 days during bridge pile installation.

6.1.1.2.3.2.2 Population-Level Effects

Pile driving noise may have adverse effects on spawning delta smelt that are present or passing through the NDD construction sites during June while pile driving is occurring. Adults occur in the north Delta and farther upstream but the results from various surveys and general life history information suggest that the proportion of the population seasonally occupying the action area is low and most likely to occur during the winter and spring (December through May), when no in-water work would occur. Some potential exists for adults to occur in the action area in June when pile driving and other in-water construction activities for the north Delta intakes are scheduled to begin. However, because of the low abundance of delta smelt in this part of their range in June

and the low quality of potential spawning habitat in the action area, the potential for exposure of delta smelt to pile driving noise is considered low. Potential exposure of the population to pile driving noise will be further minimized by implementation of an underwater sound control and abatement plan (Appendix 3.F, *General Avoidance and Minimization Measures*, AMM9 *Underwater Sound Control and Abatement Plan*) that includes the use of vibratory and other non-impact pile driving methods, attenuation devices, and other potential physical and operational measures to avoid or minimize impacts on Delta Smelt. This plan will also include hydroacoustic monitoring and compliance requirements that will be developed in coordination with USFWS, NMFS, and CDFW to avoid and minimize potential impacts on listed fish species.

6.1.1.2.3.3 Eggs/Embryos (Spring: ~March-June)

6.1.1.2.3.3.1 Individual-Level Effects

Delta Smelt eggs and embryos are demersal and adhesive, attaching to substrates with an adhesive stalk formed by the outer layer of the egg (Bennett 2005). Although the potential for exposure is low, any individual eggs in the vicinity of the intake sites would be unable to avoid prolonged exposure to pile driving noise and potential adverse effects on survival, development, or viability.

6.1.1.2.3.3.2 Population-Level Effects

Based on the small proportion of spawning adults in the action area at the time of pile driving operations and expected low utilization of the affected reaches by spawning adults, any mortality of eggs or embryos due to pile driving noise would not be expected to have a significant effect on population abundance. Any potential losses will be further reduced by the use of vibratory and other non-impact pile driving methods, attenuation devices, and other physical and operational measures that may be implemented as part of the underwater sound control and abatement plan.

6.1.1.2.3.4 Larvae/Young Juveniles (Spring: ~March-June)

6.1.1.2.3.4.1 Individual-Level Effects

Delta Smelt larvae and early juveniles originating from upstream spawning areas may encounter pile driving noise during their downstream movement to estuarine rearing areas. Although the potential for exposure is low, any larval Delta Smelt passing the intakes during impact pile driving would be unable to avoid exposure to pile driving noise and therefore could be injured or killed depending on their proximity to the source piles and the duration of exposure.

6.1.1.2.3.4.2 Population-Level Effects

Based on the proportion of the adult population occurring in or upstream of the north Delta in June, any losses of larvae or early juveniles that encounter pile driving noise would represent a small proportion of total larval production in each year of pile driving operations. Potential losses will be further reduced by the use of vibratory and other non-impact pile driving methods, attenuation devices, and other physical and operational measures that may be implemented as part of the underwater sound control and abatement plan.

6.1.1.2.3.5 Juveniles (Summer/Fall: ~July-December)

6.1.1.2.3.5.1 Individual-Level Effects

Juvenile Delta Smelt rear downstream of the proposed intake sites in the summer and fall and therefore are unlikely to be affected by pile driving noise.

6.1.1.2.3.5.2 Population-Level Effects
No population-level effects would occur.

6.1.1.2.3.5.3 Population-Level Effects
No population-level effects would occur.

6.1.1.2.4 Fish Stranding
Installation of cofferdams to isolate the construction areas for the proposed intake sites has the potential to strand fish, resulting in direct mortality of fish from dewatering, dredging, and pile driving within the enclosed areas of the channel. To minimize entrapment risk and the number of fish subject to capture and handling during fish rescue and salvage operations, cofferdam construction will be limited to the proposed in-water construction period (June 1–October 31) to avoid the peak abundance of adults and larvae in the north Delta. DWR will prepare and submit a fish rescue and salvage plan (Appendix 3.F, *General Avoidance and Minimization Measures*, AMM8 *Fish Rescue and Salvage Plan*) to the fish and wildlife agencies (NMFS, USFWS, CDFW) for review and approval prior to implementation. The plan will include detailed procedures for fish rescue and salvage, including collection, holding, handling, and release, that would apply to all in-water activities with the potential to entrap fish. All fish rescue and salvage operations will be conducted under the guidance of a qualified fish biologist. The biologist, in consultation with a designated agency biologist, will determine the appropriate fish collection and relocation methods based on site-specific conditions and construction methods. Collection methods may include seines, dip nets, and electrofishing if permitted.

6.1.1.2.4.1 Migrating Adults (December-March)
6.1.1.2.4.1.1 Individual-Level Effects
The timing of in-water construction activities (June 1–October 31), including cofferdam construction, will avoid the Delta Smelt adult migration season. Therefore, migrating adults are not at risk of being stranded.

6.1.1.2.4.1.2 Population-Level Effects
No population-level effects would occur.

6.1.1.2.4.2 Spawning Adults (February-June)
6.1.1.2.4.2.1 Individual-Level Effects
Although present in low numbers, spawning adults may be present in the action area in June and subject to stranding in cofferdams. Adults would be expected to move away from active construction areas, but some risk of stranding would exist as long as the affected areas are accessible to fish. Fish rescue and salvage activities using accepted fish collection methods can result in injury or mortality, but these effects are typically minor, and can often be avoided with appropriate training. However, adverse effects may still occur because of varying degrees of effectiveness of the collection methods and potential stress and injury associated with various capture and handling methods.

6.1.1.2.4.2.2 Population-Level Effects
Population-level effects are expected to be negligible because of the low densities of adults that may be present in the action area during cofferdam installation, the low utilization and expected

avoidance of the intake sites by spawning adults, and implementation of fish rescue and salvage activities.

6.1.1.2.4.3 Eggs/Embryos (Spring: ~March-June)

6.1.1.2.4.3.1 Individual-Level Effects

Based on the low utilization and expected avoidance of the intake sites by spawning adults, there is little or no risk of stranding of Delta Smelt eggs or embryos.

6.1.1.2.4.3.2 Population-Level Effects

No population-level effects would occur.

6.1.1.2.4.4 Larvae/Young Juveniles (Spring: ~March-June)

6.1.1.2.4.4.1 Individual-Level Effects

Although the potential for exposure is low, Delta Smelt larvae and early juveniles may be particularly vulnerable to stranding because of their limited swimming abilities and potential entrainment in open cofferdams. In addition, conventional fish collection methods are less effective and more likely to cause injury or death of these life stages compared to larger juveniles or adults.

6.1.1.2.4.4.2 Population-Level Effects

Population-level effects would be expected to be negligible based on the small proportion of adults that spawn in or upstream of the north Delta in June, the resulting low densities of larvae and juveniles passing the intake sites, and the limited influence of cofferdams on passage conditions in the river.

6.1.1.2.4.5 Juveniles (Summer/Fall: ~July-December)

6.1.1.2.4.5.1 Individual-Level Effects

Juvenile Delta Smelt rear downstream of the proposed intake sites in the summer and fall and therefore are unlikely to be stranded in cofferdams.

6.1.1.2.4.5.2 Population-Level Effects

No population-level effects would occur.

6.1.1.2.5 Direct Physical Injury

During construction of the north Delta intakes, fish could be injured or killed by direct contact with equipment or materials that enter 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, the potential for injury of listed fish species would be minimized by limiting the duration of in-water construction activities to the extent practicable and implementing the following AMMs: AMM1 *Worker Awareness Training;* AMM4 *Erosion and Sediment Control Plan; Disposal of Spoils, Reusable Tunnel Material, and Dredged Material;* AMM7 *Barge Operations Plan;* and AMM8 *Fish Rescue and Salvage Plan* (Appendix 3.F, *General Avoidance and Minimization Measures*).

6.1.1.2.5.1 Migrating Adults (December-March)

6.1.1.2.5.1.1 Individual-Level Effects

The timing of in-water construction activities (June 1–October 31) will avoid the Delta Smelt adult migration season. Therefore, migrating adults are not at risk of being injured.

6.1.1.2.5.1.2 Population-Level Effects
No population-level effects would occur.

6.1.1.2.5.2 Spawning Adults (February-June)
6.1.1.2.5.2.1 Individual-Level Effects
Spawning adults may be present in very small numbers in June and therefore subject to injury. Although adults would be expected to move away from active construction areas, it is assumed that some potential for injury exists whenever heavy equipment or materials are operated or placed in open water.

6.1.1.2.5.2.2 Population-Level Effects
Population-level effects are expected to be negligible because of the low densities of adults that may be present in the action area during in-water construction activities, and the low utilization and expected avoidance of the intake sites by spawning adults.

6.1.1.2.5.3 Eggs/Embryos (Spring: ~March-June)
6.1.1.2.5.3.1 Individual-Level Effects
Based on the low utilization and expected avoidance of the intake sites by spawning adults, there is little or no risk of injury of Delta Smelt eggs or embryos.

6.1.1.2.5.3.2 Population-Level Effects
No population-level effects would occur.

6.1.1.2.5.4 Larvae/Young Juveniles (Spring: ~March-June)
6.1.1.2.5.4.1 Individual-Level Effects
Although the potential for exposure is low, Delta Smelt larvae and early juveniles may be particularly vulnerable to injury because of their limited swimming abilities.

6.1.1.2.5.4.2 Population-Level Effects
Population-level effects would be expected to be negligible based on the small proportion of adults that spawn in or upstream of the north Delta in June, the resulting low densities of larvae and juveniles passing the intake sites, and the limited influence of construction equipment and materials on passage conditions in the river.

6.1.1.2.5.5 Juveniles (Summer/Fall: ~July-December)
6.1.1.2.5.5.1 Individual-Level Effects
Juvenile Delta Smelt rear downstream of the proposed intake sites in the summer and fall and therefore are unlikely to be injured by construction activities.

6.1.1.2.5.5.2 Population-Level Effects
No population-level effects would occur.

6.1.1.2.6 Loss or Alteration of Habitat
Construction of the north Delta intakes will result in permanent loss or alteration of aquatic habitat that includes the designated critical habitat of Delta Smelt. The effects of construction activities on water quality, including turbidity and suspended sediment, underwater noise, and contaminants, were previously discussed. A total of approximately 13.1 acres of shallow water

habitat will be permanently[3] affected by intake construction. This consists of 9.9 acres that will be altered by dredging and barge operations through changes in channel depths, benthic habitat, cover, and temporary in-water and overwater structure (barges, spud piles) within active work areas adjacent to the proposed intake structure and levee slope. The footprints of proposed intake structures, transition walls, and bank protection will result in the permanent loss of approximately 3.2 acres of shallow water habitat. Permanent losses of nearshore habitat due to the presence of the three NDD intake structures will encompass a total of 5,367 feet of shoreline.

During construction activities, DWR will implement AMM2 *Construction Best Management Practices and Monitoring*, to protect listed fish, wildlife, and plant species, their designated critical habitat, and other sensitive natural communities (Appendix 3.F, *General Avoidance and Minimization Measures*). These BMPs include a number of measures to limit the extent of disturbance of aquatic and riparian habitat during construction, and, following construction, to restore temporarily disturbed areas to pre-construction conditions. All construction and site restoration BMPs will be subject to an approved construction and post-construction monitoring plan to ensure their effectiveness. DWR proposes to offset unavoidable habitat impacts at the proposed intake sites through on-site and/or off-site mitigation, including the purchase of conservation credits at an approved conservation bank.

6.1.1.2.6.1 Migrating Adults (December-March)

6.1.1.2.6.1.1 Individual-Level Effects

Construction of the three intake structures will result in a permanent loss or alteration of 13.1 acres of shallow water habitat and 5,367 feet of channel margin habitat near the northern limit of the geographic area used by Delta Smelt for migration, potential spawning, and larval dispersal to the estuary. Cofferdams will isolate the work areas, temporarily reducing the width of the river channel and eliminating the shallow, low-velocity nearshore zones currently available to migrating Delta Smelt along the east bank of the river. The creation of deeper, higher-velocity zones adjacent to the cofferdams and riprap could also increase predator habitat. Although affecting a small proportion of the population that may migrate past these sites, these changes may impair adult passage and subject adults to an elevated risk of predation as they attempt to pass the construction sites.

6.1.1.2.6.1.2 Population-Level Effects

The loss of low-velocity shoreline areas and increased predation risk at the intake construction sites could potentially reduce the number of migrating adults that successfully pass the sites and survive to reach upstream spawning areas. The effect on passage success depends on the number attempting to pass the site on the east side of river and the ability of adults to use alternative routes (e.g., the west side of the river would remain unaffected) or spawning areas (e.g., returning downstream to spawn). Overall, however, the small proportion of the population that migrates and spawns in the reaches upstream of the intake site indicates that any population-level effects would be small.

[3] All impacts to Delta Smelt habitat are assumed to be permanent because they would occur over multiple years, which could affect multiple generations of Delta Smelt, given that the species generally lives for ~1 year.

6.1.1.2.6.2 Spawning Adults (February-June)

6.1.1.2.6.2.1 Individual-Level Effects

There appears to be little or no habitat thought to be preferred by Delta Smelt for spawning at the proposed intake sites, which are dominated by steep levee slopes, existing riprap, and low quantities of riparian and aquatic vegetation. Consequently, permanent losses of nearshore habitat resulting from construction of the intakes would have little or no effect on spawning site selection or spawning success of adults.

6.1.1.2.6.2.2 Population-Level Effects

The existing value and function of the habitat for Delta Smelt within the footprint of the proposed intakes and work areas is low compared to core areas of the species' habitat which occurs farther downstream in the estuary. Loss or alteration of this habitat would likely have a negligible population-level effect because of the small proportion of the population spawning in the action area, expected low utilization of the intake sites by spawning adults, and negligible contribution of this habitat to the overall spawning capacity of the upper estuary.

6.1.1.2.6.3 Eggs/Embryos (Spring: ~March-June)

6.1.1.2.6.3.1 Individual-Level Effects

Based on the small proportion of the population spawning in the action area, expected low utilization of the intake sites by spawning adults, and negligible contribution of this habitat to the overall spawning capacity, there is little risk of direct or indirect effects on egg/embryo production or survival.

6.1.1.2.6.3.2 Population-Level Effects

Population-level effects are expected to be negligible.

6.1.1.2.6.4 Larvae/Young Juveniles (Spring: ~March-June)

6.1.1.2.6.4.1 Individual-Level Effects

Delta Smelt larvae and early juveniles migrating from upstream spawning areas to estuarine rearing areas may be subject to an elevated risk of predation as they pass the intake construction sites because of the presence of in-water and overwater structures and the loss of shallow, low-velocity nearshore areas. To the extent that these conditions provide beneficial habitat or increased predation opportunities for predators of larvae and early juveniles (e.g., silversides; Baerwald et al. 2012), there could be an elevated risk of predation for these young life stages. However, it is not clear that these structures provide beneficial habitat as these small predators may be susceptible to the same larger predators that consume adult Delta Smelt. Therefore, elevated predation on Delta Smelt larvae is unlikely.

6.1.1.2.6.4.2 Population-Level Effects

Even if larvae and juveniles are subject to elevated predation rates as they pass the construction sites for the NDD intakes, the population-level effect would be small based on the small proportion of the population occurring in or upstream of the action area.

6.1.1.2.6.5 Juveniles (Summer/Fall: ~July-December)

6.1.1.2.6.5.1 Individual-Level Effects

Juvenile Delta Smelt rear downstream of the proposed intake sites in the summer and fall and therefore are unlikely to be affected by losses or alteration of habitat during construction.

6.1.1.2.6.5.2 Population-Level Effects

No population-level effects would occur.

6.1.1.3 Barge Landings

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

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

These locations are approximate but represent the general areas for these facilities based on their proximity to the launch shaft sites. Major construction elements of this action include barge landing construction, levee clearing and armoring (as necessary), and barge operations.

The schedule for construction of the barge landings will likely extend over 2 to 3 years. The specific design of the barge landings is unknown at this time. Permanent docks supported by steel piles are currently proposed although floating barges will be used where possible to minimize in-water construction activities. Docks would occupy an area of approximately 300 by 50 feet (0.34 acre) that would be bordered by a backfilled perimeter sheet pile wall where barges would be moored during loading and unloading operations. Dock construction will require the installation of a sheet-pile perimeter wall and 800 steel pipe piles (18-inch diameter) to support the dock. Other in-water and over-water structures may include mooring dolphins, ramps, and possibly conveyors for loading and unloading materials. Some clearing and armoring of the levee may be required to provide access and protect the levee from wave erosion.

Construction of the barge landings will result in permanent impacts to approximately 22.4 acres of tidal perennial aquatic habitat that includes the footprint of the docks, mooring structures, and adjacent channel area that will be affected by propeller wash and scour from barges and tidal action. Estimates of the amount of shallow water habitat or suitable spawning substrate potentially affected by construction are not currently available.

6.1.1.3.1 Turbidity and Suspended Sediment

Pile driving, barge operations, and levee armoring 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. In-water vibratory and impact driving of the sheet piles are expected to generate turbidity plumes that could extend beyond the immediate vicinity of the source piles depending on the direction and velocity of tidal flows. Based on an estimated installation rate of 60 piles per day, elevated turbidity and suspended levels due to pile driving activities will occur over several weeks at each landing facility. Pile driving will be restricted to the in-water construction window (June 1 through October 31) to avoid the primary periods of occurrence of listed species in the action area. Propeller wash and wakes from towing vessels and barges may also generate turbidity and suspended sediment during construction of the barge landings.

Potential turbidity and sediment impacts on listed fish species and aquatic habitat will be minimized by complying with a *Barge Operations Plan*, which includes specific measures to minimize bed scour, bank erosion, loss of submerged and emergent vegetation, and disturbance of benthic communities (Appendix 3.F, *General Avoidance and Minimization Measures*). Other AMMs that are proposed to avoid or minimize potential turbidity, suspended sediment, and other water quality impacts include AMM1 *Worker Awareness Training;* AMM2 *Construction Best Management Practices and Monitoring;* AMM3 *Stormwater Pollution Prevention Plan; Erosion and Sediment Control Plan;* AMM5 *Spill Prevention, Containment, and Countermeasure Plan;* AMM 14 *Hazardous Material Management Plan;* and AMM 6 *Disposal and Reuse of Spoils, Reusable Tunnel Material, and Dredged Material* (Appendix 3.F).

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 the proposed erosion and sediment control AMMs, no adverse water effects are anticipated during this period.

6.1.1.3.1.1 Migrating Adults (December-March)

6.1.1.3.1.1.1 Individual-Level Effects

The timing of in-water construction activities at the barge landing (June 1–October 31) will avoid the Delta Smelt adult migration season. Therefore, there would be no effect on migrating adults from temporary increases in turbidity and suspended sediment.

6.1.1.3.1.1.2 Population-Level Effects

No population-level effect would occur.

6.1.1.3.1.2 Spawning Adults (February-June)

6.1.1.3.1.2.1 Individual-Level Effects

Potential individual-level effects of elevated turbidity and suspended sediment on Delta Smelt were discussed previously (see 6.1.1.3 *North Delta Intakes*). Based on this analysis, it is generally concluded that the levels of turbidity and suspended sediment generated by in-water construction are not expected to adversely affect Delta Smelt. However, it is plausible that excessive levels of suspended sediment could disrupt spawning activity and abandonment of preferred spawning sites, or degrade potential spawning habitat through burial of suitable substrates.

6.1.1.3.1.2.2 Population-Level Effects

Based on the general timing and abundance of Delta Smelt in the east and south Delta, the potential for exposure of spawning adults to construction-related increases in turbidity and suspended sediment is low. Because Delta Smelt are generally found in the west Delta and Cache Slough/Liberty Island area during spring and summer, the majority of the population will not be exposed to construction activities at the proposed barge landing sites. In addition, the timing of in-water construction activities (June 1–October 31) will avoid most of the spawning season (January through June, with peak numbers during February through May). Thus, the potential effects of increased turbidity and suspended sediment would be limited to a small proportion of the population that may be present in the action area in June. Furthermore, potential adverse effects of sedimentation on physical habitat (spawning substrate) would be minimized by siting the barge landings on levees with steep, riprapped banks and deep nearshore areas that lack shallow water areas where spawning could occur. With the timing restrictions on in-water activities and implementation of the proposed erosion and sediment control AMMs, no population-level effects attributable to increased turbidity and suspended sediment are anticipated.

6.1.1.3.1.3 Eggs/Embryos (Spring: ~March-June)

6.1.1.3.1.3.1 Individual-Level Effects

Delta Smelt eggs and embryos are demersal and adhesive, attaching to substrates with an adhesive stalk formed by the outer layer of the egg (Bennett 2005). Although the potential for exposure is low, any eggs within the influence of the sediment plumes could be adversely affected by entrapment or suffocation if they are buried by deposited sediments.

6.1.1.3.1.3.2 Population-Level Effects

No population-level effects are anticipated because of the timing of in-water construction activities, the low proportion of the population utilizing the action area, and the low quality of spawning habitat in areas where the barge landings are likely to be sited.

6.1.1.3.1.4 Larvae/Young Juveniles (Spring: ~March-June)

6.1.1.3.1.4.1 Individual-Level Effects

Based on the general discussion of individual-level effects described previously (6.1.1.3 *North Delta Intakes*), Delta Smelt larvae and early juveniles are not likely to be adversely affected by the levels of turbidity and suspended sediment generated by in-water construction activities at the barge landings.

6.1.1.3.1.4.2 Population-Level Effects

No population-level effects are anticipated because of the timing of in-water construction activities, the low proportion of the population utilizing the action area, and the general association and feeding responses of Delta Smelt to turbidity levels generated by in-water activities.

6.1.1.3.1.5 Juveniles (Summer/Fall: ~July-December)

6.1.1.3.1.5.1 Individual-Level Effects

Juvenile Delta Smelt rear downstream of the barge landing locations in the summer and fall and therefore would be unaffected by increased turbidity and suspended sediment during in-water construction activities.

6.1.1.3.1.5.2 Population-Level Effects

No population-level effect would occur.

6.1.1.3.2 Contaminants

Construction of the barge landings poses an exposure risk to Delta Smelt from potential spills of hazardous materials from construction equipment, barges and towing vessels, and other machinery, and from potential mobilization of contaminated sediment. The risk of accidental spills of contaminants and other hazardous materials during construction of the barge landings would be similar to that described for the north Delta intakes due to the proximity of construction activities to the waters of the Delta. However, because the barge landings would be constructed on smaller waterways adjacent to major agricultural islands, these sites are more likely to contain agricultural-related toxins such as copper and organochlorine pesticides. Implementation of the following AMMs is expected to minimize the potential for introduction of contaminants into surface waters and guide rapid and effective response in the case of inadvertent spills of hazardous materials: AMM1 *Worker Awareness Training;* AMM2 *Construction Best Management Practices and Monitoring;* AMM3 *Stormwater Pollution Prevention Plan;* AMM4 *Erosion and Sediment Control Plan;* AMM14 *Hazardous Materials Management Plan;* AMM5 *Spill Prevention, Containment, and Countermeasure Plan;* AMM 6 *Disposal of Spoils, Reusable Tunnel Material, and Dredged Material;* and AMM7 *Barge Operations Plan*.

The potential for introduction of contaminants from disturbed sediments will be addressed through the development and implementation of an HMMP with specific measures to address the containment, handling, storage, and disposal of contaminated sediments. Because the potential mobilization of contaminants is closely linked to sediment disturbance and associated increases in turbidity and suspended sediment, implementation of the erosion and sediment control AMMs would further minimize this risk.

6.1.1.3.2.1 Migrating Adults (December-March)

6.1.1.3.2.1.1 Individual-Level Effects

The potential effects of contaminants on Delta Smelt were discussed previously (see 6.1.1.3 *North Delta Intakes*). The timing of in-water construction activities (June 1–October 31) will avoid the Delta Smelt adult migration season. Some risk of contaminant spills and runoff of contaminated soil would exist outside the in-water construction period but implementation of proposed pollution prevention and erosion and sediment control AMMs would effectively minimize this risk.

6.1.1.3.2.1.2 Population-Level Effects

With implementation of proposed pollution prevention and erosion and sediment control AMMs, there is little or no risk of exposure of migrating adults to contaminants. No population-level effects would occur.

6.1.1.3.2.2 Spawning Adults (February-June)

6.1.1.3.2.2.1 Individual-Level Effects

The potential effects of contaminants on Delta Smelt were discussed previously (see 6.1.1.3 *North Delta Intakes*). Based on the timing of in-water construction activities (June 1–October 31), spawning adults in the vicinity of the intake sites would be subject to direct exposure to contaminant spills or sediment-borne contaminants in June. Some risk would also exist outside

the in-water construction period. However, implementation of the proposed pollution prevention and erosion and sediment control AMMs would effectively minimize this risk throughout the construction period.

6.1.1.3.2.2.2 Population-Level Effects

No population-level effects are anticipated.

6.1.1.3.2.3 Eggs/Embryos (Spring: ~March-June)

6.1.1.3.2.3.1 Individual-Level Effects

Delta Smelt eggs and embryos are demersal and adhesive, attaching to substrates with an adhesive stalk formed by the outer layer of the egg (Bennett 2005). Although the potential for exposure is low, individual eggs in the vicinity of the barge landings would be subject to direct exposure to contaminant spills or sediment-borne contaminants during construction.

6.1.1.3.2.3.2 Population-Level Effects

No population-level effects are anticipated because of the timing of in-water construction activities, low proportion of spawning adults in the action area, and low quality of spawning habitat in areas where the barge landings are likely to be sited. Implementation of the proposed pollution prevention and erosion and sediment control AMMs would effectively minimize the risk of contaminant exposure throughout the construction period.

6.1.1.3.2.4 Larvae/Young Juveniles (Spring: ~March-June)

6.1.1.3.2.4.1 Individual-Level Effects

Based on the general discussion of potential individual-level effects of contaminants on Delta Smelt (see 6.1.1.3 *North Delta Intakes*), larvae and early juveniles may be adversely affected by direct exposure to contaminant spills or sediment-borne contaminants during construction of the intakes. However, implementation of the proposed pollution prevention and erosion and sediment control AMMs would effectively minimize this risk throughout the construction period.

6.1.1.3.2.4.2 Population-Level Effects

No population-level effects are anticipated because of the timing of in-water construction activities, low proportion of the population utilizing the action area, and implementation of the proposed pollution control and erosion and sediment control AMMs.

6.1.1.3.2.5 Juveniles (Summer/Fall: ~July-December)

6.1.1.3.2.5.1 Individual-Level Effects

Juvenile Delta Smelt rear downstream of the proposed intake locations in the summer and fall and therefore are unlikely to be affected by contaminant spills or sediment-borne contaminants during construction of the barge landings.

6.1.1.3.2.5.2 Population-Level Effects

No population-level effects would occur.

6.1.1.3.3 Underwater Noise

Impact pile driving at the barge landing sites would potentially produce underwater noise levels of sufficient intensity and duration to cause injury to fish. Currently, it is estimated that each barge landing would require vibratory and/or impact driving of several hundred sheet piles (number is unknown at this time) and 800 steel pipe piles (18-inch diameter) to construct the

dock and mooring facilities. Based on the concurrent operation of 4 impact pile drivers at each site and an estimated installation rate of 60 piles per day, pile driving noise would be expected to occur over a period of several weeks depending on the number of sheet piles required to construct the perimeter wall.

Based on the general timing and abundance of Delta Smelt in the east and south Delta, restriction of pile driving activities to June 1 through October 31 will minimize the exposure of Delta Smelt to pile driving noise. In addition, as described in Section 6.1.1.3, *North Delta Intakes*, 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 Delta Smelt and other 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 corrective actions that will be taken should the thresholds be exceeded.

6.1.1.3.3.1 Migrating Adults (December-March)

6.1.1.3.3.1.1 Individual-Level Effects

The timing of in-water construction activities (June 1–October 31) will avoid the Delta Smelt adult migration season. There would be no risk of exposure of migrating adults to impact pile driving noise.

6.1.1.3.3.1.2 Population-Level Effects

No population-level effects would occur.

6.1.1.3.3.2 Spawning Adults (February-June)

6.1.1.3.3.2.1 Individual-Level Effects

Based on the timing of pile driving operations at the barge landings (June 1–October 31) and the general timing and abundance of Delta Smelt in the east and south delta, spawning adults may be exposed to pile driving noise in June. As discussed previously (6.1.1.3 *North Delta Intakes*), the potential responses of fish to pile driving noise can range from behavioral effects to direct injury or mortality, depending on a number of biological, physical, and exposure variables. Sound exposure criteria currently in use by state and federal resource and transportation agencies in California, Oregon, and Washington to evaluate the potential for injury to pile driving activities are presented in Table 6.1-3. 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 can 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.

Other construction activities that can generate underwater noise exceeding background levels (e.g., barge operations) are not expected to result in direct injury of fish. These kinds of activities typically produce noise levels below the behavioral effects threshold of 150 dB RMS, and therefore are unlikely to adversely affect Delta Smelt or other listed fish species.

Because the extent to which impact driving will be required to install the barge landing piles is unknown at this time, the following analysis presents underwater noise impacts based on the worst-case scenario in which all piles are driven with an impact driver with no attenuation (no dewatering or attenuation devices). Assumptions for pile driving for each intake are detailed in Appendix 3.E, *Pile Driving Assumptions for the Proposed Action*, which specifies the type, size, and number of piles required, as well as the number of piles driven per day, the number of impact strikes per pile, and whether piles will be driven in water or on land.

Table 6.1-3 presents the extent, timing, and duration of pile driving noise levels predicted to exceed the interim injury and behavioral thresholds based on application of the NMFS spreadsheet model and the assumptions presented in Appendix 3.E, *Pile Driving Assumptions for the Proposed Action*. These estimates indicate that single-strike peak SPLs exceeding the injury thresholds are expected to be limited to areas within 33–46 feet of the source piles. Based on the cumulative (daily) exposure threshold (in this case, the distance to "effective quiet"), the risk of injury may extend 2,814 feet during sheet pile installation and 3,280 feet during dock pile installation. Based on a threshold of 150 dB RMS, the potential for behavioral effects would extend 13,057 and 9,607 feet away, respectively. Such exposures would occur over a period of 2-4 weeks for cofferdam installation and 13 days for dock pile installation.

Table 6.1-3. Extent, Timing, and Duration of Pile Driving Noise Levels Predicted to Exceed the Interim Injury and Behavioral Thresholds at the Barge Landing Sites

Facility or Structure	Distance to 206 dB SPL Injury Threshold (feet)	Distance to Cumulative 183 dB SEL Injury Threshold[1, 2] (feet)	Distance to 150 dB RMS Behavioral Threshold[2] (feet)	Number of Construction Seasons	Timing of Pile Driving	Duration of Pile Driving (days)
Barge Landings						
Sheet Pile Wall	<33	2,814	13,057	1	June-Oct	--[3]
Docks	46	1,774	9,607	1	June-Oct	13

[1] Distance to cumulative injury thresholds are governed by the distance to "effective quiet" (150 dB SEL).

[2] Distances 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.

3 Duration of pile driving to construct the sheet-pile perimeter wall is unknown at this time but is expected to require 2-4 weeks.

6.1.1.3.3.2.2 Population-Level Effects

Based on the general distribution and timing of spawning, potential exposure of Delta Smelt to pile driving noise would be limited to a small proportion of adults, eggs, and larvae that may occur in the vicinity of the barge landings in June. During pile driving operations, all waters extending across the width of the adjacent Delta channels (less than 1,000 feet in width) and upstream and downstream 1,774 to 2,814 feet away would be subject to noise levels exceeding

the injury thresholds. The potential for behavioral effects would extend beyond these distances but would likely be constrained by the presence of major channel bends that typically occur within 1 to 2 miles of the proposed barge landing sites. The potential for injury or behavioral effects on spawning Delta Smelt depends on the proximity of preferred spawning habitat, which is thought to include areas with complex channels, broad shoals, and tidal marsh (Sommer and Mejia 2013). Consequently, siting the barge landings on levees with steep, riprapped banks away from such areas is likely to avoid or minimize exposure of adults to pile driving noise. It should also be recognized that the above estimates represent worst-case impacts that, to the extent feasible, will be reduced by the use of vibratory and other non-impact pile driving methods, attenuation devices, and other physical and operational measures that will be identified in DWR's underwater sound control and abatement plan (Appendix 3.F, *General Avoidance and Minimization Measures*, AMM9 *Underwater Sound Control and Abatement Plan*). With the implementation of this measure and proposed restrictions on the frequency, timing, and duration of pile driving operations (Table 6.1-3), no substantial population-level effects are expected.

6.1.1.3.3.3 Eggs/Embryos (Spring: ~March-June)

6.1.1.3.3.3.1 Individual-Level Effects

Delta Smelt eggs and embryos are demersal and adhesive, attaching to substrates with an adhesive stalk formed by the outer layer of the egg (Bennett 2005). Although the potential for exposure would be low, individual eggs in the vicinity of the intake sites would be unable to avoid prolonged exposure to pile driving noise and potential adverse effects on survival, development, or viability.

6.1.1.3.3.3.2 Population-Level Effects

Based on the small proportion of spawning adults in the action area at the time of pile driving operations and expected low utilization of channel types where the barge landings will likely be sited, any mortality of eggs or embryos due to pile driving noise would not be expected to have a significant effect on population abundance. Potential losses can be further reduced by the use of vibratory and other non-impact pile driving methods, attenuation devices, and other physical and operational measures that may be implemented as part of the underwater sound control and abatement plan.

6.1.1.3.3.4 Larvae/Young Juveniles (Spring: ~March-June)

6.1.1.3.3.4.1 Individual-Level Effects

Delta Smelt larvae and early juveniles originating from upstream spawning areas may encounter pile driving noise during their downstream movement to estuarine rearing areas. Although the potential for exposure is low, any larval Delta Smelt passing the barge landings during impact pile driving would be unable to avoid exposure to pile driving noise and therefore could be injured or killed depending on their proximity to the source piles and the duration of exposure.

6.1.1.3.3.4.2 Population-Level Effects

Based on the small proportion of adults occurring in the east and south Delta in June, any losses of larvae or early juveniles that encounter pile driving noise would represent a small proportion of total larval production in each year of pile driving operations. Potential losses would be further minimized by using vibratory and other non-impact pile driving methods, attenuation devices, and other physical and operational measures that may be implemented as part of the underwater sound control and abatement plan.

6.1.1.3.3.5 Juveniles (Summer/Fall: ~July-December)

6.1.1.3.3.5.1 Individual-Level Effects

Juvenile Delta Smelt rear downstream of the proposed barge landing sites in summer and fall and therefore are unlikely to be affected by pile driving noise.

6.1.1.3.3.5.2 Population-Level Effects

No population-level effects would occur.

6.1.1.3.4 Fish Stranding

Installation of the perimeter sheet pile wall has the potential to strand fish, resulting in direct injury and mortality of fish that become trapped behind the structures. To minimize this risk, sheet pile installation will be limited to the proposed in-water construction period (June 1–October 31) to avoid the peak abundance of Delta Smelt in the action area. During periods when listed species may be present, DWR will further minimize potential losses of stranded fish by implementing a fish rescue and salvage plan (Appendix 3.F, *General Avoidance and Minimization Measures*, AMM8 *Fish Rescue and Salvage Plan*).

6.1.1.3.4.1 Migrating Adults (December-March)

6.1.1.3.4.1.1 Individual-Level Effects

The timing of sheet pile installation (June 1–October 31) will avoid the Delta Smelt adult migration season. Therefore, migrating adults are not at risk of being stranded.

6.1.1.3.4.1.2 Population-Level Effects

No population-level effects would occur.

6.1.1.3.4.2 Spawning Adults (February-June)

6.1.1.3.4.2.1 Individual-Level Effects

Spawning adults may be present in small numbers in the action area in June and therefore subject to stranding. Although adults would be expected to move away from active construction areas, it is assumed that some potential for stranding exists as long as the affected areas are accessible to fish. Fish rescue and salvage activities using accepted fish collection methods can result in injury or mortality, but these effects are typically minor, and can often be avoided with appropriate training. However, adverse effects may still occur because of varying degrees of effectiveness of collection methods and potential stress and injury associated with various capture and handling methods.

6.1.1.3.4.2.2 Population-Level Effects

Population-level effects are expected to be negligible because of the low densities of adults that may be present in the action area during sheet pile installation, the low utilization and expected avoidance of the construction sites by spawning adults, and implementation of fish rescue and salvage activities.

6.1.1.3.4.3 Eggs/Embryos (Spring: ~March-June)

6.1.1.3.4.3.1 Individual-Level Effects

Based on the low utilization and expected avoidance of active construction sites by spawning adults, there is little or no risk of stranding of Delta Smelt eggs or embryos.

6.1.1.3.4.3.2 Population-Level Effects
No population-level effects would occur.

6.1.1.3.4.4 Larvae/Young Juveniles (Spring: ~March-June)
6.1.1.3.4.4.1 Individual-Level Effects
Although the potential for exposure is low, Delta Smelt larvae and early juveniles may be particularly vulnerable to stranding because of their limited swimming abilities and potential entrainment in off-channel areas. In addition, conventional fish collection methods used during rescue and salvage efforts are less effective and more likely to cause injury or death of these life stages compared to larger juveniles or adults.

6.1.1.3.4.4.2 Population-Level Effects
Population-level effects would be expected to be negligible based on the small proportion of adults that spawn in the action area in June, the resulting low densities of larvae and juveniles passing the intake sites, and the limited influence of the sheet pile wall on passage conditions in the river.

6.1.1.3.4.5 Juveniles (Summer/Fall: ~July-December)
6.1.1.3.4.5.1 Individual-Level Effects
Juvenile Delta Smelt rear downstream of the proposed intake sites in the summer and fall and therefore are unlikely to be stranded.

6.1.1.3.4.5.2 Population-Level Effects
No population-level effects would occur.

6.1.1.3.5 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 sheetpiles or mooring piles, or struck by propellers. In addition to the proposed work window, the potential for injury of listed fish species would be minimized by limiting the duration of in-water construction activities to the extent practicable and implementing the following AMMs: AMM1 *Worker Awareness Training;* AMM4 *Erosion and Sediment Control Plan;* AMM6 *Disposal of Spoils, Reusable Tunnel Material, and Dredged Material;* AMM7 *Barge Operations Plan; and Fish Rescue and Salvage Plan* (Appendix 3.F, *General Avoidance and Minimization Measures*).

6.1.1.3.5.1 Migrating Adults (December-March)
6.1.1.3.5.1.1 Individual-Level Effects
The timing of in-water construction activities (June 1–October 31) will avoid the Delta Smelt adult migration season. Therefore, migrating adults are not at risk of being injured.

6.1.1.3.5.1.2 Population-Level Effects
No population-level effects would occur.

6.1.1.3.5.2 Spawning Adults (February-June)
6.1.1.3.5.2.1 Individual-Level Effects
Spawning adults may be present in small numbers in the action area in June and therefore subject to injury. Although adults would be expected to move away from active construction areas, it is

assumed that some potential for injury exists whenever heavy equipment or materials are operated or placed in open water.

6.1.1.3.5.2.2 Population-Level Effects

Population-level effects are expected to be negligible because of the low densities of adults that may be present in the action area during in-water construction activities, and the low utilization and expected avoidance of the intake sites by spawning adults.

6.1.1.3.5.3 Eggs/Embryos (Spring: ~March-June)

6.1.1.3.5.3.1 Individual-Level Effects

Based on the low utilization and expected avoidance of the intake sites by spawning adults, there is little or no risk of injury of Delta Smelt eggs or embryos.

6.1.1.3.5.3.2 Population-Level Effects

No population-level effects would occur.

6.1.1.3.5.4 Larvae/Young Juveniles (Spring: ~March-June)

6.1.1.3.5.4.1 Individual-Level Effects

Delta Smelt larvae and early juveniles may be particularly vulnerable to injury because of their limited swimming abilities.

6.1.1.3.5.4.2 Population-Level Effects

Population-level effects would be expected to be negligible based on the small proportion of adults that spawn in the east and south Delta in June, the resulting low densities of larvae and juveniles, and the limited influence of construction equipment and materials on passage conditions in the adjacent channels.

6.1.1.3.5.5 Juveniles (Summer/Fall: ~July-December)

6.1.1.3.5.5.1 Individual-Level Effects

Juvenile Delta Smelt rear downstream of the proposed intake sites in the summer and fall and therefore are unlikely to be injured by construction activities.

6.1.1.3.5.5.2 Population-Level Effects

No population-level effects would occur.

6.1.1.3.6 Loss or Alteration of Habitat

Construction of the barge landings will result in temporary to permanent losses or alteration of aquatic habitat in several channels of the east and south Delta that are within the designated critical habitat of Delta Smelt. Temporary effects of construction activities on water quality, including turbidity and suspended sediment, underwater noise, and contaminants, were previously discussed. With implementation of the proposed water quality and sound abatement and control AMMs, in-water construction activities will result in temporary, localized increases in turbidity, suspended sediment, and noise in the vicinity of construction sites but these parameters are expected to return to baseline levels following cessation of construction activities and will not result in long-term impacts on aquatic habitat.

Construction of the barge landing would result in permanent impacts to approximately 22.4 acres of tidal perennial aquatic habitat (approximately 3.2 acres per landing). Approximately 0.34

acres of tidal perennial aquatic habitat will be replaced by the permanent dock and mooring structures or alternatively, floating docks supported by temporary piles. During construction, and continuing during operation of the barge landings, the channel banks, bed, and waters adjacent to the dock will be periodically disturbed by propeller wash and scour from barges and tidal action, resulting in changes in water depths, benthic substrates, and loss of submerged and emergent vegetation that may be present. Estimates of the amount of shallow water habitat that could be affected by construction are not currently available.

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

6.1.1.3.6.1 Migrating Adults (December-March)

6.1.1.3.6.1.1 Individual-Level Effects

Although affecting a small proportion of the population, migrating adults may be subject to an elevated risk of predation as they pass the construction sites because of potential increases in predator habitat. The presence of in-water and overwater structures (sheet pile wall, floating docks, piles, and vessels) provides shade and cover that may attract certain predatory fish species (e.g., striped bass, largemouth bass, Sacramento pikeminnow) and increase their ability to ambush prey. These structures may also improve predation opportunities for piscivorous birds (e.g., gulls, terns, cormorants) by providing perch sites immediately adjacent to open water.

6.1.1.3.6.1.2 Population-Level Effects

Increased predation risk at the barge landing sites would potentially result in increased mortality of migrating adults. The small proportion of the population spawning in the east and south Delta indicates that the population-level effect would be small.

6.1.1.3.6.2 Spawning Adults (February-June)

6.1.1.3.6.2.1 Individual-Level Effects

Loss or alteration of aquatic habitat within the footprints of the docks, mooring structures, and operational areas of the barges may result in reductions in the amount of shallow water habitat potentially available to spawning adults. Because the barge landings will likely be sited in areas with steep, riprapped levees and deep nearshore areas, the potential for utilization of these sites by Delta Smelt for spawning is low. Consequently, permanent losses or alteration of nearshore habitat resulting from construction of the barge landings would not likely have a significant effect on spawning habitat use or spawning success of adults.

6.1.1.3.6.2.2 Population-Level Effects

Population-level effects are expected to be negligible because of the small proportion of the population spawning in the action area and expected low utilization of the barge landing sites by spawning adults.

6.1.1.3.6.3 Eggs/Embryos (Spring: ~March-June)

6.1.1.3.6.3.1 Individual-Level Effects

Based on the small proportion of the population spawning in the action area and expected low utilization of the barge landing sites by spawning adults, there is little risk of adverse effects on eggs or embryos.

6.1.1.3.6.3.2 Population-Level Effects

Population-level effects are expected to be negligible.

6.1.1.3.6.4 Larvae/Young Juveniles (Spring: ~March-June)

6.1.1.3.6.4.1 Individual-Level Effects

Delta Smelt larvae and early juveniles migrating from upstream spawning areas to estuarine rearing areas may be subject to an elevated risk of predation as they pass the barge landings because of the presence of in-water and overwater structures and the loss of shallow, low-velocity nearshore areas. To the extent that these conditions provide beneficial habitat or increased predation opportunities for predators of larvae and early juveniles (e.g., silversides; Baerwald et al. 2012), there could be an elevated risk of predation for these young life stages. However, it is not clear that these structures provide beneficial habitat as these small predators may be susceptible to the same larger predators that consume adult Delta Smelt. Therefore, elevated predation on Delta Smelt larvae is unlikely.

6.1.1.3.6.4.2 Population-Level Effects

Even if larvae and juveniles are subject to elevated predation rates as they pass the construction sites, the population-level effect would be small based on the small proportion of the population occurring in or upstream of the action area.

6.1.1.3.6.5 Juveniles (Summer/Fall: ~July-December)

6.1.1.3.6.5.1 Individual-Level Effects

Juvenile Delta Smelt rear downstream of the proposed barge landing sites in the summer and fall and therefore are unlikely to be affected by losses or alteration of habitat during construction.

6.1.1.3.6.5.2 Population-Level Effects

No population-level effects would occur.

6.1.1.4 Head of Old River Gate

A permanent gate (Head of Old River [HOR] gate) will be constructed at the HOR to prevent migrating juvenile salmonids from entering Old River from the San Joaquin River, and thereby minimize their exposure to the CVP/SWP pumping facilities. The gate will be located at the divergence of the HOR and the San Joaquin River (Appendix 3.A, *Map Book for the Proposed Action*), and will be 210 feet long and 30 feet wide, with top elevation of +15 feet (Appendix 3.C, *Conceptual Engineering Report*, Volume 2, Sheets 11, 12, and 13). The gate will include seven bottom-hinged gates, fishway, boat lock, control building, boat lock operator's building,

and communications antenna. Additional details on the intake design, construction methods, and proposed construction schedule are described in Chapter 3.

Construction of the HOR gate is expected to take 3 years. The HOR gate will be constructed in two phases using cofferdams to isolate and dewater half the channel during the first phase and the other half during the second phase. All in-water construction work, including cofferdam installation, riprap placement, dredging, and barge operations, would be restricted to August 1-November 30 to minimize or avoid potential effects on Delta Smelt and juvenile salmonids. In addition, all pile driving requiring the use of an impact pile driver in or near open water (cofferdams and foundation piles) will be restricted to this period to avoid or minimize exposure of listed species to potentially harmful underwater noise levels. Construction of the HOR gate will require dredging of approximately 500 feet of channel (150 feet upstream to 350 feet downstream from the proposed gate) and removal of up to 1,500 cubic yards of material with a barge-mounted hydraulic or a sealed clamshell dredge. The need for additional clearing and grading of the site for construction, staging, and other support facilities is expected to be minimal because of the presence of existing access roads and staging areas that have been used in the past for installation of a temporary rock barrier.

Construction of the HOR gate will result in permanent impacts to approximately 2.9 acres of tidal perennial aquatic habitat that includes the footprint of the gate and the channel segments upstream and downstream of the structure that will be affected by dredging. Estimates of the amount of shallow water habitat potentially affected by construction are not currently available.

6.1.1.4.1 Turbidity and Suspended Sediment

In-water construction activities would result in disturbance of the channel bed and banks, resulting in temporary increases in turbidity and suspended sediment levels in Old River and potentially the San Joaquin River. These activities include cofferdam construction (sheet pile installation), dredging, riprap placement, and barge operations. All other sediment-disturbing activities will be outside or isolated from the active channel and would not result in the discharge of sediment to the river. Water pumped from the cofferdams will be treated (removing all sediment) using settling basins or Baker tanks, and returned to the river. Dredging, foundation pile driving, and other construction activities will proceed within the confines of the cofferdams.

In addition to the in-water work window, a number of AMMs are proposed to avoid or minimize potential impacts on water quality and listed fish species during construction of the HOR gate. These AMMs include AMM1 *Worker Awareness Training;*AMM2 *Construction Best Management Practices and Monitoring; Stormwater Pollution Prevention Plan;* AMM4 *Erosion and Sediment Control Plan; Spill Prevention, Containment, and Countermeasure Plan;* AMM14 *Hazardous Material Management Plan;* and AMM6 *Disposal and Reuse of Spoils, Reusable Tunnel Material, and Dredged Material* (Appendix 3.F, *General Avoidance and Minimization Measures*).

Some potential exists for construction-related turbidity and suspended sediment to occur during winter and spring due to increased erosion and mobilization of sediment in runoff from disturbed levee surfaces. However, with the timing restrictions on in-water activities and implementation of the proposed erosion and sediment control AMMs, no adverse water effects are anticipated during this period.

6.1.1.4.1.1 Migrating Adults (December-March)

6.1.1.4.1.1.1 Individual-Level Effects

The timing of in-water construction activities (August 1–October 31) will avoid the Delta Smelt adult migration season. Therefore, there would be no effect on migrating adults from temporary increases in turbidity and suspended sediment.

6.1.1.4.1.1.2 Population-Level Effects

No population-level effect would occur.

6.1.1.4.1.2 Spawning Adults (February-June)

6.1.1.4.1.2.1 Individual-Level Effects

The timing of in-water construction activities (August 1–November 30) will avoid the Delta Smelt spawning season. However, increases in suspended sediment during in-water construction activities may result in localized sediment deposition, degrading potential spawning habitat of Delta Smelt through burial of suitable substrates. However, Old River in the vicinity of the proposed HOR gate does not likely support significant spawning of Delta Smelt, serving mainly as a migration corridor for adults during their migration to upstream spawning areas and larvae during their downstream dispersal to estuarine habitat. There appears to be little or no habitat thought to be preferred by Delta Smelt for spawning in this reach, which is dominated by steep levee slopes, existing riprap, and low quantities of riparian and aquatic vegetation.

6.1.1.4.1.2.2 Population-Level Effects

Most of the Delta Smelt population is distributed downstream of the proposed HOR gate (Moyle 2002) but Delta Smelt have been found as far upstream as Moss Landing (Vincik and Julienne 2012). Available monitoring data suggest that adult Delta Smelt occur in very low numbers near the HOR gate. Over 2,300 beach seine samples[4] in the San Joaquin River between Dos Reis (river mile 51) and Weatherbee (river mile 58) between 1994 and 2015 yielded four Delta Smelt (all in February–April). Nearly 30,000 trawl samples at Mossdale[5] from 1994 to 2011 resulted in the capture of 44 Delta Smelt, principally in March-June. The low abundance of Delta Smelt and low quality of potential spawning habitat in the vicinity of the HOR gate indicates that any impacts on potential spawning habitat resulting from sedimentation of suitable substrates would have negligible population-level effects.

6.1.1.4.1.3 Eggs/Embryos (Spring: ~March-June)

6.1.1.4.1.3.1 Individual-Level Effects

Delta Smelt eggs and embryos are demersal and adhesive, attaching to substrates with an adhesive stalk formed by the outer layer of the egg (Bennett 2005). Although the potential for exposure would be low, individual eggs would be subject to burial by the deposition of suspended sediment.

[4] Data were obtained from http://www.fws.gov/lodi/jfmp/, files <Beach Seines CHN _ POD Species 1976-2011.xlsx> and <Beach Seines CHN _ POD Species 2012-2015.xlsx> accessed September 14, 2015.

[5] Data were obtained from http://www.fws.gov/lodi/jfmp/, files < Mossdale Trawls CHN _ POD Species 1994-2011.xlsx> and < Mossdale Trawls CHN & POD Species 2012-2015.xlsx> accessed September 14, 2015.

6.1.1.4.1.3.2 Population-Level Effects

No population-level effects are anticipated because of the timing of in-water construction activities, low proportion of the population utilizing the action area, and low quality of spawning habitat in the vicinity of the HOR gate.

6.1.1.4.1.4 Larvae/Young Juveniles (Spring: ~March-June)

6.1.1.4.1.4.1 Individual-Level Effects

Based on the general discussion of effects above for migrating and spawning adults, Delta Smelt larvae and early juveniles are not likely to be adversely affected by turbidity and suspended sediment generated by in-water construction activities.

6.1.1.4.1.4.2 Population-Level Effects

No population-level effects are anticipated because of the timing of in-water construction activities, the low proportion of the population utilizing the action area, and general association and feeding responses of Delta Smelt to turbidity within the range generated by in-water activities.

6.1.1.4.1.5 Juveniles (Summer/Fall: ~July-December)

6.1.1.4.1.5.1 Individual-Level Effects

Juvenile Delta Smelt rear downstream of the proposed HOR gate in the summer and fall and therefore would be unaffected by increased turbidity and suspended sediment during in-water construction activities.

6.1.1.4.1.5.2 Population-Level Effects

No population-level effect would occur.

6.1.1.4.2 Contaminants

Construction of the HOR gate poses an exposure risk to listed fish species from potential spills of hazardous materials from construction equipment, barges and towing vessels, and other machinery, and from potential mobilization of contaminated sediment. The risk of accidental spills of contaminants and other potentially hazardous materials would be similar to that described for the north Delta intakes due to the proximity of construction activities to the waters of the Delta. Implementation of the following AMMs (Appendix 3.F, *General Avoidance and Minimization Measures*) is expected to minimize the potential for introduction of contaminants into surface waters and guide rapid and effective response in the case of inadvertent spills of hazardous materials: AMM1 *Worker Awareness Training; Construction Best Management Practices and Monitoring;* AMM2 *Stormwater Pollution Prevention Plan; Erosion and Sediment Control Plan;* AMM14 *Hazardous Materials Management Plan;* AMM5 *Spill Prevention, Containment, and Countermeasure Plan;* AMM6 *Disposal of Spoils, Reusable Tunnel Material, and Dredged Material;* and AMM7 *Barge Operations Plan*).

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 development and implementation of an HMMP with specific measures to address the containment, handling, storage, and disposal of contaminated sediments. Because the potential mobilization of contaminants is closely linked to sediment disturbance and associated increases

in turbidity and suspended sediment, implementation of the erosion and sediment control AMMs would further minimize this risk. Some risk of contaminant spills and runoff of contaminated soil would exist outside the in-water construction period but implementation of proposed pollution prevention and erosion and sediment control AMMs would effectively minimize this risk.

6.1.1.4.2.1 Migrating Adults (December-March)

6.1.1.4.2.1.1 Individual-Level Effects

The potential effects of contaminants on Delta Smelt were discussed previously (see 6.1.1.3 *North Delta Intakes*). The timing of in-water construction activities (August 1–November 30) will avoid the Delta Smelt adult migration season. With implementation of proposed pollution prevention and erosion and sediment control AMMs, little or no risk of contaminant exposure would exist throughout the construction period.

6.1.1.4.2.1.2 Population-Level Effects

No population-level effects would occur.

6.1.1.4.2.2 Spawning Adults (February-June)

6.1.1.4.2.2.1 Individual-Level Effects

The timing of in-water construction activities (August 1-November 30) will avoid the Delta Smelt adult migration season. With implementation of proposed pollution prevention and erosion and sediment control AMMs, little or no risk of contaminant exposure would exist throughout the construction period.

6.1.1.4.2.2.2 Population-Level Effects

No population-level effects would occur.

6.1.1.4.2.3 Eggs/Embryos (Spring: ~March-June)

6.1.1.4.2.3.1 Individual-Level Effects

The timing of in-water construction activities (August 1-November 30) will avoid the Delta Smelt incubation season. With implementation of proposed pollution prevention and erosion and sediment control AMMs, little or no risk of contaminant exposure would exist throughout the construction period.

6.1.1.4.2.3.2 Population-Level Effects

No population-level effects would occur.

6.1.1.4.2.4 Larvae/Young Juveniles (Spring: ~March-June)

6.1.1.4.2.4.1 Individual-Level Effects

The timing of in-water construction activities (August 1-November 30) will avoid the downstream migration period of Delta Smelt larvae and early juveniles. With implementation of proposed pollution prevention and erosion and sediment control AMMs, little or no risk of contaminant exposure would exist throughout the construction period.

6.1.1.4.2.4.2 Population-Level Effects

No population-level effects would occur.

6.1.1.4.2.5 Juveniles (Summer/Fall: ~July-December)

6.1.1.4.2.5.1 Individual-Level Effects

Juvenile Delta Smelt rear downstream of the proposed intake locations in the summer and fall and therefore are unlikely to be affected by contaminant spills or sediment-borne contaminants during construction of the intakes.

6.1.1.4.2.5.2 Population-Level Effects

No population-level effects would occur.

6.1.1.4.3 Underwater Noise

Impact pile driving at the HOR gate would potentially produce underwater noise levels of sufficient intensity and duration to injure or kill fish. Currently, it is estimated that the HOR gate would require the installation of 550 temporary sheet piles to construct the cofferdams and 100 14-inch steel pipe or H-piles to construct the foundation. Based on an assumed installation rate of 15 piles per day, pile driving would be expected to occur up to 19 days per season during installation of the sheet piles, and up to 4 days per season during installation of the foundation piles. DWR proposes to avoid exposure of Delta Smelt to pile driving noise and other water quality impacts by conducting all in-water construction activities between August 1 and November 30. This will effectively avoid the periods when Delta Smelt adults, larvae, and early juvenile may be present.

6.1.1.4.3.1 Migrating Adults (December-March)

6.1.1.4.3.1.1 Individual-Level Effects

The timing of impact pile driving activities (August 1–November 30) will avoid the Delta Smelt adult migration season. There would be no risk of exposure of migrating adults to impact pile driving noise.

6.1.1.4.3.1.2 Population-Level Effects

No population-level effects would occur.

6.1.1.4.3.2 Spawning Adults (February-June)

6.1.1.4.3.2.1 Individual-Level Effects

The timing of impact pile driving activities (August 1–November 30) will avoid the Delta Smelt spawning season. There would be no risk of exposure of spawning adults to impact pile driving noise.

6.1.1.4.3.2.2 Population-Level Effects

No population-level effects would occur.

6.1.1.4.3.3 Eggs/Embryos (Spring: ~March-June)

6.1.1.4.3.3.1 Individual-Level Effects

The timing of impact pile driving activities (August 1–November 30) will avoid the Delta Smelt incubation season. There would be no risk of exposure of eggs or embryos to impact pile driving noise.

6.1.1.4.3.3.2 Population-Level Effects

No population-level effects would occur.

6.1.1.4.3.4 Larvae/Young Juveniles (Spring: ~March-June)

6.1.1.4.3.4.1 Individual-Level Effects

The timing of impact pile driving activities (August 1–November 30) will avoid the downstream migration period of Delta Smelt larvae and early juveniles. There would be no risk of exposure of larvae or early juveniles to impact pile driving noise.

6.1.1.4.3.4.2 Population-Level Effects

No population-level effects would occur.

6.1.1.4.3.5 Juveniles (Summer/Fall: ~July-December)

6.1.1.4.3.5.1 Individual-Level Effects

Juvenile Delta Smelt rear downstream of the HOR gate in summer and fall and therefore are unlikely to be affected by pile driving noise.

6.1.1.4.3.5.2 Population-Level Effects

No population-level effects would occur.

6.1.1.4.4 Fish Stranding

The use of cofferdams to construct the HOR gate will exclude fish from active construction areas but could also strand fish that are not able to avoid these areas, resulting in direct injury and mortality from dewatering, dredging, and pile driving activities within the enclosed cofferdams. To minimize fish stranding losses, DWR will implement a fish rescue and salvage plan (Appendix 3.F, *General Avoidance and Minimization Measures*, AMM8 *Fish Rescue and Salvage Plan*). The plan will be submitted to the fish and wildlife agencies (NMFS, USFWS, CDFW) for review and approval prior to implementation. The plan will include detailed procedures for fish rescue and salvage, including collection, holding, handling, and release, that would apply to all in-water activities with the potential to entrap fish. All fish rescue and salvage operations will be conducted under the guidance of a qualified fish biologist. The biologist, in consultation with a designated agency biologist, will determine the appropriate fish collection and relocation methods based on site-specific conditions and construction methods. Collection methods may include seines, dip nets, and electrofishing if permitted. DWR proposes to minimize the potential for stranding of Delta Smelt and juvenile salmonids by conducting all in-water construction activities between August 1 and November 30. This will effectively avoid the periods when Delta Smelt adults, larvae, and early juvenile may be present.

6.1.1.4.4.1 Migrating Adults (December-March)

6.1.1.4.4.1.1 Individual-Level Effects

The timing of cofferdam construction (August 1–November 30) will avoid the Delta Smelt adult migration season. There would be no risk of stranding of migrating adults.

6.1.1.4.4.1.2 Population-Level Effects

No population-level effects would occur.

6.1.1.4.4.2 Spawning Adults (February-June)

6.1.1.4.4.2.1 Individual-Level Effects

The timing of cofferdam construction (August 1–November 30) will avoid the Delta Smelt spawning season. There would be no risk of stranding of spawning adults.

6.1.1.4.4.2.2 Population-Level Effects
No population-level effects would occur.

6.1.1.4.4.3 Eggs/Embryos (Spring: ~March-June)
6.1.1.4.4.3.1 Individual-Level Effects
The timing of cofferdam construction (August 1–November 30) will avoid the Delta Smelt incubation season. There would be no risk of stranding of eggs or embryos.

6.1.1.4.4.3.2 Population-Level Effects
No population-level effects would occur.

6.1.1.4.4.4 Larvae/Young Juveniles (Spring: ~March-June)
6.1.1.4.4.4.1 Individual-Level Effects
The timing of cofferdam construction (August 1–November 30) will avoid the downstream migration period of Delta Smelt larvae and early juveniles. There would be no risk of stranding of larvae or early juveniles.

6.1.1.4.4.4.2 Population-Level Effects
No population-level effects would occur.

6.1.1.4.4.5 Juveniles (Summer/Fall: ~July-December)
6.1.1.4.4.5.1 Individual-Level Effects
Juvenile Delta Smelt rear downstream of the HOR gate in summer and fall and therefore are unlikely to be stranded in the cofferdams.

6.1.1.4.4.5.2 Population-Level Effects
No population-level effects would occur.

6.1.1.4.5 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 Delta Smelt and juvenile salmonids by conducting all in-water construction activities between August 1 and November 30. This will effectively avoid the periods when Delta Smelt adults, larvae, and early juvenile may be present. In addition to the proposed work window, the potential for injury of listed fish species would be minimized to the extent practicable by limiting the duration of in-water construction activities and implementing the AMMs described in Appendix 3.F, *General Avoidance and Minimization Measures*. Applicable AMMs include AMM1 *Worker Awareness Training;* AMM4 *Erosion and Sediment Control Plan;* AMM6 *Disposal of Spoils, Reusable Tunnel Material, and Dredged Material;* AMM7 *Barge Operations Plan;* and AMM8 *Fish Rescue and Salvage Plan*.

6.1.1.4.5.1 Migrating Adults (December-March)
6.1.1.4.5.1.1 Individual-Level Effects
The timing of in-water construction activities (August 1–November 30) will avoid the Delta Smelt adult migration season. There would be no risk of injury of migrating adults.

6.1.1.4.5.1.2 Population-Level Effects
No population-level effects would occur.

6.1.1.4.5.2 Spawning Adults (February-June)
6.1.1.4.5.2.1 Individual-Level Effects
The timing of in-water construction activities (August 1–November 30) will avoid the Delta Smelt spawning season. There would be no risk of injury of spawning adults.

6.1.1.4.5.2.2 Population-Level Effects
No population-level effects would occur.

6.1.1.4.5.3 Eggs/Embryos (Spring: ~March-June)
6.1.1.4.5.3.1 Individual-Level Effects
The timing of in-water construction activities (August 1–November 30) will avoid the Delta Smelt incubation season. There would be no risk of injury of eggs or embryos.

6.1.1.4.5.3.2 Population-Level Effects
No population-level effects would occur.

6.1.1.4.5.4 Larvae/Young Juveniles (Spring: ~March-June)
6.1.1.4.5.4.1 Individual-Level Effects
The timing of in-water construction activities (August 1–November 30) will avoid the downstream migration period of Delta Smelt larvae and early juveniles. There would be no risk of injury of larvae or early juveniles.

6.1.1.4.5.4.2 Population-Level Effects
No population-level effects would occur.

6.1.1.4.5.5 Juveniles (Summer/Fall: ~July-December)
6.1.1.4.5.5.1 Individual-Level Effects
Juvenile Delta Smelt rear downstream of the HOR gate in summer and fall and therefore are unlikely to be injured by in-water construction activities.

6.1.1.4.5.5.2 Population-Level Effects
No population-level effects would occur.

6.1.1.4.6 Loss or Alteration of Habitat
Construction of the HOR gate would result in temporary to permanent losses or alteration of aquatic habitat in Old River. Temporary effects of construction activities on water quality were previously discussed. With implementation of the proposed water quality and sound abatement and control AMMs, in-water construction activities will result in temporary, localized increases in turbidity, suspended sediment, and noise in the vicinity of construction sites but these parameters are expected to return to baseline levels following cessation of construction activities and will not result in long-term impacts on aquatic habitat.

Construction of the HOR gate will result in permanent impacts to approximately 2.9 acres of tidal perennial aquatic habitat, including the footprint of the gate and the channel segments

upstream and downstream of the structure that will be affected by dredging. Estimates of the amount of shallow water habitat potentially affected by construction are not currently available.

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

6.1.1.4.6.1 Migrating Adults (December-March)

6.1.1.4.6.1.1 Individual-Level Effects

Although affecting a small proportion of the population, migrating Delta Smelt adults may be subject to potential delays in migration and increased predation as they attempt to pass the cofferdams during the three-year construction period. Cofferdams that constrict the flow to half the channel's width would increase water velocities and potentially impede the migration of adults attempting to pass the site. The presence of in-channel cofferdams and/or the partially competed HOR gate may also increase the amount of predatory fish habitat and create hydraulic conditions that improve their ability to prey on Delta Smelt as they migrate past the site.

6.1.1.4.6.1.2 Population-Level Effects

Based on the apparent low abundance of Delta Smelt in the San Joaquin River in the vicinity of HOR, potential adverse effects on migration and survival of migrating adults would likely be limited to a very small proportion of the population, resulting in negligible effects on the total spawning stock of Delta Smelt.

6.1.1.4.6.2 Spawning Adults (February-June)

6.1.1.4.6.2.1 Individual-Level Effects

Loss or alteration of aquatic habitat within the footprints of the cofferdams, riprapped banks, and dredged channel areas would reduce the amount of shallow water habitat potentially available to spawning adults. However, this portion of the Old River channel is frequently disturbed by the annual installation of a temporary rock barrier and is dominated by steep levee slopes, riprap, and low quantities of riparian and aquatic vegetation. There is little or no potential spawning habitat that would be affected by construction of HOR gate and thus little likelihood of adverse effects on spawning adults.

6.1.1.4.6.2.2 Population-Level Effects

No population-level effects are anticipated.

6.1.1.4.6.3 Eggs/Embryos (Spring: ~March-June)

6.1.1.4.6.3.1 Individual-Level Effects

Based on the lack of preferred spawning habitat for delta, the potential for adverse effects on eggs and embryos is negligible.

6.1.1.4.6.3.2 Population-Level Effects

No population-level effects are anticipated.

6.1.1.4.6.4 Larvae/Young Juveniles (Spring: ~March-June)

6.1.1.4.6.4.1 Individual-Level Effects

Similar to migrating adults, Delta Smelt larvae and early juveniles may be subject to an elevated risk of predation as they pass the cofferdams and/or partially completed HOR gate.

6.1.1.4.6.4.2 Population-Level Effects

Based on the apparent low abundance of Delta Smelt in the San Joaquin River in the vicinity of HOR, potential adverse effects on survival of larvae and juveniles would likely be limited to a very small proportion of the population, resulting in negligible effects on juvenile and adult recruitment.

6.1.1.4.6.5 Juveniles (Summer/Fall: ~July-December)

6.1.1.4.6.5.1 Individual-Level Effects

Juvenile Delta Smelt rear downstream of the HOR gate in summer and fall and therefore are unlikely to be affected by losses or alteration of habitat during construction.

6.1.1.4.6.5.2 Population-Level Effects

No population-level effects would occur.

6.1.1.5 Clifton Court Forebay

Construction activities at Clifton Court Forebay (CCF) that may potentially affect Delta Smelt include the construction of the Clifton Court Pumping Plant (CCPP), construction of divider and perimeter embankments, dredging of CCF, construction of outlet canals and siphons, excavation and connection of South CCF (SCCF) expansion area, and construction of a new SSCF intake structure and North CCF (NCCF) emergency spillway. The estimated 8-year construction period at CCF will be phased, beginning with excavation of the expansion area of the SCCF (Phase 1 and 2); removal of the embankment separating the existing CCF from the expansion area (Phase 3); dredging CCF to design depths (Phase 4); construction of the embankment dividing NCCF and SCCF (Phase 5); and construction of the NCCF east, west, and north side embankments (Phases 6, 7, and 8).

In-water construction activities, including pile driving, dredging, riprap placement, and barge operations, would be conducted over a 6-month period each year. The timing of these activities is unknown but it is assumed that all in-water construction activities would be restricted to the months of June 1 to November 30 to avoid peak abundance of listed fish species in the south Delta. Pile driving operations include the installation of an estimated 27,000 temporary sheet piles to isolate the construction areas of the CCPP, embankments, outlet canals and siphons, intake, and spillways; and 2,160 concrete or steel pipe piles to construct the permanent foundation of the NCCF siphon. A total of 4 construction seasons will likely be required to complete pile driving operations based on the estimated duration of pile installation (see Section 6.1.1.5.3 *Underwater Noise*).

Dredging would be performed with a cutter head dredge, a dragline type dredge, or other acceptable dredging technique. The NCCF will be dredged to an approximate elevation of -5.0

feet, and SCCF will be dredged to an approximate elevation of -10.0 feet. An estimated 1,932 acres of tidal perennial aquatic habitat would 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 would 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 38 months over 6 construction seasons.

Permanent impacts on aquatic habitat include the loss of 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 (Mapbook M3.A). Estimates of the amount of shallow water habitat potentially affected by construction are not currently available.

6.1.1.5.1 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 and cofferdam construction (sheet pile installation and removal). 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 North CCF (NCCF) emergency spillway. All other sediment-disturbing activities within cofferdams, upland areas, or non-fish-bearing waters pose little or no risk to listed fish species or aquatic habitat.

The potential for adverse effects of elevated turbidity and suspended sediment on listed fish species would be minimized by restricting all in-water construction activities to June 1-November 30, limiting the duration of these activities to the extent practicable, and implementing the AMMs described in Appendix 3.F, *General Avoidance and Minimization Measures* to protect listed fish species from water quality impairment. These measures include AMM1*Worker Awareness Training;* AMM2 *Construction Best Management Practices and Monitoring;* AMM3 *Stormwater Pollution Prevention Plan; Erosion and Sediment Control Plan;* AMM5 *Spill Prevention, Containment, and Countermeasure Plan;* AMM14 *Hazardous Material Management Plan,* and AMM6 *Disposal and Reuse of Spoils, Reusable Tunnel Material, and Dredged Material Plan*.

Dredging could cause extensive, long-term effects on turbidity and suspended sediment within CCF. Potential secondary effects include potential increases in chemical and biological oxygen demand associated with the decomposition of vegetation and organic material in disturbed sediments. In addition to implementing the AMMs listed above, DWR proposes to limit the potential exposure of listed species to water quality impacts by restricting the timing, extent, and frequency of major sediment-disturbing events. For example, DWR proposes to limit the extent of dredging impacts in CCF by restricting daily operations to two dredges operating for 10-hour periods (daylight hours) within 200-acre cells enclosed by silt curtains (representing approximately 10% of total surface area of CCF). In addition, dredging will be monitored and regulated through the implementation of the *Disposal and Reuse of Spoils, Reusable Tunnel Material, and Dredged Material Plan*, which includes preparation of a sampling and analysis

plan, compliance with NPDES and SWRCB water quality requirements during dredging activities, and compliance with applicable in-water work windows established by CDFW, NMFS, and USFWS.

Some potential exists for construction-related turbidity and suspended sediment to occur during winter and spring due to increased erosion and mobilization of sediment in runoff from disturbed levee surfaces. However, with the timing restrictions on in-water activities and implementation of the proposed erosion and sediment control AMMs, no adverse water effects are anticipated during this period.

6.1.1.5.1.1 Migrating Adults (December-March)

6.1.1.5.1.1.1 Individual-Level Effects

The timing of in-water construction activities at CCF (June 1–November 30) will avoid the Delta Smelt adult migration season. Therefore, there would be no effect on migrating adults from temporary increases in turbidity and suspended sediment.

6.1.1.5.1.1.2 Population-Level Effects

No population-level effect would occur.

6.1.1.5.1.2 Spawning Adults (February-June)

6.1.1.5.1.2.1 Individual-Level Effects

Potential individual-level effects of elevated turbidity and suspended sediment on Delta Smelt were discussed previously (see 6.1.1.3 *North Delta Intakes*). Based on this analysis, it is generally concluded that the levels of turbidity and suspended sediment generated by in-water construction activities are not expected to adversely affect Delta Smelt.

6.1.1.5.1.2.2 Population-Level Effects

Based on the general timing and abundance of Delta Smelt inferred from salvage and fish monitoring data, restriction of dredging and other in-water construction activities in CCF to June 1-November 30 will avoid most of the spawning season (January through June) and peak abundance of adults, eggs, and larvae in the south Delta (February through May). Salvage records indicate that adults and larvae may be present through June and July but abundance is low and declining in these months, especially in July as water temperatures typically exceed the upper tolerance levels for successful reproduction. In addition, Old River in the vicinity of CCF is highly channelized and lacks the general attributes of preferred spawning habitat (complex channels, shoals, and tidal marsh), and CCF is not considered suitable habitat because of the low likelihood of survival of larvae, juveniles, and adults that are entrained into the forebay (Castillo *et al.* 2012). No population-level effects are anticipated.

6.1.1.5.1.3 Eggs/Embryos (Spring: ~March-June)

6.1.1.5.1.3.1 Individual-Level Effects

Although increases in suspended sediment could result in the burial of eggs or embryos that may be present in the action area in June, any adverse effects on individual eggs or embryos would be negligible because the survival of larvae that successfully hatch in CCF or in the adjacent channels leading to CCF would be near zero. Therefore, no adverse individual-level effects are expected.

6.1.1.5.1.3.2 Population-Level Effects

No population-level effects are anticipated because of the timing of in-water construction activities and expected low survival of Delta Smelt in this region of the Delta.

6.1.1.5.1.4 Larvae/Young Juveniles (Spring: ~March-June)

6.1.1.5.1.4.1 Individual-Level Effects

Based on the general tolerances and adaptations of Delta Smelt to turbidity and suspended sediment, Delta Smelt larvae and early juveniles are not likely to be adversely affected by turbidity and suspended sediment generated by in-water construction activities.

6.1.1.5.1.4.2 Population-Level Effects

No population-level effects are anticipated.

6.1.1.5.1.5 Juveniles (Summer/Fall: ~July-December)

6.1.1.5.1.5.1 Individual-Level Effects

Juvenile Delta Smelt rear downstream of CCF and the adjacent south Delta channels in the summer and fall and therefore would be unaffected by increases in turbidity and suspended sediment during construction.

6.1.1.5.1.5.2 Population-Level Effects

No population-level effect would occur.

6.1.1.5.2 Contaminants

Dredging and expansion of the CCF and construction of new water conveyance facilities presents an exposure risk to Delta Smelt from potential spills of hazardous materials from construction equipment and from potential mobilization of contaminated sediment. The risk of accidental spills of oil, fuel, hydraulic fluids, concrete, paint, and other potentially hazardous substances would be similar to that described for the north Delta intakes due to the proximity of construction activities to the waters of the Delta. Implementation of the following AMMs (described in Appendix 3.F, *General Avoidance and Minimization Measures*) is expected to minimize the potential for introduction of contaminants into surface waters and guide rapid and effective response in the case of inadvertent spills of hazardous materials: AMM1*Worker Awareness Training;* AMM2 *Construction Best Management Practices and Monitoring;* AMM3 *Stormwater Pollution Prevention Plan; Erosion and Sediment Control Plan;* AMM5 *Spill Prevention, Containment, and Countermeasure Plan;* AMM14 *Hazardous Material Management Plan,* AMM6 *Disposal and Reuse of Spoils, Reusable Tunnel Material, and Dredged Material Plan,* and AMM7 *Barge Operations Plan.*

Proposed dredging, excavation, and expansion of CCF will potentially result in the release of contaminants from disturbance or exposure of sediments. 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. Contaminated sediments pose a risk to fish from direct exposure from mobilized sediment or indirectly through accumulation of contaminants in the food web. The proximity of the south Delta waterways to agricultural, industrial, and municipal sources indicates that a broad range of contaminants that are toxic to fish and other aquatic biota, including metals (e.g., copper, mercury), hydrocarbons, pesticides, and ammonia, could be present. Mud and silt in south Delta waterways have been shown to

contain elevated concentrations of contaminants, including mercury, pesticides (chlorpyrifos, diazinon, DDT), and other toxic substances (California State Water Resources Control Board 2010). Impairments in Delta waterways also include heavy metals such as selenium, cadmium, and nickel (G. Fred Lee & Associates 2004). Thus, resuspension of sediments during in-water construction could lead to degradation of water quality and adverse effects on fish or their food resources in the action area.

Prior to dredging and excavation activities, DWR proposes to evaluate the risk of contamination from sediment sources and determine appropriate testing and remediation procedures through the implementation of *Disposal and Reuse of Spoils, Reusable Tunnel Material, and Dredged Material* (AMM6), Appendix 3.F, *General Avoidance and Minimization Measures*). In addition, because the potential for mobilization of contaminants is closely linked to turbidity and suspended sediment generated by construction activities, implementation of the AMMs designed to minimize erosion and the discharge of suspended sediment (see *Turbidity and Suspended Sediment*) will also minimize potential risks associated with the mobilization of contaminated sediment. These AMMs include the development and implementation of an HMMP with specific measures to address the containment, handling, storage, and disposal of contaminated sediments.

6.1.1.5.2.1 Migrating Adults (December-March)

6.1.1.5.2.1.1 Individual-Level Effects

The potential effects of contaminants on Delta Smelt were discussed previously (see 6.1.1.3 *North Delta Intakes*). The timing of in-water construction activities (June 1–November 30) will avoid the Delta Smelt adult migration season. Some risk of contaminant spills and runoff of contaminated soil would exist outside the in-water construction period but implementation of proposed pollution prevention and erosion and sediment control AMMs would effectively minimize this risk.

6.1.1.5.2.1.2 Population-Level Effects

No population-level effects would occur.

6.1.1.5.2.2 Spawning Adults (February-June)

6.1.1.5.2.2.1 Individual-Level Effects

Based on the timing of in-water construction activities (June 1-November 30), spawning adults in CCF and Old River would be subject to direct exposure to contaminant spills or sediment-borne contaminants in June. Some risk would also exist outside the in-water construction period. However, implementation of the proposed pollution prevention and erosion and sediment control AMMs would effectively minimize this risk throughout the construction period.

6.1.1.5.2.2.2 Population-Level Effects

No population-level effects would occur.

6.1.1.5.2.3 Eggs/Embryos (Spring: ~March-June)

6.1.1.5.2.3.1 Individual-Level Effects

Based on the timing of in-water construction activities (June 1-November 30), Delta Smelt eggs and embryos in CCF and Old River would be subject to direct exposure to contaminant spills or sediment-borne contaminants in June. Some risk would also exist outside the in-water construction season. However, implementation of the proposed pollution prevention and erosion

and sediment control AMMs would effectively minimize this risk throughout the construction period.

6.1.1.5.2.3.2 Population-Level Effects

No population-level effects would occur.

6.1.1.5.2.4 Larvae/Young Juveniles (Spring: ~March-June)

6.1.1.5.2.4.1 Individual-Level Effects

Based on the timing of in-water construction activities (June 1-November 30), Delta Smelt larvae and early juveniles in CCF and Old River would be subject to direct exposure to contaminant spills or sediment-borne contaminants in June. Some risk would also exist outside the in-water construction season. However, implementation of the proposed pollution prevention and erosion and sediment control AMMs would effectively minimize this risk throughout the construction period.

6.1.1.5.2.4.2 Population-Level Effects

No population-level effects would occur.

6.1.1.5.2.5 Juveniles (Summer/Fall: ~July-December)

6.1.1.5.2.5.1 Individual-Level Effects

Juvenile Delta Smelt rear downstream of CCF and the adjacent south Delta channels in the summer and fall and therefore are unlikely to be affected by contaminant spills or sediment-borne contaminants during construction.

6.1.1.5.2.5.2 Population-Level Effects

No population-level effects would occur.

6.1.1.5.3 Underwater Noise

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. Currently, pile driving information for CCF is available only for the embankments, divider wall, siphon at NCCF outlet, and siphon at Byron Highway (Appendix 3.E, *Pile Driving Assumptions for the Proposed Action*). Pile driving operations include the installation of an estimated 27,000 temporary sheet piles to isolate the construction areas for the embankments and divider wall, and 2,160 14-inch diameter concrete or steel pipe piles to construct the permanent foundation of the NCCF siphon. Pile driving at the Byron Highway siphon is not addressed in the following analysis because all pile driving would be conducted on land and more than 200 feet from water potentially containing listed fish species. A total of 4 construction seasons will likely be required to complete pile driving operations based on the estimated duration of pile installation.

Based on the general timing and abundance of Delta Smelt in the east and south Delta, restriction of pile driving activities to June 1 through November 30 will avoid the peak spawning periods of Delta Smelt. In addition, as described in Section 6.1.1.2 *North Delta Intakes*, 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 Delta Smelt and other 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 corrective actions that will be taken should the thresholds be exceeded.

6.1.1.5.3.1 Migrating Adults (December-March)

6.1.1.5.3.1.1 Individual-Level Effects

The timing of impact pile driving activities (June 1–November 30) will avoid the Delta Smelt adult migration season. There would be no risk of exposure of migrating adults to impact pile driving noise.

6.1.1.5.3.1.2 Population-Level Effects

No population-level effects would occur.

6.1.1.5.3.2 Spawning Adults (February-June)

6.1.1.5.3.2.1 Individual-Level Effects

As discussed previously (6.1.1.3, *North Delta Intakes*), the potential responses of fish to pile driving noise can range from behavioral effects to direct injury or mortality, depending on a number of biological, physical, and exposure variables. Sound exposure criteria currently in use by state and federal resource and transportation agencies in California, Oregon, and Washington to evaluate the potential for injury to pile driving activities are presented in Table 6.1-1. 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 can 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. Other construction activities that can generate underwater noise exceeding background levels (e.g., barge operations) typically produce noise levels below the behavioral effects threshold of 150 dB RMS, and therefore are unlikely to adversely affect Delta Smelt or other listed fish species.

Because the extent to which impact driving will be required to install the temporary sheet piles and foundation piles for the NCCF siphon is unknown at this time, the following analysis presents underwater noise impacts based on the worst-case scenario in which all piles are driven with an impact driver with no attenuation (no dewatering or attenuation devices). Assumptions for pile driving for each intake are detailed in Appendix 3.E, *Pile Driving Assumptions for the Proposed Action*, which specifies the type, size, and number of piles required, as well as the number of piles driven per day, the number of impact strikes per pile, and whether piles will be driven in water or on land.

Table 6.1-4 presents the extent, timing, and duration of pile driving noise levels predicted to exceed the interim injury and behavioral thresholds based on application of the NMFS spreadsheet model and the assumptions presented in Appendix 3.E, *Pile Driving Assumptions for the Proposed Action*. These estimates indicate that single-strike peak SPLs exceeding the injury

thresholds are expected to be limited to areas within 33–46 feet of the source piles. Based on the cumulative (daily) exposure threshold (in this case, the distance to "effective quiet"), the risk of injury may extend 2,814 feet during sheet pile installation and 1,774 feet during installation of the foundation piles for the NCCF siphon. Based on a threshold of 150 dB RMS, the potential for behavioral effects would extend 13,058 and 9,607 feet away, respectively. Such exposures would occur over a period of 450 days during cofferdam installation and 72 days during foundation pile installation.

Table 6.1-4. Extent, Timing, and Duration of Pile Driving Noise Levels Predicted to Exceed the Interim Injury and Behavioral Thresholds at CCF

Facility or Structure	Distance to 206 dB SPL Injury Threshold (feet)	Distance to Cumulative 183 dB SEL Injury Threshold[1, 2] (feet)	Distance to 150 dB RMS Behavioral Threshold[2] (feet)	Number of Construction Seasons	Timing of Pile Driving	Duration of Pile Driving (days)
Clifton Court Forebay						
Cofferdams	<33	2,814	13,058	5	June-Nov	450
NCCF Siphon	46	1,774	9,607	2	June-Nov	72

[1] Distance to cumulative injury thresholds are governed by the distance to "effective quiet" (150 dB SEL).

[2] Distances 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.

6.1.1.5.3.2.2 Population-Level Effects

Based on the timing of pile driving operations (June 1-November 30) and the general timing and abundance of Delta Smelt in the south delta, spawning adults may be exposed to pile driving noise in June and possibly July. Based on worst-case conditions (impact pile driving in open water with no attenuation), spawning adults within 2,814 feet from the cofferdam sheet piles or 1,774 feet from the foundation piles would be subject to underwater noise levels exceeding the injury thresholds. These distances correspond to areas of less than 100 acres to a maximum of 571 acres (less than 5% to 25% of the total surface area of CCF), depending on the location of the source piles. The potential for behavioral effects would extend throughout most of CCF. The extent to which adult smelt spawn in CCF is unknown but the ultimate survival of larvae or juveniles in CCF has been shown to be very low due to high levels of pre-screening mortality and entrainment (Castillo *et al.* 2012). Consequently, potential injury or mortality of spawning adults from pile driving noise is unlikely to have significant population-level effects. It should also be recognized that the above estimates represent worst-case impacts that, to the extent feasible, will be reduced by the use of vibratory and other non-impact pile driving methods, attenuation devices, and other physical and operational measures that will be identified in DWR's underwater sound control and abatement plan (Appendix 3.F, *General Avoidance and Minimization Measures*, AMM9 *Underwater Sound Control and Abatement Plan*).

6.1.1.5.3.3 Eggs/Embryos (Spring: ~March-June)

6.1.1.5.3.3.1 Individual-Level Effects

Delta Smelt eggs and embryos are demersal and adhesive, attaching to substrates with an adhesive stalk formed by the outer layer of the egg (Bennett 2005). Although exposure would be

low, individual eggs or embryos would be unable to avoid prolonged exposure to pile driving noise. However, any adverse effects on individual eggs or embryos would have negligible effects on overall survival because of the low probability of survival of larvae that successfully hatch in CCF or in the adjacent channels. Therefore, no adverse individual-level effects are expected.

6.1.1.5.3.3.2 Population-Level Effects

Based on the small proportion of adults potentially spawning in CCF in June and low likelihood of survival of Delta Smelt, potential injury or mortality of eggs or embryos from pile driving noise would have negligible effects on population abundance.

6.1.1.5.3.4 Larvae/Young Juveniles (Spring: ~March-June)

6.1.1.5.3.4.1 Individual-Level Effects

Delta Smelt larvae and early juveniles are particularly sensitive to pile driving noise because of their inability to avoid prolonged exposure to intense underwater noise.

6.1.1.5.3.4.2 Population-Level Effects

No significant population-level effects would occur because of the low likelihood of survival of larvae and juveniles in CCF under existing conditions.

6.1.1.5.3.5 Juveniles (Summer/Fall: ~July-December)

6.1.1.5.3.5.1 Individual-Level Effects

Juvenile Delta Smelt rear downstream of CCF in the summer and fall and therefore are unlikely to be affected by pile driving noise.

6.1.1.5.3.5.2 Population-Level Effects

No population-level effects would occur.

6.1.1.5.4 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 will implement a fish rescue and salvage plan (Appendix 3.F, *General Avoidance and Minimization* Measures, AMM8 *Fish Rescue and Salvage Plan*). This plan will be submitted to the fish and wildlife agencies (NMFS, USFWS, CDFW) for review and approval prior to implementation. The plan will include detailed procedures for fish rescue and salvage, including collection, holding, handling, and release, that would apply to all in-water activities with the potential to entrap fish. All fish rescue and salvage operations will be conducted under the guidance of a qualified fish biologist. The biologist, in consultation with a designated agency biologist, will determine the appropriate fish collection and relocation methods based on site-specific conditions and construction methods. Collection methods may include seines, dip nets, and electrofishing if permitted.

6.1.1.5.4.1 Migrating Adults (December-March)

6.1.1.5.4.1.1 Individual-Level Effects

The timing of cofferdam and silt curtain installation (June 1–November 30) will avoid the Delta Smelt adult migration season. There would be no risk of stranding of migrating adults.

6.1.1.5.4.1.2 Population-Level Effects

No population-level effects would occur.

6.1.1.5.4.2 Spawning Adults (February-June)

6.1.1.5.4.2.1 Individual-Level Effects

Spawning adults may be present in CCF and Old River in June and possibly July. Although adults would be expected to avoid active construction areas, it is assumed that some adults may be unable to avoid or escape from areas enclosed by cofferdams or silt curtain before they are fully installed. Fish rescue and salvage activities using accepted fish collection methods will minimize these losses but some injury or mortality will still occur because of varying degrees of effectiveness of the collection methods and potential stress and injury associated with various capture and handling methods. In addition, it may be impractical or infeasible to rescue fish from large, deep areas surrounded by silt curtains in CCF. The fate of Delta Smelt that may become trapped inside silt curtains is uncertain but these fish would be subject to long periods of entrapment (3-4 months) and exposure to predators, poor water quality, or entrainment from dredging operations. Regardless, such measures may not be warranted given the high baseline levels of pre-screening mortality and entrainment of Delta Smelt in CCF.

6.1.1.5.4.2.2 Population-Level Effects

Based on the small proportion of spawning adults that may be present during cofferdam and silt curtain installation (June 1–November 30), and the low likelihood of survival of larvae and juveniles in CCF, potential injury or mortality of spawning adults from stranding would not be expected to have a significant effect on population abundance.

6.1.1.5.4.3 Eggs/Embryos (Spring: ~March-June)

6.1.1.5.4.3.1 Individual-Level Effects

Because eggs and embryos are immobile and attached to substrate or other structures during incubation, they are particularly susceptible to stranding and subsequent injury or mortality from construction activities within cofferdams and silt curtains.

6.1.1.5.4.3.2 Population-Level Effects

Based on the small proportion of adults potentially spawning in CCF in June and July and the low likelihood of survival of Delta Smelt in CCF, potential losses of eggs or embryos due to stranding in cofferdams or silt curtains would not be expected to have a significant effect on population abundance.

6.1.1.5.4.4 Larvae/Young Juveniles (Spring: ~March-June)

6.1.1.5.4.4.1 Individual-Level Effects

Delta Smelt larvae and early juveniles may be particularly vulnerable to stranding because of their limited swimming abilities. In addition, conventional fish collection methods are less effective and more likely to injure or kill these life stages compared to larger juveniles or adults.

6.1.1.5.4.4.2 Population-Level Effects

Based on the small proportion of adults potentially spawning in or adjacent to CCF in June and the low likelihood of survival of their progeny, stranding of larvae and early juveniles in cofferdams or silt curtains would not be expected to have a significant effect on population abundance.

6.1.1.5.4.5 Juveniles (Summer/Fall: ~July-December)

6.1.1.5.4.5.1 Individual-Level Effects

Juvenile Delta Smelt rear downstream of CCF in summer and fall and therefore are unlikely to be exposed to in-water construction activities.

6.1.1.5.4.5.2 Population-Level Effects

No population-level effects would occur.

6.1.1.5.5 Direct Physical Injury

Fish could be injured or killed by direct contact with equipment or materials during in-water construction activities in CCF and the adjacent Old River channel. Potential mechanisms include fish being crushed by rock (riprap), impinged by sheetpiles, entrained by dredges, or struck by propellers. In addition to the proposed in-water work period, DWR proposes to implement a number of AMMs to minimize the potential for impacts on listed fish species, including AMM1 *Worker Awareness Training;* AMM4 *Erosion and Sediment Control Plan;* AMM6 *Disposal of Spoils, Reusable Tunnel Material, and Dredged Material;* AMM7 *Barge Operations Plan;* AMM9 *Underwater Sound Control and Abatement Plan*, and AMM8 *Fish Rescue and Salvage Plan* (Appendix 3.F, *General Avoidance and Minimization Measures*).

6.1.1.5.5.1 Migrating Adults (December-March)

6.1.1.5.5.1.1 Individual-Level Effects

The timing of in-water construction activities (June 1–November 30) will avoid the Delta Smelt adult migration season. There would be no risk of injury of migrating adults.

6.1.1.5.5.1.2 Population-Level Effects

No population-level effects would occur.

6.1.1.5.5.2 Spawning Adults (February-June)

6.1.1.5.5.2.1 Individual-Level Effects

Spawning adults may be present in low numbers in CCF and Old River in June and therefore subject to injury during in-water construction activities. Although adults would be expected to move away from active construction areas, it is assumed that some potential for injury exists whenever heavy equipment or materials are operated or placed in open water in these months.

6.1.1.5.5.2.2 Population-Level Effects

Based on the small proportion of spawning adults that may be present during the in-water construction season (June 1-November 30) and the low likelihood of survival of Delta Smelt in CCF, potential losses of spawning adults due to direct injury or mortality from in-water construction activities would not be expected to have a significant effect on population abundance.

6.1.1.5.5.3 Eggs/Embryos (Spring: ~March-June)

6.1.1.5.5.3.1 Individual-Level Effects

Because eggs and embryos are immobile and attached to substrate or other structures during incubation, they are particularly vulnerable to direct injury and mortality from in-water construction activities such as dredging, pile driving, and riprap placement.

6.1.1.5.5.3.2 Population-Level Effects

Based on the small proportion of adults potentially spawning in CCF during the in-water construction season (June 1-November 30) and low likelihood of survival of Delta Smelt in CCF, potential losses of eggs or embryos due to direct injury or mortality from in-water construction activities would not be expected to have a significant effect on population abundance.

6.1.1.5.5.4 Larvae/Young Juveniles (Spring: ~March-June)

6.1.1.5.5.4.1 Individual-Level Effects

Delta Smelt larvae and early juveniles may be particularly vulnerable to direct injury and mortality from in-water construction activities because of their limited swimming abilities.

6.1.1.5.5.4.2 Population-Level Effects

Based on the small proportion of adults potentially spawning in CCF in June and July and the low likelihood of survival of Delta Smelt in CCF, potential losses of larvae or early juveniles due to direct injury or mortality from in-water construction activities would not be expected to have a significant effect on population abundance.

6.1.1.5.5.5 Juveniles (Summer/Fall: ~July-December)

6.1.1.5.5.5.1 Individual-Level Effects

Juvenile Delta Smelt rear downstream of CCF in summer and fall and therefore are unlikely to be exposed to in-water construction activities.

6.1.1.5.5.5.2 Population-Level Effects

No population-level effects would occur.

6.1.1.5.6 Loss or Alteration of Habitat

Dredging and expansion of CCF and construction of the new water conveyance facilities at CCF would result in long-term or permanent impacts on aquatic habitat. Dredging, cofferdam installation, levee armoring, and barge operations would affect an estimated 1,932 acres of tidal perennial aquatic habitat (Mapbook M3.A) through changes in water quality, water depths, vegetation, and other structural components. Temporary to long-term effects on aquatic habitat associated with increases in turbidity and suspended sediment, underwater noise, and contaminants were previously discussed. Permanent impacts on aquatic habitat include the loss of 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 (Mapbook M3.A). Estimates of the amount of shallow water habitat potentially affected by construction are not currently available.

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

plan to ensure their effectiveness. Compensation for unavoidable impacts on aquatic habitat in CCF is not proposed because CCF is not considered suitable habitat for Delta Smelt.

6.1.1.5.6.1 Migrating Adults (December-March)

6.1.1.5.6.1.1 Individual-Level Effects

The potential effects of turbidity and suspended sediment, underwater noise, and other construction-related hazards on Delta Smelt were previously discussed. Potential changes in physical habitat resulting from dredging, installation of cofferdams, and construction of new water conveyance facilities include the loss of shallow water habitat, removal of vegetation, placement of riprap, and changes in hydraulic conditions. These changes could adversely affect migrating adults by increasing predator habitat but would likely have little effect on individual spawning success because of the low quality of spawning habitat and low likelihood of survival of larvae that may be produced in this region of the Delta.

6.1.1.5.6.1.2 Population-Level Effects

CCF and Old River in the vicinity of CCF have been highly altered for the purpose of water conveyance and lack many of the structural and functional attributes (PCEs) of the designated critical habitat of Delta Smelt due to channelization, levee clearing and armoring, maintenance dredging, unfavorable hydrodynamic conditions, high predator densities, and entrainment. Although the expected changes in physical habitat resulting from construction activities could affect the survival of migrating adults, the degraded status of spawning and larval/juvenile transport habitat in this portion of the Delta suggests that there would be no measurable effect on spawning success or recruitment of larvae and juveniles to the adult population.

6.1.1.5.6.2 Spawning Adults (February-June)

6.1.1.5.6.2.1 Individual-Level Effects

The expected changes in physical habitat in CCF and Old River, including deepening of CCF, disturbance of benthic substrates, and removal of vegetation, may affect potential spawning habitat for Delta Smelt but the effects on individual spawning success would be negligible because of the low quality of spawning habitat and low likelihood of survival of larvae that may be produced in this region of the Delta.

6.1.1.5.6.2.2 Population-Level Effects

As described above, CCF and Old River in the vicinity of CCF generally lack the physical attributes of preferred spawning habitat for Delta Smelt or the habitat conditions supporting larval and juvenile transport to suitable estuarine rearing habitat. Consequently, no population-level effect would occur.

6.1.1.5.6.3 Eggs/Embryos (Spring: ~March-June)

6.1.1.5.6.3.1 Individual-Level Effects

The modification of physical habitat in CCF and Old River would have little if any effect on individual spawning success or the viability of eggs or embryos because of the low quality of spawning habitat and low likelihood of survival of larvae that may be produced in this region of the Delta.

6.1.1.5.6.3.2 Population-Level Effects

Based on the degraded status of habitat for Delta Smelt spawning and larval and juvenile transport in CCF and Old River, no substantial population-level effects are expected.

6.1.1.5.6.4 Larvae/Young Juveniles (Spring: ~March-June)

6.1.1.5.6.4.1 Individual-Level Effects

Similar to migrating adults, Delta Smelt larvae and early juveniles may experience reduced survival in CCF and Old River because of the loss of shallow water habitat, removal of vegetation, placement of riprap, and changes in hydraulic conditions, but the effects of these changes on survival would be negligible because of the low likelihood of survival of larvae that may be produced in this region of the Delta.

6.1.1.5.6.4.2 Population-Level Effects

Based on the degraded status of habitat for larval and juvenile transport in CCF and Old River, no substantial population-level effects are expected.

6.1.1.5.6.5 Juveniles (Summer/Fall: ~July-December)

6.1.1.5.6.5.1 Individual-Level Effects

Juvenile Delta Smelt rear downstream of CCF in summer and fall and therefore are unlikely to be affected by losses or alteration of habitat associated with construction activities.

6.1.1.5.6.5.2 Population-Level Effects

No population-level effects would occur.

6.1.1.6 Effects of Construction Activities on Delta Smelt Critical Habitat

Construction activities would not affect the Delta Smelt critical habitat PCEs 3 and 4 because there would be no effect on river flows or salinity as a result of these activities. The effects to PCEs 1 and 2 are described below.

6.1.1.6.1 PCE 1: Physical Habitat (Spawning Substrate)

Construction of the north Delta intakes would result in the temporary or permanent loss of approximately 13.1 acres of shallow water habitat for Delta Smelt, and construction of the HOR gate would permanently affect 2.9 acres. Estimates of the amount of shallow water habitat or suitable spawning substrate potentially affected by barge landing construction are not currently available. Based on existing site conditions, none of this habitat is considered preferred spawning habitat for Delta Smelt.

Increases in suspended sediment generated by in-water construction activities may result in localized sediment deposition in the vicinity of the proposed intakes, barge landings, and HOR gate, degrading potential spawning habitat of Delta Smelt through burial of suitable substrate. However, potential adverse effects of sedimentation on physical habitat (spawning substrate) from construction would be minimized by siting the barge landings on levees with steep, riprapped banks and deep nearshore areas that lack shallow water areas where spawning could occur. Additionally, the Sacramento River and Old River in the vicinity of the proposed NDD and HOR gate, respectively, do not likely support significant spawning of Delta Smelt. Similar to the barge landings area, there appears to be little or no habitat thought to be preferred by Delta

Smelt for spawning in the vicinity of the NDD or HOR gate, which is dominated by steep levee slopes, existing riprap, and low quantities of riparian and aquatic vegetation.

6.1.1.6.2 PCE 2: Water (Quality)

Construction activities could affect Delta Smelt critical habitat PCE 2, water quality in the vicinity of the NDD, HOR gate, and barge landings through elevated noise, increased turbidity and suspended sediments, and potential increases in contaminants, predation risks, and other construction-related hazards. Elevated noise levels from pile driving and other sources will result in a temporary reduction in water of suitable quality for Delta Smelt, adversely affecting its designated critical habitat. Adverse effects on critical habitat will occur within areas subjected to sound levels associated with potential injury and behavioral effects. Underwater noise levels will return to baseline levels following cessation of pile driving and other construction activities.

Increases in turbidity and suspended sediment levels during sheet pile and cofferdam installation, riprap placement, and barge operations will cause temporary, localized reductions in water quality. Water quality is expected to return to baseline levels following cessation of construction activities. The potential release of contaminants through spills or sediment disturbance could result in temporary impacts on water quality. With implementation of the proposed pollution prevention and erosion and sediment control AMMs, potential adverse effects on the critical habitat of Delta Smelt will likely be avoided.

Other effects include the risk of stranding and direct injury that would adversely affect the suitability of water in for Delta Smelt over four years during the in-water construction period (June 1-November 30) the vicinity of the NDD, barge landings, and HOR gate. The overall effect on the designated critical habitat of Delta Smelt would be minimal because of the timing of in-water construction activities and construction AMMs.

6.1.2 Effects of Water Facility Maintenance on Delta Smelt

6.1.2.1 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).

It is assumed that all in-water maintenance activities would be conducted within the same work window proposed for in-water construction activities (June 1-October 31), and subject to the same AMMs, including 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;* AMM14 *Hazardous Material Management Plan;* AMM6 *Disposal and Reuse of Spoils, Reusable Tunnel Material, and Dredged Material;* and AMM7 *Barge Operations Plan* (Appendix 3.F, *General Avoidance and Minimization Measures*).

6.1.2.1.1 Migrating Adults (December-March)

6.1.2.1.1.1 Individual-Level Effects

The timing of in-water maintenance activities (June 1–October 31) will avoid the Delta Smelt adult migration season. Therefore, there would be no effect on migrating adults.

6.1.2.1.1.2 Population-Level Effects

No population-level effect would occur.

6.1.2.1.2 Spawning Adults (February-June)

6.1.2.1.2.1 Individual-Level Effects

As described in 6.1.1, *Effects of Water Facility Construction on Delta Smelt*, increases in turbidity and suspended sediment, noise, and other hazards associated with dredging, riprap replacement, and barge operations (e.g., direct physical injury) could adversely affect Delta Smelt through harassment, injury, or mortality of spawning adults, depending on the location, timing, and nature of the activities. Spawning adults may also be affected by loss or degradation of spawning habitat from changes in water depths, substrate, and hydraulic conditions from sedimentation and direct disturbance of channel areas adjacent to the intakes that are periodically disturbed by dredging or levee repair activities.

6.1.2.1.2.2 Population-Level Effects

Spawning adults may be present in the Delta during February through June, with peak spawning typically occurring from March to May. Thus, the timing of in-water maintenance activities (June 1–October 31) will avoid most of the spawning season and the months when adults are most likely to occur in the north Delta. In addition, as described in 6.1.1, *Effects of Water Facility Construction on Delta Smelt*, exposure of the population to maintenance activities would be further limited by the low proportion of the population utilizing the north Delta, the low quality of spawning habitat in the affected reaches, and implementation of the AMMs described in Appendix 3.F, *General Avoidance and Minimization Measures*. Population-level effects are expected to be negligible.

6.1.2.1.3 Eggs/Embryos (Spring: ~March–June)

6.1.2.1.3.1 Individual-Level Effects

As described in 6.1.1, *Effects of Water Facility Construction on Delta Smelt*, Delta Smelt eggs and embryos are demersal and adhesive and therefore unable to avoid exposure to suspended sediment (*i.e.*, potential burial by deposited sediment), contaminants, or direct physical contact with machinery or materials (e.g., riprap) during in-water maintenance activities.

6.1.2.1.3.2 Population-Level Effects

Population-level effects are expected to be negligible based on the potential for exposure of spawning adults described above.

6.1.2.1.4 Larvae/Young Juveniles (Spring: ~March-June)

6.1.2.1.4.1 Individual-Level Effects

Delta Smelt larvae and early juveniles may encounter active dredges and levee repair activities at the intake sites during their downstream movement from upstream spawning areas to estuarine rearing areas. Although the proposed work windows and BMPs would avoid or minimize exposure of larvae and early juveniles to potential water quality impacts or other hazards, this life stage, if present, would be unable to avoid active work areas and would therefore be particularly susceptible to the hazards of in-water maintenance activities.

6.1.2.1.4.2 Population-Level Effects

Population-level effects are expected to be negligible based on the small proportion of adults that spawn in or upstream of the north Delta in June, the resulting low densities of larvae and early juveniles in this region of the Delta, and implementation of the AMMs described in Appendix 3.F, *General Avoidance and Minimization Measures*.

6.1.2.1.5 Juveniles (Summer/Fall: ~July-December)

6.1.2.1.5.1 Individual-Level Effects

Juvenile Delta Smelt rear downstream of the proposed intakes in the summer and fall and therefore would be unaffected by maintenance activities.

6.1.2.1.5.2 Population-Level Effects

No population-level effects would occur.

6.1.2.2 Barge Landings

Maintenance activities at the barge landings include regular visual inspections, routine maintenance, and periodic repairs of the docking, loading, and unloading facilities. Maintenance dredging from barges may be required to maintain sufficient water depths for access, maneuvering, and mooring of barges over the course of barge landing operations. Maintenance activities also include levee repairs (e.g., riprap replacement) and vegetation control measures on the waterside slope of the levee. 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). It is assumed that all in-water maintenance activities would be conducted within the same work window proposed for in-water construction activities (June 1-October 31), and subject to the same AMMs, including 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;* AMM14 *Hazardous Material Management Plan;* AMM6 *Disposal and Reuse of Spoils, Reusable Tunnel Material, and Dredged Material;* and AMM7 *Barge Operations Plan* (Appendix 3.F, *General Avoidance and Minimization Measures*).

6.1.2.2.1 Migrating Adults (December-March)

6.1.2.2.1.1 Individual-Level Effects

The timing of in-water maintenance activities (June 1–October 31) will avoid the Delta Smelt adult migration season. Therefore, there would be no effect on migrating adults.

6.1.2.2.1.2 Population-Level Effects

No population-level effect would occur.

6.1.2.2.2 Spawning Adults (February-June)

6.1.2.2.2.1 Individual-Level Effects

As described in 6.1.1, *Effects of Water Facility Construction on Delta Smelt*, increases in turbidity and suspended sediment, noise, and other hazards associated with dredging, riprap replacement, and barge operations (e.g., direct physical injury) could adversely affect Delta Smelt through harassment, injury, or mortality of spawning adults. Spawning adults may be affected by loss or degradation of spawning habitat from changes in water depths, substrate, and hydraulic conditions from sedimentation and direct disturbance of channel areas adjacent to the landings that are periodically disturbed by dredging or levee repair activities.

6.1.2.2.2.2 Population-Level Effects

Because Delta Smelt are generally found in the west Delta and Cache Slough/Liberty Island area during spring and summer, the majority of the population will not be exposed to maintenance activities at the proposed barge landing sites. In addition, the timing of in-water maintenance activities (June 1-October 31) will avoid most of the spawning season and the months when adults are most likely to occur in the east and south Delta. In addition, as described in 6.1.1, *Effects of Water Facility Construction on Delta Smelt*, exposure of the population to temporary and long-term effects of maintenance activities on aquatic habitat would be limited by the low quality of spawning habitat at preferred sites for barge access and loading and unloading operations.

6.1.2.2.3 Eggs/Embryos (Spring: ~March-June)

6.1.2.2.3.1 Individual-Level Effects

As described in 6.1.1, *Effects of Water Facility Construction on Delta Smelt*, Delta Smelt eggs and embryos are demersal and adhesive and therefore unable to avoid exposure to suspended sediment (*i.e.*, potential burial by deposited sediment), contaminants, or direct physical contact with machinery or materials (e.g., riprap) during in-water maintenance activities.

6.1.2.2.3.2 Population-Level Effects

Population-level effects are expected to be negligible based on the potential for exposure of spawning adults described above.

6.1.2.2.4 Larvae/Young Juveniles (Spring: ~March-June)

6.1.2.2.4.1 Individual-Level Effects

Delta Smelt larvae and early juveniles may encounter active dredges and levee repair activities at the barge landings during their downstream movement from upstream spawning areas to estuarine rearing areas. This life stage would be unable to avoid active work areas and would therefore be particularly susceptible to the hazards of in-water maintenance activities.

6.1.2.2.4.2 Population-Level Effects

Population-level effects are expected to be negligible based on the small proportion of adults that spawn in the east and south Delta in June, the resulting low densities of larvae and early juveniles in this region of the Delta, and implementation of the AMMs described in Appendix 3.F, *General Avoidance and Minimization Measures*.

6.1.2.2.5 Juveniles (Summer/Fall: ~July-December)

6.1.2.2.5.1 Individual-Level Effects

Juvenile Delta Smelt rear downstream of the proposed barge landings in the summer and fall and therefore would be unaffected by maintenance activities.

6.1.2.2.5.2 Population-Level Effects

No population-level effects would occur.

6.1.2.3 Head of Old River Gate

Maintenance of the Head of Old River (HOR) gate, including fishway, boat lock, and navigation structures, includes require regular visual inspections and adjustments of the facilities to maintain compliance with engineering and performance standards, and periodic repairs to prevent mechanical, structural, and electrical failures. Emergency maintenance is also anticipated. Routine maintenance includes regular servicing and repair of motors, compressors, and control systems, and periodic repairs to the mechanical and structural elements of the gate, fishway, and boat lock. Maintenance activities include periodic dredging to remove accumulated sediment from around the gate structure, dewatering of the gate facilities for inspection and maintenance, and replacement of riprap to repair eroded or damaged portions of the waterside levee slope. Vegetation control measures would be performed as part of levee maintenance. It is assumed that all in-water maintenance activities would be conducted within the same work window proposed for in-water construction activities (August 1-November 30), and subject to the same AMMs, including 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;* AMM14 *Hazardous Material Management Plan;* AMM6 *Disposal and Reuse of Spoils, Reusable Tunnel Material, and Dredged Material;* and AMM7 *Barge Operations Plan* (Appendix 3.F, *General Avoidance and Minimization Measures*).

Maintenance dredging may be required every 3 to 5 years to remove sediment that may potentially interfere with gate operations, navigation, and fish passage. 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 will be used to limit the dispersion of suspended sediment during dredging operations. A formal dredging plan describing specific maintenance dredging

activities will be developed prior to dredging activities. Guidelines related to dredging activities and disposal and reuse of spoils, including compliance with in-water work windows and turbidity standards, are described in AMM6 *Disposal and Reuse of Spoils, Reusable Tunnel Material, and Dredged Material* (Appendix 3.F, *General Avoidance and Minimization Measures*).

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

6.1.2.3.1 Migrating Adults (December-March)

6.1.2.3.1.1 Individual-Level Effects

The timing of in-water maintenance activities (August 1–November 30) will avoid the Delta Smelt adult migration season. Therefore, there would be no effect on migrating adults.

6.1.2.3.1.2 Population-Level Effects

No population-level effect would occur.

6.1.2.3.2 Spawning Adults (February-June)

6.1.2.3.2.1 Individual-Level Effects

The timing of in-water maintenance activities (August 1–October 31) will avoid the Delta Smelt spawning season. Therefore, there would be no direct effects of maintenance activities on spawning adults. However, spawning adults may be affected by loss or degradation of spawning habitat from changes in water depths, substrate, and hydraulic conditions from sedimentation and direct disturbance of channel areas adjacent to the HOR gate that are periodically disturbed by dredging or levee repair activities.

6.1.2.3.2.2 Population-Level Effects

As described in 6.1.1, *Effects of Water Facility Construction on Delta Smelt*, most of the Delta Smelt population is distributed downstream of the proposed HOR gate (Moyle 2002) although adults have been detected in the lower San Joaquin River near the HOR junction. Based on the general lack of habitat thought to be preferred by Delta Smelt for spawning, Old River in the action area of the proposed gate does not likely support significant spawning of Delta Smelt, serving mainly as a migration corridor for adults during their migration to upstream spawning areas and larvae during their downstream dispersal to estuarine habitat. Thus, any impacts on potential spawning habitat resulting from sedimentation or direct disturbance of the channel bed would have negligible population-level effects.

6.1.2.3.3 Eggs/Embryos (Spring: ~March-June)

6.1.2.3.3.1 Individual-Level Effects

The timing of in-water maintenance activities (August 1–November 30) will avoid the Delta Smelt incubation season. Therefore, there would be no direct effects of maintenance activities on eggs and embryos.

6.1.2.3.3.2 Population-Level Effects

Population-level effects are expected to be negligible based on the potential for exposure of spawning adults and habitat described above.

6.1.2.3.4 Larvae/Young Juveniles (Spring: ~March-June)

6.1.2.3.4.1 Individual-Level Effects

The timing of in-water maintenance activities (August 1–November 30) will avoid the potential occurrence of Delta Smelt larvae and early juveniles within the action area of the HOR gate.

6.1.2.3.4.2 Population-Level Effects

No population-level effect would occur.

6.1.2.3.5 Juveniles (Summer/Fall: ~July-December)

6.1.2.3.5.1 Individual-Level Effects

Juvenile Delta Smelt rear downstream of the HOR gate in summer and fall and therefore would be unaffected by maintenance activities.

6.1.2.3.5.2 Population-Level Effects

No population-level effects would occur.

6.1.2.4 Clifton Court Forebay

Maintenance of the water conveyance facilities and other infrastructure at CCF (including Clifton Court Pumping Plant [CCPP], divider and perimeter embankments, outlet canals and siphons, South CCF [SCCF] intake structure, and North CCF [NCCF] emergency spillway) will include regular visual inspections and adjustments of the facilities to maintain compliance with engineering and performance standards, and periodic repairs to prevent mechanical, structural, and electrical failures. Emergency maintenance is also anticipated. Maintenance requirements potentially affecting listed fish species and aquatic habitat in CCF and Old River include dredging or mechanical excavation of accumulated sediment around the pumping, intake, and outlet facilities, and embankment maintenance activities, including repairs (e.g., RSP replacement) and vegetation control on the divider and perimeter embankments. With upstream sediment removal at the north Delta sedimentation facilities and expansion of storage capacity at CCF, the need for additional dredging of NCCF and SCCF over the first 50 years following construction is expected to be minimal. It is assumed that all in-water maintenance activities would be conducted within the same work window proposed for in-water construction activities (June 1-November 30), and subject to the same AMMs, including 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;* AMM14 *Hazardous Material Management Plan;* AMM6 *Disposal and Reuse of Spoils, Reusable Tunnel Material, and Dredged Material;* and AMM7 *Barge Operations Plan* (Appendix 3.F, *General Avoidance and Minimization Measures*) (Appendix 3.F, *General Avoidance and Minimization Measures*).

6.1.2.4.1 Migrating Adults (December-March)

6.1.2.4.1.1 Individual-Level Effects

The timing of in-water maintenance activities (June 1–November) will avoid the Delta Smelt adult migration season. Therefore, there would be no effect on migrating adults.

6.1.2.4.1.2 Population-Level Effects

No population-level effect would occur.

6.1.2.4.2 Spawning Adults (February-June)

6.1.2.4.2.1 Individual-Level Effects

As described in 6.1.1, *Effects of Water Facility Construction on Delta Smelt*, increases in turbidity and suspended sediment, noise, and other hazards associated with dredging, riprap replacement, and barge operations (e.g., direct physical injury) could adversely affect Delta Smelt through harassment, injury, or mortality of spawning adults. Spawning adults may be affected by loss or degradation of spawning habitat from changes in water depths, substrate, and hydraulic conditions from sedimentation and direct disturbance of sediments adjacent to the water conveyance facilities that are periodically disturbed by dredging or levee repair activities.

6.1.2.4.2.2 Population-Level Effects

As described in 6.1.1, *Effects of Water Facility Construction on Delta Smelt*, restriction of in-water maintenance activities in CCF to June 1-November 30 will avoid most of the spawning season (January through June) and peak abundance of adults, eggs, and larvae in the south Delta (February through May). In addition, Old River in the vicinity of CCF is highly channelized and lacks the general attributes of preferred spawning habitat, and CCF is not considered suitable habitat because of the low likelihood of survival of larvae, juveniles, and adults that are entrained into the forebay (Castillo *et al.* 2012). No population-level effects are anticipated.

6.1.2.4.3 Eggs/Embryos (Spring: ~March-June)

6.1.2.4.3.1 Individual-Level Effects

As described in 6.1.1, *Effects of Water Facility Construction on Delta Smelt*, Delta Smelt eggs and embryos are demersal and adhesive and therefore unable to avoid exposure to suspended sediment (*i.e.*, potential burial by deposited sediment), contaminants, or direct physical contact with machinery or materials (e.g., riprap) during in-water maintenance activities.

6.1.2.4.3.2 Population-Level Effects

Population-level effects are expected to be negligible based on the potential for exposure of spawning adults described above.

6.1.2.4.4 Larvae/Young Juveniles (Spring: ~March-June)

6.1.2.4.4.1 Individual-Level Effects

Delta Smelt larvae and early juveniles may encounter active dredges and levee repair activities in CCF or Old River during June and possibly into early July. This life stage would be unable to avoid active work areas and would therefore be particularly susceptible to the hazards of in-water maintenance activities.

6.1.2.4.4.2 Population-Level Effects

Population-level effects are expected to be negligible based on the small proportion of adults that spawn in the south Delta in June, the resulting low densities of larvae and early juveniles in this region of the Delta, and the low likelihood of survival of larvae or early juveniles due to high pre-screen mortality and entrainment losses in CCF and the Skinner Fish Facility.

6.1.2.4.5 Juveniles (Summer/Fall: ~July-December)

6.1.2.4.5.1 Individual-Level Effects

Juvenile Delta Smelt rear downstream of the proposed barge landings in the summer and fall and therefore would be unaffected by maintenance activities.

6.1.2.4.5.2 Population-Level Effects

No population-level effects would occur.

6.1.2.5 Effects for Maintenance Activities on Delta Smelt Critical Habitat

Maintenance activities would not affect the Delta Smelt critical habitat PCEs 3 and 4 because there would be no effect on river flows or salinity as a result of these activities. The effects to PCEs 1 and 2 are described below.

6.1.2.5.1 PCE 1: Physical Habitat (Spawning Substrate)

Potential effects of maintenance activities on physical habitat include loss or degradation of spawning substrate from the deposition of sediment generated by dredging and levee repair activities. Spawning adults may also be affected by changes in water depths, substrate, and hydraulic conditions in areas adjacent to the water conveyance facilities that are periodically disturbed by dredging or levee repair activities, potentially affecting areas defined as shallow water habitat; however, as described in 6.1.1, *Effects of Water Facility Construction on Delta Smelt*, these areas re not considered preferred spawning habitat, and CCF is not part of the designated critical habitat.

6.1.2.5.2 PCE 2: Water (Quality)

Increases in turbidity, suspended sediment, and noise during dredging, levee repair activities, and other in-water maintenance activities are expected to cause temporary, localized reductions in water quality at times when few Delta Smelt are likely to be present (August 1–November 30) at the intake sites, and in Old River and CCF. Water quality is expected to return to baseline levels following cessation of maintenance activities.

6.1.3 Effects of Water Facility Operations on Delta Smelt

6.1.3.1 Introduction

This section analyzes the effects of water facility operations on Delta Smelt. There are eight main subsections:

- North Delta Exports: Analyzes the potential for entrainment, impingement, and elevated predation rates.
- South Delta Exports: Analyzes the potential for entrainment and elevated predation rates.

- Head of Old River (HOR) Gate: Analyzes potential effects on Delta hydraulics and near-field impacts (elevated predation rates and fish passage).
- Habitat Effects: Analyzes the combined effects of PA operations on Delta flows, abiotic habitat, water temperature, sediment removal (water clarity), entrainment of phytoplankton, conditions contributing to growth of *Microcystis*, and loading and bioaccumulation of contaminants (selenium).
- Delta Cross Channel: Analyzes the effects of Delta Cross Channel operations on Delta hydraulics.
- Suisun Marsh Facilities: Analyzes potential effects of the Suisun Marsh Salinity Control Gates, Roaring River Distribution System, Morrow Island Distribution System, and Goodyear Slough Outfall.
- North Bay Aqueduct: Analyzes potential for entrainment, impingement, and predation.
- Other Facilities: Analyzes the effects of Contra Costa Water District Facilities and the Clifton Court Forebay Aquatic Weed Control Program.

6.1.3.2 North Delta Exports

The reach of the Sacramento River where the NDDs are proposed to be built is considered to be near the northern extent of where Delta Smelt occur. Surveys conducted within the Sacramento River reach of the proposed NDD locations indicate few Delta Smelt are found in the vicinity. On one occasion, the species has been found as far upstream as Knights Landing (Vincik and Julienne 2012). Thus, it is expected that there will be some entrainment and impingement of Delta Smelt at the proposed NDD. For the effects analysis below, population-level effects were considered in light of survey data in the general vicinity of the proposed intakes that were examined to inform the extent of exposure of the species. The survey data used included USFWS beach seine data (1976–2011, January–December), Interagency Ecological Program (IEP) fall midwater trawl data (1991–2010, September–December), and CDFW striped bass egg and larval survey data (1991–1994, February–July). For each of these surveys, data from stations on the Sacramento River between Georgiana Slough and approximately the northern limit of the statutory Delta (City of Sacramento at the I Street Bridge) were summarized to represent the potential occurrence of Delta Smelt that could be entrained or impinged (Figure 6.1-1). Summed catch data for these locations were then compared to other survey locations, which were designated as downstream sites. In addition, for migrating adult Delta Smelt, a DSM2-PTM-based analysis was used to infer potential spatial overlap with the NDD.

The analyses of the potential effects of north Delta exports on Delta Smelt that are presented in this section are limited to the near-field effects of the NDD (entrainment, impingement/screen contact, and predation). Potential far-field effects on Delta Smelt habitat are considered in Section 6.1.3.5, *Habitat Effects*, because both north and south Delta exports contribute to such effects together and it would be impractical to attempt to parse out these effects for the facilities separately.

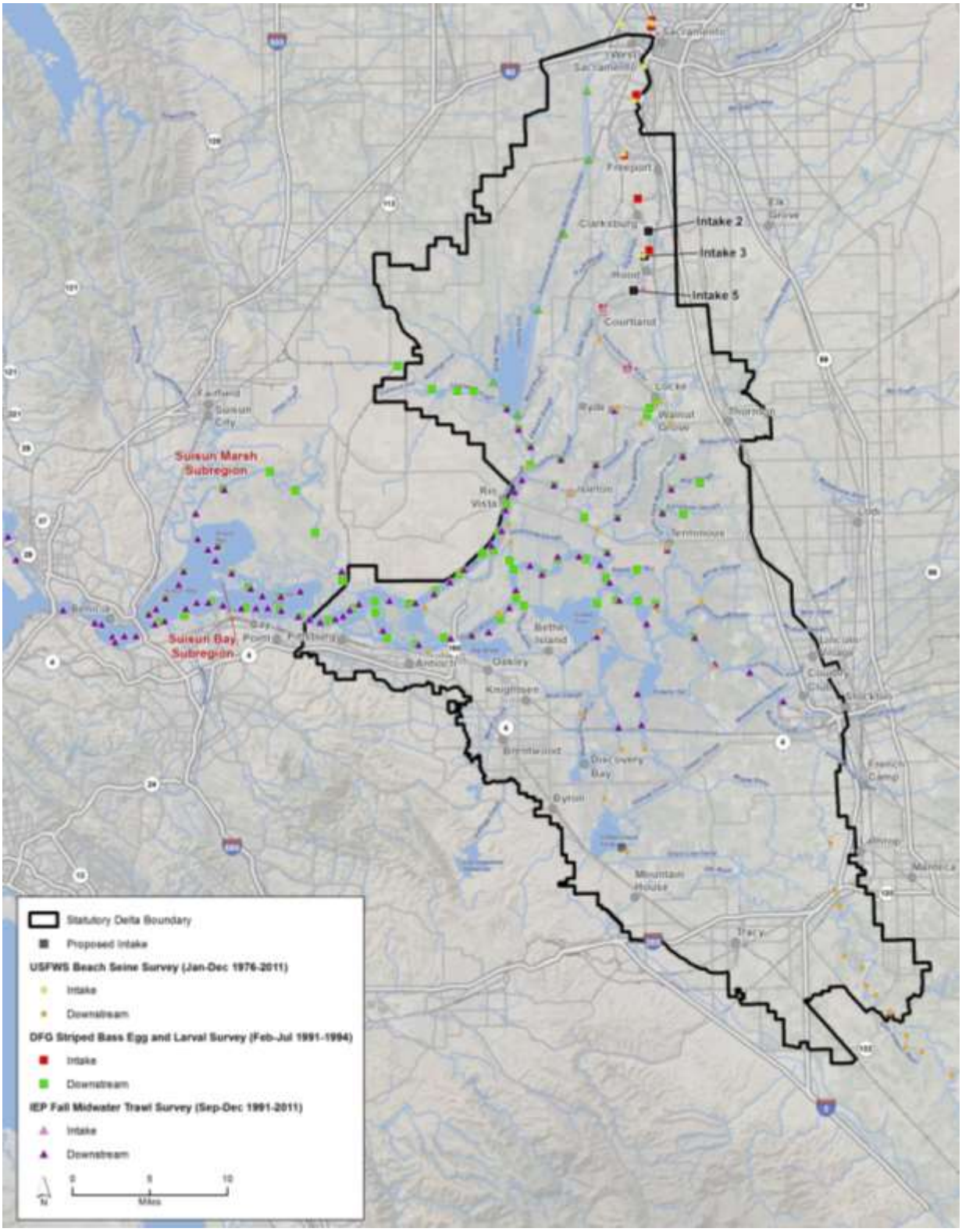


Figure 6.1-1. Survey Station Locations Used to Assess the Potential Presence of Delta Smelt Near the Proposed CVP/SWP North Delta Intakes

6.1.3.2.1 Entrainment

6.1.3.2.1.1 Migrating Adults (December-March)

6.1.3.2.1.1.1 Individual-Level Effects

Based on Delta Smelt body depth to body length ratios and using the screening effectiveness analysis described in Appendix 6.A, *Quantitative Methods for Biological Assessment of Delta Smelt*, Section 6.A.2.2, the proposed NDD screen mesh of 1.75 mm would prevent Delta Smelt greater than standard length of around 20-21 mm from being entrained through the fish screens. Therefore, Delta Smelt older than approximately 90 days (Hobbs *et al.* 2007) could not be entrained through the NDD fish screens. All adult Delta Smelt exceed 90 days of age and 20-21 mm in length. Therefore, there would be no adverse effect to individual adult Delta Smelt.

6.1.3.2.1.1.2 Population-Level Effects

As there would be no individual-level adverse effect, there would be no population-level adverse effect to migrating adult Delta Smelt from entrainment at the NDD.

6.1.3.2.1.2 Spawning Adults (February-June)

6.1.3.2.1.2.1 Individual-Level Effects

As described for migrating adult Delta Smelt, the proposed NDD screen mesh of 1.75 mm would prevent Delta Smelt greater than standard length of around 22 mm from being entrained. Therefore, there would be no adverse effect to individual spawning adult Delta Smelt.

6.1.3.2.1.2.2 Population-Level Effects

Following from no individual-level adverse effect, there therefore would be no population-level adverse effect to spawning adult Delta Smelt from entrainment at the NDD.

6.1.3.2.1.3 Eggs/Embryos (Spring: ~March-June)

6.1.3.2.1.3.1 Individual-Level Effects

Delta Smelt eggs and embryos are demersal and adhesive, attaching to substrates with an adhesive stalk formed by the outer layer of the egg (Bennett 2005). As such, individual eggs would not be subject to entrainment and there would be no individual-level adverse effect.

6.1.3.2.1.3.2 Population-Level Effects

The demersal and adhesive nature of Delta Smelt eggs means that there would be no adverse population-level effects from the NDD with respect to entrainment.

6.1.3.2.1.4 Larvae/Young Juveniles (Spring: ~March-June)

6.1.3.2.1.4.1 Individual-Level Effects

As noted for adult Delta Smelt, based on Delta Smelt body depth to body length ratios (Appendix 6.A, *Quantitative Methods for Biological Assessment of Delta Smelt, S*ection 6.A.2.2), the proposed screen mesh of 1.75 mm would exclude Delta Smelt greater than standard length of around 20-21 mm (generally, fish less than 90 days old). Therefore, Delta Smelt smaller than 20-21 mm could be entrained; however, fish that are over 20-21 mm may also be injured or killed by impingement whether they pass all the way through the screen or not because they may not be able free themselves from the fish screen if water is being drawn through it; impingement is discussed further in Section 6.1.3.2.2.

The Freeport Regional Water Authority's water intake is the most analogous to the proposed NDD. The intake is located at Freeport Bend (river mile 47 on the Sacramento River) and therefore is ~6 river miles upstream of the PA's Intake 2, the most upstream of the three proposed intakes. The Freeport intake is also considerably smaller than the proposed NDD: the intake has a capacity up to 286 cfs (*i.e.*, about 10% of the 3,000 cfs for each NDD intake), and the fish screen panels are 9.92 feet wide by 10.71 feet tall (compared to 15.6 feet wide by 12.5 to 17.0 feet for the NDD screens), with a total of 16 fish screens (compared to 66–90 screens for the NDD intakes 2, 3, and 5). Both facilities are designed to meet a 0.2 ft/s approach velocity criterion. Entrainment monitoring was undertaken in winter/spring of water years 2012–2014, although pumping rate was low in 2012 and 2013 (generally 23 cfs or less), whereas in 2014 pumping rate was greater (132–163 cfs) (ICF International 2015a). Hoop net and larval light trap monitoring behind the fish screens did not detect delta smelt in any of the years sampled, although in 2014 three unidentifiable smelt larvae were detected, in addition to two wakasagi larvae (*Hypomesus nipponensis*). USFWS trawls and beach seining upstream of the Freeport intake (Sherwood Harbor and Garcia Bend) have sometimes detected Delta Smelt during the period of entrainment monitoring, so adults and therefore possibly larvae are present in the general area, albeit in low abundance. The analysis of the Freeport intake suggests that when Delta Smelt larvae do occur in front of the NDD screens, some entrainment will occur.

For this effects analysis, it is assumed that entrainment risk of early life stage Delta Smelt is related to the proportion of river flow diverted by the intakes, with the risk increasing as higher proportions of flow are diverted (as shown for other species by ICF Jones & Stokes 2008). Given this assumption, the CalSim monthly mean modeling outputs can be used to provide estimates of the proportion of flow diverted, by dividing the NDD flow by the Sacramento River flow at Freeport. The proportion of flow diverted by the NDD increases as bypass flow constraints decrease: in wet years, the median proportion of flow diverted ranged from 7% in April (range 0% to 15%) to 32% in June (range 7–38%); in contrast, in critical years, the median percentage of flow diverted ranged from 3% in April (range 0% to 6%) to 6% in June (range 6% to 8%) (Table 6.1-5). Thus, the risk to individual fish is expected to be lower in drier years and the risk would be lower in April and May than in March or June.

Table 6.1-5. Summary Statistics of CalSim-Modeled Average Monthly North Delta Diversion as a Percentage of Sacramento River at Freeport Flows for the Proposed Action

Water Year Type		March	April	May	June
Wet	Maximum	35%	15%	21%	38%
	75th percentile	26%	9%	12%	35%
	Mean	20%	7%	9%	29%
	Median	17%	7%	8%	32%
	25th percentile	13%	5%	5%	25%
	Minimum	6%	0%	3%	7%
Above Normal	Maximum	34%	14%	15%	38%
	75th percentile	24%	9%	11%	36%
	Mean	21%	6%	8%	30%
	Median	19%	5%	10%	32%
	25th percentile	15%	4%	5%	28%
	Minimum	13%	1%	2%	16%
Below Normal	Maximum	31%	8%	12%	36%
	75th percentile	24%	7%	6%	28%
	Mean	16%	4%	4%	19%
	Median	13%	4%	2%	21%
	25th percentile	9%	0%	1%	6%
	Min	6%	0%	0%	6%
Dry	Max	32%	15%	16%	37%
	75th percentile	22%	6%	6%	26%
	Mean	18%	4%	4%	17%
	Median	20%	1%	3%	13%
	25th percentile	13%	0%	2%	6%
	Minimum	6%	0%	0%	6%
Critical	Maximum	17%	6%	6%	8%
	75th percentile	6%	4%	6%	6%
	Mean	7%	3%	4%	6%
	Median	6%	3%	4%	6%
	25th percentile	6%	1%	2%	6%
	Minimum	6%	0%	0%	6%

6.1.3.2.1.4.2 Population-Level Effects

Catch of Delta Smelt per cubic meter in the egg and larval survey in 1991–1994 was an order of magnitude lower in the vicinity of the proposed north Delta intakes than in downstream areas Table 6.1-6), and total catch in the vicinity of the intakes was considerably less than total catch downstream. Catch density tended to be greatest in April and May which, as shown previously, are expected to be the months when the lowest proportion of Sacramento River water would be diverted by the NDD (Table 6.1-5). These pieces of evidence suggest that any adverse population-level effect from entrainment by the NDD would be small.

It is not possible to provide a precise estimate of the proportion of the larval population that might be entrained by the NDD. However, to provide a coarse perspective, the ratio (intake/downstream) of the mean densities in April and May were 0.04–0.06 (*i.e.*, the density in the intake area was 4–6% that of the downstream area). Volumetric estimates of Delta channels used in DSM2 (Jones & Stokes 2005, Section 5.2, Table 5.2-1) suggest the downstream portion of the Delta included in the egg and larval survey (see Figure 6.1-1; note that much of the south Delta is excluded) is over 20 times greater than the volume of the Sacramento River upstream of Georgiana Slough and Delta Cross Channel, from which the intake density estimates were taken. Therefore, perhaps 0.25% of larvae could occur in the NDD reach. If 10% of water was diverted, this suggests that the order of magnitude of population-level larval entrainment from the NDD would be considerably less than 0.1% (and closer to 0.01%). Mean estimates of potential March–June larval population-level entrainment by the NDD using a DSM2-PTM analysis described in Appendix 6.A, *Quantitative Methods for Biological Assessment of Delta Smelt*, Section 6.A.3.2, ranged from <0.1% in critical years to nearly 0.2% in other water year types (see further discussion in the Entrainment section for South Delta Exports). However, that analysis assumed density in the Sacramento River was the same as at all locations in the north Delta, including Cache Slough and surrounding areas, where density would be expected to be higher than in the Sacramento River, which may have biased these estimates somewhat high.

Further perspective on the proportion of the Delta Smelt population that could occur near the NDD was provided by a DSM2-PTM analysis incorporating movement into the upper 10% of the water column during flood tides, to simulate the upstream migration of adult Delta Smelt; as described in more detail in Section 6.1.3.2.2.1.2, this analysis also provided evidence that a very low proportion of the Delta Smelt population (migrating adults, and therefore their progeny) would be expected to occur near the NDD, as no particles originating downstream were entrained at the NDD (or moved upstream of Isleton; Table 6.1-8, indicating that there is no hydraulic reason to expect significant fractions of the Delta Smelt population to reach the NDDs.

Table 6.1-6. Number of Delta Smelt Larvae Collected and Catch per Cubic Meter during the CDFW Striped Bass Egg and Larval Survey in the Action Area

Year	Month	Number of Samples		Total Caught (Intake Area)	Total Caught (Downstream Area)	Proportion Caught (Intake Area/Total)	Catch Per Cubic Meter (Intake Area)	Catch Per Cubic Meter (Downstream)
		Intake Area	Downstream					
1991	2	14	74	2	0	1.00	0.01	0.00
	3	7	82	0	25	0.00	0.00	0.10
	4	21	362	2	33	0.06	0.01	0.13
	5	105	442	31	101	0.23	0.15	0.51
	6	70	279	2	24	0.08	0.01	0.12
1992	2	34	205	0	7	0.00	0.00	0.03
	3	55	348	4	38	0.10	0.02	0.17
	4	77	482	43	202	0.18	0.19	0.93
	5	101	509	6	228	0.03	0.03	1.10
	6	76	353	0	36	0.00	0.00	0.16
	7	12	167	0	1	0.00	0.00	0.00
1993	2	27	273	0	185	0.00	0.00	0.82
	3	59	405	16	284	0.05	0.07	1.32
	4	55	415	38	318	0.11	0.19	1.44
	5	64	419	44	487	0.08	0.19	3.03
	6	48	411	0	102	0.00	0.00	1.23
	7	8	237	0	55	0.00	0.00	0.37
1994	2	40	306	0	25	0.00	0.00	0.11
	3	64	453	20	565	0.03	0.09	2.46
	4	56	431	8	1723	0.00	0.04	7.39
	5	64	491	4	338	0.01	0.02	1.82
	6	56	432	0	258	0.00	0.00	1.31
	7	32	235	0	46	0.00	0.00	0.18
mean	2	28.8	214.5	0.5	54.3	0.25	0.00	0.24
	3	46.3	322.0	10.0	228.0	0.05	0.04	1.01
	4	52.3	422.5	22.8	569.0	0.09	0.10	2.47
	5	83.5	465.3	21.3	288.5	0.09	0.10	1.62
	6	62.5	368.8	0.5	105.0	0.02	0.00	0.71
	7	17.3	213.0	0.0	34.0	0.00	0.00	0.19

Source: California Department of Fish and Game unpublished data.

6.1.3.2.1.5 Juveniles (Summer/Fall: ~July-December)

6.1.3.2.1.5.1 Individual-Level Effects

As described for adult Delta Smelt, the proposed NDD screen mesh of 1.75 mm would prevent Delta Smelt greater than standard length of around 22 mm from being entrained, and therefore would be expected to allow juvenile Delta Smelt to avoid entrainment but not necessarily

impingement. There would be no adverse effect to individual juvenile Delta Smelt from entrainment.

6.1.3.2.1.5.2 Population-Level Effects

Based on the lack of effect to individual juvenile Delta Smelt, there would not be an adverse population-level effect from entrainment at the NDD to Delta Smelt juveniles.

6.1.3.2.2 Impingement and Screen Contact

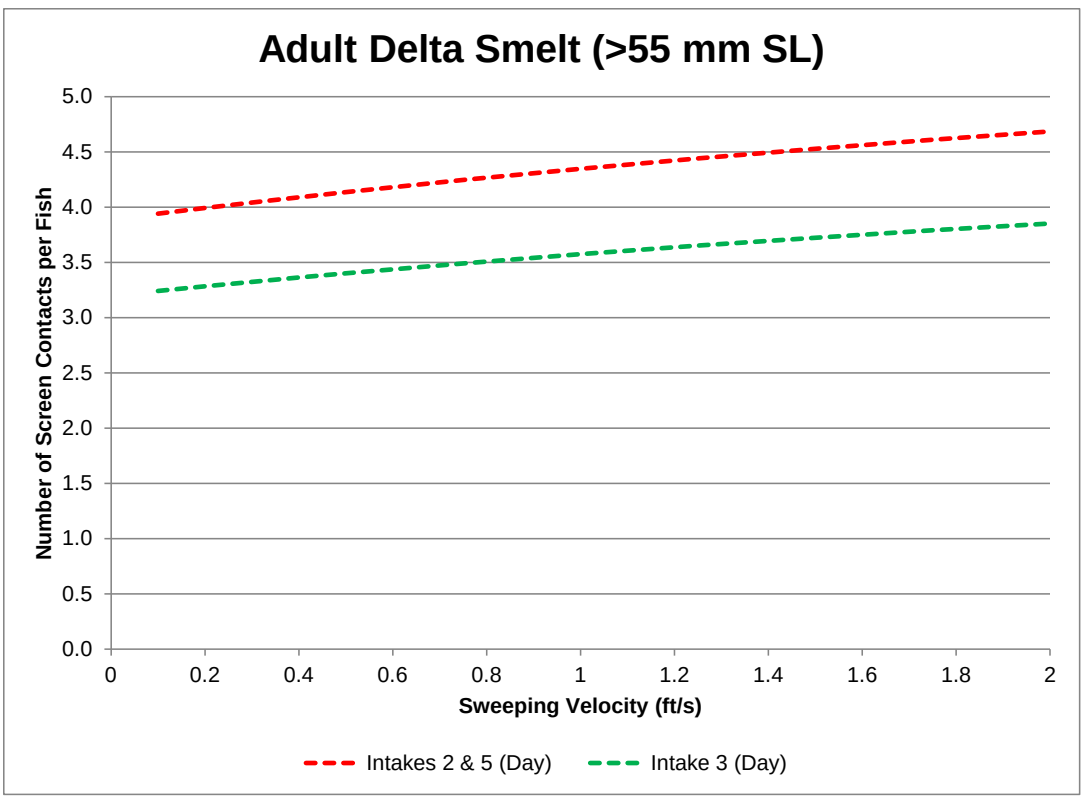
6.1.3.2.2.1 Migrating Adults (December-March)

6.1.3.2.2.1.1 Individual-Level Effects

As noted in Chapter 3, *Description of the Proposed Action*, the NDD would be operated such that approach velocity is consistent with recommendations for Delta Smelt (0.2 ft/s). However, there remains the potential that Delta Smelt larger than the minimum screenable size of ~20-21 mm could contact the NDD screens and be injured or die. This potential exists for several reasons: (1) even at 0.2-ft/s approach velocity, Delta Smelt had some injurious screen contact in an experimental flume (White *et al.* 2007), (2) the sweeping flow velocity at which it was assumed that NDD diversions could commence (0.4 ft/s; see Section 5.A.5.2.4.9, *North Delta Diversion Bypass Flows*, in Appendix 5.A, *CALSIM Methods and Results*, and Section 5.B.2.3.5, *North Delta Diversion Operations*, in Appendix 5.B, *DSM2 Modeling and Results*) is within the velocity range at which captive Delta Smelt switched swimming modes from a noncontinuous stroke and glide behavior to continuous swimming, resulting in swimming failure because of inability (or unwillingness) to swim steadily (Swanson *et al.* 1998), and (3) the proposed fish screens are very long requiring that Delta Smelt will need to swim continuously against what they consider strong current for lengthy periods of time and it has not been determined that they can or will do so. The behavior-based PTM analysis (see Section 6.1.3.2.2.1.2, *Population-Level Effects*) supports the hypothesis that adult Delta Smelt migrating upstream in the vicinity of the NDD need to use the lower velocity periphery of the channel to swim upstream against unidirectional flow during periods when the NDD would be operating (*i.e.*, the typical tidal surfing behavioral conceptual model [Bennett and Burau 2015] would not move fish this far upstream). As a result, individuals that do migrate this far upstream may face a higher risk of contact with the screens if they migrated along the left bank of the river where the NDD would be located. Juvenile/adult injury and mortality has been found to occur following screen contact in laboratory experiments conducted at the UC Davis Fish Treadmill Facility (Swanson *et al.* 2005; White *et al.* 2007), and stress (measured as plasma cortisol) is positively correlated with screen contact in adult Delta Smelt (Young *et al.* 2010).

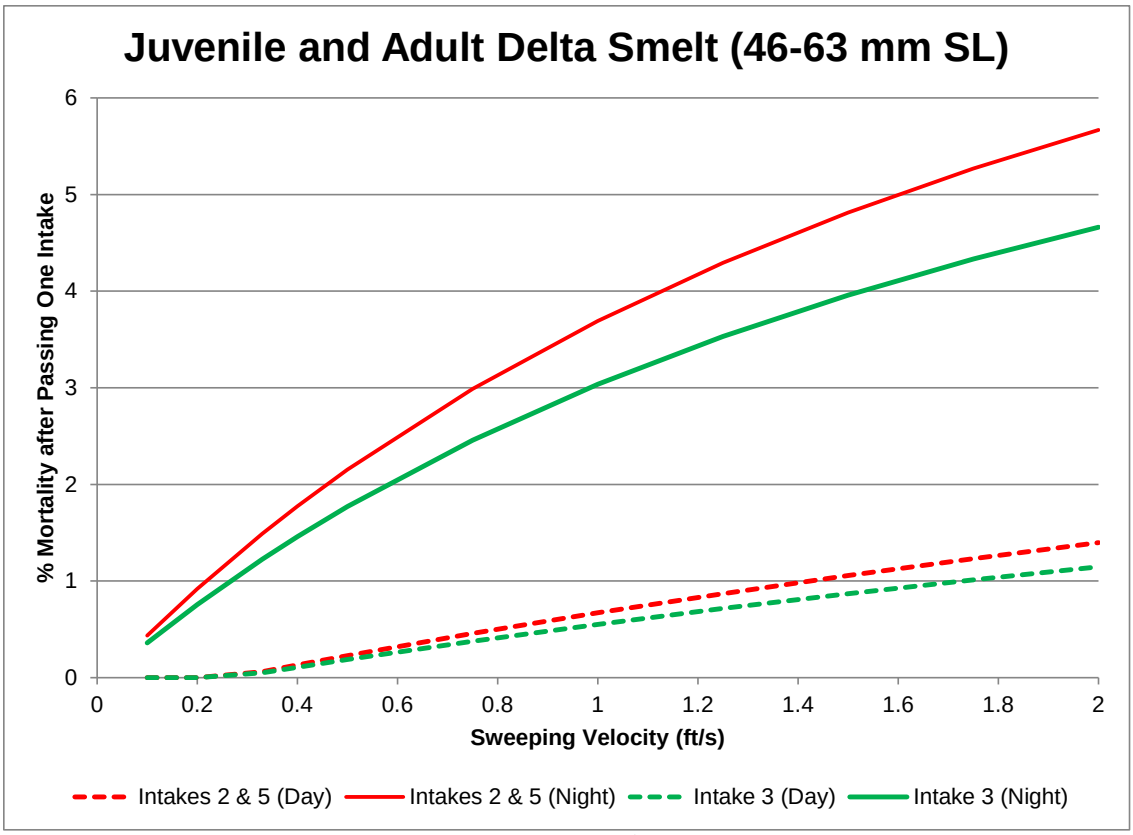
The published studies on Delta Smelt from the UC Davis Fish Treadmill Facility were used to assess the potential for screen contact, screen passage, and mortality. As described in Appendix 6.A, *Quantitative Methods for Biological Assessment of Delta Smelt*, Section 6.A.2.3, two of the methods (Section 6.A.2.3.1.1 *Adult Delta Smelt (Number of Screen Contacts)*; Section 6.A.2.3.1.2, *Juvenile and Adult Delta Smelt (Percentage Mortality)*) were based on an assessment methodology undertaken as part of the BDCP Fish Facilities Technical Team planning effort. From these analyses, it is estimated the adult Delta Smelt passing one of the NDD screens—moving against the flow, *i.e.*, in an upstream direction, based on the laboratory studies—would contact the screen 3 to 5 times, and that there would be little variation in this estimate across a wide range of sweeping velocity (Figure 6.1-2). In addition, application of the relationships from the laboratory studies show that mortality is estimated to be 1% or less for fish

encountering one of the intakes when sweeping velocity is low (0.2–0.3 ft/s), possibly increasing to 4–6% at sweeping velocity above 1.5 ft/s if encountered at night (Figure 6.1-3). A third analysis (Section 6.A.2.3.1.3 *Adult Delta Smelt (Screen Passage and Survival)*) was adapted from an analysis provided by USFWS. This analysis focused on the ability of Delta Smelt moving upstream near the left bank of the river to pass the lowermost NDD fish screen, given historic Sacramento River at Freeport water velocity, and also examined potential survival of those successfully passing the screen. Using December-June Freeport velocity information, the probability that an individual adult Delta Smelt would successfully pass the lowermost NDD fish screen was estimated to range from 0.073 to 0.075. When the data were restricted to the more likely December-March period, the estimate was 0.040 (0.0398 to 0.0405). The survival estimates for fish that actually pass the screen were relatively high and had low variability: mean ± standard deviation = 0.916 ± 0.0079, but the survival estimates had little influence on passage (*P*) because river velocity is almost always too high for Delta Smelt to swim the required distance upstream. As described in Section 3.2.2.2, *Fish Screen Design*, 22-foot-wide refugia could be provided between each of the six screen bay groups at the three intakes, which, if effective, could provide resting areas and predator refuge for Delta Smelt occurring near the intakes. However, given that the refugia are still in the conceptual design phase and there is uncertainty as to their effectiveness for Delta Smelt, the analyses presented above only accounted for the refugia by excluding the refugia length from the estimates of overall screen length at each intake.



Note: This plot is only relevant to the Delta Smelt occurring in the reach of the Sacramento River where the proposed NDD would be situated, and of those, only the ones encountering the intake screens at the river margins where the on-bank intakes would be sited.

Figure 6.1-2. Estimated Number of Screen Contacts of Adult Delta Smelt Encountering Fish Screens the Length of Intakes 2 and 5 (1,350 feet) and Intake 3 (1,110 feet) at an Approach Velocity of 0.2 feet per second during the Day



Note: This plot is only relevant to the Delta Smelt occurring in the reach of the Sacramento River where the proposed NDD would be situated, and of those, only the ones encountering the intake screens at the river margins where the on-bank intakes would be sited.

Figure 6.1-3. Estimated 48-hour Mortality of Juvenile and Adult Delta Smelt Encountering Fish Screens The Length of Intakes 2 and 5 (1,350 feet) and Intake 3 (1,110 feet) at an Approach Velocity of 0.2 feet per second during the Day and Night

Overall, the UC Davis Fish Treadmill studies indicate that there is potential for lethal and nonlethal take of juvenile and adult Delta Smelt from screen contact and impingement, for the subset of the population occurring in the reach of the river where the NDD would be located. However, monitoring by sonar cameras and diver surveys at the Freeport intake to evaluate impingement impacts did not reveal any impinged fish (eggs, larvae, or later life stages) in 2014 (or in 2011–2013), and there was no significant debris accumulation on screen panels (which can affect screen performance). A hydraulic evaluation of the Freeport intake in 2014 showed that approach velocity ranged from 0.09 ft/s to 0.27 ft/s and that 70% of approach velocity measurements did not exceed the target design approach velocity of 0.2 ft/s, although the facility was operating at 85% of capacity (ICF International 2015b). The analysis of the ability of migrating adult Delta Smelt to pass the most downstream intake if occurring near the left bank suggested that only a very small proportion (4%) of fish would be expected to do so. If successfully passing one intake and remaining near the left bank, the remaining Delta Smelt would have to pass the two other intakes, again with a similarly low probability of success. The extent to which these factors could constitute a barrier to migration to upstream habitat would depend on the ability of Delta Smelt to use lower velocity habitat on the right (west) bank of the river, near the channel bottom, or within the refugia along the intakes.

6.1.3.2.2.1.2 Population-Level Effects

For an assessment of distribution in relation to the NDD based on seine data, Delta Smelt adults for this analysis were assumed to be represented by fish ≥60 mm fork length (FL), based on Moyle's (2002) designation of adults as ~55-mm standard length. The proportion of Delta Smelt ≥60 mm FL collected in the reach of the Sacramento River where the proposed intakes would be situated averaged slightly below one fifth of the total catch from seining and was highly variable between years, with mean catch per seine in some years comparable to downstream areas, and in other years substantially lower. It should be noted that seining is not extensive in some of the more important areas of Delta Smelt's current distribution (e.g., the Cache Slough and Sacramento Deep Water Ship Channel area, Suisun Bay and the Sacramento-San Joaquin river confluence) but seine sampling in the Sacramento River is quite common in order to target the Chinook salmon fry the survey was designed to monitor (Table 6.1-7). Seine data do indicate that adult Delta Smelt occur in low numbers in the reach of the river where the proposed north Delta intakes would be sited; however, as the proposed intake location is outside the main range of Delta Smelt, the potential for any adverse effect at the population level from impingement is minimal to nil. Further perspective on the proportion of the Delta Smelt population that could occur near the NDD was provided by a DSM2-PTM analysis incorporating movement into the upper 10% of the water column during flood tides (*i.e.* modeled tidal surfing behavior), to simulate the upstream migration of adult Delta Smelt, as described in Section 6.A.2.1 of Appendix 6.A, *Quantitative Methods for Biological Assessment of Delta Smelt*. This analysis also provided evidence that a very low proportion of the migrating adult Delta Smelt population would be expected to occur near the NDD if relying on tidal migration upstream (Bennett and Burau 2015), as no particles originating downstream were entrained at the NDD (or moved upstream of Isleton on the Sacramento River[6]; Table 6.1-8). Therefore tidal migration upstream toward the NDD would not be enhanced by the PA.

Conceptually, the population-level effect of the NDD on migrating adult Delta Smelt passage is the individual take of fish caused by impingement-related injury or mortality (including incidental loss to predators) multiplied by the fraction of the adult population that is anticipated to reach the NDD *and* attempt to pass them, but is unable to do so. Based on application of the equation predicting mortality as a function of contact rate, temperature, and approach velocity to February 1991 conditions (Appendix 6.A, Appendix 6.A, *Quantitative Methods for Biological Assessment of Delta Smelt*, Section 6.A.2.3.1.3 *Adult Delta Smelt (Screen Passage and Survival)*), the predicted mortality rate of fish swimming past the fish screen is about eight percent. If for the sake of argument, one percent of all adult Delta Smelt attempt to pass one or more of the NDDs, the population loss would be eight percent of one percent, which is 0.08 percent or about eight of every 10,000 fish. As described in Section 6.A.2.3.1.3 *Adult Delta Smelt (Screen Passage and Survival)* of Appendix 6.A, February 1991 was a low flow period in a drought in which river velocity was less and therefore more likely to have allowed upstream migration by Delta smelt at a sufficient rate to pass the first NDD intake. As such, it would be expected that a smaller fraction of the population would attempt or even be able to successfully pass the intake during higher flow periods. It is not known what fraction of the adult Delta Smelt population ascends the Sacramento River and how that fraction varies from year to year. The catches and CPUEs of Delta Smelt using beach seines were summarized in Table 6.1-7, but these

[6] A breakdown of the fates of particles by geographic subregion is also provided in Section 6.A.2.1.2 of Appendix 6.A.

are challenging to compare quantitatively because, as described in Appendix 6.A, *Quantitative Methods for Biological Assessment of Delta Smelt*, Section 6.A.2.3.1.3, *Adult Delta Smelt (Screen Passage and Survival)*, fish ascending the Sacramento River very likely have to use nearshore habitat sampled by the beach seines much more extensively than they do further downstream in the estuary. In addition, there is no known reason that Delta Smelt *have to* ascend the Sacramento River past the proposed NDD locations in order to spawn; most spawning seems to occur in Suisun Marsh, the river channels around Sherman Island, and in the Cache Slough/Deepwater Shipping Channel area. Thus, it is also possible that there will be no measurable population-level impact caused by migrating adult Delta Smelt either prevented from continuing past the NDD or being injured/impinged trying to pass them, because few or no individuals may attempt to keep moving upstream along the left bank once they encounter elevated velocities associated with the first diversion. However, Delta Smelt can currently ascend the river along its east bank if they choose to do so. Thus, the loss of low-velocity shoreline and increase in shoreline water velocity along the river's east (left) bank that will occur as a result of the NDD fish screens will have an impact to critical habitat because it will alter the capacity of the fish to ascend the river along its east bank. As previously discussed in the Individual-Level Effects section, the overall magnitude of this potential effect on individual Delta Smelt would depend on the ability of Delta Smelt to use lower velocity habitat on the right bank of the river, near the channel bottom, or within the refugia along the intakes. However, given the spatial distribution of most of the Delta Smelt population, *i.e.*, well downstream of the NDD, any effects from not being able to access habitat upstream of the NDD are not expected to affect Delta Smelt at a population level.

Table 6.1-7. Number of Delta Smelt (≥60 mm Fork Length) Collected and Catch per Seine during USFWS Beach Seine Sampling in the Action Area (December–March)

Year	Number of Samples		Total Caught (Intake Area)	Total Caught (Downstream Area)	Proportion Caught (Intake Area/Total)	Catch Per Seine (Intake Area)	Catch Per Seine (Downstream)
	Intake Area	Down-stream					
1977	15	15	0	0	.	0.00	0.00
1978	4	4	0	0	.	0.00	0.00
1979	4	7	0	0	.	0.00	0.00
1980	4	27	0	0	.	0.00	0.00
1981	10	35	0	13	0.00	0.00	0.37
1982	16	48	2	3	0.40	0.13	0.06
1983	13	54	4	5	0.44	0.31	0.09
1984	17	71	4	2	0.67	0.24	0.03
1985	12	39	0	0	.	0.00	0.00
1986	15	60	0	0	.	0.00	0.00
1987	12	48	0	0	.	0.00	0.00
1988	12	48	0	1	0.00	0.00	0.02
1989	12	48	0	0	.	0.00	0.00
1990	4	13	0	0	.	0.00	0.00
1991	16	58	0	0	.	0.00	0.00
1992	20	68	0	0	.	0.00	0.00
1993	13	41	0	2	0.00	0.00	0.05

Year	Number of Samples		Total Caught (Intake Area)	Total Caught (Downstream Area)	Proportion Caught (Intake Area/Total)	Catch Per Seine (Intake Area)	Catch Per Seine (Downstream)
	Intake Area	Down-stream					
1994	16	70	0	0	.	0.00	0.00
1995	44	41	1	2	0.33	0.02	0.05
1996	94	100	0	13	0.00	0.00	0.13
1997	29	34	0	2	0.00	0.00	0.06
1998	48	66	1	0	1.00	0.02	0.00
1999	38	83	0	0	.	0.00	0.00
2000	83	82	0	2	0.00	0.00	0.02
2001	61	75	0	1	0.00	0.00	0.01
2002	52	81	0	2	0.00	0.00	0.02
2003	41	72	0	3	0.00	0.00	0.04
2004	51	82	0	1	0.00	0.00	0.01
2005	67	74	0	0	.	0.00	0.00
2006	21	48	0	0	.	0.00	0.00
2007	36	86	0	0	.	0.00	0.00
2008	33	78	0	0	.	0.00	0.00
2009	28	81	0	0	.	0.00	0.00
2010	32	63	0	1	0.00	0.00	0.02
2011	29	66	0	0	.	0.00	0.00
Mean	29	56	0	2	0.18	0.02	0.03
5th percentile	4	11	0	0	0.00	0.00	0.00
25th percentile	13	41	0	0	0.00	0.00	0.00
Median	20	60	0	0	0.00	0.00	0.00
75th percentile	40	75	0	2	0.35	0.00	0.03
95th percentile	72	84	3	7	0.75	0.16	0.10

Source: U.S. Fish and Wildlife Service Delta Juvenile Fish Monitoring Program (Speegle pers. comm.).

Table 6.1-8. Adult Delta Smelt Upstream Movement Analysis Based on DSM2-PTM: Fate (Mean Percentage) of Particles By Release Location, Water Year Type, and Flux or Entrainment Location After 30 Days.

Release Location	Water Year Type	Downstream Flux Past Martinez			Downstream Flux Past Chipps Island			Entrainment into Clifton Court Forebay (State Water Project)			Entrainment into Jones Pumping Plant (Central Valley Project)			Entrainment into North Bay Aqueduct Barker Slough Pumping Plant			Upstream Flux Past Isleton			North Delta Diversion		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Cache Sl. at Liberty Island (Node 323)	W	63.0	61.2	-1.8 (-3%)	70.1	67.9	-2.1 (-3%)	1.5	1.0	-0.5 (-36%)	0.9	0.7	-0.2 (-24%)	0.5	0.7	0.1 (19%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)
	AN	61.6	60.0	-1.6 (-3%)	68.5	68.3	-0.2 (0%)	0.9	0.7	-0.2 (-22%)	0.6	0.2	-0.4 (-68%)	0.1	0.1	0.0 (-3%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)
	BN	19.3	13.8	-5.5 (-29%)	27.2	21.4	-5.8 (-21%)	0.7	0.7	0.0 (-6%)	0.5	0.3	-0.2 (-31%)	0.1	0.1	0.0 (8%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)
	D	11.6	9.5	-2.0 (-17%)	15.8	13.6	-2.2 (-14%)	0.7	0.7	0.0 (-4%)	0.6	0.5	-0.2 (-24%)	0.0	0.0	0.0 (13%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)
	C	1.3	0.9	-0.4 (-30%)	3.6	2.7	-0.9 (-24%)	0.1	0.1	0.0 (-25%)	0.1	0.1	0.0 (-14%)	0.0	0.0	0.0 (-28%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)
Decker Island (Node 353)	W	77.1	73.9	-3.3 (-4%)	87.3	84.4	-2.9 (-3%)	0.9	0.5	-0.4 (-48%)	0.5	0.5	0.0 (-2%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)
	AN	73.7	74.7	1.0 (1%)	79.3	79.9	0.6 (1%)	2.3	2.4	0.1 (7%)	1.5	1.0	-0.5 (-34%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)
	BN	38.0	30.9	-7.1 (-19%)	49.2	46.9	-2.3 (-5%)	4.4	3.1	-1.3 (-29%)	3.1	2.6	-0.5 (-15%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)
	D	20.2	18.3	-1.9 (-9%)	32.2	28.6	-3.6 (-11%)	5.9	4.5	-1.4 (-24%)	4.0	4.0	0.1 (2%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)
	C	5.3	4.4	-0.9 (-18%)	10.3	8.8	-1.5 (-15%)	7.2	6.5	-0.7 (-9%)	4.2	3.6	-0.5 (-13%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)
Montezuma Slough (Node 420)	W	18.9	18.5	-0.4 (-2%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)
	AN	0.6	0.6	0.0 (2%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)
	BN	0.2	0.0	-0.2 (-86%)	0.0	0.0	0.0 (-80%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)
	D	0.3	0.2	-0.1 (-45%)	-0.1	-0.1	0.1 (-50%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)
	C	0.9	0.6	-0.3 (-31%)	-0.5	-0.3	0.2 (-36%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)
Chipps Island (Node 465)	W	83.6	80.6	-3.0 (-4%)	94.1	92.3	-1.9 (-2%)	0.2	0.1	-0.1 (-52%)	0.1	0.1	0.0 (-25%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)
	AN	78.5	78.9	0.4 (1%)	84.8	85.2	0.4 (0%)	1.3	1.4	0.1 (9%)	1.0	0.7	-0.3 (-29%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)
	BN	43.6	39.5	-4.1 (-9%)	57.6	58.1	0.5 (1%)	2.1	1.1	-1.0 (-48%)	1.4	0.9	-0.5 (-33%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)
	D	27.6	24.9	-2.8 (-10%)	44.2	40.4	-3.8 (-9%)	2.6	1.7	-0.9 (-35%)	1.8	1.6	-0.2 (-10%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)
	C	7.3	6.6	-0.7 (-10%)	13.2	12.2	-1.0 (-7%)	3.1	2.4	-0.7 (-23%)	2.0	1.3	-0.6 (-31%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)	0.0	0.0	0.0 (0%)

Note: Grey shading indicates that no particles had this fate for either the NAA or PA.

6.1.3.2.2.2 Spawning Adults (February-June)

6.1.3.2.2.2.1 Individual-Level Effects

Presumably the risk to adult Delta Smelt from impingement at the NDD would be greater for actively migrating adults, if spawning adults hold in a similar location prior to, during, and after spawning (possibly to spawn more than once). However, for those spawning adults moving past the NDD, the risk of impingement-related injury and mortality would be as described for migrating adults.

6.1.3.2.2.2.2 Population-Level Effects

As with migrating adults during December-March, in some years, the catch per unit effort of adult (≥60 mm) Delta Smelt in the vicinity of the NDD is comparable to that in downstream areas, although the bulk of the catch still occurs downstream and, as noted previously, the seine survey was designed to collect Chinook salmon fry (as opposed to Delta Smelt) (Table 6.1-9). The reported catch from the early years, particularly before the 1990s, is uncertain as it is widely recognized that Delta Smelt were frequently misidentified by survey staff. As with migrating adults, given the spatial distribution of most of the Delta Smelt population, *i.e.*, well downstream of the NDD, any effects from not being able to access habitat upstream of the NDD are not expected to affect spawning adult Delta Smelt at a population level.

Table 6.1-9. Number of Delta Smelt (≥60 mm Fork Length) Collected and Catch per Seine during USFWS Beach Seine Sampling in the Action Area (February-June)

Year	Number of Samples		Total Caught (Intake Area)	Total Caught (Downstream Area)	Proportion Caught (Intake Area/Total)	Catch Per Seine (Intake Area)	Catch Per Seine (Downstream)
	Intake Area	Down-stream					
1976	29	126	10	187	0.05	0.34	1.48
1977	87	169	9	115	0.07	0.10	0.68
1978	68	147	36	124	0.22	0.53	0.84
1979	71	282	28	411	0.06	0.39	1.46
1980	74	308	1	36	0.03	0.01	0.12
1981	83	273	78	195	0.29	0.94	0.72
1982	69	233	9	112	0.07	0.13	0.48
1983	52	213	13	56	0.19	0.25	0.26
1984	49	185	10	8	0.56	0.20	0.04
1985	47	191	0	29	0.00	0.00	0.15
1986	18	108	1	19	0.05	0.06	0.18
1987	32	124	0	19	0.00	0.00	0.15
1988	31	116	0	2	0.00	0.00	0.02
1989	37	154	0	5	0.00	0.00	0.03
1990	11	39	0	0	.	0.00	0.00
1991	28	94	4	0	1.00	0.14	0.00
1992	62	227	4	15	0.21	0.06	0.07
1993	81	255	18	7	0.72	0.22	0.03
1994	80	415	0	72	0.00	0.00	0.17
1995	134	355	5	10	0.33	0.04	0.03

Year	Number of Samples		Total Caught (Intake Area)	Total Caught (Downstream Area)	Proportion Caught (Intake Area/Total)	Catch Per Seine (Intake Area)	Catch Per Seine (Downstream)
	Intake Area	Down-stream					
1996	158	348	4	40	0.09	0.03	0.11
1997	132	342	6	20	0.23	0.05	0.06
1998	78	331	7	65	0.10	0.09	0.20
1999	70	434	28	34	0.45	0.40	0.08
2000	102	419	16	38	0.30	0.16	0.09
2001	82	395	2	21	0.09	0.02	0.05
2002	73	439	7	4	0.64	0.10	0.01
2003	76	404	17	23	0.43	0.22	0.06
2004	78	403	26	19	0.58	0.33	0.05
2005	81	420	25	2	0.93	0.31	0.00
2006	82	368	5	52	0.09	0.06	0.14
2007	62	387	1	8	0.11	0.02	0.02
2008	68	373	1	0	1.00	0.01	0.00
2009	85	397	6	4	0.60	0.07	0.01
2010	85	361	26	5	0.84	0.31	0.01
2011	80	348	35	5	0.88	0.44	0.01
Mean	72	287	12	45	0.33	0.16	0.18
5th percentile	25	104	0	0	0.00	0.00	0.00
25th percentile	57	188	1	5	0.07	0.02	0.02
Median	74	331	6	19	0.22	0.09	0.06
75th percentile	82	391	18	46	0.57	0.24	0.16
95th percentile	133	424	35	145	0.95	0.46	0.75
Source: U.S. Fish and Wildlife Service Delta Juvenile Fish Monitoring Program (Speegle pers. comm.).							

6.1.3.2.2.3 Eggs/Embryos (Spring: ~March-June)

6.1.3.2.2.3.1 Individual-Level Effects

As noted for entrainment, Delta Smelt eggs and embryos are demersal and adhesive, and so would not be subject to impingement.

6.1.3.2.2.3.2 Population-Level Effects

The demersal and adhesive nature of Delta Smelt eggs means that there would be no adverse population-level effects from the NDD with respect to impingement.

6.1.3.2.2.4 Larvae/Young Juveniles (Spring: ~March-June)

6.1.3.2.2.4.1 Individual-Level Effects

Delta Smelt larvae and young juveniles that are large enough (>20-21 mm) to be excluded from entrainment by the NDD screens would be susceptible to impingement and screen contact. There are no quantitative laboratory studies to inform the potential risk to these sizes of fish, in contrast

to larger juveniles and adults (> 45 mm; see previous discussion for migrating adults). However, it seems reasonable to assume that the potential injury and mortality effects on these early, more fragile life stages would be greater than for larger Delta Smelt, for which mortality was estimated to be up to ~6% of the small number of fish passing each of the longer intakes (2 and 5) during the night at the highest sweeping velocity.

6.1.3.2.2.4.2 Population-Level Effects

As described in the discussion for NDD entrainment risk, the available egg and larval survey data suggest that a very low proportion of the early life stages would be in the Sacramento River near the NDD (possibly < 0.1%). Therefore, adverse effects from impingement and screen contact would only affect a small proportion of the population, and be unlikely to have population-level effects.

6.1.3.2.2.5 Juveniles (Summer/Fall: ~July-December)

6.1.3.2.2.5.1 Individual-Level Effects

The analysis presented previously for migrating adult Delta Smelt also included consideration of juvenile sizes of Delta Smelt (> 45 mm) and suggested that mortality could occur for up to ~6% of the fish passing each of the longer intakes (2 and 5) during the night at the highest sweeping velocity.

6.1.3.2.2.5.2 Population-Level Effects

Survey data and the opinions of numerous experts that have sampled the Delta extensively[7] suggest that juvenile Delta Smelt are mostly distributed downstream of the proposed north Delta intakes. During fall (September–December), very few Delta Smelt have been collected at the midwater trawl stations near the proposed intakes, with catches occurring in only 3 years from 1991 to 2010 (Table 6.1-10); these years were critically dry, wet, and below normal water year types. Relatively few Delta Smelt <60 mm FL (fork length) were collected during seining in July–December, and those were mostly collected downstream (Table 6.1-11). Therefore, it is concluded that the population-level effects of impingement at the NDD would usually be near zero (Table 6.1-9).

[7] These opinions are reflected in the distribution of surveys targeting Delta Smelt, e.g., the Spring Kodiak Trawl survey (see map at http://www.dfg.ca.gov/delta/data/skt/skt_stations.asp).

Table 6.1-10. Number of Delta Smelt Collected and Catch per Trawl during the Fall Midwater Trawl Survey (September–December)

Year	Number of Samples		Total Caught		Proportion (Intake Area/Total)	Mean Catch Per Trawl	
	Intake Area	Downstream Area	Intake Area	Downstream Area		Intake Area	Downstream Area
1991	9	590	0	855	0.00	0.00	1.45
1992	21	685	0	223	0.00	0.00	0.33
1993	18	875	0	1040	0.00	0.00	1.19
1994	24	805	4	438	0.01	0.17	0.54
1995	21	713	0	924	0.00	0.00	1.30
1996	22	719	0	460	0.00	0.00	0.64
1997	18	626	1	345	0.00	0.06	0.55
1998	6	509	0	427	0.00	0.00	0.84
1999	12	532	0	997	0.00	0.00	1.87
2000	13	581	0	1126	0.00	0.00	1.94
2001	21	628	0	702	0.00	0.00	1.12
2002	9	356	0	143	0.00	0.00	0.40
2003	12	359	0	222	0.00	0.00	0.62
2004	12	357	0	170	0.00	0.00	0.48
2005	12	359	0	28	0.00	0.00	0.08
2006	8	351	0	39	0.00	0.00	0.11
2007	12	360	0	27	0.00	0.00	0.08
2008	12	356	0	22	0.00	0.00	0.06
2009	12	382	0	23	0.00	0.00	0.06
2010	12	384	1	49	0.02	0.08	0.13

Source: California Department of Fish and Game unpublished data.

Table 6.1-11. Number of Juvenile Delta Smelt (<60 mm Fork Length) Collected and Catch per Seine during USFWS Beach Seine Sampling in the Action Area (July–December)

Year	Number of Samples		Total Caught (Intake Area)	Total Caught (Downstream Area)	Proportion Caught (Intake Area/Total)	Catch Per Seine (Intake Area)	Catch Per Seine (Downstream)
	Intake Area	Down-stream					
1977	16	21	0	29	0.00	0.00	1.38
1979	20	74	0	19	0.00	0.00	0.26
1980	26	105	0	2	0.00	0.00	0.02
1982	16	40	0	0	.	0.00	0.00
1983	1	1	0	0	.	0.00	0.00
1990	4	4	0	0	.	0.00	0.00
1992	21	43	0	0	.	0.00	0.00
1993	55	117	0	0	.	0.00	0.00
1994	119	246	1	1	0.50	0.01	0.00
1995	319	249	6	0	1.00	0.02	0.00
1996	394	334	0	0	.	0.00	0.00
1997	283	317	0	10	0.00	0.00	0.03
1998	234	385	0	6	0.00	0.00	0.02
1999	215	337	0	3	0.00	0.00	0.01
2000	187	325	0	12	0.00	0.00	0.04
2001	221	454	0	32	0.00	0.00	0.07
2002	206	550	0	2	0.00	0.00	0.00
2003	215	538	0	8	0.00	0.00	0.01
2004	230	530	0	5	0.00	0.00	0.01
2005	238	512	0	2	0.00	0.00	0.00
2006	221	512	0	2	0.00	0.00	0.00
2007	262	521	0	4	0.00	0.00	0.01
2008	240	499	0	0	-	0.00	0.00
2009	245	492	0	0	-	0.00	0.00
2010	242	426	0	0	-	0.00	0.00
2011	238	438	0	0	-	0.00	0.00
2012	95	95	0	0	-	0.00	0.00
Mean	175	313	0	4	0.10	0.00	0.02
5th percentile	7	13	0	0	0.00	0.00	0.00
25th percentile	65	108	0	0	0.00	0.00	0.00
Median	218	336	0	2	0.00	0.00	0.00
75th percentile	240	497	0	5	0.00	0.00	0.01
95th percentile	310	536	1	17	0.65	0.01	0.06

Source: U.S. Fish and Wildlife Service Delta Juvenile Fish Monitoring Program (Speegle pers. comm.).

6.1.3.2.3 Predation at the North Delta Diversions

6.1.3.2.3.1 Migrating Adults (December-March)

6.1.3.2.3.1.1 Individual-Level Effects

Delta Smelt occurring in front of the NDD screens may be susceptible to an elevated risk of predation as they approach and attempt to pass the fish screens because the structures would result in a vertical wall with little cover, other than (possibly) the proposed in-screen refugia and the hydraulic effects of the water diversion described above. It is uncertain to what extent the predation rate in front of the screens will differ from the predation rate that would otherwise occur in this reach without the NDD present because there are no data available to estimate predation rates on Delta Smelt in this reach. A hydroacoustic survey as part of Freeport intake monitoring in 2014 (when diversions were over 130 cfs) found that predator-sized fish (*i.e.*, 12 inches long [305 mm long] and larger) density at the intake was similar or less than the density in upstream and downstream control reaches (ICF International 2015a), although only four surveys were undertaken, so there are few data from which to draw conclusions[8]. As discussed in Section 6.1.1.3, *Water Facilities Construction*, riprap used in association with the intakes could result in increased predator habitat and therefore predation risk. Inclusion of the conservation measure to reduce predation potential may limit predation risk (Section 6.1.4.2, *Localized Reduction of Predatory Fishes to Minimize Predator Density at North and South Delta Export Facilities*), but there is uncertainty in the effectiveness of this measure given that the area is open to immigration and emigration of predators and turnover may be appreciable in a relatively short period of time (Cavallo *et al.* 2013).

6.1.3.2.3.1.2 Population-Level Effects

The potential adverse effect to individual migrating adult Delta Smelt from predation at the NDD would be a minimal adverse effect at the population level because, as discussed previously for impingement and screen contact, there generally would be expected to be a very small proportion of the Delta Smelt population near the NDD.

6.1.3.2.3.2 Spawning Adults (February-June)

6.1.3.2.3.2.1 Individual-Level Effects

To the extent that spawning adult Delta Smelt occur near the NDD, similar effects as described above for migrating adults would be expected, *i.e.*, potentially elevated predation. However, individual spawning adults would not be expected to undergo major movements, and therefore would be likely to have limited risk of predation at the NDD.

6.1.3.2.3.2.2 Population-Level Effects

As with migrating adult Delta Smelt, there generally would be expected to be a small proportion of the spawning Delta Smelt population near the NDD, so there would be a minimal adverse effect from predation at the NDD on this life stage.

[8] NMFS also has been conducting hydroacoustic surveys of predator-sized fish near the Freeport intake; these data were not yet available for inclusion in this effects analysis.

6.1.3.2.3.3 Eggs/Embryos (Spring: ~March-June)

6.1.3.2.3.3.1 Individual-Level Effects

Following Bennett (2005), it is generally thought that egg/embryo habitat for Delta Smelt consists of shallow sandy areas, which is not the type of habitat that would be found at the NDD. There therefore would be no effects on individual eggs or embryos.

6.1.3.2.3.3.2 Population-Level Effects

Following from the lack of individual-level effects of the NDD in terms of predation, there would therefore be no adverse population-level effect on eggs/embryos.

6.1.3.2.3.4 Larvae/Young Juveniles (Spring: ~March-June)

6.1.3.2.3.4.1 Individual-Level Effects

To the extent that the NDD provide beneficial habitat for predators of larval and early juvenile Delta Smelt (e.g., silversides; Baerwald *et al.* 2012), there could be an elevated risk of predation for these young life stages. However, it is not clear that the NDD would provide beneficial habitat, as presumably these small predators would be susceptible to the same larger predators that could consume adult Delta Smelt. Therefore, elevated predation on Delta Smelt larvae is unlikely.

6.1.3.2.3.4.2 Population-Level Effects

Even if all of the larvae passing the screens were eaten, the population-level effect would be small, based on the low (potentially < 0.1%) proportion of the population occurring near the NDD; see more detailed discussion in the analysis of the effects of entrainment.

6.1.3.2.3.5 Juveniles (Summer/Fall: ~July-December)

6.1.3.2.3.5.1 Individual-Level Effects

As with adult Delta Smelt, elevated levels of predation risk could occur to individual juvenile Delta Smelt occurring near the NDD.

6.1.3.2.3.5.2 Population-Level Effects

Even if all of the juvenile Delta Smelt near the NDDs were eaten, the potential for population-level effects of predation on juvenile Delta Smelt near the NDD would be minimal because, as discussed for impingement and screen contact, monitoring data indicate a very small proportion of the population occurs near the NDD.

6.1.3.3 South Delta Exports

6.1.3.3.1 Entrainment

The entrainment of Delta Smelt into the Banks and Jones pumping plants is a direct effect of SWP and CVP operations. See Brown *et al.* (1996) for a description of fish salvage operations from which Delta Smelt entrainment estimates have historically been derived (e.g., Kimmerer 2008). However, the salvage estimates are indices - most entrained fish are not observed (Table 6.1-12), so most of the fish are not salvaged and therefore do not survive. Bennett (2005) suggested that many, if not most, of the Delta Smelt that do reach the fish facilities likely die due to handling stress and predation, however recent studies suggest there may be relatively high survival of adult Delta Smelt during collection, handling, transport, and release when they are salvaged during cool temperature conditions (Morinaka 2013). Pre-screen loss due to predation

near and within the CVP and SWP fish facilities, is an additional cause of mortality for Delta Smelt. Pre-screen loss of captive-reared Delta Smelt released into Clifton Court Forebay ranged from about 90% to 100% for adults and nearly 100% for juveniles during a recent study (Castillo *et al.* 2012)[9].

Table 6.1-12. Factors Affecting Delta Smelt Entrainment and Salvage

Factor	Adults	Larvae < 20 mm	Larvae >20 mm and Juveniles	Source
Pre-screen loss (predation prior to encountering fish salvage facilities)	CVP: unquantified; SWP: 89.9–100%	Unquantified	CVP: unquantified; SWP: 99.9%	SWP: Castillo *et al.* (2012)
Fish facility efficiency	CVP: 13%; SWP: 43–89%	~0%	CVP: likely < 13% at all sizes, << 13% below 30 mm (based on adult data); SWP: 24–30%	CVP (Kimmerer 2008; adults only); SWP: Castillo *et al.* (2012)
Collection screens efficiency	~100%	~0%	<100% until at least 30 mm	USFWS (2011a)
Identification protocols	Identified from subsamples, then expanded in salvage estimates	Not identified	Identified from subsamples, then expanded in salvage estimates	USFWS (2011a)
Collection and handling	48-hour experimental mean survival of 93.5% (not statistically different from control) in 2005; 88.3% in 2006 (significantly less than 99.8% of control)	Unquantified	48-hour experimental mean survival of 61.3% in 2005 and 50.9% in 2006 (both significantly less than mean control survival of 82.0–85.9%)	Morinaka (2013)
Trucking and release (excluding post-release predation)	No significant additional mortality beyond collection and handling (above)	Unquantified	No significant additional mortality than collection and handling (above), although mean survival was 37.4% in 2005	Morinaka (2013)

The population-level effects of Delta Smelt entrainment vary; Delta Smelt entrainment can be characterized as a sporadically significant influence on population dynamics. Kimmerer (2008) estimated that annual entrainment of the Delta Smelt population (adults and their progeny combined) ranged from approximately 10 to 60% per year from 2002–2006. Major population

[9] Although relatively high temperatures (for juveniles) and relatively low pumping (for juveniles and adults) could have affected the magnitude of pre-screen loss estimated by Castillo et al. (2012), high pre-screen loss has been estimated for other species such as Chinook salmon (Gingras 1997) and steelhead (Clark et al. 2009).

declines during the early 1980s (Moyle *et al.* 1992) and during the recent POD years (Sommer *et al.* 2007) were both associated with hydrodynamic conditions that greatly increased Delta Smelt entrainment losses as indexed by numbers of fish salvaged. However, currently published analyses of long-term associations between Delta Smelt salvage and subsequent abundance do not support the hypothesis that entrainment is driving population dynamics year in and year out (Bennett 2005; Manly and Chotkowski 2006; Kimmerer 2008; Mac Nally *et al.* 2010; Maunder and Deriso 2011[10]; Miller *et al.* 2012). However, this is an area of scientific debate with some researchers finding that entrainment (or water diversions during the time period when entrainment would be of concern) may affect population dynamics (Rose *et al.* 2013; Thomson *et al.* 2010). The USFWS (2008) and NMFS (2009) BiOps and their RPA actions related to south Delta entrainment have reduced the potential for entrainment loss since 2008–2009.

6.1.3.3.1.1 Migrating Adults (December–March)

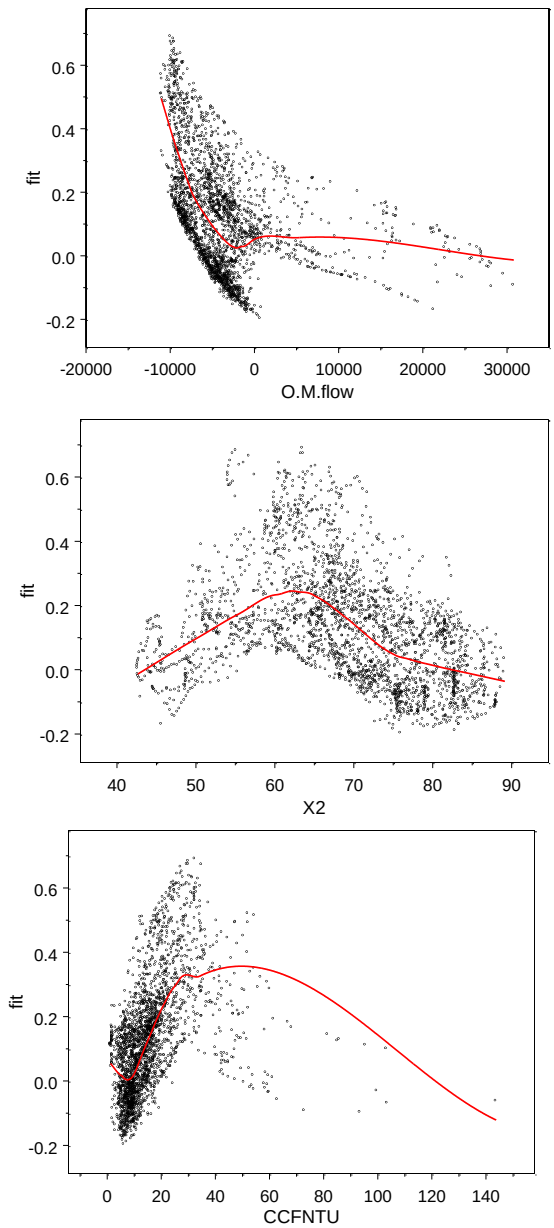
6.1.3.3.1.1.1 Individual-Level Effects

Adult Delta Smelt are entrained into the south Delta export facilities during spawning migrations (Grimaldo *et al.* 2009; Sommer *et al.* 2011). Their spawning migrations occur during the winter when precipitation increases the freshwater flow and turbidity in the Delta. Salvage of adult Delta Smelt at the south Delta export facilities is an index of entrainment, albeit a very rough index (IEP MAST Team 2015: 59). Salvage of adults has mainly occurred from late December through March (Kimmerer 2008; Grimaldo *et al.* 2009). For migrating adults, the risk of entrainment is influenced by flow cues and turbidity in the south Delta (Grimaldo *et al.* 2009). Old and Middle Rivers are distributary channels of the San Joaquin River. Project pumping (*i.e.*, the export of water from the Delta) can cause the tidally filtered or "net" flows in these channels to move "upstream". This occurs because water removed by Banks and Jones, along with other diversions in the area, is back-filled by tidal and river flows. This phenomenon is mathematically depicted as negative flow. Negative Old and Middle River (OMR) flows and greater turbidity are often associated with adult Delta Smelt entrainment, but no particular OMR flow assures entrainment will or will not occur. The net OMR flows indicate how strongly the tidally averaged flows in these channels are moving toward Banks and Jones pumping plants. Thus, it is possible the net flows themselves are the mechanism that increases entrainment risk for Delta Smelt. However, high exports can also lead to strong tidal asymmetry in Old and Middle Rivers where flood tides toward the pumps become much stronger than the ebb tides away from the pumps (U.S. Fish and Wildlife Service 2011a), so altered tidal flows are a second, covarying mechanism that could increase Delta Smelt's risk of entrainment.

The empirical shape of the associations between estuarine salinity distribution (X2), OMR, turbidity and adult Delta Smelt salvage normalized by the FMWT is shown in Figure 6.1-4. Normalized Delta Smelt salvage is correlated in a nonlinear way with X2. An interpretation of this is that the intermediate river flow or X2 conditions are associated with the highest salvage because flows are high enough to disperse turbidity around the Delta, but not so high that most Delta Smelt are distributed seaward of the Delta. Figure 6.1-4 shows that even when X2 and

[10] The automated statistical procedure that Maunder and Deriso (2011) developed to choose a "best" life cycle model based on their input data determined that a model with strong density-dependence between generations and a very strong influence of adult entrainment was the best-fitting statistical model. However, the authors determined that the density-dependence was too strong and the parameter estimate for the entrainment effect was too high to be plausible, so they determined the second best-fitting model was the most believable LCM. This second best-fitting model did not retain entrainment as an important predictor of Delta Smelt population dynamics.

south Delta turbidity are accounted for, there is no OMR flow that assures Delta Smelt entrainment will or will not occur. The predicted relationship is a smooth, accelerating function with increasing normalized salvage as OMR flow becomes more negative (Figure 6.1-4).



Note: The scatter in each panel is caused by the interacting effects of the other two variables.

Figure 6.1-4. Empirical Trends in Predictions of Adult Delta Smelt Salvage (y-axis) During December–March, 1993–2013, as a Function of Old and Middle River Flow (O.M. flow, cfs), X2 (km from Golden Gate Bridge), and Turbidity at Clifton Court Forebay (CCFNTU, NTU)

The association of adult Delta Smelt with turbid water (see Figure 42 of U.S. Fish and Wildlife Service 2011a) can lead to greater entrainment by the south Delta export facilities when turbid conditions occur in the regions that are under the hydraulic influence of the export facilities

(Grimaldo *et al.* 2009). Recognition of the combined importance of OMR flow and turbidity is provided in the USFWS proposal to set incidental take of Delta Smelt as a function of OMR flow and turbidity, given a population abundance estimate.[11]

Under the PA, OMR flows would be less negative than under the NAA during the months of concern for adult Delta Smelt (Figure 6.1-5, **Figure 6.1-6**, Figure 6.1-7, Figure 6.1-8; see Table 5.A.6-25 and Figures 5.A.6-25-1 to 5.A.6-25-19 in Appendix 5.A, *CALSIM Methods and Results*). As described in Chapter 3, Section 3.3.2.2, *Operational Criteria for South Delta CVP/SWP Export Facilities*, the OMR flow requirements would be those of USFWS (2008) and NMFS (2009) until completion of the NDD, after which the newly proposed criteria would generally improve OMR flows more in wetter years under the PA compared to the existing BiOps; provided, as discussed in Chapter 3, that the research and results of the Collaborative Science and Adaptive Management program show these criteria are required to avoid jeopardy of any endangered or threatened species or result in the destruction or adverse modification of designated critical habitat for those species. Real-time management of entrainment risk would also occur (if needed), in a manner similar to the existing Smelt Working Group process. It therefore would be expected that individual Delta Smelt would be less susceptible to entrainment under the PA than the NAA. This is analyzed at the population level in the next section.

[11] The proposal is available at http://deltacouncil.ca.gov/sites/default/files/2015/10/Item%201%20USFWS%20reports%20-%20Past,%20Present%20and%20Future%20Approaches%20to%20Incidental%20Take.pdf (accessed October 24, 2015) and is one of the subjects of the 2015 Long-term Operations Biological Opinions Annual Science Review.

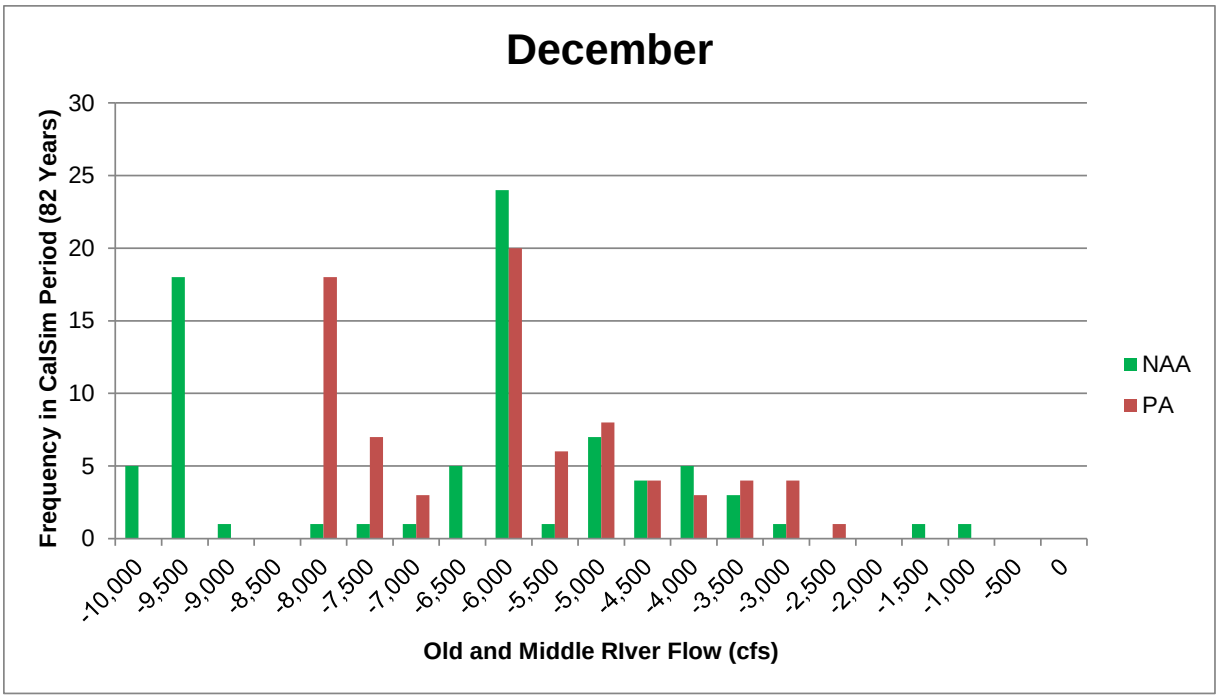


Figure 6.1-5. Frequency of December Old and Middle River Flows in Water-Year 1922–2003 Period Simulated with CalSim

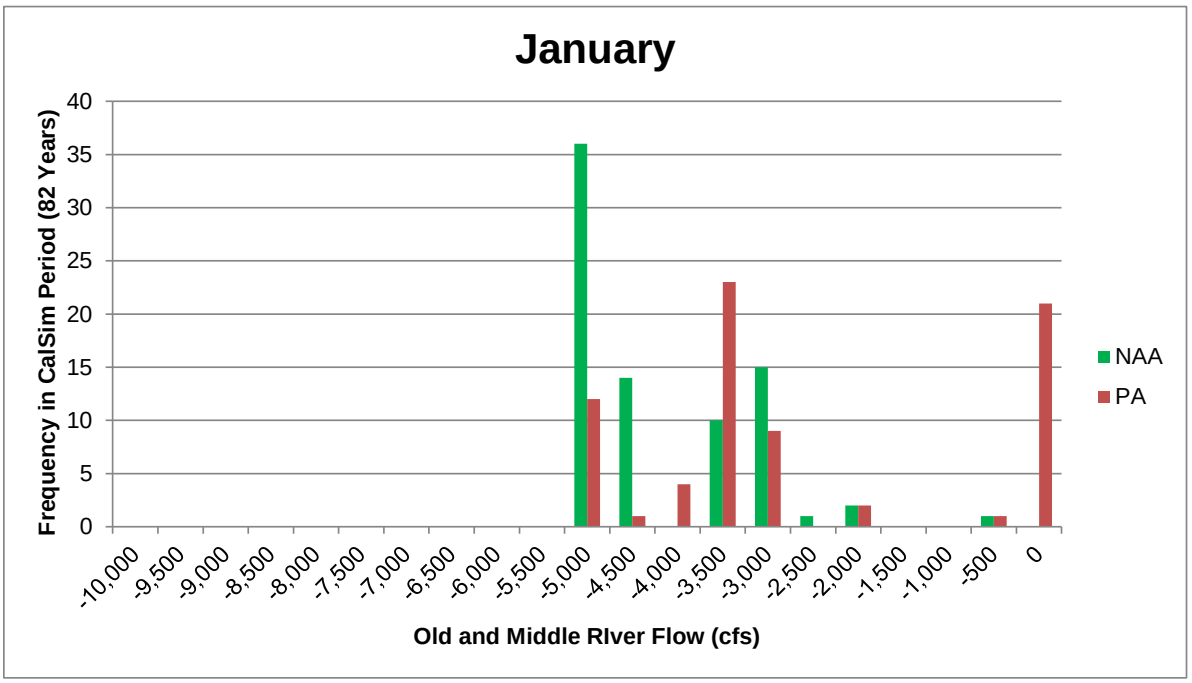


Figure 6.1-6. Frequency of December Old and Middle River Flows in Water-Year 1922–2003 Period Simulated with CalSim

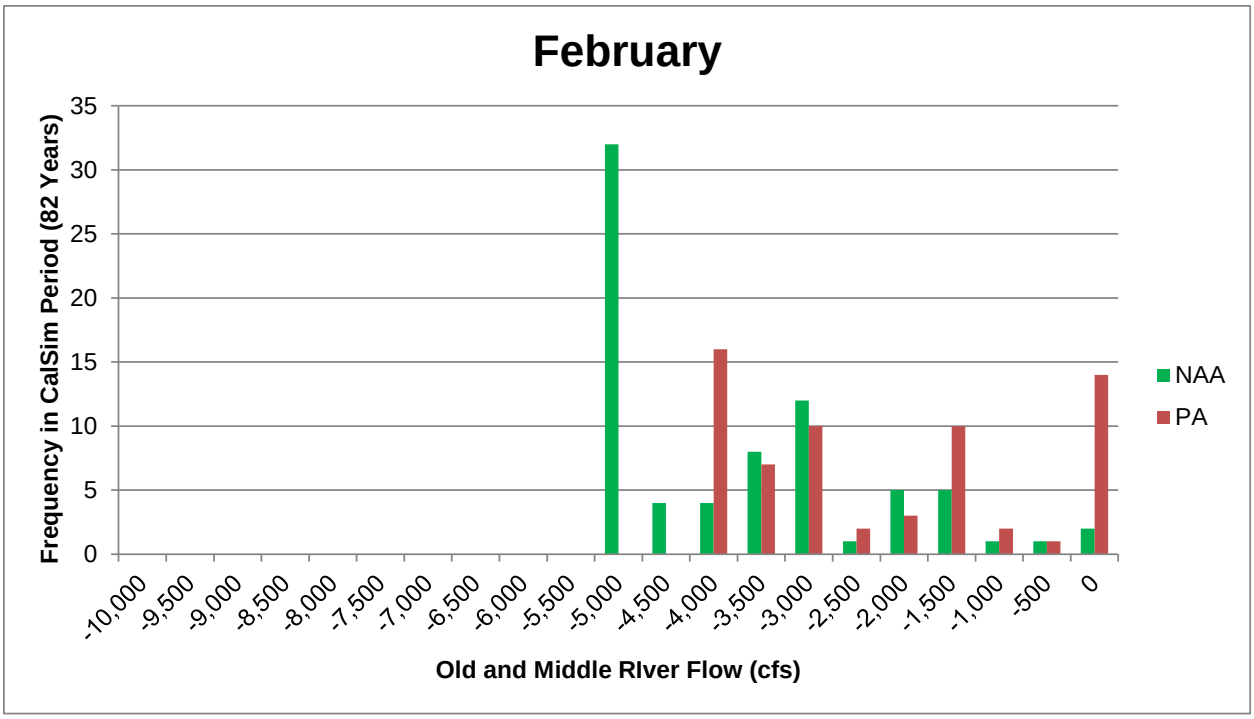


Figure 6.1-7. Frequency of February Old and Middle River Flows in Water-Year 1922–2003 Period Simulated with CalSim

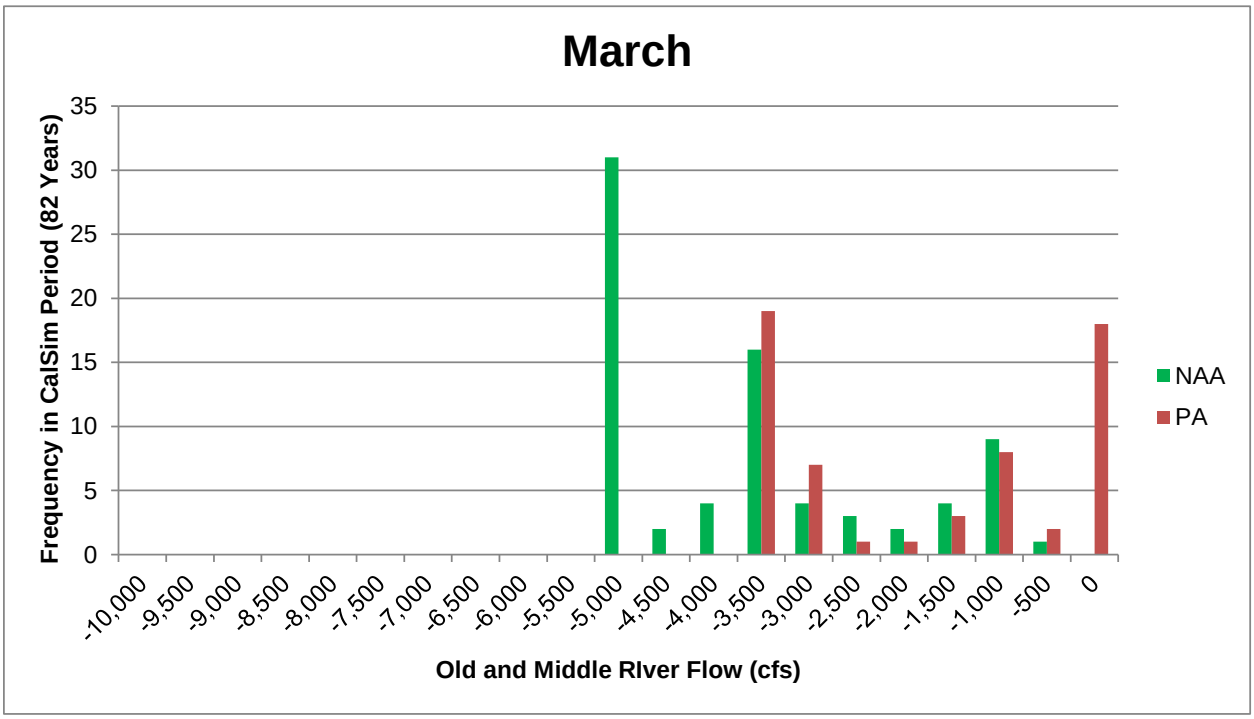


Figure 6.1-8. Frequency of March Old and Middle River Flows in Water-Year 1922–2003 Period Simulated with CalSim

6.1.3.3.1.1.2 Population-Level Effects

No tools are currently available with which to model adult entrainment risk at the south Delta export facilities in relation to future operations as well as it can be hindcast (*i.e.*, estimates of historical proportional loss as a function of historical OMR flows, for example), because of the difficulty in forecasting turbidity and abundance. For this effects analysis, the proportional entrainment of adult Delta Smelt was estimated using OMR flow predictions derived from CalSim II model outputs (U.S. Fish and Wildlife Service 2008; Appendix 6.A, *Quantitative Methods for Biological Assessment of Delta Smelt*, Section 6.A.3.1). As noted in Appendix 6.A, although much of the variability in proportional loss is left unexplained by this regression equation and the confidence intervals on the original estimates are relatively wide in some cases, the predictions in the models do follow the expected trend that salvage and population losses will decrease in response to the proposed action.

The analysis indicates that proportional entrainment loss of adult Delta Smelt would be lower under the PA than NAA, with variable differences when the results are summarized by water year type (Table 6.1-13; Figure 6.1-9). In drier years, the need to maintain suitable bypass flows in the Sacramento River and to maintain D-1641 compliant Delta outflows limits the use of the NDD. The result is predictions that there will be little difference between the NAA and PA in south Delta exports and entrainment loss of adult Delta Smelt. The USFWS (2008) and NMFS (2009) BiOps and their RPA actions related to south Delta entrainment have considerably reduced the potential for entrainment loss since 2008–2009. Therefore, even in drier water years, the predicted entrainment of adult Delta Smelt is considerably lower than what sometimes occurred historically. The overall conclusion is that the adverse effect of adult Delta Smelt entrainment in the south Delta would be appreciably lessened under the PA.

Less entrainment risk to migrating adults may result in a greater proportion of adults successfully spawning in the lower San Joaquin River. Spring Kodiak trawling in the lower San Joaquin River suggests frequent occurrence of spawning adults in this area (~10% of samples from 2002–2009 [Merz *et al.* 2011]; ~22% of samples during intensive sampling during extreme drought conditions in 2014 [Polansky *et al.* 2014]), which may imply a modest beneficial population-level effect. Recognition of the need to manage entrainment risk as a function of both OMR flows and south Delta turbidity is likely to guide management under both the NAA and PA, as illustrated by the previously mentioned USFWS proposal for the 2016 incidental take limit calculation.

Table 6.1-13. Mean Estimated Annual Proportional Entrainment Loss of Adult Delta Smelt at CVP/SWP South Delta Export Facilities by Water-Year Type for the No Action Alternative (NAA) and Proposed Action (PA), Based on the USFWS (2008) Proportional Entrainment Regression

Water Year Type	NAA	PA	PA vs. NAA[1]
All	0.08	0.06	-0.02 (-20%)
Wet	0.07	0.04	-0.03 (-40%)
Above Normal	0.08	0.06	-0.02 (-25%)
Below Normal	0.08	0.07	-0.01 (-15%)
Dry	0.08	0.07	-0.01 (-8%)
Critical	0.07	0.07	0.00 (-3%)

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

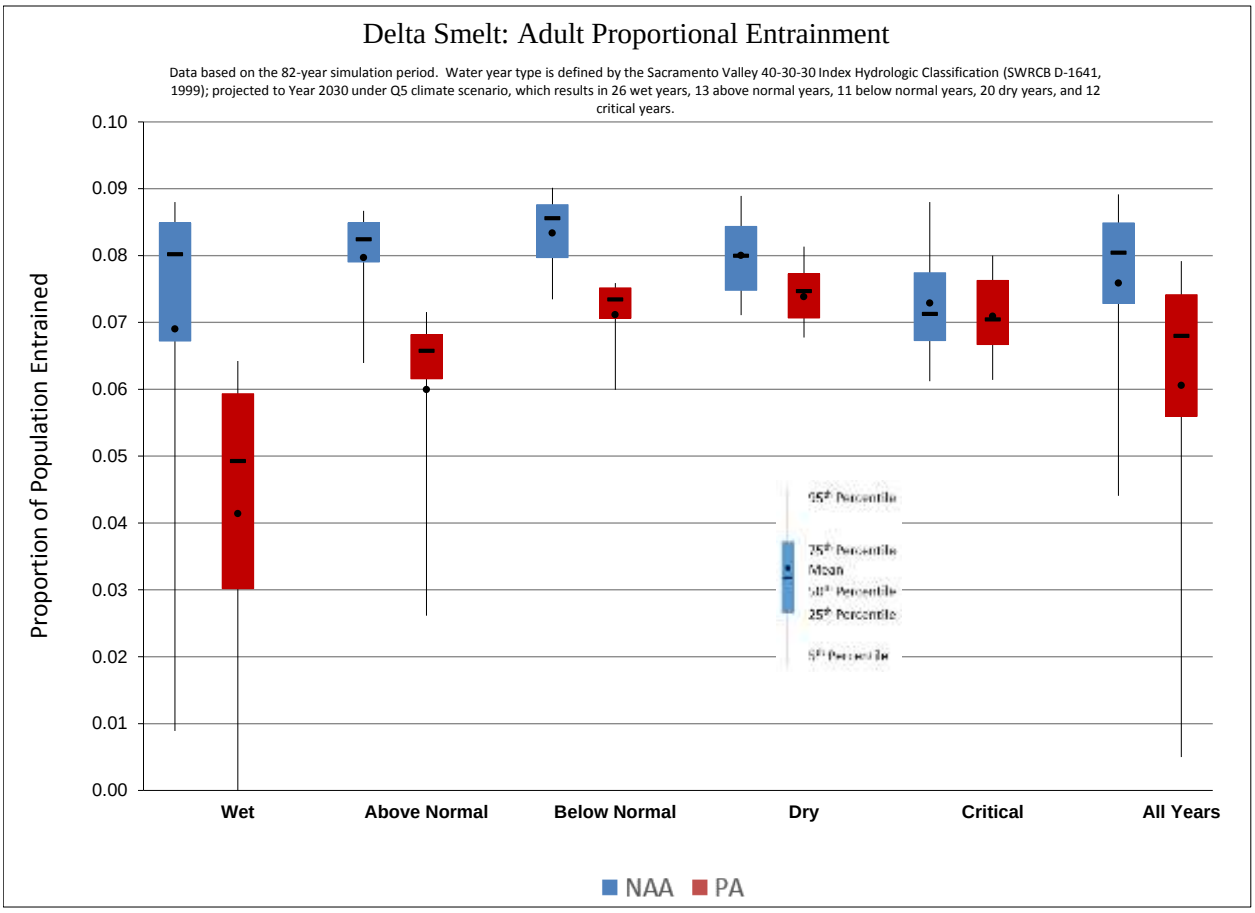


Figure 6.1-9. Box Plots of Adult Delta Smelt Proportional Entrainment from the Regression of USFWS (2008), Grouped by Water Year Type

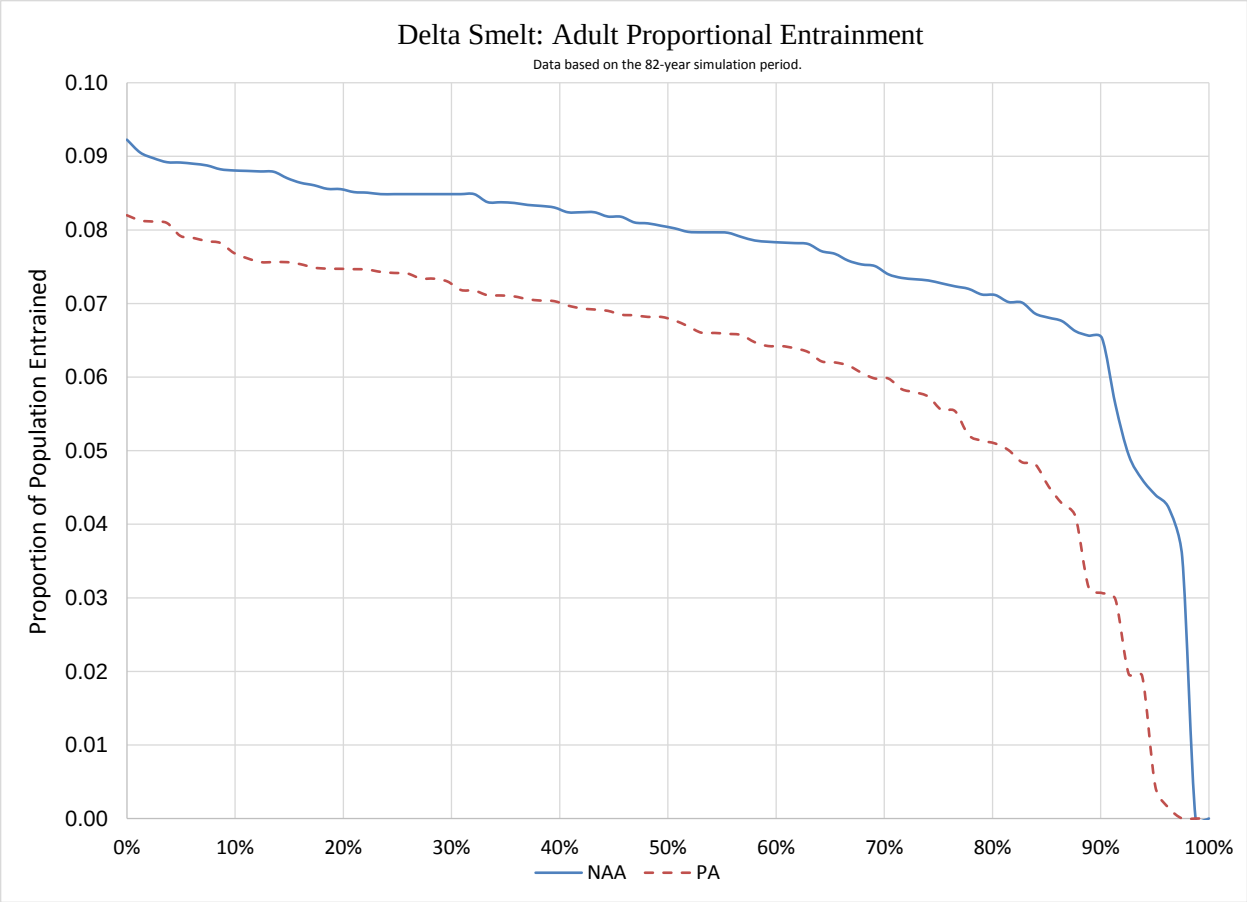


Figure 6.1-10. Exceedance Plot of Adult Delta Smelt Proportional Entrainment from the Regression of USFWS (2008)

6.1.3.3.1.2 Spawning Adults (February-June)

6.1.3.3.1.2.1 Individual-Level Effects

After completion of the migration to spawning areas, spawning adults presumably hold in a similar location prior to, during, and after spawning (possibly to spawn more than once). Therefore, there may not be appreciable risk of entrainment at the south Delta export facilities once the adults begin staging. The primary risk to adults occurs during the spawning migration, as described previously, but the persistently less negative OMR flows predicted for the PA suggest that entrainment risk will be reduced throughout the spawning season regardless of nuances about adult behavior and movements.

6.1.3.3.1.2.2 Population-Level Effects

Under the assumption that spawning adults are not undergoing broad-scale migrations, there would not be an adverse population-level effect of entrainment from south Delta exports to this life stage, but the persistently less negative OMR flows predicted for the PA suggest that proportional entrainment will be reduced and kept very similar to current conditions throughout the spawning season regardless of nuances about adult behavior and movements. As previously discussed, less entrainment risk for migrating adult Delta Smelt may increase the availability of lower San Joaquin River spawning habitat.

6.1.3.3.1.3 Eggs/Embryos (Spring: ~March-June)

6.1.3.3.1.3.1 Individual-Level Effects

As noted for entrainment and impingement at the NDD, Delta Smelt eggs and embryos are demersal and adhesive, and so would not be subject to entrainment at the south Delta export facilities.

6.1.3.3.1.3.2 Population-Level Effects

The demersal and adhesive nature of Delta Smelt eggs means that there would be no adverse population-level effects from south Delta exports with respect to entrainment.

6.1.3.3.1.4 Larvae/Young Juveniles (Spring: ~March-June)

6.1.3.3.1.4.1 Individual-Level Effects

Most age–0 Delta Smelt entrainment at the south Delta export facilities occurs during the true larval stage and is not observed and counted (Kimmerer 2008). The salvage of age-0 Delta Smelt reflects the tail end of the entrainment of age–0 cohorts that started before the fish were large enough to be observed in the fish salvage facilities. Delta smelt are not counted in fish salvage until they reach a minimum length of 20 mm. Kimmerer (2008) showed that Delta Smelt salvage was inefficient until the fish were 30 mm long (by which time they are morphologically juveniles; Mager *et al.* 2004). Delta Smelt typically reach 20-30 mm in May and June. Thus, April is likely to be the month of highest south Delta entrainment of age-0 Delta Smelt, while May-June are the months of highest salvage (Kimmerer 2008).

USFWS (2008) translated Kimmerer's (2008) data-intensive age-0 Delta Smelt entrainment estimates into multiple linear regression equations using multi-month averages of X2 and OMR flow as predictor variables. The regressions were a quantitative representation of the following conceptual model: (1) the geographic distribution of much of the population is strongly associated with Delta outflow (or its surrogate, X2; Dege and Brown 2004). Thus, Delta outflow may influence the proportion of the age-0 Delta Smelt population that rears in the Delta during the spring and early summer where it is potentially vulnerable to entrainment, and (2) OMR reflects the hydrodynamic influence of the water projects' diversions on the southern half of the Delta and thus the degree of entrainment risk for fishes in that region (Kimmerer 2008; Grimaldo *et al.* 2009). Long-term declines in April–May exports and E:I ratio, and April–June X2 (all results of State Board Decision 1641) may all have contributed to reduced entrainment risk of age-0 Delta Smelt; implementation of the RPAs from USFWS (2008) and NMFS (2009) has likely further reduced entrainment since 2008-2009, as a result of restrictions on export pumping that are made in consideration of environmental conditions that result in listed fishes being susceptible to entrainment (e.g., greater south Delta turbidity for Delta Smelt). In addition, entrainment risk may be continuing to decline due to a general shift in Delta Smelt spawning distribution toward the north Delta (Kimmerer 2011; Miller 2011).

Under the PA, individual larval/juvenile Delta Smelt would be susceptible to entrainment at the south Delta export facilities. The analysis presented below focuses on the population-level effect, by examining the proportion of the population that could be entrained under PA and NAA.

6.1.3.3.1.4.2 Population-Level Effects

For this effects analysis, two approaches were used to estimate entrainment effects on larval/young juvenile Delta Smelt. First, proportional entrainment loss regression equations from

the USFWS (2008) were used to estimate differences in potential larval/juvenile Delta Smelt entrainment at the south Delta export facilities given the basic operations simulated in CalSim II (Appendix 6.A, *Quantitative Methods for Biological Assessment of Delta Smelt,* Section 6.A.3.1.2). These regressions used two averaging periods: March–June and April–May. The analyses indicate that the proportional entrainment of larval/juvenile Delta Smelt would tend to be very similar under the PA and the NAA (Table 6.1-14; Table 6.1-15; Figure 6.1-11; and Figure 6.1-12).

Table 6.1-14. Mean Annual Proportional Entrainment Loss of Larval and Juvenile Delta Smelt at CVP/SWP South Delta Export Facilities by Water-Year Type for the No Action Alternative (NAA) and Proposed Action (PA), Based on the USFWS (2008) Proportional Entrainment Regression Using Mean March-June Old and Middle River Flows and X2.

Water Year Type	NAA	PA	PA vs. NAA[1]
All	0.12	0.11	-0.01 (-10%)
Wet	0.04	0.02	-0.02 (-43%)
Above Normal	0.08	0.05	-0.03 (-40%)
Below Normal	0.16	0.15	-0.01 (-4%)
Dry	0.16	0.16	0.00 (-1%)
Critical	0.22	0.22	0.00 (1%)

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

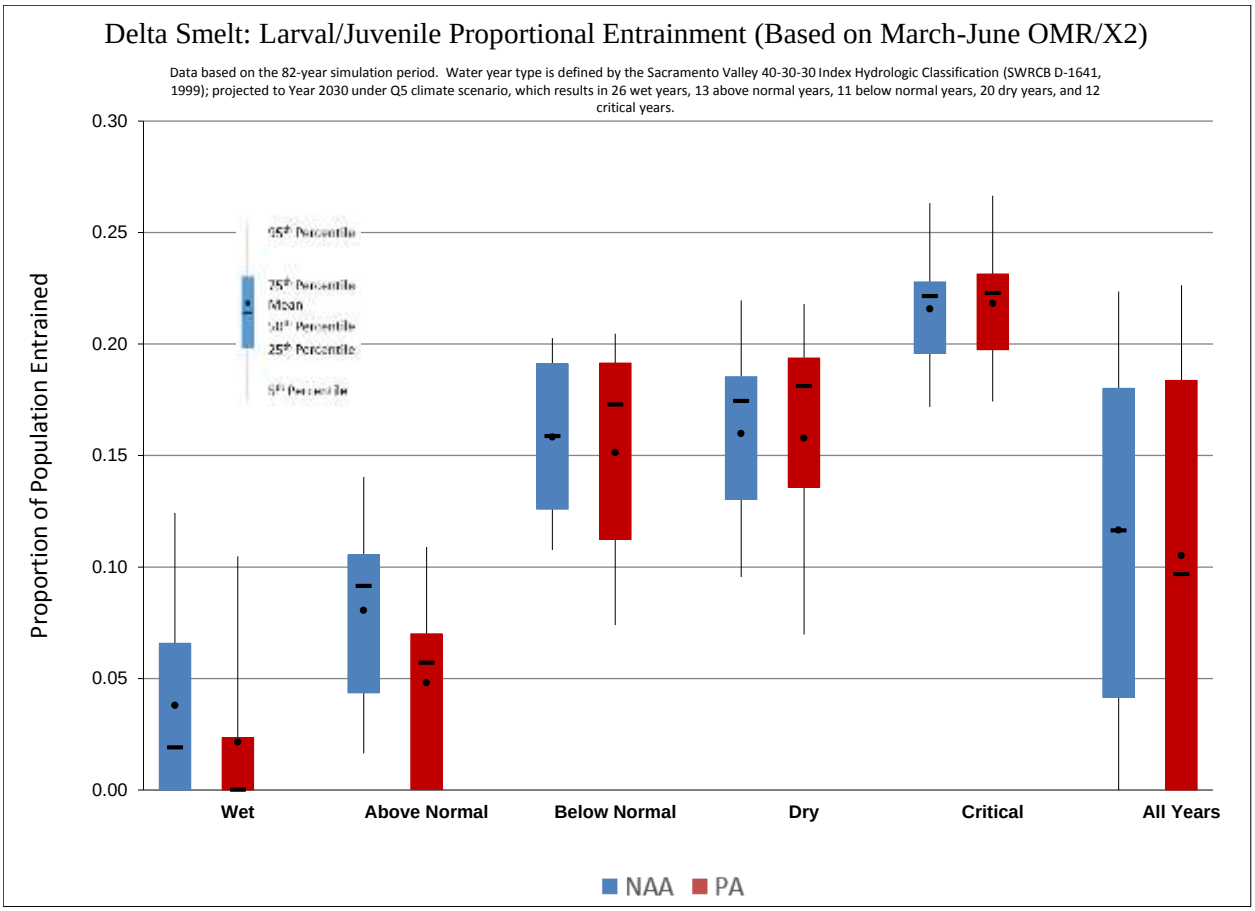


Figure 6.1-11. Box Plots of Larval/Juvenile Delta Smelt Proportional Entrainment from the Regression of USFWS (2008), Grouped by Water Year Type, Based on Mean March-June Old and Middle River Flows and X2

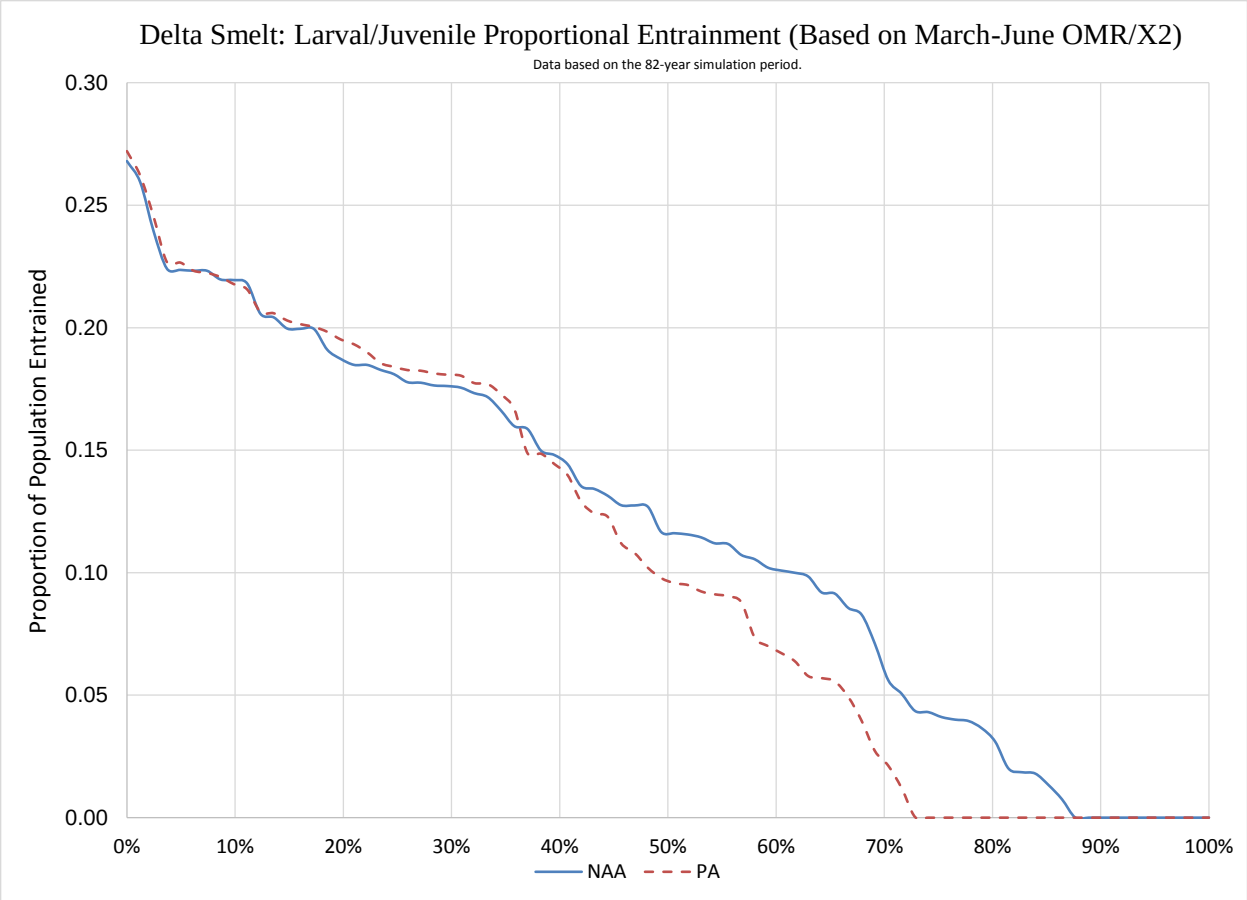


Figure 6.1-12. Exceedance Plot of Larval/Juvenile Delta Smelt Proportional Entrainment from the Regression of USFWS (2008), Based on Mean March-June Old and Middle River Flows and X2

Table 6.1-15. Mean Annual Proportional Entrainment Loss of Larval and Juvenile Delta Smelt at CVP/SWP South Delta Export Facilities by Water-Year Type for the No Action Alternative (NAA) and Proposed Action (PA), Based on the USFWS (2008) Proportional Entrainment Regression Using Mean April-May Old and Middle River Flows and X2.

Water Year Type	NAA	PA	PA vs. NAA[1]
All	0.09	0.09	0.00 (3%)
Wet	0.01	0.01	0.00 (2%)
Above Normal	0.04	0.03	0.00 (-11%)
Below Normal	0.12	0.13	0.01 (7%)
Dry	0.14	0.14	0.00 (2%)
Critical	0.21	0.22	0.01 (3%)

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

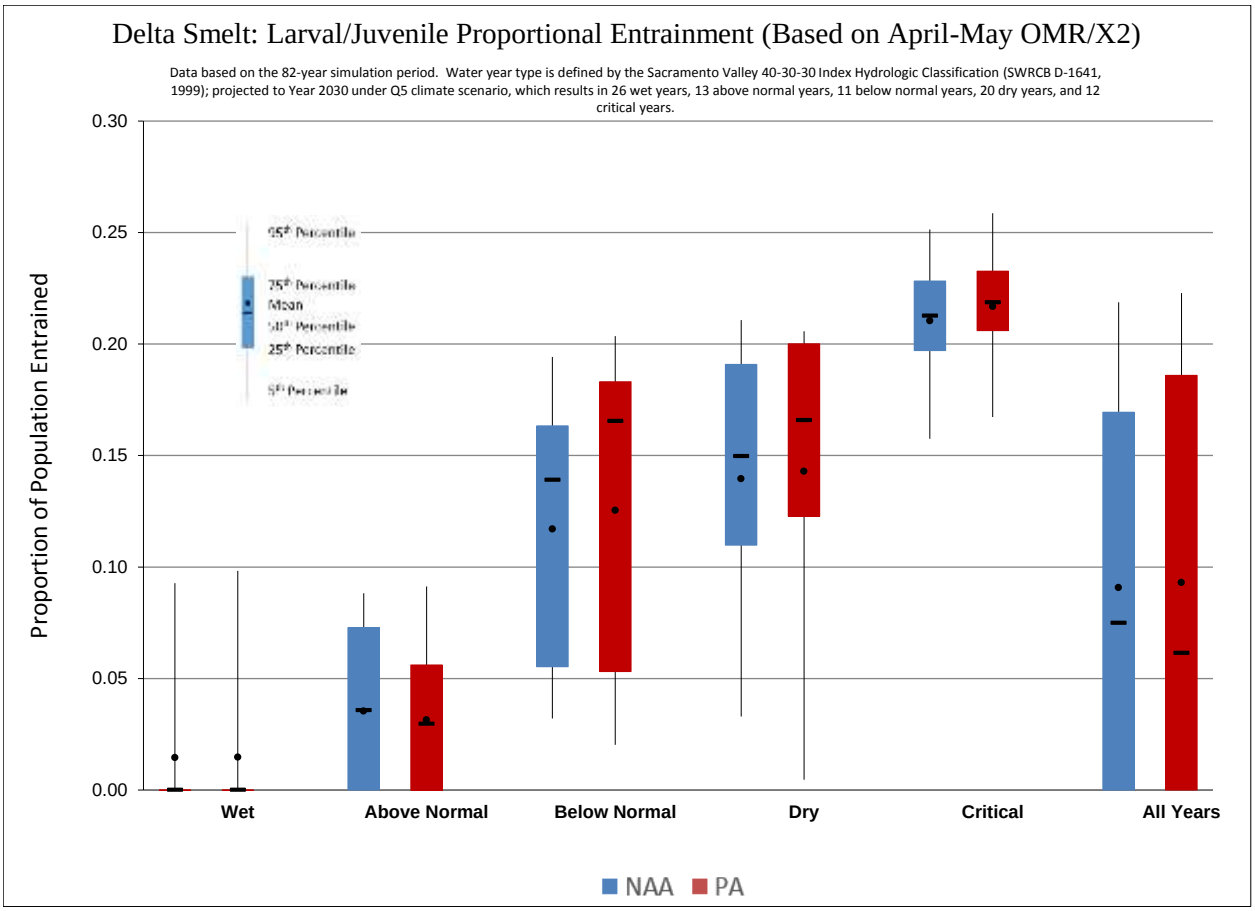
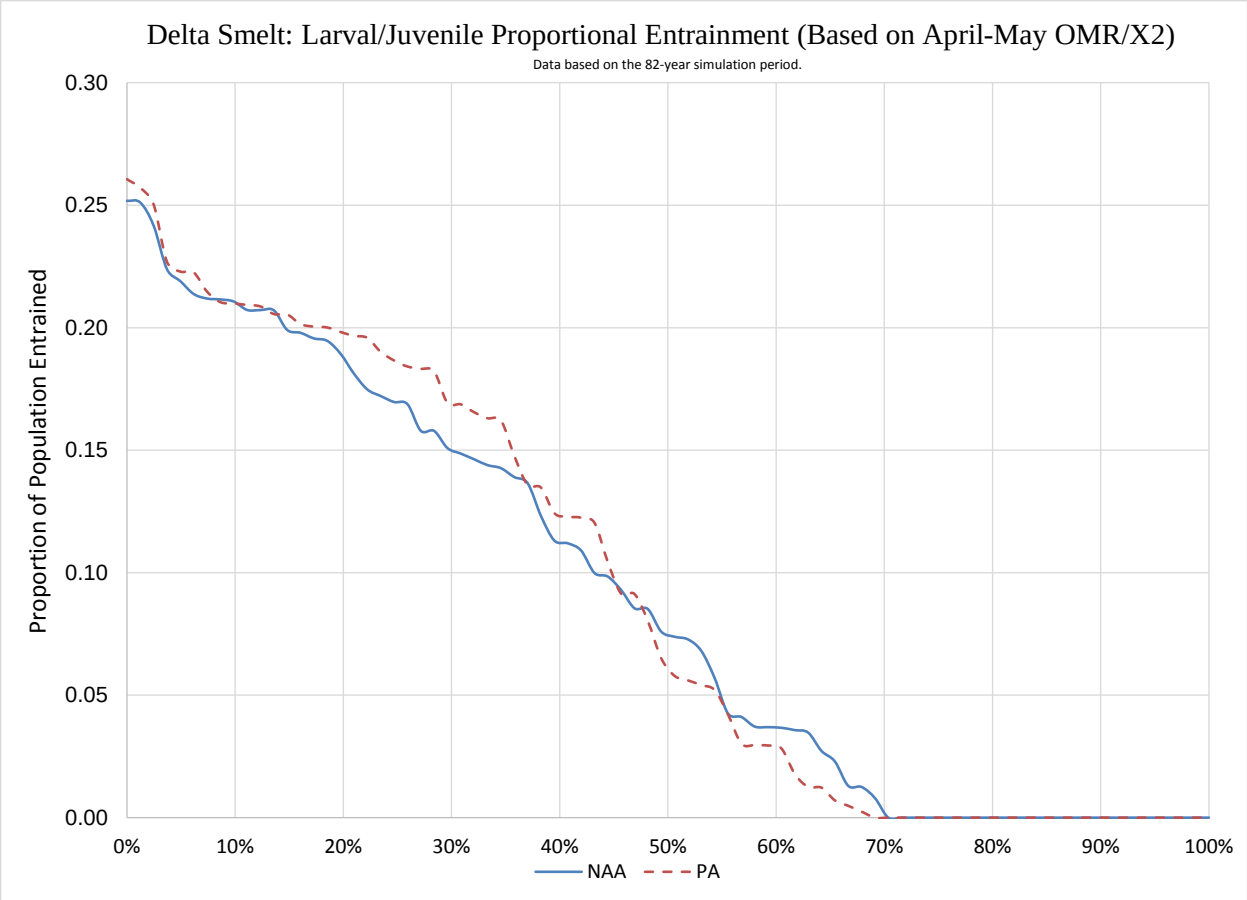


Figure 6.1-13. Box Plots of Larval/Juvenile Delta Smelt Proportional Entrainment from the Regression of USFWS (2008), Grouped by Water Year Type, Based on Mean April-May Old and Middle River Flows and X2



Note: x-axis indicates the percentage of years that the entrainment estimate would be expected to be exceeded.

Figure 6.1-14. Exceedance Plot of Larval/Juvenile Delta Smelt Proportional Entrainment from the Regression of USFWS (2008), Based on Mean April-May Old and Middle River Flows and X2

The second approach used to estimate larval/juvenile entrainment was based on DSM2-PTM. Note that this alternative method is not expected to produce results that are dramatically different than the method used by USFWS (2008) because survey-based and PTM based estimates are generally correlated (Kimmerer 2008). However, the PTM based approach is a more spatially explicit way to estimate population-level entrainment loss because it accounts for particle fates throughout the Delta and considered losses not only at the south Delta export facilities, but also at the NDD and the North Bay Aqueduct (NBA).The previously described analyses of proportional entrainment at the south Delta export facilities and the NDD are limited in that they cannot be compared directly, for the calculations are not made with the same analytical tool. The PTM analysis summarized below addresses this shortcoming, and also allows assessment of the potential entrainment at the NDD and NBA. The method is described in detail in Appendix 6.A, *Quantitative Methods for Biological Assessment of Delta Smelt*, Section 6.A.3.2, and essentially involved the following steps:

- Use the historical 20-mm Survey(1995–2011) data to apply a post-processed weighting to DSM2-PTM particle release locations in order to represent assumed hatching distributions of larval Delta Smelt;

- Match the Delta outflows that occurred for the 20-mm Survey months from which the hatching distributions were derived to the closest Delta outflow for each month simulated in DSM2-PTM (March–June, 1922–2003);

- Calculate the percentage entrainment at the CVP/SWP south Delta export facilities, NDD, and NBA, while accounting for the percentage of the population that was not within the Delta (and therefore not vulnerable to entrainment in the SWP or CVP's diversions located in the Delta).

As described in Appendix 6.A, *Quantitative Methods for Biological Assessment of Delta Smelt*, Section 6.A.3.2, it should be noted that there are two important limitations to this PTM-based analysis. First, a number of 20-mm Survey stations in the Cache Slough area were only sampled in the later years of the survey, and were not included when calculating the particle starting distributions. If NBA pumping is the same in the NAA and PA, then this could affect the absolute value of the entrainment predictions, but not their relative differences. Second, there are no 20-mm Survey stations above the NDD, so the NDD received the same weighting of particles as other stations in the north Delta: from the 1995-2011 20-mm Survey data, the mean percentage at each of these stations was 2.7% (range 0% to nearly 10%).

The percentage of Delta Smelt larvae assumed to occur downstream of the Delta decreased as water years became drier (Table 6.1-16), in keeping with the expectation that entrainment risk generally would be greater in drier years, when the population tends to be distributed further upstream. This is consistent with the influence of X2 on the regression methods described above. The results of the entrainment analysis suggested that, accounting for the four main SWP and CVP entrainment locations in the Delta, there would be less entrainment under the PA than NAA, averaged over the March-June period, in wetter years, whereas in drier years, there would be little to no difference between PA and NAA. However, there were important differences by month (Table 6.1-16; Figure 6.1-15, Figure 6.1-16, Figure 6.1-17, Figure 6.1-18, Figure 6.1-19, Figure 6.1-20, Figure 6.1-21, Figure 6.1-22). Total entrainment was driven by trends in south Delta entrainment, which, when examined month by month, suggested that under the PA there may be some increases in CVP entrainment (particularly in April/May) but generally greater decreases in SWP entrainment (except in April). The overall pattern of entrainment at the south Delta export facilities combined in terms of differences between PA and NAA across water year types matches the general pattern observed in the USFWS proportional entrainment regression analysis for March–June (Table 6.1-17) and April–May (Table 6.1-18). The relatively greater entrainment under PA suggested by the DSM2-PTM analysis in drier years in large part reflects not only slightly less (more negative) OMR flows because of the HOR gate (as well as modeling assumption differences related to the San Luis rule curve), but also that there has historically been a higher proportion of larvae in the central and south Delta in drier years (Appendix 6.A, *Quantitative Methods for Biological Assessment of Delta Smelt*, Table 6.A-5). There is very little difference in Delta outflow between NAA and PA in April and May (Table 5.A.6-26 in Appendix 5.A, *CALSIM Methods and Results*), which means that the influences of the NAA and PA on larval distribution would be expected to be broadly similar.

The percentage of particles entrained at the NDD under the PA always averaged well below 1% (Table 6.1-16); this percentage would be greater if it was assumed that a greater percentage of Delta Smelt larvae originate upstream of the NDD, or lower if it was assumed that a lower

percentage originated upstream of the NDD. As described in Section 6.1.3.2.1.4.2, extrapolation of catch density in the egg and larval survey suggested that a small proportion (perhaps ~0.25%) of the larval Delta Smelt population might occur in the NDD reach. In addition, further perspective on the proportion of the Delta Smelt population that could occur near the NDD was provided by the DSM2-PTM analysis incorporating simplified model behavior to mimic hypothesized migration strategies (*i.e.* "tidal surfing") suggests that the fraction of Delta Smelt expected to migrate past the NDDs is ~ 0.000 (see Section 6.1.3.2.2.1.2). Thus, it is possible that the fraction of Delta Smelt larvae assumed in this analysis to originate upstream of the NDDs could be too high. Adjusting the weighting percentage of particles representing Delta Smelt larvae that were inserted in the Sacramento River at Sacramento downward[12] to reflect lower occurrence than the other locations in the Cache Slough and North Delta area (see Table 6.A-5 in Appendix 6.A) gave considerably lower entrainment at the NDD under PA (water-year-type means of 0.00-0.01% in March-May, and 0.03-0.05% in June) than with the unadjusted original values, but only slightly less of a relative difference between NAA and PA in total entrainment: for example, in April, the mean total entrainment was 18% greater under PA in wet years (compared to 22% without the adjustment), 1% greater under PA in above normal years (compared to 2% without the adjustment), 35% greater under PA in above normal years (compared to 37% without the adjustment), 22% greater under PA in dry years (compared to 22% without the adjustment), and 13% greater under PA in above normal years (compared to 14% without the adjustment).

For the DSM2-PTM analysis described here for larval/juvenile Delta Smelt, there was little difference in entrainment at the NBA, reflecting similar operations under the PA and NAA (Table 6.1-16).

The results of the DSM2-PTM modeling do not incorporate real-time management that would occur under both the NAA and PA, incorporating the latest information gained from the results of coordinated monitoring and research under the Collaborative Science and Adaptive Management Program about fish distribution and other factors that would affect entrainment risk. Therefore, it may be possible to manage exports and HOR gate operations more carefully to avoid increasing entrainment. Additional discussion of HOR gate effects is provided in Section 6.1.3.4, *Head of Old River Gate Operations.*

[12] Specifically, the values were adjusted to be the minimum of 0.1 of the previous unadjusted value, or 0.25%; the percentages at the other locations in the Cache Slough and North Delta area were increased to give the same total percentage for the area as in the original, unadjusted analysis.

Table 6.1-16. Percentage of Particles Representing Delta Smelt Larvae Entrained over 30 Days into Clifton Court Forebay (State Water Project), Jones Pumping Plant (Central Valley Project), the North Delta Diversion, and the North Bay Aqueduct Barker Slough Pumping Plant, from DSM2 Particle Tracking Modeling.

Month	Water Year Type[1]	% Downstream of Delta	Clifton Court Forebay (State Water Project)			Jones Pumping Plant (Central Valley Project)			North Delta Diversion			North Bay Aqueduct Barker Slough Pumping Plant			Total Entrainment		
			NAA	PA	PA vs. NAA[2]	NAA	PA	PA vs. NAA[2]	NAA	PA	PA vs. NAA[2]	NAA	PA	PA vs. NAA[2]	NAA	PA	PA vs. NAA[2]
March-June Monthly Mean	W	43.92	3.03	1.41	-1.62 (-53%)	2.06	1.07	-0.99 (-48%)	0.00	0.18	0.18	1.18	1.18	0.00 (0%)	6.27	3.85	-2.43 (-39%)
	AN	28.39	5.16	2.47	-2.70 (-52%)	3.77	2.49	-1.29 (-34%)	0.00	0.19	0.19	1.27	1.28	0.01 (1%)	10.21	6.42	-3.79 (-37%)
	BN	14.13	5.72	4.36	-1.35 (-24%)	4.04	4.36	0.32 (8%)	0.00	0.18	0.18	2.20	2.22	0.02 (1%)	11.96	11.12	-0.83 (-7%)
	D	13.77	7.37	5.51	-1.87 (-25%)	4.54	5.47	0.92 (20%)	0.00	0.19	0.19	1.71	1.72	0.02 (1%)	13.63	12.88	-0.74 (-5%)
	C	5.97	3.85	2.84	-1.01 (-26%)	3.20	4.22	1.02 (32%)	0.00	0.08	0.08	1.22	1.32	0.10 (8%)	8.27	8.46	0.18 (2%)
March	W	54.69	3.24	0.92	-2.32 (-72%)	1.68	0.28	-1.40 (-84%)	0.00	0.29	0.29	1.19	1.20	0.01 (1%)	6.11	2.68	-3.43 (-56%)
	AN	57.96	5.78	1.28	-4.50 (-78%)	3.38	0.77	-2.61 (-77%)	0.00	0.04	0.04	0.16	0.16	0.00 (2%)	9.32	2.25	-7.07 (-76%)
	BN	31.80	9.74	6.83	-2.91 (-30%)	5.48	5.67	0.19 (4%)	0.00	0.28	0.28	2.62	2.63	0.01 (0%)	17.84	15.41	-2.43 (-14%)
	D	23.27	9.61	8.20	-1.40 (-15%)	6.78	7.64	0.85 (13%)	0.00	0.34	0.34	1.36	1.30	-0.05 (-4%)	17.75	17.48	-0.27 (-2%)
	C	13.31	5.65	3.90	-1.75 (-31%)	3.62	5.01	1.40 (39%)	0.00	0.13	0.13	1.01	1.39	0.39 (39%)	10.27	10.44	0.17 (2%)
April	W	54.11	0.63	0.78	0.15 (25%)	0.18	0.40	0.22 (126%)	0.00	0.05	0.05	1.17	1.17	0.00 (0%)	1.98	2.40	0.43 (22%)
	AN	36.60	1.88	1.74	-0.14 (-7%)	0.54	0.70	0.16 (29%)	0.00	0.06	0.06	0.98	0.98	0.00 (0%)	3.39	3.47	0.08 (2%)
	BN	12.20	2.03	2.47	0.44 (22%)	0.55	1.64	1.09 (199%)	0.00	0.05	0.05	1.84	1.91	0.07 (4%)	4.41	6.07	1.65 (37%)
	D	22.43	4.38	4.29	-0.09 (-2%)	2.16	3.92	1.76 (81%)	0.00	0.02	0.02	1.38	1.47	0.08 (6%)	7.93	9.70	1.77 (22%)
	C	6.21	2.72	2.54	-0.18 (-7%)	2.27	3.23	0.96 (43%)	0.00	0.03	0.03	0.87	0.87	0.00 (0%)	5.85	6.66	0.81 (14%)
May	W	43.42	0.87	0.45	-0.42 (-48%)	0.27	0.21	-0.06 (-21%)	0.00	0.05	0.05	1.17	1.17	0.00 (0%)	2.31	1.88	-0.42 (-18%)
	AN	16.96	2.30	1.08	-1.22 (-53%)	0.72	0.73	0.02 (2%)	0.00	0.18	0.18	2.36	2.37	0.01 (0%)	5.38	4.36	-1.02 (-19%)
	BN	10.43	2.66	1.91	-0.76 (-28%)	0.70	1.85	1.15 (164%)	0.00	0.06	0.06	2.74	2.74	0.00 (0%)	6.10	6.56	0.45 (7%)
	D	8.14	5.13	3.64	-1.50 (-29%)	1.93	3.29	1.36 (71%)	0.00	0.07	0.07	2.41	2.44	0.03 (1%)	9.47	9.43	-0.04 (0%)
	C	2.06	4.25	3.29	-0.97 (-23%)	3.17	5.12	1.94 (61%)	0.00	0.05	0.05	1.49	1.50	0.01 (1%)	8.92	9.96	1.04 (12%)
June	W	23.48	7.39	3.50	-3.89 (-53%)	6.11	3.39	-2.73 (-45%)	0.00	0.33	0.33	1.19	1.20	0.01 (1%)	14.70	8.42	-6.28 (-43%)
	AN	2.04	10.69	5.77	-4.92 (-46%)	10.45	7.74	-2.71 (-26%)	0.00	0.46	0.46	1.60	1.62	0.02 (1%)	22.75	15.59	-7.16 (-31%)
	BN	2.07	8.43	6.25	-2.19 (-26%)	9.44	8.30	-1.14 (-12%)	0.00	0.32	0.32	1.60	1.60	-0.01 (0%)	19.48	16.46	-3.01 (-15%)
	D	1.25	10.37	5.89	-4.48 (-43%)	7.30	7.03	-0.27 (-4%)	0.00	0.31	0.31	1.68	1.69	0.01 (1%)	19.36	14.93	-4.43 (-23%)
	C	2.29	2.78	1.65	-1.13 (-41%)	3.73	3.50	-0.23 (-6%)	0.00	0.08	0.08	1.53	1.53	0.00 (0%)	8.05	6.77	-1.28 (-16%)

Note:
[1] W = Wet, AN = Above Normal, BN = Below Normal, D = Dry, C = Critical.
[2] Negative values indicated lower entrainment loss under the proposed action (PA) than under the no action alternative (NAA).

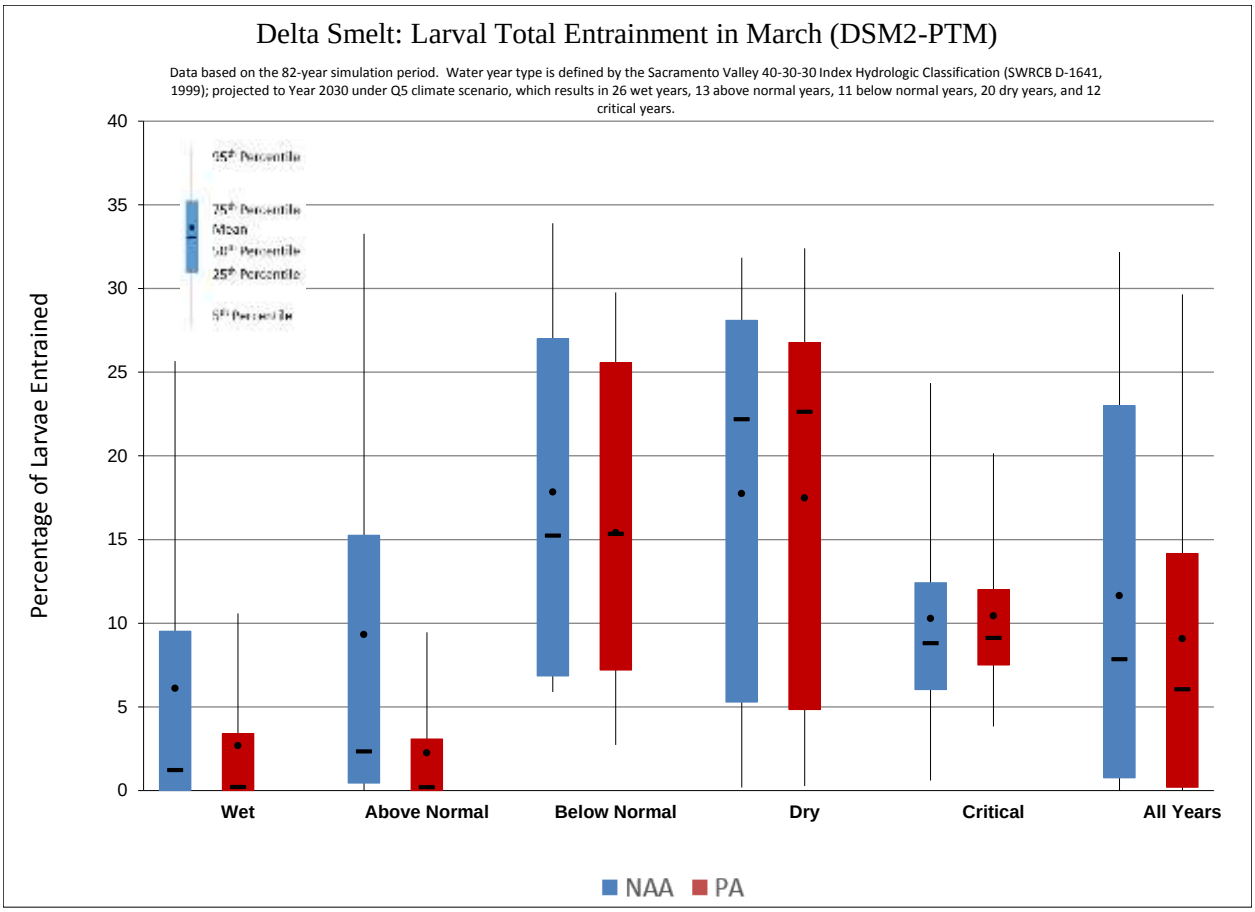


Figure 6.1-15. Box Plot of Percentage of Particles Representing Delta Smelt Larvae Entrained over 30 Days into Clifton Court Forebay (State Water Project), Jones Pumping Plant (Central Valley Project), the North Delta Diversion, and the North Bay Aqueduct Barker Slough Pumping Plant, Grouped by Water Year Type, from DSM2 Particle Tracking Modeling of March 1922–2003

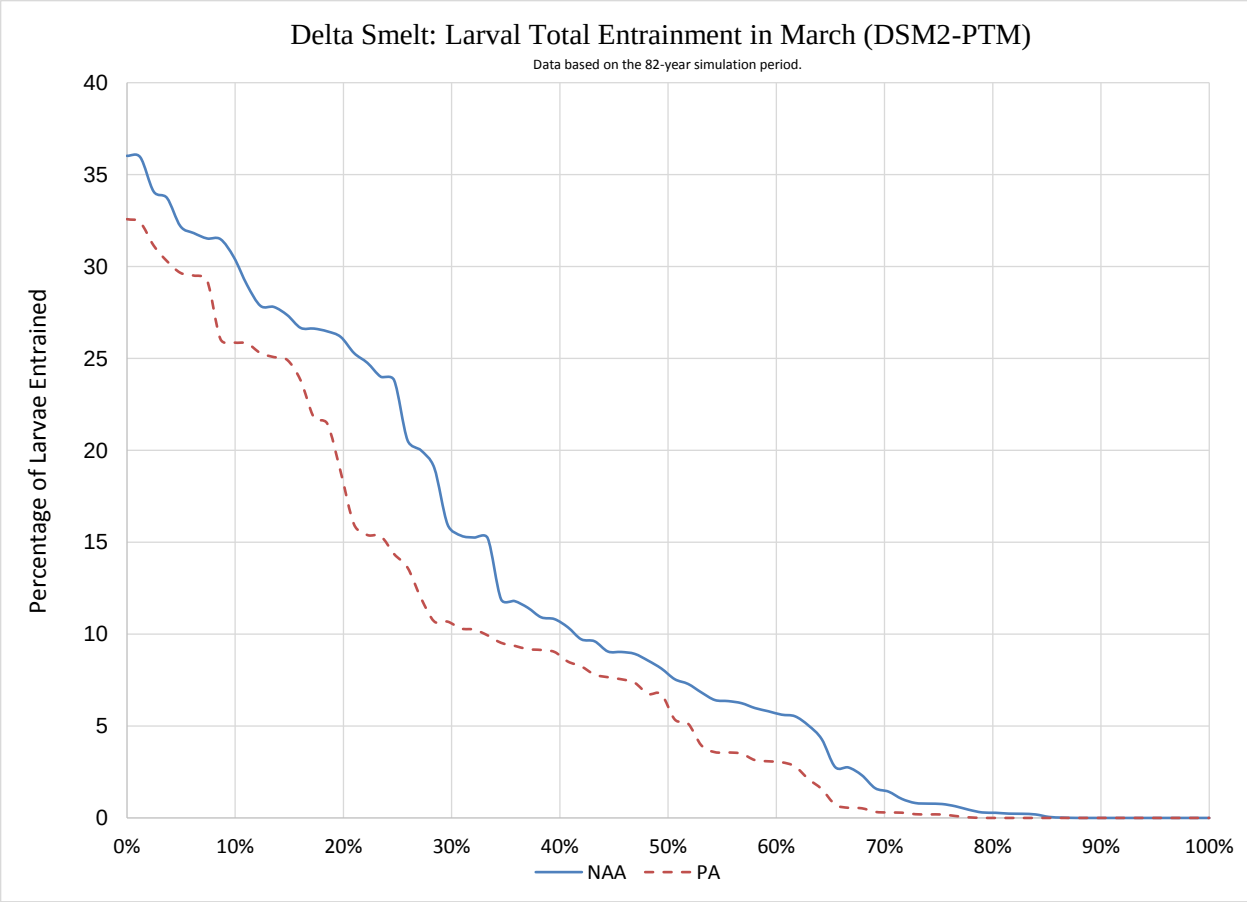


Figure 6.1-16. Exceedance Plot of Percentage of Particles Representing Delta Smelt Larvae Entrained over 30 Days into Clifton Court Forebay (State Water Project), Jones Pumping Plant (Central Valley Project), the North Delta Diversion, and the North Bay Aqueduct Barker Slough Pumping Plant, Grouped by Water Year Type, from DSM2 Particle Tracking Modeling of March 1922–2003

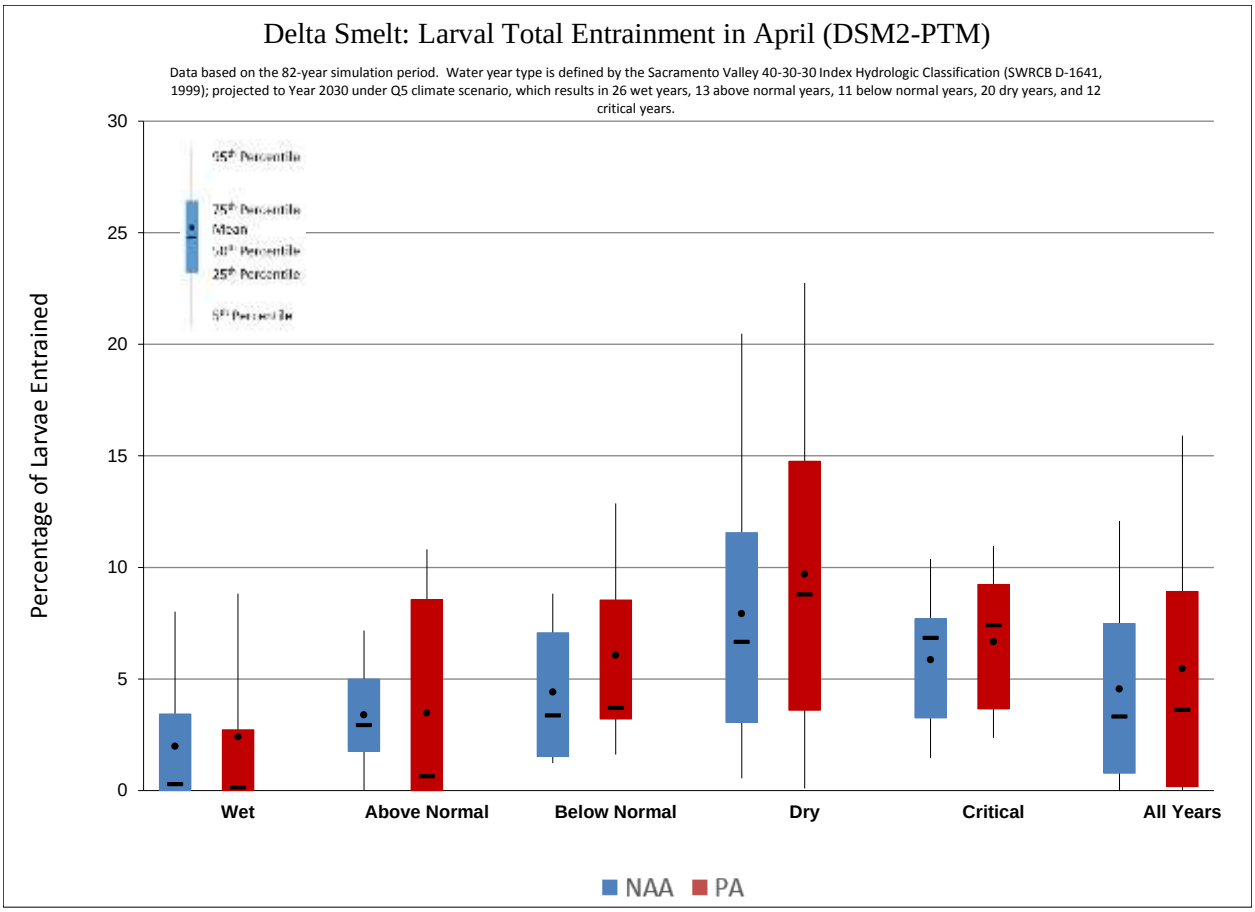


Figure 6.1-17. Box Plot of Percentage of Particles Representing Delta Smelt Larvae Entrained over 30 Days into Clifton Court Forebay (State Water Project), Jones Pumping Plant (Central Valley Project), the North Delta Diversion, and the North Bay Aqueduct Barker Slough Pumping Plant, Grouped by Water Year Type, from DSM2 Particle Tracking Modeling of April 1922–2003

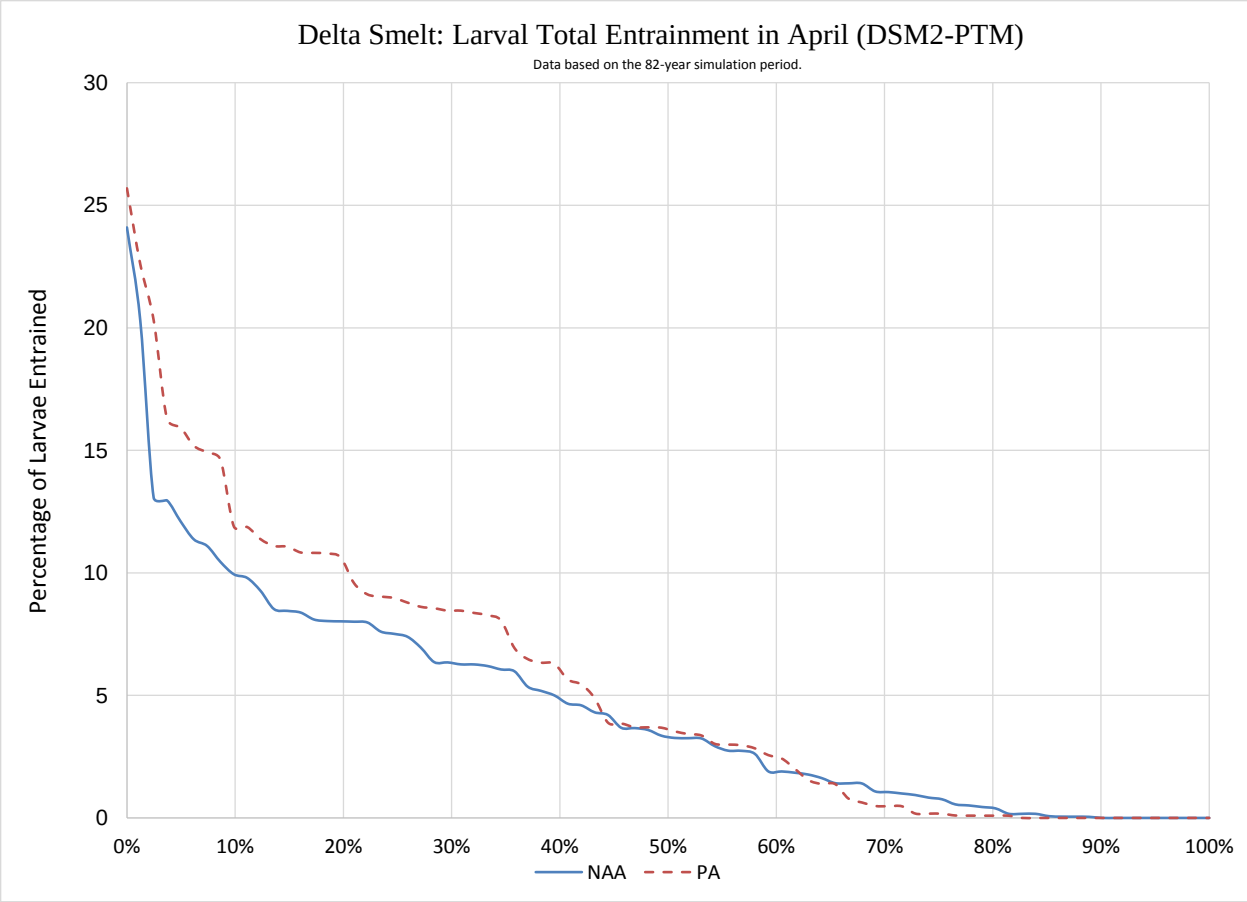


Figure 6.1-18. Exceedance Plot of Percentage of Particles Representing Delta Smelt Larvae Entrained over 30 Days into Clifton Court Forebay (State Water Project), Jones Pumping Plant (Central Valley Project), the North Delta Diversion, and the North Bay Aqueduct Barker Slough Pumping Plant, Grouped by Water Year Type, from DSM2 Particle Tracking Modeling of April 1922–2003

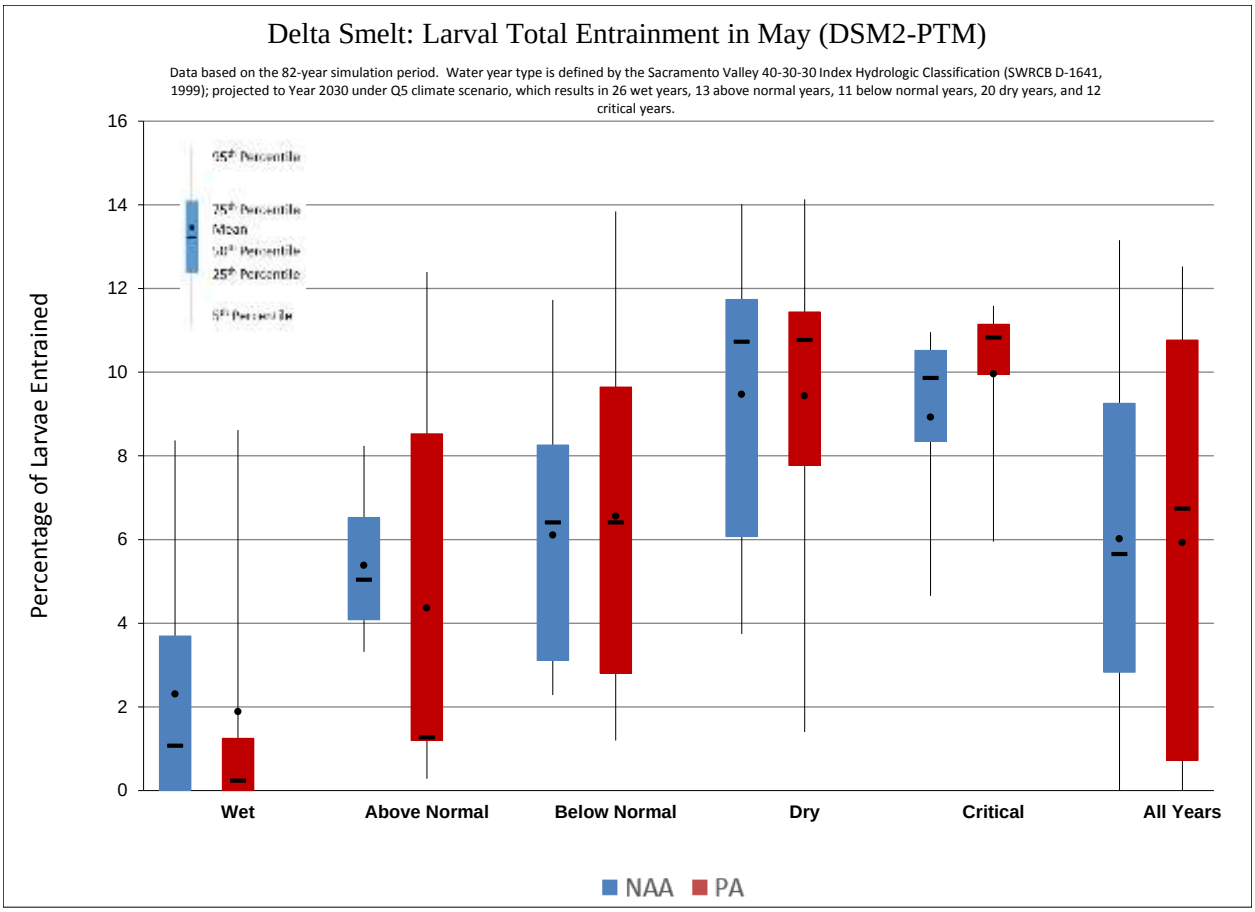


Figure 6.1-19. Box Plot of Percentage of Particles Representing Delta Smelt Larvae Entrained over 30 Days into Clifton Court Forebay (State Water Project), Jones Pumping Plant (Central Valley Project), the North Delta Diversion, and the North Bay Aqueduct Barker Slough Pumping Plant, Grouped by Water Year Type, from DSM2 Particle Tracking Modeling of May 1922–2003

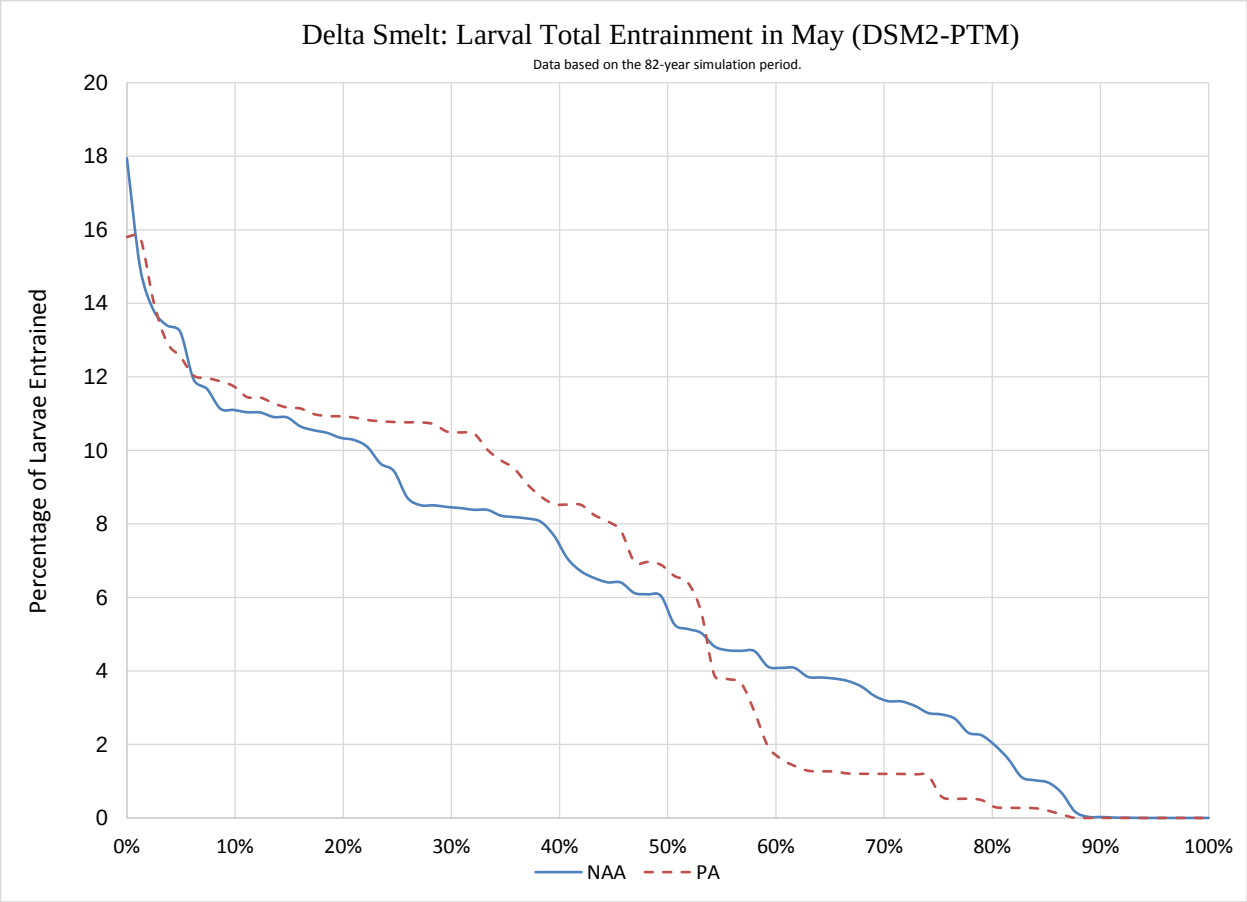


Figure 6.1-20. Exceedance Plot of Percentage of Particles Representing Delta Smelt Larvae Entrained over 30 Days into Clifton Court Forebay (State Water Project), Jones Pumping Plant (Central Valley Project), the North Delta Diversion, and the North Bay Aqueduct Barker Slough Pumping Plant, Grouped by Water Year Type, from DSM2 Particle Tracking Modeling of May 1922–2003

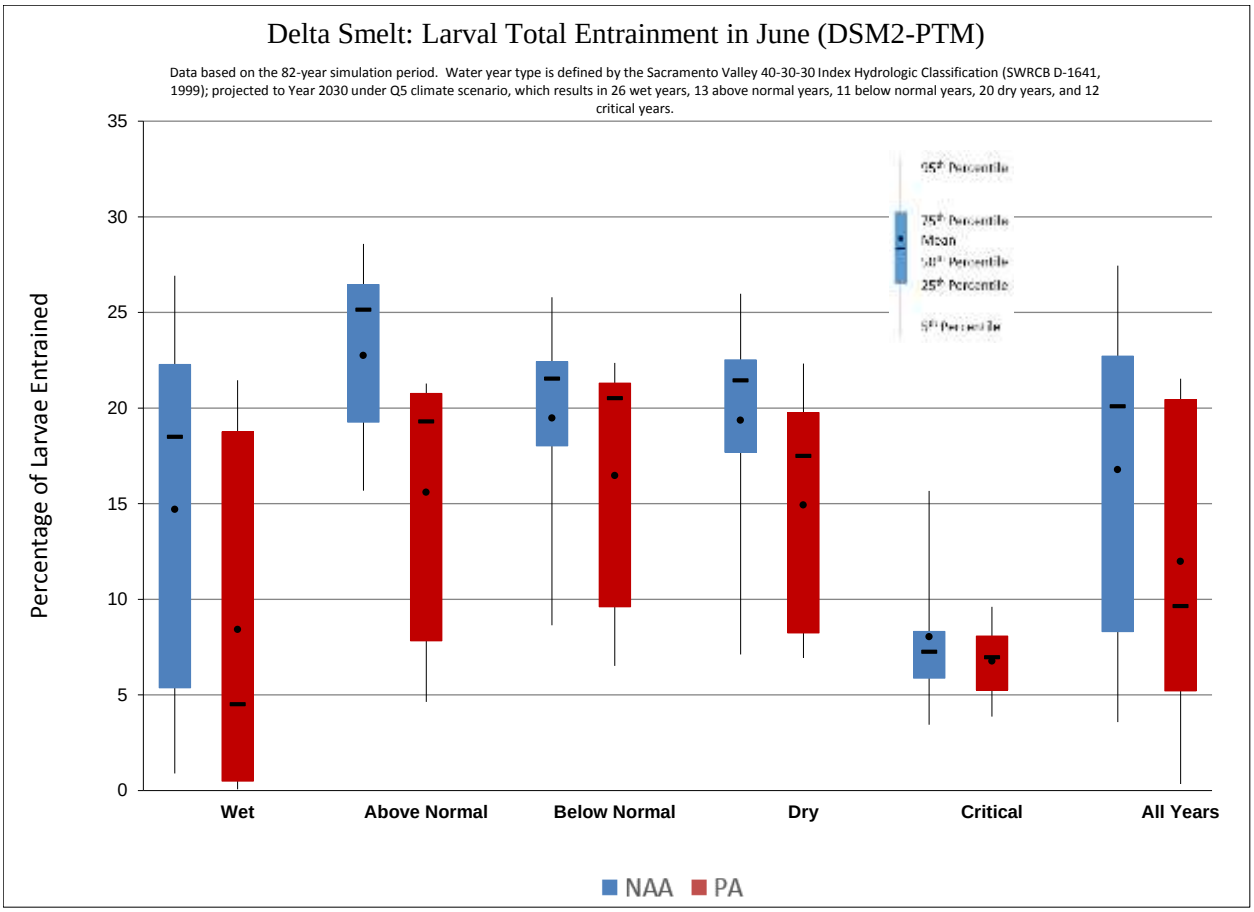


Figure 6.1-21. Box Plot of Percentage of Particles Representing Delta Smelt Larvae Entrained over 30 Days into Clifton Court Forebay (State Water Project), Jones Pumping Plant (Central Valley Project), the North Delta Diversion, and the North Bay Aqueduct Barker Slough Pumping Plant, Grouped by Water Year Type, from DSM2 Particle Tracking Modeling of June 1922–2003

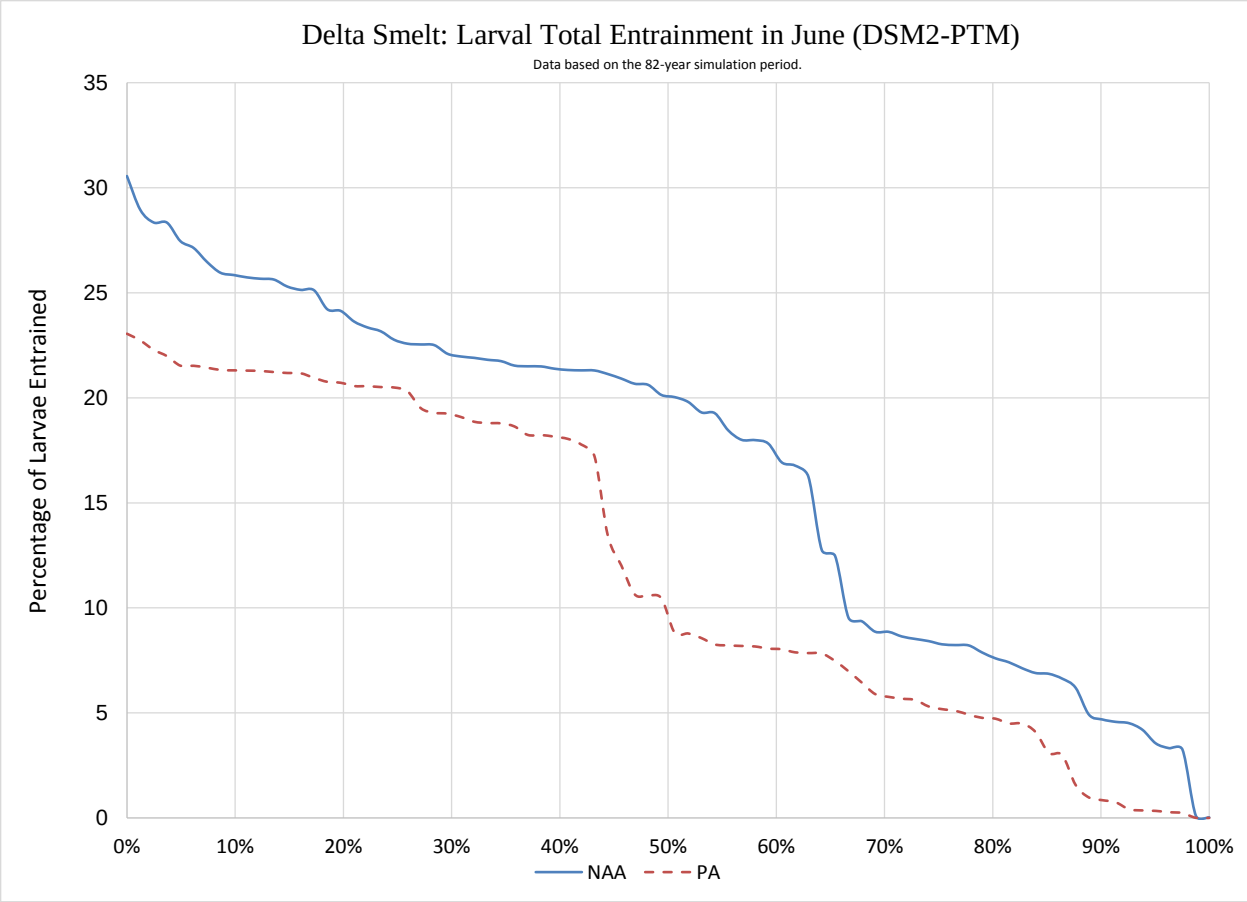


Figure 6.1-22. Exceedance Plot of Percentage of Particles Representing Delta Smelt Larvae Entrained over 30 Days into Clifton Court Forebay (State Water Project), Jones Pumping Plant (Central Valley Project), the North Delta Diversion, and the North Bay Aqueduct Barker Slough Pumping Plant, Grouped by Water Year Type, from DSM2 Particle Tracking Modeling of June 1922-2003

Table 6.1-17. Comparison of Trends in Delta Smelt Larval Entrainment Loss at the South Delta Export Facilities from the USFWS March-June Proportional Entrainment Regression and DSM2-PTM Results for March-June (Monthly Mean).

Water Year Type	USFWS Proportional Entrainment Regression[1]			DSM2-PTM Results (% Entrained at South Delta Only)		
	NAA	PA	PA vs. NAA[2]	NAA	PA	PA vs. NAA[1]
Wet	3.79	2.15	-1.64 (-43%)	5.09	2.48	-2.61 (-51%)
Above Normal	8.05	4.81	-3.25 (-40%)	8.94	4.95	-3.98 (-45%)
Below Normal	15.83	15.13	-0.70 (-4%)	9.76	8.73	-1.03 (-11%)
Dry	15.98	15.78	-0.20 (-1%)	11.92	10.97	-0.94 (-8%)
Critical	21.57	21.82	0.25 (1%)	7.05	7.06	0.01 (0%)

Note:
[1] Proportions have been changed to percentages for consistency with the DSM2-PTM results. [2]Negative values indicated lower entrainment loss under the proposed action (PA) than under the no action alternative (NAA).

Table 6.1-18. Comparison of Trends in Delta Smelt Larval Entrainment Loss at the South Delta Export Facilities from the USFWS April-May Proportional Entrainment Regression and DSM2-PTM Results for April-May (Monthly Mean).

Water Year Type	USFWS Proportional Entrainment Regression[1]			DSM2-PTM Results (% Entrained at South Delta Only)		
	NAA	PA	PA vs. NAA[2]	NAA	PA	PA vs. NAA[1]
Wet	1.45	1.47	0.02 (2%)	0.97	0.92	-0.05 (-5%)
Above Normal	3.53	3.14	-0.39 (-11%)	2.72	2.12	-0.59 (-22%)
Below Normal	11.70	12.54	0.84 (7%)	2.97	3.93	0.96 (32%)
Dry	13.96	14.29	0.33 (2%)	6.80	7.56	0.76 (11%)
Critical	21.04	21.69	0.65 (3%)	6.21	7.08	0.88 (14%)

Note:
[1] Proportions have been changed to percentages for consistency with the DSM2-PTM results. [2]Negative values indicated lower entrainment loss under the proposed action (PA) than under the no action alternative (NAA).

6.1.3.3.1.5 Juveniles (Summer/Fall: ~July-December)

6.1.3.3.1.5.1 Individual-Level Effects

Juvenile Delta Smelt can be entrained at the south Delta export facilities after June, but patterns of salvage suggest that entrainment loss is very low after June (see Figure 3 of Kimmerer 2008). Recognizing this, USFWS (2008) established June 30 as the latest date to which restrictions on south Delta export pumping are presently applied to limit entrainment of larval/young juvenile Delta Smelt. The restrictions can end earlier than this if the daily mean water temperature at Clifton Court Forebay reaches 25°C for three consecutive days, because this indicates that conditions are no longer conducive to smelt survival (U.S. Fish and Wildlife Service 2008: 368), consistent with broad-scale observations on distribution (Nobriga *et al.* 2008).

6.1.3.3.1.5.2 Population-Level Effects

The entrainment of juvenile Delta Smelt during July-November is expected to be very low as it has been in the recent past, because the south Delta water is warmer and clearer than the habitat that Delta Smelt occupy (Nobriga *et al.* 2008). Thus, entrainment of juvenile Delta Smelt is not expected to impact the population.

6.1.3.3.2 Predation at the South Delta Export Facilities

6.1.3.3.2.1 Migrating Adults (December-March)

6.1.3.3.2.1.1 Individual-Level Effects

The previously presented analyses of entrainment effects of the PA on migrating adult Delta Smelt at the south Delta export facilities incorporated predation loss, e.g., prescreen losses across Clifton Court Forebay when estimating a proportion of the population that was ultimately lost due to changes in exports via their effect on OMR flow (Kimmerer and Nobriga 2008). For adult Delta Smelt, predation probably kills a large proportion of individuals before they actually reach the fish facilities or the export pumps behind them (Castillo *et al.* 2012; see Table 6.1-12). Thus, a lower entrainment risk to individual Delta Smelt under the PA in relation to NAA, should decrease mortality rates experienced by the adult stock[13]. To the extent that the localized reduction of predatory fishes conservation measure, discussed further in Section 6.1.4.2, *Localized Reduction of Predatory Fishes to Minimize Predator Density at North and South Delta Export Facilities*, reduces predator abundance in Clifton Court Forebay, predation risk to adult Delta Smelt could be reduced under the PA. However, there is uncertainty in the efficacy of this conservation measure, given that previous efforts did not yield measurable changes in predator population size within the Forebay (Brown *et al.* 1996).

6.1.3.3.2.1.2 Population-Level Effects

Given that a measurable proportion of the migrating adult Delta Smelt population can be lost to entrainment and associated predation, lower entrainment under PA should translate into lower overall adult mortality, compared to NAA.

[13] Note that the proportional loss regressions used to assess entrainment include losses from predation.

6.1.3.3.2.2 Spawning Adults (February-June)

6.1.3.3.2.2.1 Individual-Level Effects

It is not known whether an individual Delta Smelt occupying the south Delta faces a higher risk of predation than an individual occupying another staging or spawning location (e.g., Suisun Marsh, Decker Island, Sacramento Deepwater Shipping Channel).

6.1.3.3.2.2.2 Population-Level Effects

As described for entrainment, under the assumption that spawning adults are not undertaking broad-scale migrations, there are no data available to suggest they face an adverse population-level effect of predation beyond what occurs at the SWP and CVP facilities. Similar to migrating adults, lower entrainment under PA should translate into lower overall adult mortality, compared to NAA.

6.1.3.3.2.3 Eggs/Embryos (Spring: ~March-June)

6.1.3.3.2.3.1 Individual-Level Effects

As noted for entrainment at the south Delta export facilities, Delta Smelt eggs and embryos are demersal and adhesive and would not be subject to changes in predation at the south Delta export facilities as a result of changes in south Delta water exports under the PA relative to NAA. There also would not be an effect of localized predatory fish reduction, as the sizes of fish targeted by this action would be larger than the sizes of fish that typically prey upon early life stages of Delta Smelt (e.g., silversides; Baerwald *et al.* 2012).

6.1.3.3.2.3.2 Population-Level Effects

Changes to exports are not expected to change the distribution of Delta Smelt eggs once they have been spawned. Thus, this is not a likely impact mechanism.

6.1.3.3.2.4 Larvae/Young Juveniles (Spring: ~March-June)

6.1.3.3.2.4.1 Individual-Level Effects

As summarized in Table 6.1-12, predation losses of larval Delta Smelt in association with the south Delta export facilities have not been quantified, whereas losses of juvenile Delta Smelt have been shown to be substantial, at least under some conditions (Castillo *et al.* 2012), as is the case with other species (Gingras 1997; Clark *et al.* 2009). The influence of water project operations on facility-associated predation on larval and small juvenile Delta Smelt is built into the proportional loss estimates described above, which were based on estimates from Kimmerer (2008). There is no additional effect to analyze under this impact mechanism.

6.1.3.3.2.4.2 Population-Level Effects

As described for the Individual-Level Effects, the influence of water project operations on facility-associated predation on larval and small juvenile Delta Smelt is built into the proportional loss estimates described above. There is no additional effect to analyze under this impact mechanism.

6.1.3.3.2.5 Juveniles (Summer/Fall: ~July-December)

6.1.3.3.2.5.1 Individual-Level Effects

As discussed for entrainment, individual juvenile Delta Smelt would be expected to generally have left the south Delta as temperatures increase, so it is not anticipated that there would be changes in predation risk to individuals at or near the south Delta export facilities.

6.1.3.3.2.5.2 Population-Level Effects

There would be minimal population-level effects of changes in predation at the south Delta export facilities to juvenile Delta Smelt because this life stage is largely absent from the south Delta in summer/fall.

6.1.3.4 Head of Old River Gate Operations

6.1.3.4.1 Migrating Adults (December-March)

6.1.3.4.1.1 Individual-Level Effects

The potential for effects of the HOR gate is similar to the effects described for the south Delta Temporary Barriers Project (TBP), as previously noted by USFWS (2008: 225-226). Unlike the rock barrier currently used in some years, however, HOR gate operations would occur in the context of real-time changes in both gate position and management of north and south Delta exports in order to limit the potential for adverse hydraulic effects to adult Delta Smelt during their winter dispersal. In particular, careful management of OMR flows in consideration of fish distribution and turbidity cues (among other factors), would be undertaken to limit adverse effects to Delta Smelt. USFWS (2008: 225-226) noted the potential for negative effects of the TBP, including a HOR gate, on Delta Smelt:

> The TBP does not alter total Delta outflow, or the position of X2. However, the TBP causes changes in the hydraulics of the Delta, which may affect delta smelt. The HORB blocks San Joaquin River flow, which prevents it from entering Old River at that point. This situation increases the flow toward Banks and Jones from Turner and Columbia cuts, which can increase the predicted entrainment risk for particles in the East and Central Delta by up to about 10 percent (Kimmerer and Nobriga 2008). In most instances, net flow is directed towards the Banks and Jones pumps and local agricultural diversions. Computer simulations have shown that placement of the barriers changes South Delta hydrodynamics, increasing Central Delta flows toward the export facilities (Reclamation 2008). In years with substantial numbers of adult delta smelt moving into the Central Delta, increases in negative OMR flow caused by installation of the [temporary barriers] can increase entrainment. The directional flow towards Banks and Jones increases the vulnerability of fish to entrainment. Larval and juvenile delta smelt are especially susceptible to these flows.
>
> The varying proposed operational configurations of the TBP, natural variations in fish distribution, and a number of other physical and environmental variables limit statistical confidence in assessing fish salvage when the TBP is operational versus when it is not. In 1996, the installation of the spring HORB caused a sharp reversal of net flow in the South Delta to the upstream direction. Coincident with this change was a strong peak in delta smelt salvage (Nobriga *et al.* 2000). This observation indicates that short-term salvage can significantly increase when the HORB is installed in such a manner that it causes a sharp change or reversal of positive net daily flow in the South and Central Delta.

Based on the assessment by USFWS (2008), there is the potential for the HOR gate to result in short-term negative effects to Delta Smelt by influencing the hydraulics of Old and Middle

Rivers, particularly in terms of creating greater short-term increased reverse OMR flows when the HOR gate is initially closed. However, the general improvements to OMR flows because of less south Delta exports, combined with the flexibility to manage the proposed HOR gate in real time would limit the potential for adverse effects. If necessary, opening and closing of the HOR gate could be done in consideration of the most recent fish distribution information (e.g., Spring Kodiak Trawl or 20-mm Survey) as well as simulation (e.g., PTM) modeling of the likely effects of the HOR gate operational switches; adjustments to south Delta exports could then be done accordingly to avoid short-term increases in entrainment.

In addition to broad-scale, far-field effects of the HOR gate on south Delta hydrodynamics, there may be localized effects on migrating adult Delta Smelt. Studies of the rock barrier installed at the HOR in 2012 suggested the structure created eddies that could have resulted in enhanced predatory fish habitat and increased predation on juvenile salmonids (California Department of Water Resources 2015a); such adverse effects could also occur to Delta Smelt as a result of HOR gate operations.

6.1.3.4.1.2 Population-Level Effects

Over 2,300 beach seine samples[14] in the San Joaquin River between Dos Reis (river mile 51) and Weatherbee (river mile 58) between 1994 and 2015 yielded only four Delta Smelt (all during February–April). Nearly 30,000 trawl samples at Mossdale[15] from 1994 to 2011 resulted in the capture of 44 Delta Smelt, principally during March-June. As described in the individual-level effects sections, careful management of OMR flows and HOR gate operations will limit movement of adult Delta Smelt into the south Delta where they would be subject to high entrainment risk and impact mechanisms directly associated with the presence and operation of the HOR gates. Therefore, there should be no meaningful adverse effect to the population of migrating adult Delta Smelt.

6.1.3.4.2 Spawning Adults (February-June)

6.1.3.4.2.1 Individual-Level Effects

The effects to spawning adults are assumed to be the same as those described above for migrating individuals (section 6.1.3.4.1.1).

6.1.3.4.2.2 Population-Level Effects

The effects to spawning adults are assumed to be the same as those described above for migrating individuals (section 6.1.3.4.1.2).

6.1.3.4.3 Eggs/Embryos (Spring: ~March-June)

6.1.3.4.3.1 Individual-Level Effects

As noted for other potential effects of the PA, Delta Smelt eggs and embryos are demersal and adhesive, and so the potential hydrodynamic effects of the HOR gate would not be expected to result in adverse effects to individuals.

[14] Data were obtained from http://www.fws.gov/lodi/jfmp/, files <Beach Seines CHN _ POD Species 1976-2011.xlsx> and <Beach Seines CHN _ POD Species 2012-2015.xlsx> accessed September 14, 2015.
[15] Data were obtained from http://www.fws.gov/lodi/jfmp/, files < Mossdale Trawls CHN _ POD Species 1994-2011.xlsx> and < Mossdale Trawls CHN & POD Species 2012-2015.xlsx> accessed September 14, 2015.

6.1.3.4.3.2 Population-Level Effects

The demersal and adhesive nature of Delta Smelt eggs means that there would be no adverse population-level effects from the HOR gate.

6.1.3.4.4 Larvae/Young Juveniles (Spring: ~March-June)

6.1.3.4.4.1 Individual-Level Effects

Larval/young juvenile Delta Smelt are inherently more vulnerable to far-field hydrodynamic effects of exports and barrier/gate operations (e.g., greater risk of south Delta entrainment with HOR gate closure). It is not known if they are more vulnerable than adults to near-field effects (e.g., greater predation because of near-field changes in hydraulics). As described above, modeling in support of the PA does not indicate that there will be a consistent decrease in the proportional entrainment of larval and small juvenile Delta Smelt, in part because of the modeling assumption about the frequency of HOR gate closures during spring.

6.1.3.4.4.2 Population-Level Effects

Based on the infrequent occurrence of adult Delta Smelt near the HOR gate, it is likely that larval and young juvenile Delta Smelt will only very rarely occur near the HOR gate. Thus, there should be no population impact of the structures themselves.

6.1.3.4.5 Juveniles (Summer/Fall: ~July-December)

6.1.3.4.5.1 Individual-Level Effects

Effects to individual juvenile Delta Smelt from HOR gate operations would be similar to those for adult Delta Smelt, in terms of potential for broad-scale and local effects; however, as discussed in population-level effects next, these effects would apply to very few individuals.

6.1.3.4.5.2 Population-Level Effects

Based on the infrequent occurrence of adult Delta Smelt near the HOR gate, it is likely that larval and young juvenile Delta Smelt will only very rarely occur near the HOR gate. Thus, there should be no population impact of the structures themselves.

6.1.3.5 Habitat Effects

6.1.3.5.1 Abiotic Habitat

Conceptually, the freshwater flow regime and its interaction with the system bathymetry and landscape affect the quantity and quality of available habitat (e.g., Peterson 2003). The USFWS (2008) BiOp's RPA included an action to increase Delta outflow in fall following wet and above normal years based on specific targets for X2, the geographic location of the 2-ppt salinity isohaline in the estuary. This action aimed to restore a greater extent and quality of fall habitat for juvenile Delta Smelt in wetter years in order to counteract the lower variability and smaller size of the low-salinity zone during fall of recent years (fall abiotic habitat) that had been assessed by USFWS (2008) to have occurred as a result of CVP/SWP operations (see also Feyrer *et al.* 2011; Cloern and Jassby 2012). This RPA element has been included as part of the PA and this section compares results for PA versus NAA using the abiotic habitat index of Feyrer *et al.* (2011); there is scientific debate and uncertainty regarding this method, as described in Appendix 6.A, *Quantitative Methods for Biological Assessment of Delta Smelt*. Year-around summaries of X2 are provided in Appendix 5.A, *CALSIM Methods and Results* (box plots: 5.A.6-29-1 to 5.A.6-29-6; exceedance plots: Figures 5.A.6-29-7 to 5.A.6-29-19; Table 5.A.6-29).

6.1.3.5.1.1 Juveniles (Fall: ~September-December)

6.1.3.5.1.1.1 Individual-Level Effects

As described by USFWS (2008: 233), during the fall (September-December), Delta Smelt are maturing pre-adults that rely heavily on suitable habitat conditions in the low salinity portion of the estuary. USFWS (2008: 233) briefly defined suitable habitat for Delta Smelt during this time period as "the abiotic and biotic components of habitat that allow Delta Smelt to survive and grow to adulthood: biotic components of habitat include suitable amounts of food resources and sufficiently low predation pressures; abiotic components of habitat include the physical characteristics of water quality parameters, especially salinity and turbidity."

As noted by Feyrer *et al.* (2007; 2011), analyses conducted over this portion of the Delta Smelt life cycle provide support for a population-level effect of fall habitat conditions or indices of those conditions. In addition, analyses by Miller *et al.* (2012) and Rose *et al.* (2013a, b) suggest that prey density/food limitation during this part of the life cycle may also have population-level effects on Delta Smelt.

As previously noted, in the USFWS (2008) BiOp, the RPA included an action to increase Delta outflow in fall following wet and above normal years based on specific targets for X2. This action aimed to restore a greater extent of fall habitat for juvenile Delta Smelt following wetter years in order to counteract a trend toward lower variability and smaller size of the low-salinity zone during fall of recent years (Feyrer *et al.* 2011; Cloern and Jassby 2012). Feyrer *et al.* (2011) suggested that increased habitat area provides more space for individuals to safely live and reproduce, presumably lessening the likelihood of density-dependent effects (e.g., food limitation, disease, and predation), and lessening the probability of stochastic events increasing the risk of mortality (e.g., cropping by predators, contaminant events, or the direct/indirect effects of water diversions).

As described in Section 3.3.2, *Operational Criteria*, of Chapter 3, *Description of the Proposed Action*, the fall X2 action from the USFWS (2008) BiOp has also been proposed to be included in the PA provided, as discussed in Chapter 3, that the research and results of the Collaborative Science and Adaptive Management program show it is required to avoid jeopardy of any endangered or threatened species or result in the destruction or adverse modification of designated critical habitat for those species. Thus, no meaningful difference in fall abiotic habitat index is expected to occur. To confirm this, a quantitative examination of the PA effects on abiotic habitat suitability was undertaken based on the abiotic habitat index method of Feyrer *et al.* (2011) (Appendix 6.A, *Quantitative Methods for Biological Assessment of Delta Smelt,* Section 6A.4.1). The considerable similarity in mean fall abiotic habitat index by water-year type between NAA and PA emphasizes that there would be little difference in fall outflow management under the PA in all water year types, relative to NAA (Table 6.1-19; Figure 6.1-23 and Figure 6.1-24). Any differences are model "noise".

Table 6.1-19. Mean Fall Abiotic Habitat Index, Based on the Method of Feyrer *et al.* (2011).

Water Year Type	NAA	PA	PA vs. NAA[1]
All	5,026	5,048	21 (0%)
Wet	7,251	7,245	-6 (0%)
Above Normal	5,386	5,441	55 (1%)
Below Normal	3,748	3,742	-6 (0%)
Dry	3,845	3,911	66 (2%)
Critical	2,985	2,985	0 (0%)

Note:
[1] Negative values indicated abiotic habitat index under the proposed action (PA) than under the no action alternative (NAA).

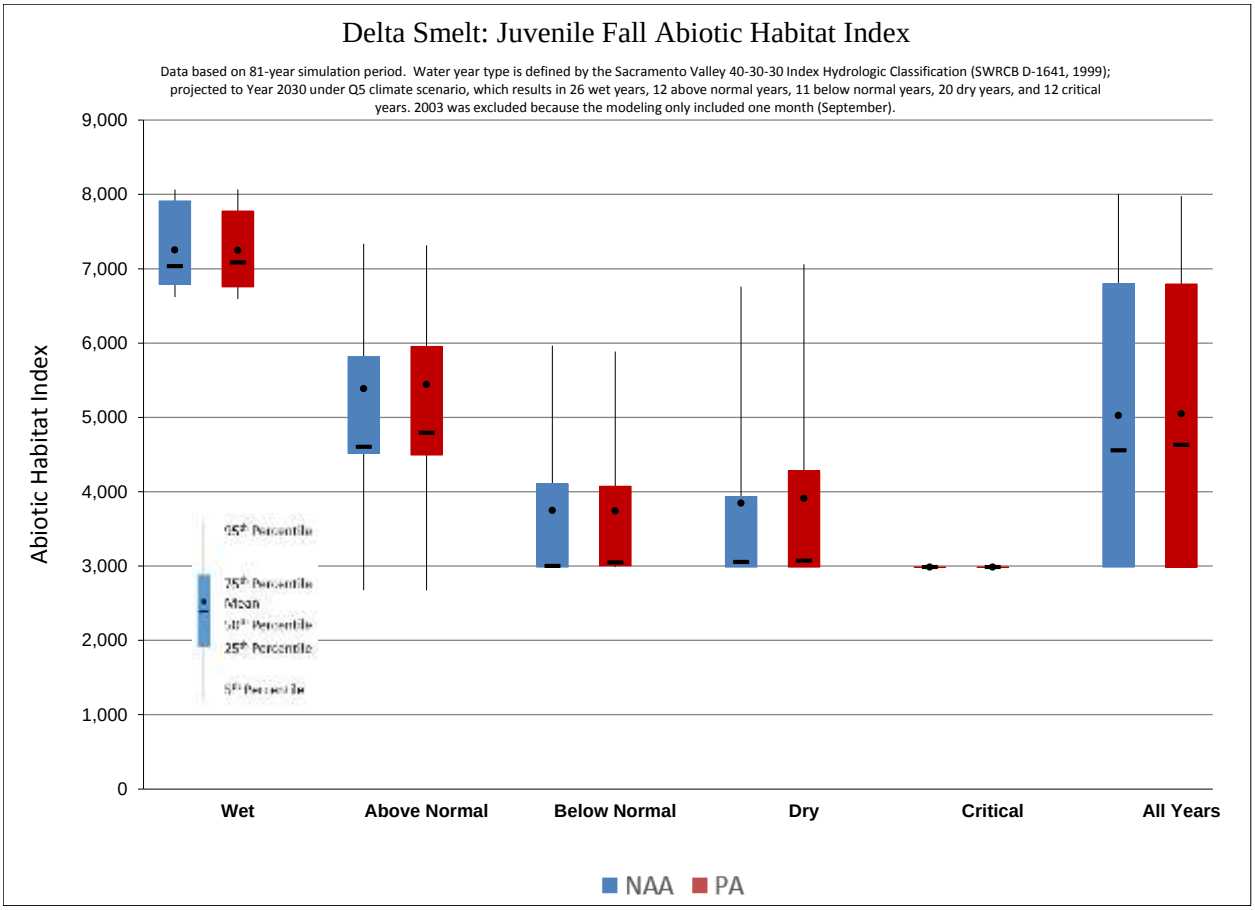


Figure 6.1-23. Box Plot of Mean Fall Abiotic Habitat Index, Grouped by Water Year Type, Based on the Method of Feyrer *et al.* (2011)

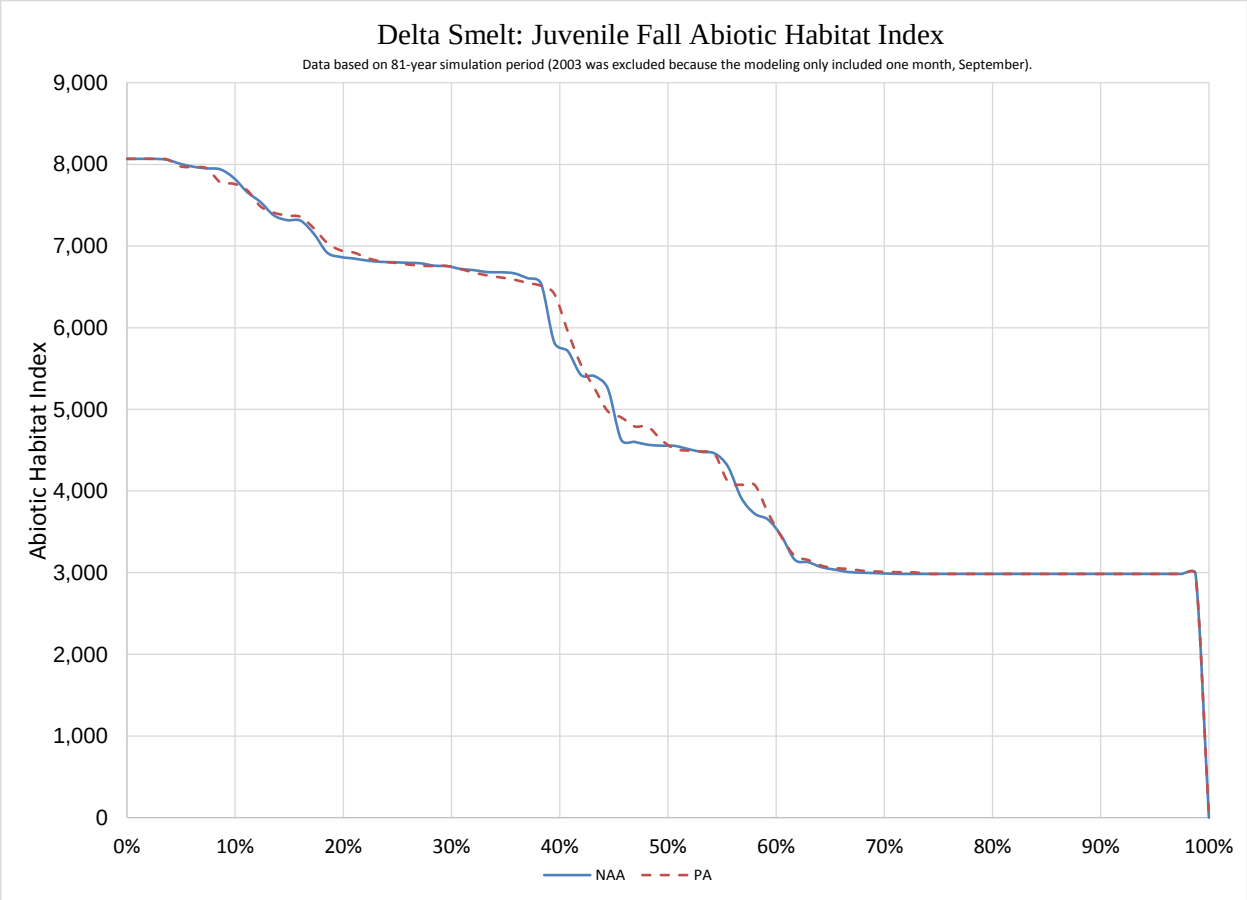


Figure 6.1-24. Exceedance Plot of Mean Fall Abiotic Habitat Index, Based on the Method of Feyrer *et al.* (2011).

6.1.3.5.1.1.2 Population-Level Effects

The PA would not have an adverse effect on Delta Smelt juveniles in the fall.

6.1.3.5.2 Water Temperature

As noted in the effects analysis for NMFS-managed species (Chapter 5, *Effects Analysis for Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale*), Kimmerer (2004: 19-20) described water temperature in the San Francisco Estuary as depending mainly on air temperature, and that even in the Delta the relationship between air and water temperature is only slightly affected by freshwater inflow. As examples, Kimmerer (2004: 20) noted that at Freeport, high inflow reduces water temperature on warm days, presumably because water reaches the Delta before its temperature equilibrates with air temperature, and 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). Specifically, Delta water temperatures are primarily driven by air temperatures and the lagged effects from previous days' conditions (Wagner et al. 2011).

However, operational changes under the PA with respect to dual conveyance means that it is prudent to investigate whether water temperature is expected to differ between the NAA and the PA, and if so, why. To do this, DSM2-QUAL modeling was undertaken to predict water temperatures for the NAA and PA scenarios at four locations: 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, *DSM2 Temperature Modeling*, of Appendix 5.B, *DSM2 Methods and Results*, with results in Section 5.B.5, *DSM2 Results*, of the same appendix. The analysis below focuses on the two stations of greatest relevance to Delta Smelt: Rio Vista and Prisoners Point. Note that the nature of the DSM2-QUAL modeling is such that absolute projections of water temperature must be made with caution (e.g., regional correction factors must be applied), but site-specific comparisons between scenarios can be made. As described in Attachment 5.B.A.4, *DSM2 Temperature Modeling*, of Appendix 5.B, the DSM2 QUAL simulations result in somewhat higher different water temperatures than historical conditions: For Rio Vista, the DSM2-QUAL estimates of water temperature are 0.3–0.6°C less than historical in April–June; 0.3–0.5°C greater than historical in July–August; and 0.1–0.5°C less than historical in September-November. No specific comparison was made for Prisoner's Point, but comparisons for nearby stations in the east Delta (Mokelumne River at San Joaquin River and Little Potato Slough) were always biased low, averaging -0.2°C to -0.8°C.

6.1.3.5.2.1 Migrating Adults (December-March)

6.1.3.5.2.1.1 Individual-Level

From examination of exceedance plots of Rio Vista mean water temperatures (Figure 5.B.5.40-1 in Appendix 5.B, *DSM2 Methods and Results*, Section 5.B.5), the only discernible differences in water temperature were in March, and these were small differences (~0.1°C greater under PA). At Prisoners Point (Figure 5.B.5.41-1 in Appendix 5.B, Section 5.B.5), differences were evident in January-March, presumably as a result of the HOR gate retaining a greater proportion of slightly warmer San Joaquin River water in the main stem, combined with less Sacramento River inflow entering the interior Delta. Differences in March were of the order of 0.3–0.4°C. Although differences in water temperature between NAA and PA were modeled, these were during a relatively cool part of the year and therefore are not expected to have significant effects on migrating adults in that portion of the Delta.

From examination of exceedance plots of Rio Vista mean water temperatures (Figure 5.B.5.40-1 in Appendix 5.B, *DSM2 Methods and Results*, Section 5.B.5), there were no discernible differences in water temperature (maximum "differences" were well within model noise, e.g., ~0.1°C greater under PA in March). At Prisoners Point (Figure 5.B.5.41-1 in Appendix 5.B, Section 5.B.5), modeled differences were comparable to model noise during January-March (+0.3 to +0.4°C), presumably as a result of the HOR gate retaining a greater proportion of the slightly warmer San Joaquin River water in the main stem, combined with less Sacramento River inflow entering the interior Delta. This may reflect a water temperature change that would actually occur, but if it did, it would occur during a cool part of the year and therefore should not affect Delta Smelt.

6.1.3.5.2.1.2 Population-Level Effects

Migrating adult Delta Smelt may experience slightly warmer temperatures in the lower San Joaquin River, but given that these temperatures would be expected to well within the tolerance of the species, there should not be any population level impact.

6.1.3.5.2.2 Spawning Adults (February-June)

6.1.3.5.2.2.1 Individual-Level Effects

As described previously for migrating adult Delta Smelt, there might be slightly greater water temperatures under PA compared to NAA in the San Joaquin River. Delta smelt may begin spawning in the San Joaquin River in February, and will spawn during March of most years (see data collected for Spring Kodiak Trawling; https://www.wildlife.ca.gov/Conservation/Delta/Spring-Kodiak-Trawl). Previously published modeling studies have indicated that warmer temperatures (caused by climate change) would tend to result in earlier spawning, but they provide no indication that the duration of the spawning window would be affected (Wagner *et al.* 2011; Brown *et al.* 2013). Earlier spawning could result in spawning adults being of smaller mean size, as they would have had less time to grow to maturity (Brown *et al.* 2013).

6.1.3.5.2.2.2 Population-Level Effects

The recent simulation-based life cycle modeling by Rose *et al.* (2013a,b) indicates that egg supply has been a major factor affecting Delta Smelt abundance in the recent past. Climate change is anticipated to warm Delta water temperatures and as such could affect the length of time that Delta Smelt have to reach adulthood (Brown *et al.* 2013). If this occurs, it would affect egg supply. As described above, it is uncertain whether the PA will actually affect water temperature in the Delta, but if it does, that effect would be very minor and very localized. Thus, it is unlikely that project effects on water temperature would translate into a population-level effect on Delta Smelt. 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).

6.1.3.5.2.3 Eggs/Embryos (Spring: ~March–June)

6.1.3.5.2.3.1 Individual-Level Effects

Most Delta Smelt hatch during March-May. In warm years, hatching can begin in February and in cool years, it can extend at least into June. Bennett (2005: 17) reviewed Delta Smelt embryo and larval survival data from laboratory studies and found that optimal hatching occurred at 15–17°C. As previously noted for adult Delta Smelt, there would be little if any difference in temperature between NAA and PA because river flows have such a minor influence on water temperatures in the Delta except at the inflowing river margins (Kimmerer 2004; Wagner *et al.* 2011). Although strict comparisons to absolute thresholds are not appropriate for the DSM2-QUAL data, the general pattern for Prisoners Point in March suggests that the greater water temperature under PA would be slightly closer toward optimum hatching temperature than under NAA (Figure 5.B.5.41-1 in Appendix 5.B, *DSM2 Methods and Results*, Section 5.B.5), whereas in May, temperatures under PA may be marginally further away from optimum compared to NAA, although these differences were very small. Bennett (2005: 17) also noted that incubation time of embryos decreases with increasing water temperature, from around 18 days at 10°C to 9 days at 15°C and 7 days at 20°C. Therefore, for example, a 0.3°C greater water temperature

under PA could give a 0.5-day shorter incubation time for Delta Smelt occurring in the lower San Joaquin River.

6.1.3.5.2.3.2 Population-Level Effects

The slightly greater Prisoners Point water temperature under PA that was estimated by DSM2-QUAL could result in shorter embryo incubation time, as well as slightly lower or higher hatching success, depending on the month. The effects would be limited to the portion of the Delta Smelt population occurring in the San Joaquin River which, as inferred from the spawning adult distribution (see previous discussion), generally would be expected to be a lower proportion of the population than would occur in the north Delta. As previously noted, in general it is expected that air temperature would be the main driver on water temperature in the Delta (Wagner *et al.* 2011), and the differences between PA and NAA scenarios were very small.

6.1.3.5.2.4 Larvae/Young Juveniles (Spring: ~March-June)

6.1.3.5.2.4.1 Individual-Level Effects

Bennett's (2005: 17) review of the laboratory studies on water temperature effects on larval Delta Smelt found that greater water temperature leads to smaller length at hatching and smaller length at first feeding. The marginally higher water temperatures estimated under the PA relative to NAA in at Prisoners Point (see discussion above) therefore could result in Delta Smelt that are slightly smaller, although the differences between scenarios was very small. There could be several effects to Delta Smelt from this smaller size (IEP MAST Team 2015: 37). First, small size would result in small gape size, which would limit the size of prey items that could be eaten. Second, there may be greater vulnerability to a wider range of predators. Third, smaller larvae could be more susceptible to hydrodynamic transport toward the south Delta export facilities for a given level of pumping. Bennett (2005: 11) noted that there is higher mortality of larvae above 20°C; the DSM2-QUAL modeling data for Prisoners Point in June suggested that there could be a slight increase in the number of days in this range (Figures 5.B.5.41-3 to 5.B.5.41-6 in Appendix 5.B, *DSM2 Methods and Results,* Section 5.B.5; although as noted previously, it is not appropriate to examine more than general patterns when comparing the NAA and PA scenarios).

6.1.3.5.2.4.2 Population-Level Effects

Overall, the DSM2-QUAL analysis suggested that there may be slightly lower larval Delta Smelt survival in the lower San Joaquin River because of slightly higher water temperature. This would affect the portion of the population occupying this area. Data from the 20-mm survey indicate that larval Delta Smelt occur frequently in this area (see Table 7 of Merz *et al.* 2011), so an appreciable portion of the population could be subject to this adverse effect. However, as previously noted, in general it is expected that air temperature would be the main driver on water temperature in the Delta and flow effects would be of minor importance (Wagner *et al.* 2011).

6.1.3.5.2.5 Juveniles (Summer/Fall: ~July-December)

6.1.3.5.2.5.1 Individual-Level Effects

Water temperatures above 20°C become increasingly stressful to juvenile Delta Smelt up to the range that has been observed to be lethal (~25–29°C; Swanson *et al.* 2000; Komoroske *et al.* 2014). The DSM2-QUAL modeling results suggested water temperature would be similar or slightly warmer under the PA compared to NAA, at both the Sacramento River at Rio Vista and San Joaquin River at Prisoners Point during the summer (July–September). The differences that occurred in the warmer 50% years indicated about 0.1–0.2°C greater temperature under the PA

(Figure 5.B.5.40-1 and Figure 5.B.5.41-1 in Appendix 5.B, *DSM2 Methods and Results*, Section 5.B.7)

6.1.3.5.2.5.2 Population-Level Effects

As reviewed by the IEP MAST team (2015), high summer water temperature has a negative effect on the Delta Smelt population, as it has been linked to Delta Smelt subadult abundance in the fall (Mac Nally *et al.* 2010) and long-term population dynamics (Maunder and Deriso 2011; Rose *et al.* 2013a, b). The marginally greater water temperature in the summer could have a small adverse effect on the whole Delta Smelt population, through mechanisms such as reduced habitat extent, increased metabolic requirements (reduced energy intake for growth), and greater susceptibility to disease or the effects of contaminants (IEP MAST Team 2015). The difference in water temperature was small, however, perhaps suggesting limited adverse effects at the population level, particularly given that air temperature is the main driver of Delta water temperature and effects of flow have very little importance (Wagner *et al.* 2011).

6.1.3.5.3 Sediment Removal (Water Clarity)

Water clarity (turbidity) is a very important habitat characteristic for Delta Smelt and is a significant predictor of larval feeding success (presumably by providing a visual contrast to enable the larvae to locate and ingest prey; Baskerville-Bridges *et al.* 2004) and juvenile distribution (Nobriga *et al.* 2008; Feyrer *et al.* 2011) that has been correlated to long-term changes in abundance or survival either by itself or in combination with other factors (Thomson *et al.* 2010; Maunder and Deriso 2011). Cloern *et al.* (2011) noted the uncertainty in future turbidity trends in the Delta: specifically, it is unclear whether a 40-year average decline in turbidity of 1.6% per year will continue at this rate, slow down, or level off. Should such a trend continue, it presumably will further decrease the downward trend in Delta Smelt habitat quality estimated by Feyrer *et al.* (2011) (as described in Brown *et al.* (2013).

Most sediment entering the Delta comes from the Sacramento River (Wright and Schoellhamer 2004). The NDD is expected to divert a portion of the Sacramento River's sediment load, which could result in higher water clarity downstream because less sediment may over time allow greater erosion and less wind- and velocity-driven resuspension of sediment into the water column. The BDCP public draft included estimates of sediment diverted by the NDD at the late long term time frame (2060) based on historic sediment load estimates for 1991–2002 (see Section 5C.D.3 in the BDCP public draft, Attachment 5C.D to Appendix 5.C, *Upstream Water Temperature Methods and Results*). For the present effects analysis of the PA, very similar analytical methods were used based on sediment load estimates for water years 1991–2003, matched to CalSim flow and NDD diversion estimates for the same years. The analysis suggested that a mean of 10% (range: 5–15%) of combined sediment load entering the Delta from combined inflow at Freeport and the Yolo Bypass would be removed by the NDD. Considering only the Sacramento River load at Freeport, it was estimated that a mean of 11% (range: 7–16%) of sediment load would be removed by the NDD. If this sediment, some of which will be collected in the sedimentation basins (described in Section 3.2.2, *North Delta Diversions*, of Chapter 3, *Description of the Proposed Action*) is not returned to the system, it is possible that water transparency in the Delta will increase over time due to project operations. However, the extent of increases in water clarity cannot be accurately predicted without application of a full suspended sediment model incorporating the whole estuary; modeling has been noted to be necessary for assessment of the effects of managing regional transport of

sediment in the Delta (Schoellhamer *et al.* 2012). Thus, the following effects analysis should be understood to have low certainty. Note that the analysis did not attempt to provide a quantitative estimate for sediment removal by the south Delta export facilities under the NAA or PA; based on the estimates by Wright and Schoellhamer (2005), sediment removal by the south Delta export facilities in 1999-2002 averaged around 2% of the sediment entering the Delta at Freeport, i.e., an order of magnitude less than estimated to be removed at the NDD, so the net sediment removal under the PA (NDD exports plus less south Delta exports than NAA) would be expected to be appreciably greater than sediment removal under NAA. As described in Section 3.2.10.6, *Dispose Spoils*, in Chapter 3, DWR will collaborate with USFWS and CDFW to develop and implement a sediment reintroduction plan that provides the desired beneficial habitat effects of maintained turbidity while addressing related permitting concerns (the proposed sediment reintroduction is expected to require permits from the Water Control Board and USACE). This would mitigate the effects of sediment removal by the NDD.

6.1.3.5.3.1 Migrating Adults (December-March)

6.1.3.5.3.1.1 Individual-Level Effects

As described previously for south Delta entrainment, some adult Delta Smelt migrate upstream in response to winter increases in suspended sediment and flow (Grimaldo *et al.* 2009). Suspended sediment may conceal Delta Smelt from visual predators (reviewed by Sommer and Mejia 2013), so that increases in water clarity may result in lower survival. Turbidity could also influence Delta Smelt's sampling gear avoidance, as suggested by Latour (2015). Given the timing of the upstream migration in the often high-flow winter months, during which suspended sediment concentration is greatest (Table 6.1-20), removal of sediment by the NDD may have limited adverse effects on individual Delta Smelt because the transparency of inflowing Sacramento River would not be expected to be altered in real-time. To the extent there is a concern for sediment removal affecting water clarity, it may be a long-term, population-level concern rather than a real-time concern for individual migrating adult Delta Smelt.

6.1.3.5.3.1.2 Population-Level Effects

Following from the discussion of individual-level effects, population-level adverse effects on migrating adult Delta Smelt from sediment removal by the NDD may be limited by the occurrence of this life stage in higher flow months, when suspended sediment concentration often is relatively high. The population-level impact of sediment removal at the NDD cannot be reliably predicted at this time. If there is an effect, it may be manifested in the long term. As previously described, DWR will collaborate with USFWS and CDFW to develop and implement a sediment reintroduction plan that provides the desired beneficial habitat effects of maintained turbidity while addressing related permitting concerns.

Table 6.1-20. Mean Monthly Suspended Sediment in the Sacramento River at Freeport, 1957-2014 (mg/l).

Month	Concentration
January	99
February	104
March	86
April	63
May	51
June	34
July	32
August	29
September	33
October	28
November	40
December	77

Source: http://waterdata.usgs.gov/nwis/monthly/?referred_module=sw&site_no=11447650&por_11447650_4=2209860,80154,4,1956-10,2014-09&start_dt=1956-10&end_dt=2014-09&format=html_table&date_format=YYYY-MM-DD&rdb_compression=file&submitted_form=parameter_selection_list. Accessed: September 17, 2015.

6.1.3.5.3.2 Spawning Adults (February-June)

6.1.3.5.3.2.1 Individual-Level Effects

Given the timing of the upstream migration in the often high-flow winter months, during which suspended sediment concentration is greatest (Table 6.1-20), removal of sediment by the NDD may have limited adverse effects on individual Delta Smelt because the transparency of inflowing Sacramento River would not be expected to be altered in real-time. To the extent there is a concern for sediment removal affecting water clarity, it may be a long-term, population-level concern, not a real-time concern, for individual Delta Smelt. However, as described in Section 3.2.10.6, *Dispose Spoils*, DWR will collaborate with CDFW and USFWS to develop and implement a sediment reintroduction plan that would mitigate the effects of sediment removal by the NDD.

6.1.3.5.3.2.2 Population-Level Effects

The population-level impact of sediment removal at the NDDs cannot be reliably predicted at this time. If there is an effect, it may be manifested in the long term. The extent of this effect cannot be accurately estimated without use of a full suspended sediment model. As noted in the individual-level effects discussion, sediment reintroduction would mitigate any effects of sediment removal by the NDD.

6.1.3.5.3.3 Eggs/Embryos (Spring: ~March-June)

6.1.3.5.3.3.1 Individual-Level Effects

Increases in water clarity during the latter parts of spring when river inflow's suspended sediment concentration goes down (Table 6.1-20) may have the potential to result in adverse effects to individual Delta Smelt eggs/embryos should they become more visible to predators. To the extent there is a concern for sediment removal affecting water clarity, it may be a long-term, population-level concern, not a real-time concern for individual Delta Smelt. As described for

other life stages, development and implementation of a sediment reintroduction plan would mitigate any effects of sediment removal by the NDD.

6.1.3.5.3.3.2 Population-Level Effects

As noted for spawning Delta Smelt, the population-level impact of sediment removal at the NDDs cannot be reliably predicted at this time. If there is an effect, it may be manifested in the long term. The extent of this effect cannot be accurately estimated without use of a full suspended sediment model. As noted in the individual-level effects discussion, sediment reintroduction would mitigate any effects of sediment removal by the NDD.

6.1.3.5.3.4 Larvae/Young Juveniles (Spring: ~March-June)

6.1.3.5.3.4.1 Individual-Level Effects

As noted earlier, water clarity is related to larval/young juvenile Delta Smelt feeding success (Baskerville-Bridges *et al.* 2004) and spatial distribution (Sommer and Mejia 2013). As with eggs/embryos and the latter portion of the spawning adult life stage, the occurrence of larval/young juvenile Delta Smelt bridges the transition between higher flow winter months and lower flow summer months, during which time the suspended sediment concentration in inflowing Sacramento River water decreases and resuspension of sediment delivered in the higher flow months becomes more important. As noted for other life stages, to the extent there is a concern for sediment removal affecting water clarity, it may be a long-term, population-level concern, not a real-time concern for individual Delta Smelt. Development and implementation of a sediment reintroduction plan would mitigate any effects of sediment removal by the NDD.

6.1.3.5.3.4.2 Population-Level Effects

As noted for other life stages, the population-level impact of sediment removal at the NDDs cannot be reliably predicted at this time. If there is an effect, it may be manifested in the long term. The extent of this effect cannot be accurately estimated without use of a full suspended sediment model. As noted in the individual-level effects discussion, sediment reintroduction would mitigate any effects of sediment removal by the NDD.

6.1.3.5.3.5 Juveniles (Summer/Fall: ~July-December)

6.1.3.5.3.5.1 Individual-Level Effects

Occurrence of juvenile Delta Smelt during the low-flow time of year when suspended sediment concentration in inflow is at a minimum (Table 6.1-20) suggests that the NDD's removal of sediment could affect individual juvenile Delta Smelt by increasing water clarity, given the importance of resuspension of sediment delivered to the estuary by higher flows in winter/early spring. As noted for other life stages, to the extent there is a concern for sediment removal affecting water clarity, it may be a long-term, population-level concern, not a real-time concern for individual Delta Smelt. Development and implementation of a sediment reintroduction plan would mitigate any effects of sediment removal by the NDD.

6.1.3.5.3.5.2 Population-Level Effects

As noted for other life stages, the population-level impact of sediment removal at the NDDs cannot be reliably predicted at this time. If there is an effect, it may be manifested in the long term. The extent of this effect cannot be accurately estimated without use of a full suspended sediment model. As noted in the individual-level effects discussion, sediment reintroduction would mitigate any effects of sediment removal by the NDD., *Dispose Soils*

6.1.3.5.4 Entrainment of Food Web Materials

As highlighted by Arthur *et al.* (1996), Jassby and Cloern (2000) and Jassby *et al.* (2002), and the USFWS (2008) BiOp, CVP/SWP water exports directly entrain phytoplankton and zooplankton which are the base of the food web supporting the production of Delta Smelt. Although these food web materials are exported (and export-related hydrodynamics limit transport of a lot of production into Suisun Bay; Jassby and Cloern 2000), it is not known whether export losses greatly affect overall fish production because other large impacts are also occurring in tandem (clam grazing and ammonium inhibition of per capita diatom growth rates). Entrainment of phytoplankton and zooplankton by the south Delta export facilities generally would be expected to be somewhat less under the PA, but the NDD would add a new source of loss along the Sacramento River. The impact of this was examined using an assessment of phytoplankton carbon entrained, based on cholorophyll *a* concentration data for Hood (representing the load of entrained phytoplankton), in relation to the biomass of phytoplankton in the Delta (taken from Antioch chlorophyll *a* data, multiplied up to the volume of the Delta). The methods for this analysis are presented in Appendix 6.A, *Quantitative Methods for Biological Assessment of Delta Smelt*, Section 6A.4.2. This analysis is essentially an approximation of potential entrainment of phytoplankton carbon load that could be entrained by the NDD. Factors that could offset any potential effects to Delta Smelt include the in situ productivity of phytoplankton carbon within the Delta, which could be relatively large, and reduced entrainment of phytoplankton carbon by the south Delta export facilities under the PA. These factors are discussed qualitatively in the analysis.

Median (50th percentile) estimates of phytoplankton carbon load entrained by the NDD ranged from around 0.2 metric tons/day in April and May (5th to 95th percentile ranges were 0.00–0.02 to ~ 1.8 metric tons/day) to ~ 1.6 metric tons/day in February (5th to 95th percentile range ~ 0.13 to 5.7 metric tons/day) (Table 6.1-21). Estimates of phytoplankton carbon biomass in the Delta for 2004–2015 ranged from just under 23 metric tons (December 2011) to over 230 metric tons (May 2010) (Table 6.1-22). Thus, the percentage of Delta phytoplankton carbon biomass estimated to be entrained by the NDD ranged from 0.0% based on the 5th percentile of entrained load estimates at the NDD during several months up to 12% at the 95th percentile load estimate combined with the minimum biomass estimate in December (Table 6.1-23). The median estimates of total fraction of phytoplankton biomass removed by the NDDs ranged from ~ 0.5% to 2% per month when compared to minimum Delta phytoplankton carbon biomass estimates, down to ~ 0.1% to 1% when compared to maximum Delta phytoplankton carbon biomass estimates. On the basis of the 95th percentiles, it appears that the NDD would seldom if ever entrain more than ~5% of the Delta's standing stock of phytoplankton in any given month.

Table 6.1-21. Percentiles of Phytoplankton Carbon Load Estimated to be Entrained (metric tons/day) by the NDD.

Month	Min.	5%	10%	20%	30%	40%	50%	60%	70%	80%	90%	95%	Max.
Jan.	0.00	0.11	0.13	0.17	0.21	0.29	0.50	1.20	1.88	2.28	3.18	4.31	35.16
Feb.	0.00	0.13	0.17	0.25	0.41	1.01	1.62	2.09	2.52	3.03	4.24	5.35	11.51
Mar.	0.00	0.11	0.17	0.26	0.45	0.91	1.33	1.85	2.38	2.89	3.48	3.90	8.51
Apr.	0.00	0.00	0.01	0.04	0.07	0.13	0.20	0.30	0.47	0.70	1.22	1.76	12.95
May	0.00	0.02	0.04	0.07	0.10	0.14	0.19	0.26	0.38	0.58	1.09	1.77	10.78
Jun.	0.05	0.11	0.13	0.17	0.24	0.40	0.65	0.93	1.20	1.48	2.01	2.51	4.80
Jul.	0.00	0.03	0.06	0.40	0.65	0.91	1.12	1.34	1.51	1.66	2.10	2.44	3.77
Aug.	0.00	0.02	0.03	0.07	0.20	0.47	0.64	0.82	0.99	1.27	1.56	1.89	3.15
Sep.	0.00	0.01	0.04	0.15	0.22	0.30	0.37	0.46	0.56	0.73	1.12	1.43	5.35
Oct.	0.00	0.00	0.01	0.04	0.13	0.24	0.33	0.43	0.55	0.69	0.92	1.13	2.82
Nov.	0.00	0.00	0.01	0.04	0.14	0.22	0.33	0.46	0.64	0.91	1.32	1.67	4.73
Dec.	0.00	0.03	0.07	0.13	0.17	0.20	0.24	0.30	0.42	0.81	2.08	2.76	9.72

Note: Values in shaded cells were used in subsequent estimation of percentage of Delta biomass entrained by the NDD.

Table 6.1-22. Mean Daily Biomass (metric tons) of Phytoplankton Carbon Estimated to be Present in the Delta During 2004-2015.

Month	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Min.	Max.
Jan.		125.3	109.2	62.9	139.3	92.3	127.0	71.3	66.7	104.6	66.7	140.1	62.9	140.1
Feb.		95.8	75.2	124.4	122.0	109.4	110.8	82.5	133.8	104.8	122.6	129.4	75.2	133.8
Mar.		132.6	81.6	107.0	116.8	110.1	106.1	123.4	117.8	162.3	125.7	174.8	81.6	174.8
Apr.		96.7	115.9	46.1	156.8	129.4	142.1	89.4	115.4	155.3	116.2	148.1	46.1	156.8
May		96.9	85.1	51.3	110.0	88.6	231.2	47.2	82.3	124.2	86.8	103.4	47.2	231.2
Jun.		90.1	78.1	53.7	95.9	81.1	81.5	46.5	80.3	69.2	66.4	104.7	46.5	104.7
Jul.		100.2	76.6	67.1	83.0	64.3	76.7	66.0	77.6	50.1	70.5	109.4	50.1	109.4
Aug.		74.4	60.2	83.0	76.0	63.6	62.9	89.7	66.7	46.2	84.2		46.2	89.7
Sep.	36.2	49.6	79.7	124.9	71.8	61.9	72.3	84.3	53.6	43.0	84.8		36.2	124.9
Oct.	31.6	75.8	76.2	112.5	59.4	88.3	63.5	106.6	106.8	42.2	73.6		31.6	112.5
Nov.	41.1	61.8	50.6	56.5	61.4	75.3	48.6	112.0	49.4	51.7	76.5		41.1	112.0
Dec.	41.5	71.6	58.3	78.7	72.9	72.5	56.5	22.8	106.0	69.2	121.6		22.8	121.6

Note: Values in shaded cells were used in subsequent estimation of percentage of Delta biomass entrained by the NDD.

Table 6.1-23. Range of Percentage of Phytoplankton Carbon Biomass in the Delta Estimated to be Entrained by the NDD.

Month	Based on Minimum Biomass				Based on Maximum Biomass		
	5%	50%	95%		5%	50%	95%
Jan.	0.2%	0.8%	6.8%		0.1%	0.4%	3.1%
Feb.	0.2%	2.2%	7.1%		0.1%	1.2%	4.0%
Mar.	0.1%	1.6%	4.8%		0.1%	0.8%	2.2%
Apr.	0.0%	0.4%	3.8%		0.0%	0.1%	1.1%
May	0.1%	0.4%	3.7%		0.0%	0.1%	0.8%
Jun.	0.2%	1.4%	5.4%		0.1%	0.6%	2.4%
Jul.	0.1%	2.2%	4.9%		0.0%	1.0%	2.2%
Aug.	0.0%	1.4%	4.1%		0.0%	0.7%	2.1%
Sep.	0.0%	1.0%	3.9%		0.0%	0.3%	1.1%
Oct.	0.0%	1.1%	3.6%		0.0%	0.3%	1.0%
Nov.	0.0%	0.8%	4.1%		0.0%	0.3%	1.5%
Dec.	0.1%	1.1%	12.1%		0.0%	0.2%	2.3%

The loss of phytoplankton carbon at the NDD also must be considered in the context of all CVP/SWP water diversions because inflows to and exports from the Delta strongly affect the flux of bioavailable carbon into the confluence and Suisun Bay (Arthur *et al.* 1996; Jassby and Cloern 2000). If used as the only source for Delta exports and without any change in total Delta exports, the NDD would in principle increase the export of biological productivity to the western Delta and Suisun Bay because the San Joaquin River is much richer in its organic matter load than the Sacramento River (Jassby and Cloern 2000). The PA does not cease exports from the south Delta, but it does reduce them considerably, generally by half or more: the long-term (1922–2003) average reduction compared to NAA from the CalSim modeling ranged from 45% less under PA in January to ~70% less in October; only in December (12% less under the PA) were the differences not close to half or more (Appendix 5.A, *CALSIM Methods and Results*, Figures 5.A.6-27-1 to 5.A.6-27-19 and Table 5.A.6-27). Jassby *et al.* (2002) estimated that on average during spring through fall, the Delta produces 44 metric tons/day of phytoplankton carbon and another 12 metric tons/day flows into the Delta from its tributaries. Of that 56 tons/day, the south Delta export facilities remove ~8 metric tons/day or about 14% (Jassby *et al.* 2002)[16]. It is anticipated that the overall long-term ~50% reduction in south Delta exports will increase the loading of relatively productive San Joaquin River water to the western Delta and Suisun Bay (Table 6.1-24) and therefore should offset some or all of the loss attributable to the NDD, and perhaps could even provide a net beneficial effect.

[16] An additional ~5 metric tons per day were estimated to be removed by agricultural diversions. Such losses would present under both the NAA and PA.

Table 6.1-24. Mean Percentage of Water at Collinsville Originating in the San Joaquin River, from DSM2-QUAL Fingerprinting.

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

CalSim estimates of total Delta exports also provide context for the difference in potential food web productivity between PA and NAA: total Delta exports on average (1922–2003) would be somewhat greater under PA (almost 4.9 million acre feet/year) than under NAA (just under 4.7 million acre feet/year). In general, total Delta exports would be less under PA than NAA in September-November; similar in April-May and August; and generally lower under PA than NAA in the remaining months, to varying degrees (Appendix 5.A, *CALSIM Methods and Results*, Figures 5.A.6-28-1 to 5.A.6-28-19 and Table 5.A.6-28). If phytoplankton availability was a linear function of SWP/CVP exports, then the annual average change in biomass would be around -4%. However, the timing of differences in exports in relation to different life stages is important, and consideration should also be made of the in situ productivity that would occur in the Delta, and the relative contribution of this to the Delta Smelt food web. This is addressed in the analyses of effects to the different Delta Smelt life stages, presented next.

6.1.3.5.4.1 Migrating Adults (December-March)

6.1.3.5.4.1.1 Individual-Level Effects

The primary mechanisms by which entrainment of planktonic organisms might affect individual Delta Smelt is by temporarily reducing density of zooplankton immediately downstream of the NDDs or by reducing the load of phytoplankton further into the estuary, causing some unknown reduction in food for the zooplankton that Delta Smelt eat. These are highly unlikely to cause starvation of any individual Delta Smelt and would most likely fall between no effect and some immeasurably small impact on growth rates of individual fish.

6.1.3.5.4.1.2 Population-Level Effects

At the population level, the effects of entrainment of phytoplankton carbon are likely to be low in terms of affecting Delta Smelt prey abundance. As noted by Baxter *et al.* (2010: 59) and the IEP MAST Team (2015: 76), there has been little study of prey importance for adult Delta Smelt, and there is no evidence for food limitation in the adult life stage.

6.1.3.5.4.2 Spawning Adults (February-June)

6.1.3.5.4.2.1 Individual-Level Effects

As described for migrating adults, the primary mechanisms by which entrainment of planktonic organisms might affect individual Delta Smelt is by temporarily reducing density of zooplankton immediately downstream of the NDDs or by reducing the load of phytoplankton further into the estuary causing some unknown reduction in food for the zooplankton that Delta Smelt eat. These are highly unlikely to cause starvation of any individual Delta Smelt and would most likely fall between no effect and some immeasurably small impact on growth rates of individual fish.

6.1.3.5.4.2.2 Population-Level Effects

As described for migrating adults, at the population level, the effects of entrainment of phytoplankton carbon are likely to be low in terms of affecting Delta Smelt prey abundance. As previously described, there has been little study of prey importance for adult Delta Smelt, and there is no evidence for food limitation in the adult life stage.

6.1.3.5.4.3 Eggs/Embryos (Spring: ~March-June)

6.1.3.5.4.3.1 Individual-Level Effects

This life stage does not feed externally and so would not be affected by entrainment of food web materials.

6.1.3.5.4.3.2 Population-Level Effects

As stated for individual effects, this life stage does not feed externally and so would not be affected by entrainment of food web materials.

6.1.3.5.4.4 Larvae/Young Juveniles (Spring: ~March-June)

6.1.3.5.4.4.1 Individual-Level Effects

As with adult Delta Smelt, lower loads of phytoplankton carbon into the estuary because of NDD entrainment could translate into less food for individual Delta Smelt larvae and young juveniles, but this is not an assured outcome. It was estimated that a range from less than 0.1% to over 5% of phytoplankton carbon entering the Delta could be entrained by the NDD in March–June (Table 6.1-23). However, the phytoplankton has to be converted into copepod biomass to be prey for larval Delta Smelt and that process is not always directly related to phytoplankton density as indexed by chlorophyll *a* concentrations in the water (e.g., Kimmerer 2002). Given lower south Delta exports when north Delta exports are relatively high, there may be a net increase in phytoplankton carbon production in the Delta due to higher loading from the comparatively productive San Joaquin River that could offset some or possibly even all of the loss estimated for the NDD, and perhaps could even provide a net beneficial effect.

6.1.3.5.4.4.2 Population-Level Effects

The feeding success of Delta Smelt larvae appears to be related to prey density (Nobriga 2002). Some statistical analyses of Delta Smelt population dynamics have shown evidence that prey abundance for Delta Smelt during the larval and early juvenile life stage affects Delta Smelt abundance (Maunder and Deriso 2011; Miller *et al.* 2012), while others have found less support for this hypothesis (Mac Nally *et al.* 2010; Thomson *et al.* 2010). The hypothesis was also not supported in a recent empirical study of Delta Smelt feeding ecology and food limitation (Slater and Baxter 2014). In this study, evidence of food limitation was greater for juvenile fish in the late summer than it was for larvae or small juveniles during the late spring. Most likely, food limitation would act as a chronic problem extending across multiple life stages (Rose *et al.* 2013a,b). Less phytoplankton carbon loading to the estuary because of NDD entrainment could reduce the abundance of Delta Smelt's zooplankton prey. However, the estimates of phytoplankton carbon entrainment were not large (up to 5.4% at the higher end 95th percentile (Table 6.1-22). This, in conjunction with observations that in situ production of phytoplankton carbon within the Delta is several times greater than inputs from freshwater inflow (Jassby *et al.* 2002) and that this in situ production is the dominant supply to the planktonic food web that includes Delta Smelt (Sobczak *et al.* 2002), suggests that the entrainment of phytoplankton carbon by the NDD would only have a minor, if any, adverse population-level effect, particularly given the offsetting increases in relatively more productive San Joaquin River water during these months (Table 6.1-24).

6.1.3.5.4.5 Juveniles (Summer/Fall: ~July-December)

6.1.3.5.4.5.1 Individual-Level Effects

The empirical evidence for food limitation during this life stage is generally stronger than it is for other life stages (Slater and Baxter 2014; Hammock *et al.* 2015). Thus, lower phytoplankton carbon load available to the food web (as a result of NDD entrainment) could result in less prey for individual juvenile Delta Smelt. During July-November, it was estimated that less than 5% of phytoplankton standing stock could be entrained by the NDD (95th percentile for high end estimates; Table 6.1-23). It is possible this loss will be offset by higher loading of phytoplankton from the San Joaquin River such that there is no effect to individual Delta Smelt.

6.1.3.5.4.5.2 Population-Level Effects

As described in the Individual-Level Effects section, there could be less prey available for juvenile Delta Smelt because of NDD exports. It is possible this loss will be offset by higher loading of phytoplankton from the San Joaquin River, as well as in situ production of phytoplankton, such that there is no effect to the Delta Smelt population.

6.1.3.5.5 Microcystis

The toxic cyanobacteria *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 Antioch, and Franks Tract (Lehman *et al.* 2010). As reviewed by Brooks *et al.* (2012), *Microcystis* could affect Delta Smelt through direct ingestion, consumption of prey containing high concentrations of toxins, or toxic effects to prey leading to lower prey abundance. *Microcystis* blooms generally occur from June to October, when water temperature is at least 19°C (Lehman *et al.* 2013)[17]. However, this analysis focused on July-November to stay consistent with the general timing of Delta Smelt's juvenile life stage, which co-occurs with *Microcystis* blooms. Lehman *et al.* (2013) suggested that net flows are probably the most important factor maintaining *Microcystis* blooms because low flows with longer residence times allow the slow-growing colonies to accumulate into blooms. Other factors including nutrients are also of importance to *Microcystis* (Lehman *et al.* 2014), but these are not readily predictable for comparison of the NAA and PA scenarios, which introduces some uncertainty to the results.

The potential effects of PA water operations on *Microcystis* were assessed using two approaches. First, the frequency of flow conditions conducive to *Microcystis* occurrence (as defined by Lehman *et al.* 2013) was assessed in the San Joaquin River past Jersey Point (QWEST) and in the Sacramento River at Rio Vista (QRIO), based on DSM2-HYDRO modeling. Second, DSM2-QUAL water temperature modeling (Section 6.1.3.5.2, *Water Temperature*) and DSM2-PTM for estimates of residence time (Appendix 6.A, *Quantitative Methods for Biological Assessment of Delta Smelt,* Section 6.A.4.3, methods discussion) were used to inform the potential for *Microcystis* occurrence, given the importance of water temperature and the probable importance of residence time (although there are no published relationships between *Microcystis* occurrence and residence time in the Delta). Note that more weight is placed on the analysis based on the published flow conditions at which *Microcystis* occurs (Lehman *et al.* 2013), because there are

[17] During the current drought conditions, *Microcystis* has been detected in appreciable quantities in December, presumably because relatively warm temperatures and low inflow have favored growth beyond the typical period of occurrence.

no published analyses between *Microcystis* occurrence and residence time. Both sets of quantitative analyses (*i.e.*, the flow analysis and the residence time/temperature analysis) focused on the summer/fall (July-November) period because it is during this time of the year that *Microcystis* blooms are likely to occur. Note that other factors including nutrients are also of importance to *Microcystis* (Lehman *et al.* 2014), but these are not readily predictable for comparison of the NAA and PA scenarios, which introduces some uncertainty to the results based only on flow or residence time/temperature.

The first analysis examined the frequency of years during July-November in which mean monthly flows were within the range at which *Microcystis* has been shown to occur, per Lehman *et al.* (2013: 155): -240 to 50 m^3/s (approx. -8,500 to 1,800 cfs) for QWEST, and 100-450 m^3/s (approx. 3,500 to 15,900 cfs) for QRIO[18]. This analysis suggested that flow conditions conducive to *Microcystis* bloom occurrence would tend to occur less frequently under the PA than NAA in the San Joaquin River, based on QWEST. For NAA, the percentage of years with QWEST within the range for *Microcystis* occurrence ranged from 89% in October to 98% in August, whereas for PA, the range was from 9% of years in October to 99% of years in August (Table 6.1-25). In neither the NAA nor the PA scenario were mean monthly flows below the range noted for *Microcystis* occurrence, whereas for PA there were substantially more years above the range than for NAA. The results reflected greater mean QWEST flows under the NAA compared to PA, with monthly means under the PA ranging from just under 0 m^3/s (-100 cfs) in August (compared to -168 m^3/s or -5,900 cfs under NAA) to 245 m^3/s (8,600 cfs) in October (compared to 16 m^3/s or 570 cfs under NAA). These results are attributable to less south Delta export pumping under PA than NAA.

[18] The DSM2-HYDRO output locations used for estimating QWEST were RSAN018 + SLTRM004 + SLDUT007; and for QRIO was RSAC101.

Table 6.1-25.Percentage of Modeled Years (1922-2003) in Which Mean Monthly Flow in the San Joaquin River Past Jersey Point (QWEST) Was Below, Within, and Above the Range for *Microcystis* Occurrence (Lehman *et al.* 2013).

	NAA					PA			
	Below Range (< -240 m^3/s)	**Within Range (-240 to 50 m^3/s)**	**Above Range (> 50 m^3/s)**	**Mean Flow, m^3/s (cfs)**		**Below Range (< -240 m^3/s)**	**Within Range (-240 to 50 m^3/s)**	**Above Range (> 50 m^3/s)**	**Mean Flow, m^3/s (cfs)**
July	0%	95%	5%	-162 (-5,714)		0%	78%	22%	68 (2,384)
August	0%	98%	2%	-168 (-5,931)		0%	99%	1%	-3 (-103)
September	0%	96%	4%	-128 (-4,531)		0%	52%	48%	191 (6,729)
October	0%	89%	11%	16 (568)		0%	9%	91%	245 (8,637)
November	0%	91%	9%	-39 (-1,391)		0%	53%	47%	178 (6,281)

Implementation of north Delta export pumping under the PA would result in less Sacramento River flow compared to NAA, as reflected in the examination of QRIO (Table 6.1-26). The percentage of years within the range at which *Microcystis* has been noted to occur ranged from 59% in September to 89% in August under NAA, compared to a range from 48% in September to 96% in July for PA (Table 6.1-26). Given that Lehman *et al.'s* (2013) suggested mechanism for the importance of flow was lower flows leading to sufficiently long residence time to allow *Microcystis* colonies to accumulate into blooms, flows below the range noted for *Microcystis* occurrence by Lehman *et al.* (100-450 m^3/s) could also be favorable for bloom occurrence, whereas flows above the range may reduce residence time sufficiently to limit bloom formation. The percentage of years in which mean monthly flow was above the range that Lehman *et al.* (2013) found for *Microcystis* occurrence was less under PA than NAA in July (0%, compared to 10% under NAA), September (0%, compared to 29% under NAA), and November (10%, compared to 16% under NAA). On the basis of differences in QRIO flow, therefore, there could be greater potential for *Microcystis* occurrence in the lower Sacramento River under the PA than NAA. However, this is presently not an area of intense *Microcystis* blooms and if it remains turbid in the future, it is expected that current conditions will continue.

Table 6.1-26.Percentage of Modeled Years (1922-2003) in Which Mean Monthly Flow in the Sacramento River at Rio Vista Was Below, Within, and Above the Range for *Microcystis* Occurrence (Lehman *et al.* 2013).

	NAA					PA			
	Below Range (< -100 m^3/s)	**Within Range (-100 to 450 m^3/s)**	**Above Range (> 450 m^3/s)**	**Mean Flow, m^3/s (cfs)**		**Below Range (< -100 m^3/s)**	**Within Range (-100 to 450 m^3/s)**	**Above Range (> 450 m^3/s)**	**Mean Flow, m^3/s (cfs)**
July	5%	85%	10%	702 (24,793)		4%	96%	0%	396 (13,984)
August	11%	89%	0%	462 (16,331)		11%	89%	0%	282 (9,942)
September	12%	59%	29%	754 (26,612)		52%	48%	0%	457 (16,136)
October	15%	84%	1%	420 (14,839)		15%	84%	1%	291 (10,275)
November	7%	77%	16%	769 (27,162)		0%	90%	10%	541 (19,097)

The results of the DSM2-PTM-based residence time analysis presented here focus only on the particle insertion locations upstream (east) of Suisun Bay and Suisun Marsh, because this is where effects of the proposed action (PA) on hydraulic residence time are highest. The effects of the PA on residence time varied by subregion. As previously described, there has been no published analysis of the relationship between *Microcystis* occurrence and residence time, so there is uncertainty as to what the differences described here may mean in terms of potential for *Microcystis* occurrence. The results showed that regions with short residence times sometimes are predicted to have large proportional changes in residence time (e.g., locations near the NDDs) and regions with comparatively long residence times typically had moderate to low proportional changes in residence time (Table 6.1-27 through Table 6.1-47). Differences between NAA and PA ranged from almost no change in the Sacramento River Deepwater Shipping Channel to sometimes substantial increases in predicted residence times (e.g., Disappointment Slough where median predictions ranged from -3.8 to + 11.9 days, Mildred Island where median predictions ranged from + 5.8 to + 16.5 days, and Victoria Canal where median predictions ranged from + 3.0 to + 11.7 days). These results indicate that *Microcystis* may have considerably more opportunity for growth in parts of the southern Delta where water temperatures are relatively high during the summer and present-day blooms are often observed.

Table 6.1-27. Summary Statistics of Residence Time (Days) in the Upper Sacramento River Subregion from DSM2-PTM.

Percentile	July			August			September			October			November		
	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
5%	0.4	0.7	0.3 (65%)	0.6	1.2	0.6 (107%)	0.5	0.7	0.3 (57%)	0.5	1.1	0.7 (148%)	0.4	0.8	0.4 (99%)
25%	0.5	1.1	0.7 (135%)	0.6	1.5	0.8 (126%)	0.5	1.0	0.5 (83%)	0.8	1.4	0.7 (87%)	0.6	1.1	0.4 (69%)
50% (median)	0.5	1.2	0.7 (124%)	0.7	1.8	1.1 (164%)	1.2	2.2	1.0 (89%)	1.0	1.7	0.6 (63%)	1.0	1.4	0.4 (45%)
75%	0.8	1.4	0.6 (76%)	1.8	2.0	0.2 (14%)	2.4	2.7	0.4 (15%)	1.6	1.9	0.2 (13%)	1.8	1.7	0.0 (-2%)
95%	2.4	2.7	0.2 (9%)	3.2	3.1	0.0 (-1%)	20.1	11.5	-8.7 (-43%)	2.3	2.3	0.0 (0%)	16.2	10.6	-5.5 (-34%)

Table 6.1-28. Summary Statistics of Residence Time (Days) in the Sacramento River Near Ryde Subregion from DSM2-PTM.

Percentile	July			August			September			October			November		
	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
5%	0.3	0.4	0.1 (33%)	0.5	0.9	0.4 (69%)	0.5	0.6	0.1 (29%)	0.3	0.6	0.3 (76%)	0.4	0.7	0.3 (85%)
25%	0.5	0.8	0.4 (80%)	0.6	1.1	0.5 (89%)	0.5	0.7	0.2 (33%)	0.6	1.2	0.5 (83%)	0.5	0.9	0.4 (78%)
50% (median)	0.5	1.0	0.5 (89%)	0.7	1.3	0.6 (89%)	0.7	1.5	0.8 (113%)	0.9	1.5	0.6 (65%)	0.8	1.3	0.6 (72%)
75%	0.7	1.2	0.5 (65%)	1.3	1.8	0.5 (40%)	1.7	2.1	0.5 (29%)	1.4	1.7	0.2 (16%)	1.1	1.5	0.4 (32%)
95%	1.8	1.7	-0.1 (-6%)	2.4	2.7	0.2 (10%)	2.5	2.5	0.0 (0%)	2.1	2.3	0.2 (12%)	1.9	1.9	0.0 (-1%)

Table 6.1-29. Summary Statistics of Residence Time (Days) in the Sacramento River Ship Channel Subregion from DSM2-PTM.

Percentile	July			August			September			October			November		
	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
5%	43.3	43.4	0.1 (0%)	43.2	43.1	0.0 (0%)	43.2	43.2	0.0 (0%)	42.5	42.5	0.0 (0%)	39.8	39.7	-0.1 (0%)
25%	43.4	43.5	0.0 (0%)	43.3	43.4	0.1 (0%)	43.3	43.3	0.0 (0%)	43.4	43.3	0.0 (0%)	42.3	42.2	0.0 (0%)
50% (median)	43.6	43.6	0.0 (0%)	43.7	43.8	0.1 (0%)	43.7	43.7	0.1 (0%)	43.7	43.6	0.0 (0%)	43.1	43.1	0.0 (0%)
75%	44.0	44.1	0.0 (0%)	44.0	44.1	0.0 (0%)	43.9	44.0	0.0 (0%)	43.9	43.9	0.0 (0%)	44.1	44.0	0.0 (0%)
95%	44.3	44.3	0.0 (0%)	44.2	44.2	0.0 (0%)	44.3	44.3	0.1 (0%)	44.4	44.4	0.0 (0%)	44.3	44.3	0.0 (0%)

Table 6.1-30. Summary Statistics of Residence Time (Days) in the Cache Slough and Liberty Island Subregion from DSM2-PTM.

Percentile	July			August			September			October			November		
	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
5%	20.4	22.5	2.1 (10%)	16.5	19.5	3.0 (18%)	13.1	14.2	1.1 (8%)	11.4	13.8	2.4 (21%)	8.3	9.6	1.3 (15%)
25%	21.3	23.3	2.0 (9%)	17.2	20.8	3.6 (21%)	14.8	17.5	2.7 (18%)	14.6	17.1	2.4 (17%)	11.5	13.1	1.6 (14%)
50% (median)	22.0	23.8	1.8 (8%)	18.3	21.1	2.8 (15%)	16.1	18.7	2.7 (16%)	15.9	18.2	2.2 (14%)	13.4	14.5	1.2 (9%)
75%	22.7	25.1	2.4 (11%)	20.6	22.1	1.5 (7%)	18.2	21.1	2.9 (16%)	17.6	18.6	1.0 (6%)	14.9	15.6	0.7 (5%)
95%	25.8	27.0	1.2 (5%)	22.3	23.7	1.4 (6%)	22.5	22.3	-0.2 (-1%)	19.0	19.5	0.5 (3%)	16.7	16.4	-0.3 (-2%)

Table 6.1-31. Summary Statistics of Residence Time (Days) in the Sacramento River Near Rio Vista Subregion from DSM2-PTM.

Percentile	July			August			September			October			November		
	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
5%	1.4	2.0	0.7 (48%)	5.8	7.4	1.6 (27%)	3.2	1.8	-1.4 (-43%)	3.8	2.7	-1.1 (-29%)	3.6	3.9	0.3 (9%)
25%	6.6	7.7	1.2 (17%)	9.2	9.2	0.0 (0%)	5.0	2.7	-2.3 (-46%)	5.6	5.3	-0.3 (-5%)	5.0	5.3	0.3 (5%)
50% (median)	7.4	11.9	4.5 (60%)	10.4	13.6	3.2 (31%)	7.8	9.0	1.2 (16%)	9.2	8.1	-1.1 (-12%)	6.2	6.6	0.5 (7%)
75%	13.7	14.9	1.1 (8%)	14.7	17.0	2.3 (16%)	15.5	14.7	-0.8 (-5%)	11.9	10.2	-1.7 (-14%)	8.0	9.9	1.9 (24%)
95%	17.3	17.1	-0.2 (-1%)	17.9	19.6	1.7 (10%)	18.9	17.9	-1.0 (-5%)	15.9	14.7	-1.1 (-7%)	12.3	12.1	-0.2 (-2%)

Table 6.1-32. Summary Statistics of Residence Time (Days) in the Lower Sacramento River Subregion from DSM2-PTM.

Percentile	July			August			September			October			November		
	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
5%	3.2	4.7	1.6 (49%)	10.1	12.2	2.1 (21%)	4.8	3.5	-1.3 (-26%)	6.7	6.7	0.0 (0%)	6.1	6.0	-0.1 (-2%)
25%	9.1	12.3	3.2 (35%)	13.5	13.6	0.1 (1%)	7.0	4.4	-2.6 (-37%)	8.8	8.4	-0.4 (-5%)	7.5	7.4	-0.1 (-1%)
50% (median)	12.9	15.0	2.1 (17%)	17.4	18.7	1.3 (8%)	13.4	12.5	-0.9 (-7%)	13.4	12.9	-0.5 (-4%)	10.2	10.8	0.6 (6%)
75%	20.9	21.0	0.2 (1%)	21.7	23.4	1.7 (8%)	22.6	21.2	-1.5 (-6%)	18.4	16.9	-1.5 (-8%)	13.2	14.6	1.4 (11%)
95%	22.4	22.2	-0.2 (-1%)	23.5	24.4	0.9 (4%)	24.3	23.4	-0.9 (-4%)	20.9	20.5	-0.4 (-2%)	18.7	18.4	-0.3 (-1%)

Table 6.1-33. Summary Statistics of Residence Time (Days) in the Lower San Joaquin River Subregion from DSM2-PTM.

Percentile	July			August			September			October			November		
	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
5%	3.1	4.6	1.4 (45%)	12.0	12.7	0.7 (6%)	5.5	3.7	-1.8 (-32%)	7.5	6.8	-0.7 (-9%)	7.1	5.2	-2.0 (-27%)
25%	11.3	13.0	1.7 (15%)	15.4	14.2	-1.2 (-8%)	10.4	4.3	-6.1 (-58%)	9.8	7.8	-2.0 (-21%)	9.6	8.1	-1.5 (-15%)
50% (median)	14.1	16.0	2.0 (14%)	17.8	18.3	0.5 (3%)	14.5	11.9	-2.6 (-18%)	13.4	11.5	-1.9 (-14%)	12.2	10.9	-1.3 (-11%)
75%	20.4	21.5	1.1 (5%)	22.4	23.3	1.0 (4%)	22.9	20.7	-2.2 (-10%)	19.9	16.7	-3.2 (-16%)	14.5	15.7	1.2 (8%)
95%	22.7	23.4	0.7 (3%)	24.8	25.2	0.4 (2%)	25.5	24.3	-1.1 (-4%)	22.3	21.0	-1.3 (-6%)	19.3	20.1	0.8 (4%)

Table 6.1-34. Summary Statistics of Residence Time (Days) in the San Joaquin River at Twitchell Island Subregion from DSM2-PTM.

Percentile	July			August			September			October			November		
	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
5%	2.7	3.1	0.4 (14%)	9.5	12.1	2.6 (27%)	8.1	4.3	-3.8 (-47%)	8.4	5.3	-3.2 (-38%)	7.6	6.0	-1.6 (-21%)
25%	10.2	13.5	3.3 (32%)	10.8	13.6	2.8 (26%)	10.3	5.9	-4.3 (-42%)	12.4	8.0	-4.3 (-35%)	10.6	9.6	-1.0 (-9%)
50% (median)	12.0	16.1	4.1 (35%)	12.6	17.0	4.5 (36%)	11.6	13.3	1.6 (14%)	14.5	11.8	-2.7 (-18%)	12.6	11.8	-0.8 (-6%)
75%	13.6	18.1	4.5 (33%)	19.4	20.4	1.1 (6%)	19.0	20.0	1.0 (5%)	18.2	16.9	-1.4 (-8%)	15.3	15.9	0.6 (4%)
95%	21.0	21.1	0.1 (0%)	23.4	22.2	-1.2 (-5%)	23.0	22.6	-0.4 (-2%)	20.8	20.2	-0.6 (-3%)	18.9	19.7	0.8 (4%)

Table 6.1-35. Summary Statistics of Residence Time (Days) in the San Joaquin River at Prisoners Point from DSM2-PTM.

Percentile	July			August			September			October			November		
	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
5%	2.7	3.0	0.3 (10%)	4.3	8.4	4.1 (95%)	4.4	5.3	0.9 (20%)	7.5	6.5	-1.0 (-14%)	3.9	6.6	2.7 (68%)
25%	4.9	9.7	4.7 (96%)	5.0	10.5	5.5 (109%)	5.4	7.7	2.3 (43%)	9.8	8.3	-1.5 (-15%)	7.4	8.4	1.0 (14%)
50% (median)	6.0	10.7	4.7 (79%)	6.3	11.0	4.7 (74%)	7.4	11.0	3.7 (50%)	10.7	11.0	0.3 (3%)	8.6	10.6	2.0 (24%)
75%	7.3	12.2	4.9 (66%)	12.5	13.3	0.9 (7%)	10.9	15.0	4.1 (38%)	14.1	14.8	0.7 (5%)	11.1	12.4	1.3 (11%)
95%	13.6	14.8	1.2 (9%)	18.7	16.2	-2.5 (-13%)	16.8	16.7	-0.1 (-1%)	16.5	17.2	0.7 (4%)	14.6	15.0	0.4 (3%)

Table 6.1-36. Summary Statistics of Residence Time (Days) in the North and South Forks Mokelumne River Subregion from DSM2-PTM.

Percentile	July			August			September			October			November		
	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
5%	4.9	8.7	3.8 (79%)	3.0	6.7	3.7 (126%)	3.9	5.8	1.9 (50%)	6.3	7.5	1.2 (18%)	5.6	5.3	-0.2 (-4%)
25%	12.6	15.6	3.0 (24%)	4.2	8.9	4.7 (112%)	6.7	8.7	2.0 (30%)	9.4	8.7	-0.7 (-7%)	7.1	9.7	2.6 (36%)
50% (median)	20.8	20.8	0.0 (0%)	8.3	11.9	3.6 (44%)	11.4	12.4	1.0 (9%)	10.0	10.7	0.7 (7%)	8.9	10.3	1.4 (16%)
75%	26.1	24.6	-1.5 (-6%)	17.2	17.9	0.7 (4%)	17.0	17.7	0.7 (4%)	13.6	14.0	0.4 (3%)	11.1	12.5	1.3 (12%)
95%	34.2	31.5	-2.7 (-8%)	27.2	20.1	-7.1 (-26%)	24.7	22.2	-2.5 (-10%)	21.5	16.6	-4.9 (-23%)	16.5	14.2	-2.3 (-14%)

Table 6.1-37. Summary Statistics of Residence Time (Days) in the Disappointment Slough Subregion from DSM2-PTM.

Percentile	July			August			September			October			November		
	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
5%	12.1	15.5	3.4 (29%)	10.9	18.2	7.2 (66%)	10.8	15.2	4.4 (40%)	13.2	9.5	-3.7 (-28%)	14.7	15.1	0.3 (2%)
25%	17.9	26.7	8.9 (50%)	20.8	20.9	0.1 (1%)	16.8	18.4	1.6 (9%)	15.8	17.8	2.0 (13%)	18.6	17.9	-0.6 (-3%)
50% (median)	25.0	36.9	11.8 (47%)	25.7	29.9	4.2 (16%)	20.6	23.0	2.4 (12%)	19.6	22.9	3.3 (17%)	24.8	21.0	-3.8 (-15%)
75%	34.0	39.4	5.5 (16%)	29.3	33.0	3.8 (13%)	23.3	25.1	1.8 (8%)	23.7	28.7	5.0 (21%)	29.0	29.6	0.7 (2%)
95%	38.2	41.9	3.7 (10%)	34.2	35.6	1.4 (4%)	27.5	29.3	1.8 (7%)	27.5	30.8	3.3 (12%)	34.9	33.2	-1.7 (-5%)

Table 6.1-38. Summary Statistics of Residence Time (Days) in the San Joaquin River Near Stockton Subregion from DSM2-PTM.

Percentile	July			August			September			October			November		
	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
5%	1.3	1.5	0.2 (12%)	3.2	3.9	0.7 (22%)	4.1	4.3	0.1 (4%)	3.0	3.5	0.5 (17%)	2.8	3.1	0.4 (13%)
25%	5.8	7.8	2.0 (35%)	6.5	8.0	1.5 (23%)	5.9	6.8	0.9 (16%)	4.1	5.1	1.0 (25%)	4.4	5.0	0.6 (14%)
50% (median)	13.9	11.7	-2.3 (-16%)	9.7	9.8	0.1 (1%)	6.7	8.6	1.9 (29%)	5.2	6.2	1.1 (21%)	5.7	6.8	1.1 (19%)
75%	18.1	13.0	-5.0 (-28%)	12.1	10.9	-1.1 (-9%)	8.7	9.8	1.1 (13%)	6.4	7.4	1.1 (17%)	7.5	7.6	0.2 (2%)
95%	29.2	23.0	-6.2 (-21%)	15.1	14.4	-0.7 (-5%)	10.0	11.0	1.1 (11%)	8.3	9.0	0.7 (8%)	8.7	9.3	0.6 (7%)

Table 6.1-39. Summary Statistics of Residence Time (Days) in the Mildred Island Subregion from DSM2-PTM.

Percentile	July			August			September			October			November		
	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
5%	3.0	7.1	4.1 (138%)	1.8	5.0	3.3 (183%)	2.0	7.4	5.4 (270%)	2.9	8.9	6.0 (205%)	2.1	4.1	2.0 (93%)
25%	4.4	15.5	11.1 (255%)	2.2	8.1	5.8 (262%)	3.2	9.2	6.0 (188%)	3.7	11.6	7.9 (215%)	3.0	6.1	3.1 (106%)
50% (median)	6.9	23.4	16.5 (238%)	3.7	9.5	5.9 (160%)	4.7	10.7	6.0 (127%)	5.2	13.0	7.8 (150%)	4.6	13.9	9.3 (205%)
75%	11.1	27.1	16.0 (144%)	13.6	11.9	-1.7 (-12%)	6.9	14.9	8.0 (115%)	9.5	16.5	7.0 (73%)	15.9	15.7	-0.2 (-1%)
95%	25.1	30.0	4.9 (20%)	19.3	19.6	0.3 (2%)	15.4	16.8	1.4 (9%)	21.6	22.6	1.0 (4%)	21.1	21.5	0.4 (2%)

Table 6.1-40. Summary Statistics of Residence Time (Days) in the Holland Cut Subregion from DSM2-PTM.

Percentile	July			August			September			October			November		
	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
5%	1.4	3.8	2.4 (169%)	1.2	3.7	2.4 (198%)	1.5	4.7	3.3 (225%)	2.5	6.5	3.9 (156%)	1.8	3.3	1.5 (81%)
25%	2.0	4.2	2.2 (114%)	1.6	5.1	3.5 (226%)	1.8	5.5	3.7 (208%)	3.4	8.0	4.6 (134%)	2.6	4.0	1.4 (52%)
50% (median)	2.5	4.8	2.3 (95%)	2.4	5.7	3.3 (139%)	3.0	7.5	4.5 (154%)	3.9	8.6	4.7 (123%)	3.3	5.8	2.5 (75%)
75%	3.5	6.0	2.5 (73%)	5.4	6.6	1.1 (21%)	5.7	8.8	3.1 (55%)	5.8	9.1	3.3 (57%)	4.9	8.5	3.7 (76%)
95%	5.6	6.8	1.2 (22%)	9.8	7.8	-2.0 (-21%)	9.7	9.7	-0.1 (-1%)	7.5	9.8	2.3 (31%)	6.9	9.6	2.8 (41%)

Table 6.1-41. Summary Statistics of Residence Time (Days) in the Franks Tract Subregion from DSM2-PTM.

Percentile	July			August			September			October			November		
	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
5%	9.4	10.7	1.2 (13%)	10.0	11.1	1.1 (11%)	9.0	8.2	-0.8 (-9%)	9.1	8.6	-0.5 (-5%)	8.1	8.0	-0.1 (-1%)
25%	10.9	12.2	1.3 (12%)	10.9	13.2	2.4 (22%)	10.3	9.4	-0.8 (-8%)	11.1	9.7	-1.5 (-13%)	11.2	10.3	-0.9 (-8%)
50% (median)	11.6	14.4	2.8 (24%)	11.9	16.1	4.3 (36%)	11.8	14.1	2.3 (20%)	13.9	12.5	-1.4 (-10%)	12.3	12.0	-0.3 (-3%)
75%	12.8	16.6	3.8 (30%)	17.0	17.8	0.8 (5%)	16.2	17.4	1.1 (7%)	15.4	13.8	-1.6 (-10%)	14.4	15.1	0.7 (5%)
95%	16.9	17.5	0.6 (3%)	18.0	19.9	1.9 (10%)	18.7	18.5	-0.2 (-1%)	18.6	17.0	-1.7 (-9%)	18.1	18.0	-0.1 (-1%)

Table 6.1-42. Summary Statistics of Residence Time (Days) in the Rock Slough and Discovery Bay Subregion from DSM2-PTM.

Percentile	July			August			September			October			November		
	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
5%	4.8	7.4	2.6 (54%)	3.9	8.5	4.6 (119%)	4.7	11.0	6.3 (135%)	5.4	8.4	3.0 (55%)	5.0	6.9	1.9 (37%)
25%	5.6	8.8	3.3 (59%)	5.3	9.7	4.4 (84%)	5.6	14.6	8.9 (159%)	7.3	10.0	2.8 (38%)	5.9	8.2	2.3 (39%)
50% (median)	6.4	10.0	3.7 (57%)	5.7	11.9	6.2 (109%)	6.8	17.5	10.7 (158%)	8.8	15.2	6.4 (72%)	7.5	9.8	2.2 (29%)
75%	7.3	11.4	4.1 (56%)	10.1	15.9	5.9 (58%)	16.6	19.3	2.7 (17%)	12.1	17.1	5.0 (42%)	10.8	12.1	1.3 (12%)
95%	10.7	13.9	3.1 (29%)	19.2	22.3	3.1 (16%)	19.8	25.2	5.4 (27%)	20.6	19.2	-1.4 (-7%)	12.2	13.6	1.5 (12%)

Table 6.1-43. Summary Statistics of Residence Time (Days) in the Old River Subregion from DSM2-PTM.

Percentile	July			August			September			October			November		
	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
5%	0.5	1.5	1.0 (212%)	0.4	1.4	1.0 (275%)	0.6	1.7	1.1 (199%)	0.6	2.5	1.9 (304%)	0.7	1.3	0.6 (82%)
25%	0.7	1.8	1.1 (164%)	0.6	1.6	1.1 (189%)	0.8	2.5	1.7 (208%)	1.0	3.4	2.3 (228%)	0.9	1.7	0.8 (89%)
50% (median)	1.0	2.3	1.3 (131%)	1.0	2.0	1.0 (102%)	1.1	3.5	2.5 (231%)	1.3	5.9	4.6 (363%)	1.1	1.9	0.7 (64%)
75%	1.4	2.8	1.4 (101%)	2.0	2.5	0.5 (23%)	1.9	6.4	4.5 (243%)	1.7	8.0	6.4 (382%)	1.8	7.2	5.4 (299%)
95%	4.2	3.8	-0.3 (-8%)	4.1	4.8	0.7 (17%)	2.7	12.0	9.3 (347%)	2.4	12.0	9.6 (393%)	2.8	8.6	5.8 (205%)

Table 6.1-44. Summary Statistics of Residence Time (Days) in the Middle River Subregion from DSM2-PTM.

Percentile	July			August			September			October			November		
	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
5%	0.5	0.8	0.3 (62%)	0.4	0.7	0.3 (78%)	0.4	1.1	0.7 (180%)	0.5	1.5	1.0 (196%)	0.4	0.7	0.3 (58%)
25%	0.6	1.1	0.6 (101%)	0.4	0.9	0.5 (114%)	0.4	1.2	0.7 (177%)	0.6	2.0	1.4 (228%)	0.6	0.9	0.3 (51%)
50% (median)	0.7	1.3	0.6 (93%)	0.5	1.0	0.5 (99%)	0.5	1.4	0.8 (155%)	0.7	2.8	2.1 (292%)	0.7	1.1	0.4 (63%)
75%	0.8	1.6	0.8 (100%)	0.9	1.1	0.3 (29%)	0.8	1.6	0.8 (95%)	1.0	7.9	7.0 (727%)	0.8	10.9	10.1 (1,218%)
95%	2.4	4.5	2.1 (88%)	1.9	1.7	-0.2 (-13%)	1.3	2.4	1.1 (84%)	1.2	18.0	16.8 (1351%)	1.1	11.8	10.7 (979%)

Table 6.1-45. Summary Statistics of Residence Time (Days) in the Victoria Canal Subregion from DSM2-PTM.

Percentile	July			August			September			October			November		
	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
5%	0.3	2.5	2.2 (713%)	0.2	0.5	0.3 (116%)	0.3	0.7	0.4 (170%)	0.3	3.7	3.4 (1082%)	0.3	0.5	0.2 (51%)
25%	0.3	7.4	7.0 (2074%)	0.3	2.2	2.0 (731%)	0.3	4.1	3.8 (1339%)	0.4	5.4	5.1 (1353%)	0.4	0.6	0.2 (57%)
50% (median)	1.3	13.0	11.7 (939%)	4.6	7.6	3.0 (64%)	1.2	7.2	5.9 (480%)	0.6	10.5	9.9 (1734%)	0.6	7.1	6.5 (1052%)
75%	10.0	19.9	9.9 (99%)	14.5	14.2	-0.3 (-2%)	10.6	11.6	1.0 (10%)	3.9	14.7	10.8 (278%)	4.9	11.1	6.2 (126%)
95%	16.8	25.4	8.7 (52%)	26.4	21.1	-5.3 (-20%)	20.4	19.9	-0.5 (-3%)	15.7	17.8	2.1 (13%)	12.3	14.1	1.8 (15%)

Table 6.1-46. Summary Statistics of Residence Time (Days) in the Grant Line Canal and Old River Subregion from DSM2-PTM.

Percentile	July			August			September			October			November		
	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
5%	2.2	3.0	0.8 (35%)	9.3	9.3	-0.1 (-1%)	2.7	6.2	3.4 (125%)	3.6	3.1	-0.5 (-14%)	4.4	5.4	1.0 (23%)
25%	29.3	29.6	0.3 (1%)	20.2	23.5	3.2 (16%)	8.5	10.0	1.5 (18%)	6.7	4.3	-2.4 (-36%)	8.2	8.1	-0.1 (-1%)
50% (median)	38.7	40.0	1.4 (4%)	27.3	29.1	1.8 (6%)	16.9	23.3	6.4 (38%)	13.6	10.1	-3.4 (-25%)	11.8	9.2	-2.7 (-22%)
75%	40.4	41.0	0.6 (1%)	36.2	35.5	-0.7 (-2%)	32.9	35.8	3.0 (9%)	19.5	14.7	-4.8 (-24%)	14.4	11.2	-3.3 (-23%)
95%	42.8	42.0	-0.9 (-2%)	40.8	37.0	-3.8 (-9%)	38.1	38.0	-0.1 (0%)	24.2	24.8	0.6 (3%)	21.2	13.1	-8.0 (-38%)

Table 6.1-47. Summary Statistics of Residence Time (Days) in the Upper San Joaquin River Subregion from DSM2-PTM.

Percentile	July				August				September				October				November		
	NAA	PA	PA vs. NAA		NAA	PA	PA vs. NAA		NAA	PA	PA vs. NAA		NAA	PA	PA vs. NAA		NAA	PA	PA vs. NAA
5%	0.2	0.2	0.0 (0%)		0.2	0.2	0.0 (-1%)		0.4	0.4	0.0 (-2%)		0.3	0.3	0.0 (16%)		0.3	0.3	0.0 (-8%)
25%	0.8	0.7	-0.1 (-11%)		0.9	0.8	-0.1 (-16%)		0.7	0.7	-0.1 (-10%)		0.5	0.6	0.1 (23%)		0.4	0.3	0.0 (-6%)
50% (median)	2.0	1.4	-0.7 (-33%)		1.5	1.2	-0.3 (-18%)		1.0	0.8	-0.1 (-13%)		0.6	0.7	0.1 (25%)		0.5	0.5	0.0 (-8%)
75%	3.3	1.8	-1.5 (-46%)		1.9	1.6	-0.3 (-15%)		1.2	1.1	-0.2 (-14%)		0.7	0.8	0.2 (27%)		0.6	0.6	0.0 (-7%)
95%	13.5	6.7	-6.8 (-50%)		2.8	2.4	-0.4 (-15%)		1.5	1.3	-0.2 (-16%)		0.8	0.9	0.1 (18%)		0.6	0.6	0.0 (-1%)

6.1.3.5.5.1 Migrating Adults (December–March)

6.1.3.5.5.1.1 Individual-Level Effects

Microcystis blooms occur during the summer and early fall so there will be no effect on migrating adult Delta Smelt during the winter months.

6.1.3.5.5.1.2 Population-Level Effects

As there would be no adverse effect to individual migrating adult Delta Smelt from *Microcystis*, there would likewise be no adverse population-level effect.

6.1.3.5.5.2 Spawning Adults (February–June)

6.1.3.5.5.2.1 Individual-Level Effects

Microcystis blooms occur during the summer and early fall so there will be no effect on adult Delta Smelt during the spring months. The general temperature threshold for *Microcystis* blooms (20°C) is a temperature at which egg hatch success for Delta Smelt is exceptionally low (Bennett 2005), so there is little if any opportunity for a *Microcystis* bloom to harm an individual spawning adult Delta Smelt.

6.1.3.5.5.2.2 Population-Level Effects

The general temperature threshold for *Microcystis* blooms (20°C) is a temperature at which egg hatch success for Delta Smelt is exceptionally low (Bennett 2005), so there is little if any opportunity for a *Microcystis* bloom to harm the population of spawning adult Delta Smelt.

6.1.3.5.5.3 Eggs/Embryos (Spring: ~March–June)

6.1.3.5.5.3.1 Individual-Level Effects

The general temperature threshold for *Microcystis* blooms (20°C) is a temperature at which egg hatch success for Delta Smelt is exceptionally low (Bennett 2005), so there is little if any opportunity for a *Microcystis* bloom to harm individual Delta Smelt eggs.

6.1.3.5.5.3.2 Population-Level Effects

The general temperature threshold for *Microcystis* blooms (20°C) is a temperature at which egg hatch success for Delta Smelt is exceptionally low (Bennett 2005), so there is little if any opportunity for a *Microcystis* bloom to harm Delta Smelt eggs.

6.1.3.5.5.4 Larvae/Young Juveniles (Spring: ~March-June)

6.1.3.5.5.4.1 Individual-Level Effects

There is some potential overlap in timing between larval life stages of Delta Smelt and *Microcystis* blooms. However, this impact is captured in the discussion of the juvenile stage which has most of the seasonal overlap with blooms.

6.1.3.5.5.4.2 Population-Level Effects

The very limited potential effects to individual larval/young juvenile Delta Smelt would be reflected in minimal population-level adverse effects to this life stage.

6.1.3.5.5.5 Juveniles (Summer/Fall: ~July-December)

6.1.3.5.5.5.1 Individual-Level Effects

As previously discussed in the water temperature analysis, climate change is likely to increase summer water temperature but it is not clear whether the PA would change water temperature. The warming climate may however increase the length of the viable growing season for

Microcystis blooms and that effect would interact with PA-related changes in residence time and possibly other conditions (e.g., nutrient loads; Lehman *et al.* 2013) to affect the duration and intensity of blooms. The threshold could be reached earlier in the year under the PA (see previous discussion of timing shifts for spawning Delta Smelt), which would increase the length of exposure for Delta Smelt and their prey, although air temperature as opposed to flow (operations) is the primary driver of water temperature in the Delta (Wagner *et al.* 2011). On the basis of the previously presented analysis based on the published ranges of flows that *Microcystis* occurs at (Lehman *et al.* 2013), greater flows in the lower San Joaquin River (QWEST) under the PA generally would be expected to give somewhat less potential for *Microcystis* to occur in that area, relative to the NAA; under the PA, a greater percentage of years were above the range of flows at which *Microcystis* has occurred. Therefore, under the PA, individual juvenile Delta Smelt could experience a lower likelihood of lethal or sublethal effects, or have greater feeding opportunities if lower prevalence of *Microcystis* results in less toxicity to zooplankton prey or a greater abundance of phytoplankton available for zooplankton, for example (Lehman *et al.* 2010; Brooks *et al.* 2012). However, as summarized in the analysis of residence time presented at the start of this section, higher residence time was most evident in predictions for the central/south Delta subregions, but also occurred elsewhere to some extent, for instance in the lower Sacramento River (Chipps Island to Rio Vista) and the Cache Slough/Liberty Island area. With the possibility of longer duration and more intense *Microcystis* blooms resulting in part from longer residence time, individual juvenile Delta Smelt may experience a greater likelihood of lethal or sublethal toxicity, or have lower prey availability (Ger *et al.* 2009; 2010; Lehman *et al.* 2010; Acuña *et al.* 2012; Brooks *et al.* 2012).

6.1.3.5.5.5.2 Population-Level Effects

Most of the Delta Smelt population is not distributed in the southern Delta during the summer and fall because the water is too warm and too clear (Feyrer *et al.* 2007; Nobriga *et al.* 2008). Therefore, the Delta Smelt population does not overlap the peak of the ***Microcystis*** bloom in space and time. Nonetheless, there is overlap in the low-salinity zone and Microcystis can be toxic to copepods so there is potential for the regionally higher residence times to intensify blooms that harm or kill Delta Smelt directly, by killing their prey, or by increasing toxin concentrations within their prey. In the lower San Joaquin River, the analysis based on QWEST flow suggested that generally there would be less potential for *Microcystis* occurrence under the PA. The analysis based on residence time showed that in portions of the south Delta there may be potential for greater *Microcystis* occurrence because of greater residence time, although there are no published relationships between *Microcystis* and residence time from which to make firm conclusions. There is potential to mitigate such effects through preferential south Delta export pumping: the modeling currently assumes that in the summer months (July–September), the first 3,000 cfs of exports would be from the south Delta, with any additional allowable exports able to be diverted from either the north or the south Delta, and preference for this additional pumping generally being given to the north Delta (because of higher water quality); it would be possible to shift to additional south Delta pumping as opposed to north Delta pumping in order to reduce water residence time, for example. Given that multiple factors affect *Microcystis* bloom occurrence and maintenance, the analysis presented here has some uncertainty given that only two factors—albeit very important factors—were examined.

6.1.3.6 Delta Cross Channel

6.1.3.6.1 Migrating Adults (December-March)

6.1.3.6.1.1 Individual-Level Effects

USFWS (2008: 174) suggested that "closures of the DCC for juvenile salmonid protection are likely to create more natural hydrologies in the Delta, by keeping Sacramento River flows in the Sacramento River and Georgiana Slough, which provide flow cues for migrating adult Delta Smelt." Closure of the DCC would occur during most, if not all, of the December-March upstream migration period of adult Delta Smelt, and essentially would not differ between NAA and PA (see Table 5.A.6-31 in Appendix 5.A, *CALSIM Methods and Results*). Therefore any individual-level effects on adult Delta Smelt (e.g., flow cues for migration) would be similar between NAA and PA.

6.1.3.6.1.2 Population-Level Effects

As noted for individual-level effects, any population-level effects of DCC closure (e.g., providing flow cues for migrating adult Delta Smelt) would be similar between NAA and PA scenarios.

6.1.3.6.2 Spawning Adults (February-June)

6.1.3.6.2.1 Individual-Level Effects

Given that the main effect of DCC operations on adult Delta Smelt may be on migrating adults (U.S. Fish and Wildlife Service 2008: 174), as discussed above, there would be limited potential for DCC operations to affect individual spawning adults, which presumably would be much less limited in terms of movements and may be holding near spawning locations. Any effect would be very similar for NAA and PA (see Table 5.A.6-31 in Appendix 5.A, *CALSIM Methods and Results*).

6.1.3.6.2.2 Population-Level Effects

The limited potential for individual-level effects of DCC operations on spawning adult Delta Smelt would result in minimal potential for population-level effects, with any effects being similar between NAA and PA.

6.1.3.6.3 Eggs/Embryos (Spring: ~March-June)

6.1.3.6.3.1 Individual-Level Effects

Given that the DCC's principal effects would be on the motile life stages of Delta Smelt (by changing flows in Delta channels), the demersal and adhesive egg/embryo life stage would not be affected by DCC operations.

6.1.3.6.3.2 Population-Level Effects

Lack of individual-level effects from DCC operations on Delta Smelt eggs/embryos means that there would be no population-level effects.

6.1.3.6.4 Larvae/Young Juveniles (Spring: ~March-June)

6.1.3.6.4.1 Individual-Level Effects

USFWS (2008: 174) noted that "Larval and juvenile Delta Smelt are probably not strongly affected by the DCC if it is closed or open. Previous PTM modeling done for the [Smelt Working Group] has shown that having the DCC open or closed does not significantly affect

flows in the Central Delta (Kimmerer and Nobriga 2008). There could be times, however, when the DCC closure affects Delta Smelt by generating flows that draw them into the South Delta." Any such effects are captured in the PTM modeling that was undertaken in relation to south Delta entrainment (Section 6.1.3.3.1.4, *Larvae/Young Juveniles (Spring: March-June*)). There would be little to no difference in DCC operations between NAA and PA, with the DCC only being for an average of 5 days more under PA in wet years (see Table 5.A.6-31 in Appendix 5.A, *CALSIM Methods and Results*).

6.1.3.6.4.2 Population-Level Effects

Given the limited potential for DCC operations to affect individual larval/young juvenile Delta Smelt (U.S. Fish and Wildlife Service 2008: 174), there would be expected to be a minimal population-level effect which would essentially not differ between NAA and PA.

6.1.3.6.5 Juveniles (Summer/Fall: ~July-December)

6.1.3.6.5.1 Individual-Level Effects

Given that the main effect of DCC operations would be to change the quantity of Sacramento River flow entering the interior Delta (central/south Delta), there would be expected to be minimal effects to juvenile Delta Smelt given that habitat suitability in this area is low during this portion of the life history (Nobriga *et al.* 2008). In the fall, the DCC may be open somewhat more often under the PA (see Section 6.1.3.3.1.4, *Larvae/Young Juveniles (Spring: March-June*)).). This is because of several operational criteria described in Section 5.A.5.1.4.2 of Appendix 5.A, *CALSIM Methods and Results*. The CalSim modeling showed that in September of ~20% of years, sufficient water was exported by the NDD that the 25,000-cfs threshold for closure of the DCC is not exceeded, whereas it is exceeded under the NAA in the same years and results in closure of the DCC more than under PA (see Table 5.A.6-31 in Appendix 5.A). Additionally, in October-November, reservoir releases later in the year under the NAA triggered the 7,500-cfs Sacramento River at Wilkins Slough threshold assumed to coincide with juvenile salmon migration into the Delta, which resulted in a greater number of days with DCC closed under NAA. Last, the DCC may also have been open more under the PA to maintain water quality conditions per D-1641 (Rock Slough salinity standard). However, given that most juvenile Delta Smelt would be expected to be in the low-salinity zone or in the Cache Slough area during this time period, any effects would be expected to be limited; the extent and location of the low-salinity zone would not differ between NAA and PA during September-December, as shown in the analysis of abiotic habitat for juvenile Delta Smelt (Section 6.1.3.5.1.1, *Juveniles (Fall: September-December)*).

6.1.3.6.5.2 Population-Level Effects

The limited potential for DCC gate operations on individual juvenile Delta Smelt would result in minimal potential for effect at the population level, and this would be similar between NAA and PA.

6.1.3.7 Suisun Marsh Facilities

6.1.3.7.1 Suisun Marsh Salinity Control Gates

6.1.3.7.1.1 Migrating Adults (December-March)

6.1.3.7.1.1.1 Individual-Level Effects

Migrating adult Delta Smelt may be entrained behind the SMSCG when the SMSCG are closed (U.S. Fish and Wildlife Service 2008: 218), with operations expected to occur during ~10-20 days per year based on recent historical observations (Section 3.3.2.5.1, *Suisun Marsh Salinity Control Gates*). As further described by USFWS (2008: 218), "Fish may enter Montezuma Slough from the Sacramento River when the gates are open to draw freshwater into the marsh and then may not be able to move back out when the gates are closed. It is not known whether this harms Delta Smelt in any way, but they could be exposed to predators hovering around the SMSCG or they could have an increased risk of exposure to water diversions in the marsh" (see subsequent sections for effects of the RRDS, MIDS, and Goodyear Slough outfall). USFWS (2008: 218) also noted that "The degree to which movement around the LSZ is constrained by opening and closing the SMSCG is unknown." Any effects of the SMSCG on Delta Smelt movement in Montezuma Slough would be similar between NAA and PA, based on the December-March flows in Montezuma Slough just upstream of the SMSCG being similar (see Table 5.B.5-29 in Appendix 5.B, *DSM2 Modeling and Results*).

USFWS (2008: 219) also noted that SMSCG affects the distribution of the LSZ (indexed by X2), causing it to shift upstream for a given level of Delta inflow and exports, which could affect susceptibility to entrainment at the south Delta export facilities. However, as noted by USFWS (2008: 219), operations to meet D-1641 would limit such potential effects; these operations would be undertaken under the NAA and PA, and are reflected in there being little meaningful difference between NAA and PA in X2 during December-March (see Table 5.A.6-29 in Appendix 5.A, *CALSIM Methods and Results*).

6.1.3.7.1.1.2 Population-Level Effects

Given that the SMSCG would be expected to be operated for no more than around 10-20 days per year, this may limit potential population-level effects on migrating adult Delta Smelt. As described in the individual-level effects, any effects would be expected to be similar between NAA and PA.

6.1.3.7.1.2 Spawning Adults (February-June)

6.1.3.7.1.2.1 Individual-Level Effects

Spawning adult Delta Smelt would be less susceptible to the effects of the SMSCG than migrating adult Delta Smelt because they would not be undertaking the broad-scale movements of migrating adults. Movement may still be restricted, however, and near-field effects (e.g., predation) similar to those suggested by USFWS (2008: 218) could occur. Any such effects would be similar for NAA and PA based on the February-June flows in Montezuma Slough just upstream of the SMSCG being similar (see Table 5.B.5-29 in Appendix 5.B, *DSM2 Modeling and Results*).

6.1.3.7.1.2.2 Population-Level Effects

Given the relatively limited area of effect for the SMSCG in terms of affecting spawning adult Delta Smelt, relative to the overall area of potential spawning habitat, it may be that there would

be minimal population-level effects on spawning adult Delta Smelt from the SMSCG; the magnitude of any effects would be similar for the NAA and PA.

6.1.3.7.1.3 Eggs/Embryos (Spring: ~March-June)

6.1.3.7.1.3.1 Individual-Level Effects

Operation of the SMSCG would not affect Delta Smelt eggs/embryos, which as previously noted are demersal and adhesive.

6.1.3.7.1.3.2 Population-Level Effects

The lack of individual-level effects means that there would be no population-level effects of the SMSCG on Delta Smelt eggs/embryos.

6.1.3.7.1.4 Larvae/Young Juveniles (Spring: ~March-June)

6.1.3.7.1.4.1 Individual-Level Effects

As noted for adult Delta Smelt life stages, operation of the SMSCG could trap larval/young juvenile Delta Smelt in Montezuma Slough downstream of the SMSCG, with resultant near-field (e.g., predation) and far-field (greater entrainment susceptibility at diversions within Suisun Marsh; see subsequent sections). Any such effects would be similar for NAA and PA based on the March-June flows in Montezuma Slough just upstream of the SMSCG being similar (see Table 5.B.5-29 in Appendix 5.B, *DSM2 Modeling and Results*).

6.1.3.7.1.4.2 Population-Level Effects

Given that the range of habitat that can be occupied by larval/young juvenile Delta Smelt is large compared to the area affected by the SMSCG, as well as the similarity of NAA and PA operations of the SMSCG in a manner consistent with recent operations, any population-level effects of the SMSCG on larval/young juvenile Delta Smelt would be expected to be small and would not differ between NAA and PA.

6.1.3.7.1.5 Juveniles (Summer/Fall: ~July-December)

6.1.3.7.1.5.1 Individual-Level Effects

Similar effects to those noted for adult Delta Smelt could also occur for juvenile Delta Smelt with respect to SMSCG operations, *i.e.*, near-field predation or movement blockage, as well as susceptibility to effects of Suisun Marsh diversions. Any such effects would be similar for NAA and PA based on the July-December flows in Montezuma Slough just upstream of the SMSCG being similar (see Table 5.B.5-29 in Appendix 5.B, *DSM2 Modeling and Results*). As described for migrating adult Delta Smelt, USFWS (2008: 218) emphasized the potential upstream shift in the low salinity zone (indexed by X2) that is associated with SMSCG operations, for a given Delta inflow and exports. However, the analysis of abiotic fall rearing habitat presented in Section 6.1.3.5.1.1, *Juveniles (Fall: September-December)* illustrated that X2 and the low salinity zone would be similar between NAA and PA, reflecting adherence of both scenarios to the USFWS (2008) BiOp RPA requiring fall X2 management.

6.1.3.7.1.5.2 Population-Level Effects

The relatively few days (~10-20) which the SMSCG might be operated, coupled with SWP/CVP management of X2 for juvenile Delta Smelt fall rearing habitat per the USFWS (2008) BiOp RPA, suggests that there would be minimal population-level effects of the SMSCG on juvenile Delta Smelt, and that these would not differ between NAA and PA.

6.1.3.7.2 Roaring River Distribution System

6.1.3.7.2.1 Migrating Adults (December-March)

6.1.3.7.2.1.1 Individual-Level Effects

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, eliminating the risk of entrainment and minimizing the risk of impingement, so that any potential adverse effects to individual migrating adult Delta Smelt would be minimal.

6.1.3.7.2.1.2 Population-Level Effects

There would be expected to be essentially no population-level effects from the RRDS on migrating adult Delta Smelt.

6.1.3.7.2.2 Spawning Adults (February-June)

6.1.3.7.2.2.1 Individual-Level Effects

As with migrating adult Delta Smelt, the screens on the RRDS intake would be expected to minimize any potential adverse effects to individual spawning adult Delta Smelt.

6.1.3.7.2.2.2 Population-Level Effects

There would be expected to be essentially no population-level effects from the RRDS on spawning adult Delta Smelt.

6.1.3.7.2.3 Eggs/Embryos (Spring: ~March-June)

6.1.3.7.2.3.1 Individual-Level Effects

As previously noted, Delta Smelt eggs and embryos are demersal and adhesive, attaching to substrates with an adhesive stalk formed by the outer layer of the egg (Bennett 2005). As such, individual eggs would not be subject to entrainment and there would be no individual-level adverse effect from the RRDS.

6.1.3.7.2.3.2 Population-Level Effects

The demersal and adhesive nature of Delta Smelt eggs means that there would be no adverse population-level effects from the RRDS with respect to entrainment.

6.1.3.7.2.4 Larvae/Young Juveniles (Spring: ~March-June)

6.1.3.7.2.4.1 Individual-Level Effects

Based on the RRDS screen specifications and applying the methods used for the NDD (Appendix 6.A, *Quantitative Methods for Biological Assessment of Delta Smelt*, Section 6.A.2.2), individual larval and young juvenile Delta Smelt smaller than around 30 mm (SL) could be susceptible to entrainment by the three RRDS intake culverts. Small juveniles slightly larger than this size could be impinged on the screens without being entrained. Prior to screening of the intakes, Pickard *et al.* (1982) found appreciable number of older life stages were entrained[19] which, although partly a function of greater overall abundance of Delta Smelt at the time of the study (1980-1982), suggests that larval/juvenile entrainment also occurs.

[19] Sampled individuals were 30-100 mm FL, which to some extent would have been a function of the mesh size (3.2 mm) on the fyke nets used on the culverts.

6.1.3.7.2.4.2 Population-Level Effects

Any population-level effects on larval/young juvenile Delta Smelt from the RRDS that do occur would be expected to be similar between NAA and PA, and would represent a continuation of existing operations; as previously noted, flows in Montezuma Slough as a result of SMSCG operations were similar for NAA and PA. Entrainment risk into RRDS appears limited, given that DSM2-PTM modeling for the DFG (2009) longfin smelt incidental take permit application did not observe any particles entering RRDS. Therefore, the population-level effect of the RRDS would be expected to be minimal.

6.1.3.7.2.5 Juveniles (Summer/Fall: ~July-December)

6.1.3.7.2.5.1 Individual-Level Effects

As with migrating adult Delta Smelt, the screens on the RRDS intake would be expected to minimize any potential adverse effects to individual juvenile Delta Smelt.

6.1.3.7.2.5.2 Population-Level Effects

There would be expected to be minimal, if any, population-level effects from the RRDS on juvenile Delta Smelt.

6.1.3.7.3 Morrow Island Distribution System

6.1.3.7.3.1 Migrating Adults (December-March)

6.1.3.7.3.1.1 Individual-Level Effects

Individual migrating adult Delta Smelt could be entrained by the three unscreened 48-inch intakes that form the MIDS intake. However, Enos *et al.* (2007:17) noted that this would generally only occur in wet years, per Hobbs *et al.* (2005); Enos *et al.* (2007) did not collect any adult Delta Smelt during sampling of the MIDS intake in 2004-2006, although they did capture adult Delta Smelt with purse seines during sampling in the adjacent Goodyear Slough.

6.1.3.7.3.1.2 Population-Level Effects

The population-level effects of the MIDS to migrating adult Delta Smelt would be minimal, if any, given that entrainment would only be expected to occur in wet years. Any entrainment under the PA would also be likely to occur under the NAA, given that operations of the MIDS would not be changing (see Tables 5.B.5-31, 5.B.5-32, and 5.B.5-33 in Appendix 5.B, *DSM2 Modeling and Results*).

6.1.3.7.3.2 Spawning Adults (February-June)

6.1.3.7.3.2.1 Individual-Level Effects

As with migrating adult Delta Smelt, spawning adults would only be susceptible to entrainment at the MIDS in wet years.

6.1.3.7.3.2.2 Population-Level Effects

As with migrating adult Delta Smelt, the population-level effects of the MIDS to spawning adult Delta Smelt would be minimal, if any, given that entrainment would only be expected to occur in wet years; any entrainment would be expected to be similar under NAA and PA.

6.1.3.7.3.3 Eggs/Embryos (Spring: ~March-June)

6.1.3.7.3.3.1 Individual-Level Effects

As previously noted, the demersal and adhesive nature of Delta Smelt eggs/embryos means that they would not be subject to entrainment and there would be no individual-level adverse effect from the MIDS.

6.1.3.7.3.3.2 Population-Level Effects

The demersal and adhesive nature of Delta Smelt eggs/embryos means that there would be no adverse population-level effects from the RRDS with respect to entrainment.

6.1.3.7.3.4 Larvae/Young Juveniles (Spring: ~March-June)

6.1.3.7.3.4.1 Individual-Level Effects

Individual larval/young juvenile Delta Smelt could be entrained by the MIDS, although Enos *et al.* (2007) did not collect any individuals during sampling in 2004-2006. Enos *et al.* (2007: 17) noted that under normal operations, MIDS is often closed or diverting very little during spring, which may provide some protection of spring-spawning and spring-migrating fish, particularly open-water fish like Delta Smelt that do not aggregate around in-stream structures such as diversions.

6.1.3.7.3.4.2 Population-Level Effects

As noted by USFWS (2008: 218), entrainment into MIDS may be unlikely based on particle tracking studies that have demonstrated low entrainment vulnerability for particles released at random locations throughout Suisun Marsh (3.7 percent), and almost no vulnerability (<0.1 percent) to particles released at Rio Vista (Culberson *et al.* 2004). This suggests at most a minimal population-level adverse effect, which would be similar under NAA and PA (see Tables 5.B.5-31, 5.B.5-32, and 5.B.5-33 in Appendix 5.B, *DSM2 Modeling and Results*).

6.1.3.7.3.5 Juveniles (Summer/Fall: ~July-December)

6.1.3.7.3.5.1 Individual-Level Effects

To the extent that juvenile Delta Smelt occur near the MIDS, they could be entrained, as with other life stages; none were collected during the extensive sampling by Enos *et al.* (2007) during 2004-2006, however.

6.1.3.7.3.5.2 Population-Level Effects

Given the absence of juvenile Delta Smelt in entrainment samples at MIDS by Enos *et al.* (2007), the population-level effect of the MIDS would be expected to be minimal. Any effect would be similar between NAA and PA.

6.1.3.7.4 Goodyear Slough Outfall

6.1.3.7.4.1 Migrating Adults (December-March)

6.1.3.7.4.1.1 Individual-Level Effects

Opening of the Goodyear Slough outfall culvert flap gates results in a small net flow south, with fresher water from Suisun Slough being drawn into Goodyear Slough. Although this may increase the possibility of entry of migrating adult Delta Smelt into Goodyear Slough, and therefore increases the potential for entrainment by the MIDS intakes (as previously discussed), operation of the flap gates also improves circulation and therefore may provide a beneficial effect.

6.1.3.7.4.1.2 Population-Level Effects

As discussed previously for MIDS, the available sampling data in the area suggest that migrating adult Delta Smelt would only be susceptible to effects from the Goodyear Slough outfall in wet years (Enos *et al.* 2007), and at most only a minimal population-level effect would therefore be likely to occur, with this effect being common to NAA and PA on the basis of similar flows in Goodyear Slough (see Table 5.B.5-34 in Appendix 5.B, *DSM2 Modeling and Results*).

6.1.3.7.4.2 Spawning Adults (February-June)

6.1.3.7.4.2.1 Individual-Level Effects

As with migrating adults, potential effects to individuals include entrainment into Goodyear Slough and therefore more potential for entrainment by MIDS, as well as beneficial effects from improved circulation.

6.1.3.7.4.2.2 Population-Level Effects

As discussed for migrating adults, the available information suggests that the population-level effect of the Goodyear Slough outfall would be minimal because of infrequent Delta Smelt occurrence in the area, with the effect not differing between NAA and PA.

6.1.3.7.4.3 Eggs/Embryos (Spring: ~March-June)

6.1.3.7.4.3.1 Individual-Level Effects

Eggs/embryos would not be susceptible to any entrainment effects from the Goodyear Slough outfall, but may experience improved circulation because of flap gate operations which may be beneficial during incubation.

6.1.3.7.4.3.2 Population-Level Effects

As noted for adult Delta Smelt, only a small portion of Delta Smelt eggs/embryos would be expected to occur in Goodyear Slough (*i.e.*, possibly only in wet years), so the population-level effects of the Goodyear Slough outfall would be small and similar between NAA and PA.

6.1.3.7.4.4 Larvae/Young Juveniles (Spring: ~March-June)

6.1.3.7.4.4.1 Individual-Level Effects

As with adult Delta Smelt, operation of the Goodyear Slough outfall could increase entrainment into Goodyear Slough and therefore give more potential for entrainment by MIDS, as well as providing beneficial effects from improved circulation.

6.1.3.7.4.4.2 Population-Level Effects

As noted for adult Delta Smelt and in the analysis of the effects of the MIDS, only a small portion of Delta Smelt larvae/young juveniles would be expected to occur in Goodyear Slough, at most resulting in small population-level effects that would be similar between NAA and PA.

6.1.3.7.4.5 Juveniles (Summer/Fall: ~July-December)

6.1.3.7.4.5.1 Individual-Level Effects

Similar to adult Delta Smelt, operation of the Goodyear Slough outfall could increase entrainment into Goodyear Slough of juvenile Delta Smelt and therefore give more potential for entrainment by MIDS, as well as providing beneficial effects from improved circulation.

6.1.3.7.4.5.2 Population-Level Effects

As concluded for other life stages, only a small portion of Delta Smelt juveniles would be expected to occur in Goodyear Slough, resulting in no more than a small population-level effect that would be similar between NAA and PA.

6.1.3.8 North Bay Aqueduct

6.1.3.8.1 Migrating Adults (December-March)

6.1.3.8.1.1 Individual-Level Effects

As noted by USFWS (2008: 217), the NBA fish screen at the Barker Slough pumping plant was designed to exclude Delta Smelt larger than 25 mm and as such would be expected to exclude migrating adult Delta Smelt from being entrained by the NBA. As described in section 3.3.2.6, *Operational Criteria for the North Bay Aqueduct Intake*, the intake is screened to comply with Delta Smelt screening criteria, which would be expected to limit the potential for entrainment and impingement. If predatory fish are concentrated near the fish screen, Delta Smelt that are excluded from being screened could be susceptible to increased predation. Pumping rates at the North Bay Aqueduct Barker Slough Intake generally would be similar under the NAA and PA (see Table 5.B.5-35 in Appendix 5.B, *DSM2 Modeling and Results*), so the potential risk of impingement and predation may also be similar.

6.1.3.8.1.2 Population-Level Effects

Exclusion of migrating adult Delta Smelt by the fish screens at the Barker Slough pumping plant, coupled with predation risk being similar between the NAA and PA, would greatly limit the potential for adverse effects from the NBA, so that population-level effects would be minimal.

6.1.3.8.2 Spawning Adults (February-June)

6.1.3.8.2.1 Individual-Level Effects

As with migrating adult Delta Smelt, the Barker Slough pumping plant's fish screen would exclude spawning adult Delta Smelt from entrainment into the NBA, with some potential for impingement and predation that would be similar between NAA and PA.

6.1.3.8.2.2 Population-Level Effects

As with migrating adult Delta Smelt, exclusion of spawning adult Delta Smelt by the fish screens at the Barker Slough pumping plant, coupled with impingement and predation risk being similar between the NAA and PA, so that population-level effects would be minimal.

6.1.3.8.3 Eggs/Embryos (Spring: ~March-June)

6.1.3.8.3.1 Individual-Level Effects

As previously noted, the demersal and adhesive nature of Delta Smelt eggs/embryos means that they would not be subject to entrainment and there would be no individual-level adverse effect from the NBA.

6.1.3.8.3.2 Population-Level Effects

The demersal and adhesive nature of Delta Smelt eggs/embryos means that there would be no adverse population-level effects from the NBA with respect to entrainment.

6.1.3.8.4 Larvae/Young Juveniles (Spring: ~March-June)

6.1.3.8.4.1 Individual-Level Effects

Larval and young juvenile Delta Smelt could be subject to entrainment at the Barker Slough pumping plant, given that the fish screen excludes Delta Smelt of 25 mm and greater; as noted for the NDD, individuals slightly greater than 25 mm could experience adverse effects from impingement. However, as noted by USFWS (2008: 217), a study of a fish screen built to Delta Smelt standards in Horseshoe Bend on the Sacramento River found that over 99% of fish were excluded from entrainment, even though most fish were only 15-25 mm long (Nobriga *et al.* 2004); USFWS (2008: 217) concluded on that basis that the fish screen at the NBA may protect many, if not most, of the Delta Smelt larvae that hatch and rear in Barker Slough.

6.1.3.8.4.2 Population-Level Effects

As previously discussed in Section 6.1.3.3.1.4, *Larvae/Young Juveniles (Spring: March-June*)). the DSM2-PTM analysis of larval Delta Smelt entrainment showed that in general, estimated entrainment at the NBA under the PA and NAA was similar (Table 6.1-15), reflecting the fact that operational criteria would not differ between NAA and PA. Therefore any adverse effects would be similar between scenarios.

6.1.3.8.5 Juveniles (Summer/Fall: ~July-December)

6.1.3.8.5.1 Individual-Level Effects

As with adult Delta Smelt, juvenile Delta Smelt would be expected to be excluded from entrainment at the NBA by the fish screens of the Barker Slough pumping plant, although some impingement and near-field predation could occur. Pumping rates at the North Bay Aqueduct Barker Slough Intake generally would be similar under the NAA and PA (see Table 5.B.5-35 in Appendix 5.B, *DSM2 Modeling and Results*), so the potential risk of impingement and predation may also be similar.

6.1.3.8.5.2 Population-Level Effects

Exclusion of juvenile Delta Smelt by the fish screens at the Barker Slough pumping plant would avoid adverse population-level effects from NBA diversions in terms of entrainment, and generally similar pumping between NAA and PA would limit the potential for near-field predation and impingement risk.

6.1.3.9 Other Facilities

6.1.3.9.1 Contra Costa Canal Rock Slough Intake

6.1.3.9.1.1 Migrating Adults (December-March)

6.1.3.9.1.1.1 Individual-Level Effects

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 Delta Smelt 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), leading to operation of the fish screen only on ebb tides (National Marine Fisheries Service 2015b). At these times, migrating adult Delta Smelt could be susceptible to entrainment. The operational issues with the fish screen have 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. During the December-March period of most relevance to migrating adult Delta Smelt, Rock Slough intake diversions would be very similar between NAA and PA, indicating that the potential for adverse effects to migrating adult Delta Smelt would be similar under the PA compared to NAA. Resolution of the aforementioned issues with screen effectiveness would be expected to minimize the potential for any adverse effects to individual migrating adult Delta Smelt.

6.1.3.9.1.1.2 Population-Level Effects

USFWS (2008: 217) noted that Rock Slough is a dead-end slough with poor habitat for Delta Smelt, so the numbers of Delta Smelt using Rock Slough are usually low, as reflected in very few Delta Smelt having been collected during sampling at the intake. This, combined with relatively small diversions that are very similar between NAA and PA (see discussion in the Individual-Level Effects) suggests that any population-level effect of the Rock Slough intake on migrating adult Delta Smelt would be minimal.

6.1.3.9.1.2 Spawning Adults (February-June)

6.1.3.9.1.2.1 Individual-Level Effects

The issues discussed for migrating adult Delta Smelt with respect to screen effectiveness of the Rock Slough intake also apply to spawning adult Delta Smelt. Modeled pumping of the Rock Slough intake suggested that diversions under the PA generally would be similar to NAA in February, March and June, but not in April and May, when diversions were modeled to be greater under the PA (see Table 5.B.5-36 in Appendix 5.B, *DSM2 Modeling and Results*). The overall diversions for the Rock Slough intake and the other CCWD intakes on Old River and Middle River do not differ greatly between NAA and PA, suggesting that Rock Slough may have been favored in the modeling of PA for operational reasons, e.g., Old and Middle River flow criteria, for example. This could indicate greater potential for adverse effects to spawning adult Delta Smelt under the PA compared to NAA. However, as noted for migrating adult Delta Smelt, resolution of the aforementioned issues with screen effectiveness would be expected to minimize the potential for any adverse effects to individual spawning adult Delta Smelt.

6.1.3.9.1.2.2 Population-Level Effects

As described for migrating adult Delta Smelt, it would be expected that there would be minimal, if any, population-level effects on spawning adult Delta Smelt because Delta Smelt appear to occur in low numbers in Rock Slough, as a result of poor habitat (U.S. Fish and Wildlife Service 2008: 217).

6.1.3.9.1.3 Eggs/Embryos (Spring: ~March-June)

6.1.3.9.1.3.1 Individual-Level Effects

As previously noted, the demersal and adhesive nature of Delta Smelt eggs/embryos means that they would not be subject to entrainment and there would be no individual-level adverse effect from the Rock Slough intake.

6.1.3.9.1.3.2 Population-Level Effects

The demersal and adhesive nature of Delta Smelt eggs/embryos means that there would be no adverse population-level effects from the NBA with respect to entrainment.

6.1.3.9.1.4 Larvae/Young Juveniles (Spring: ~March-June)

6.1.3.9.1.4.1 Individual-Level Effects

As noted in the previous discussions for adult Delta Smelt, there have been operational issues with the Rock Slough intake's effectiveness. Regardless of these issues, some larval and juvenile Delta Smelt could be sufficiently small to not be screened by the Rock Slough intake's fish screen, which would be expected to exclude fish of ~22 mm (see Section 6.1.3.2.1.1.1, *Individual-Level Effects*, related to the NDD). Modeled pumping of the Rock Slough intake suggested that diversions under the PA generally would be similar to NAA in March and June, but not in April and May, when diversions would be greater under the PA (see Table 5.B.5-36 in Appendix 5.B, *DSM2 Modeling and Results*). The overall diversions for the Rock Slough intake and the other CCWD intakes on Old River and Middle River do not differ greatly between NAA and PA, suggesting that Rock Slough may have been favored in the modeling of PA for operational reasons, e.g., Old and Middle River flow criteria, for example. Operation of the Rock Slough intake would be included in the no-fill and no-diversion periods associated with all diversions for CCWD, which would minimize the potential for larval entrainment.

6.1.3.9.1.4.2 Population-Level Effects

As noted by USFWS (2008: 224), larval fish monitoring found few larval Delta Smelt being entrained at the Rock Slough intake, which suggests that any population-level effect of the intake would be very small, particularly in light of the no-fill and no-diversion criteria that are in place to protect listed species during spring.

6.1.3.9.1.5 Juveniles (Summer/Fall: ~July-December)

6.1.3.9.1.5.1 Individual-Level Effects

Potential effects to juvenile Delta Smelt would be similar to those previously discussed for adult Delta Smelt in terms of potential entrainment. Diversions at the Rock Slough intake would be essentially the same under PA as NAA during July-December (see Table 5.B.5-36 in Appendix 5.B, *DSM2 Modeling and Results*), so any entrainment would be expected to be similar.

6.1.3.9.1.5.2 Population-Level Effects

There would be expected to be minimal, if any, population-level effect from diversions at the Rock Slough intake during the juvenile Delta Smelt life stage because habitat suitability in Rock Slough generally is poor for Delta Smelt (USFWS: 217), and abiotic habitat conditions in the summer in the south Delta also are poor for Delta Smelt (Nobriga *et al.* 2008).

6.1.3.9.2 Clifton Court Forebay Aquatic Weed Control Program

6.1.3.9.2.1 Migrating Adults (December-March)

6.1.3.9.2.1.1 Individual-Level Effects

Herbicide treatment of aquatic weeds in Clifton Court Forebay in July/August would avoid potential effects to Delta Smelt migrating adults because treatment would occur well after migration was complete. Mechanical removal of aquatic weeds in Clifton Court Forebay would occur on an as needed basis and therefore could coincide with occurrence of migrating adult Delta Smelt. Delta Smelt generally would not be expected to found near aquatic weeds (Ferrari *et*

al. 2014), but may occur near the weeds if both fish and weeds are concentrated into particular areas by prevailing water movement in the Forebay. Any potential adverse effects to individual Delta Smelt from mechanical removal of water hyacinth or other aquatic weeds (e.g., injury from contact with cutting blades) possibly would be offset to some extent 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.

6.1.3.9.2.1.2 Population-Level Effects

Given the mixture of potential adverse and beneficial effects from mechanical removal of aquatic weeds in Clifton Court Forebay, it is unlikely that there would be a population-level effect on migrating adult Delta Smelt.

6.1.3.9.2.2 Spawning Adults (February-June)

6.1.3.9.2.2.1 Individual-Level Effects

Herbicide treatment of aquatic weeds in Clifton Court Forebay in July/August would avoid potential effects to Delta Smelt spawning adults because any spawning adults present in the Forebay would occur earlier in the year. Any mechanical removal effects would be as described for migrating adults.

6.1.3.9.2.2.2 Population-Level Effects

As described for migrating adults, it is unlikely that there would be a population-level effect on spawning adult Delta Smelt from mechanical removal of aquatic weeds in Clifton Court Forebay.

6.1.3.9.2.3 Eggs/Embryos (Spring: ~March-June)

6.1.3.9.2.3.1 Individual-Level Effects

Herbicide treatment of aquatic weeds in Clifton Court Forebay in July/August would avoid potential effects to Delta Smelt eggs/embryos because eggs/embryos would occur earlier in the year. Mechanical removal of aquatic weeds on an as-needed basis could coincide with egg/embryo occurrence, but may be limited in effect if focusing on water hyacinth in the upper water column, which would avoid eggs/embryos adhering to benthic substrates.

6.1.3.9.2.3.2 Population-Level Effects

Any population-level adverse effects from physical predator reduction methods at Clifton Court Forebay would be minimal to nil, given the lack of temporal and spatial overlap for potential individual-level effects and the low probability of eggs/embryos to survive the salvage process in subsequent life stages.

6.1.3.9.2.4 Larvae/Young Juveniles (Spring: ~March-June)

6.1.3.9.2.4.1 Individual-Level Effects

As with adults and eggs/embryos, larval/young juvenile Delta Smelt would not temporally overlap the period of herbicide treatment of aquatic weeds in Clifton Court Forebay (July-August). Mechanical removal effects may be similar to those noted previously for migrating adult Delta Smelt.

6.1.3.9.2.4.2 Population-Level Effects

Population-level effects from mechanical removal at Clifton Court Forebay would be essentially zero, given the mixture of potential adverse and beneficial effects and the low probability of larvae/young juveniles to survive the salvage process.

6.1.3.9.2.5 Juveniles (Summer/Fall: ~July-December)

6.1.3.9.2.5.1 Individual-Level Effects

There would be essentially no potential for individual juvenile Delta Smelt to be adversely affected by either herbicide treatment or mechanical removal of aquatic weeds because this life stage occurs outside of Clifton Court Forebay; Delta Smelt that are susceptible to entrainment into Clifton Court Forebay are either migrating adults or larvae/young juveniles, and the waters in the Forebay would be expected to become too warm for juvenile Delta Smelt by July.

6.1.3.9.2.5.2 Population-Level Effects

Following from the lack of individual-level effects, there would be no population-level effect on juvenile Delta Smelt.

6.1.3.10 Effects from Water Facility Operations on Delta Smelt Critical Habitat

The assessment of effects from water facility operations on Delta Smelt critical habitat presented in this section follows the basic structure of the analyses of Individual-Level and Population-Level effects presented in Sections 6.1.3.2 to 6.1.3.9, with the effects generally analyzed by facility. One exception is Section 6.1.3.10.4, *Habitat Effects*, which discusses the effects to critical habitat in relation to the factors discussed in Section 6.1.3.5, *Habitat Effects, i.e.*, abiotic habitat, water temperature, sediment removal, and *Microcystis*.

6.1.3.10.1 North Delta Exports

6.1.3.10.1.1 PCE 1: Physical Habitat (Spawning Substrate)

The potential effect of north Delta exports on spawning substrate could occur only if the NDD remove enough sand from the inflowing sediment load (over several decades of operation) to significantly change the location or quantity of existing sandy beaches, as discussed further in Section 6.1.3.10.4.1. The ability of migrating adult Delta Smelt to access spawning substrate upstream of the NDD could be affected by changes in river flow/velocity near the NDD; see discussion for PCE 3.

6.1.3.10.1.2 PCE 2: Water (Quality)

Water that otherwise would be of suitable quality for Delta Smelt may be affected by the loss of low-velocity habitat to the NDD, which make them susceptible to injury or death by entrainment, impingement, or screen contact, and could affect access to habitat at and upstream of the NDD. This is discussed further in relation to PCE 3. In addition, enhanced predation along the NDD could affect the function of PCE 2. Potential effects to other aspects of PCE 2 such as sediment removal (influencing water clarity) and entrainment of food web materials are discussed in Section 6.1.3.10.4, *Habitat Effects*.

6.1.3.10.1.3 PCE 3: River Flow (Facilitating Movement)

The NDD would affect the river flow PCE 3 by changing water velocity, which could make Delta Smelt susceptible to entrainment (smaller life stages), impingement, or screen contact,

which could result in injury or death, although their potential to occur in the vicinity of the NDD is very low. Any effects would be avoided and minimized by the location of the NDD, as well as screen design and operational criteria (e.g., 0.2 ft/s approach velocity), with final design subject to review and approval by the fish and wildlife agencies (i.e., USFWS, NMFS, and CDFW) (see Chapter 3, Section 3.2.2.2, *Fish Screen Design*). As assessed in Section 6.1.3.2.2.1, *Migrating Adults (December-March)*, for effects to migrating adult Delta Smelt, the higher velocity habitat along the screens of the NDD would be likely to reduce, along the east bank of the Sacramento River, the probability of accessing upstream designated critical habitat—which extends to the upstream boundary of the statutory Delta at the I Street Bridge in Sacramento—for Delta Smelt. This habitat is likely to have limited value to Delta Smelt, other than perhaps providing a relatively small area of spawning habitat. The extent to which the PA could limit access to the relatively small area of upstream critical habitat would depend on the extent that Delta Smelt would use lower velocity habitat on the right (west) bank of the river (opposite the NDD), near the channel bottom, or within the refugia along the intakes. Due to these considerations, the PA is not considered to appreciably diminish the overall critical habitat value for both survival and recovery of Delta Smelt in regards to PCE 3. However, recognizing the potential effect to partially limit access of designated critical habitat upstream of the NDD, DWR proposes to compensate by providing up to 55 acres of tidal wetland restoration, with the final acreage to be based on the extent that continuing beach seine monitoring at Garcia Bend demonstrates that Delta Smelt occur upstream at rates similar to those observed before the start of NDD construction and operation. The 55 acres represents a preliminary estimate of the extent of sandy beach habitat (PCE 1) from the lowermost extent of intake 5 to the upstream boundary of designated critical habitat, based on examination of aerial photographs (Section 6.A.2.4, *Compensation for Potential Reduced Access to Critical Habitat Upstream of NDD*, in Appendix 6.A, *Quantitative Methods for Biological Assessment of Delta Smelt*). The initial estimate of 55 acres would be refined with field surveys.

6.1.3.10.1.4 PCE 4: Salinity (Low Salinity Zone)

The location and extent of the low salinity zone is determined by Delta outflow, which would be affected by north and south Delta exports combined. See the discussion related to PCE 4 in Section 6.1.3.10.4.4, *PCE 4: Salinity (Low Salinity Zone).*

6.1.3.10.2 South Delta Exports

6.1.3.10.2.1 PCE 1: Physical Habitat (Spawning Substrate)

Spawning substrate would not be affected by operations of the south Delta export facilities.

6.1.3.10.2.2 PCE 2: Water (Quality)

The general reduction in entrainment risk for Delta Smelt under the PA with respect to the south Delta export facilities, as a result of less south Delta pumping and improved south Delta hydrodynamic conditions, would be expected to beneficially affect the water quality PCE. Although there would still be an effect to PCE 3 because of the PA, it would be less than under NAA.

6.1.3.10.2.3 PCE 3: River Flow (Facilitating Movement)

As with PCE 2, less south Delta pumping and improved south Delta hydrodynamic conditions would be expected to beneficially modify the river flow PCE. Although there would still be an effect to PCE 3 because of the PA, it would be less than under NAA.

6.1.3.10.2.4 PCE 4: Salinity (Low Salinity Zone)

The location and extent of the low salinity zone is determined by Delta outflow, which would be affected by north and south Delta exports combined. See the discussion related to PCE 4 in Section 6.1.3.10.4.4, *PCE 4: Salinity (Low Salinity Zone).*

6.1.3.10.3 Head of Old River Gate Operations

6.1.3.10.3.1 PCE 1: Physical Habitat (Spawning Substrate)

Spawning substrate would not be affected by operations of the HOR gate.

6.1.3.10.3.2 PCE 2: Water (Quality)

Operations of the HOR gate have some potential to affect the water PCE, e.g., by affecting susceptibility to entrainment at the south Delta export facilities (see PCE 3 discussion) when water quality is otherwise suitable, and affecting water temperature (see discussion for PCE 2 in Section 6.3.10.4, *Habitat Effects (Combined North/South Delta Exports*).

6.1.3.10.3.3 PCE 3: River Flow (Facilitating Movement)

As demonstrated in the analysis of larval/young juvenile entrainment, closure of the HOR gate has the potential to affect river flow in the south Delta, and therefore the risk of entrainment. The CALSIM II modeling to support the PA indicates that OMR flow rules can be met with the proposed HOR gates closed up to 50% of the time during the spring months.

6.1.3.10.3.4 PCE 4: Salinity (Low Salinity Zone)

Head of Old River gate operations would not affect the extent or location of the low salinity zone nursery habitat.

6.1.3.10.4 Habitat Effects

6.1.3.10.4.1 PCE 1: Physical Habitat (Spawning Substrate)

The spawning microhabitat of Delta Smelt is not presently known, but the current conceptual model is that it is sandy beaches (Bennett 2005). If this conceptual model is correct, spawning substrate would only be modified by water operations if they remove enough sand from the inflowing sediment load (over several decades of operation) to significantly change the location or quantity of existing sandy beaches. Whether or not this would happen cannot be accurately estimated without use of a full suspended sediment model. As described in 6.1.3.5.3, *Sediment Removal (Water Clarity)*, DWR will collaborate with USFWS and CDFW to develop and implement a sediment reintroduction plan that provides the desired beneficial habitat effects of maintained turbidity while addressing related permitting concerns (the proposed sediment reintroduction is expected to require permits from the Water Control Board and USACE). This would mitigate the effects of sediment removal by the NDD.

6.1.3.10.4.2 PCE 2: Water (Quality)

As noted in the effects by life stages presented in Section 6.1.3.5.2, *Water Temperature*, water temperature under the PA could be somewhat greater than under the NAA for spawning, larval/young juvenile, and juvenile Delta Smelt. 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); therefore, the effects to PCE 2 may be limited.

Water transparency is a key habitat attribute for Delta Smelt. Thus, any reduction in sediment entering the Delta because of entrainment at the NDD that is sufficient to increase water clarity would affect the water quality PCE. Whether or not this would happen cannot be accurately estimated without use of a full suspended sediment model, and may be a long-term effect. As noted for PCE 1, DWR will collaborate with USFWS and CDFW to develop and implement a sediment reintroduction plan that provides the desired beneficial habitat effects of maintained turbidity while addressing related permitting concerns, which would be intended to minimize potential effects to PCE 2.

Entrainment of phytoplankton carbon by the NDD, if not sufficiently offset by potential decreases in south Delta entrainment of the same materials and in-Delta production, would have the potential to decrease the availability of prey for Delta Smelt by reducing food available for Delta Smelt prey. As described in Section 6.1.3.5.4, *Entrainment of Food Web Materials*, in general only a small percentage (5% or less) of the standing stock of phytoplankton would be expected to be entrained in this manner, so the effect to PCE 2 may be limited.

Greater prevalence of *Microcystis* because of operational effects under the PA relative to NAA has the potential to affect the water quality PCE in some Delta channels (see Section 6.1.3.5.5, *Microcystis*). As noted in Section 6.1.3.5.5.5.2, *Population-Level Effects*, the modeling currently assumes that in the summer months (July–September), the first 3,000 cfs of exports would be from the south Delta, with any additional allowable exports able to be diverted from either the north or the south Delta, and preference for this additional pumping generally is given to the north Delta (because of higher water quality); it would be possible to shift to additional south Delta pumping as opposed to north Delta pumping in order to reduce water residence time, which may reduce the potential for effects of *Microcystis*.

6.1.3.10.4.3 PCE 3: River Flow (Facilitating Movement)

The potential effects to PCE 3 with respect to the winter/spring periods during which time Delta Smelt may be susceptible to entrainment, impingement, and other effects from north and south Delta exports were presented in Sections 6.1.3.10.1.3, *PCE3: River Flow (Facilitating Movement)* and 6.1.3.10.2.3. During the fall rearing period for juvenile Delta Smelt, the PA proposes essentially the same Delta outflow as the NAA, so this PCE would not be affected (see Section 6.1.3.5.1, *Abiotic Habitat*).

6.1.3.10.4.4 PCE 4: Salinity (Low Salinity Zone)

As discussed for PCE 5, the PA proposes essentially the same Delta outflow as the NAA during the period of juvenile fall rearing that may occur within the low salinity zone, so this PCE would not be affected.

6.1.3.10.5 Suisun Marsh Facilities

6.1.3.10.5.1 PCE 1: Physical Habitat (Spawning Substrate)

Operations of the Suisun Marsh facilities (SMSCG, MIDS, RRDS, and Goodyear Slough Outfall) would not affect the spawning substrate PCE for Delta Smelt.

6.1.3.10.5.2 PCE 2: Water (Quality)

In general, the Suisun Marsh facilities would have little effect on water quality for Delta Smelt. Although water quality in Montezuma Slough may otherwise be suitable for Delta Smelt close to

the RRDS intake, the risk of entrainment of larval/young juvenile Delta Smelt through the RRDS intake screens (or impingement on the screens) would produce a localized effect to this PCE, in combination with PCE 3. This would also be true for the unscreened MIDS in Goodyear Slough. Operation of the Goodyear Slough outfall is intended to improve water circulation in Suisun Marsh and therefore would be expected to provide beneficial effects to the water quality PCE for Delta Smelt critical habitat.

6.1.3.10.5.3 PCE 3: River Flow (Facilitating Movement)

As noted in the discussion for migrating adult Delta Smelt, operation of the SMSCG could entrain Delta Smelt into Montezuma Slough downstream of the SMSCG during ebb tide, and not allow return with the flood tide as the gates are closed. The DSM2-HYDRO modeling data demonstrated that these effects would be very similar between NAA and PA, and the extent to which movement around the low salinity zone is constrained is unknown (U.S. Fish and Wildlife Service 2008: 218). Operation of the RRDS and MIDS intakes results in a localized effect on channel flow in Montezuma Slough for larval/early juvenile Delta Smelt and Goodyear Slough for Delta Smelt, which may result in entrainment into the RRDS and/or MIDS, respectively. This effect would be similar under the NAA and PA, and represents a continuation of ongoing operations.

6.1.3.10.5.4 PCE 4: Salinity (Low Salinity Zone)

As discussed in the analysis of effects to juvenile Delta Smelt, although operation of the SMSCG moves the low salinity zone (indexed by X2) upstream for a given Delta outflow, operations would be managed in such a way that X2 would be very similar between NAA and PA, so there would be no effect on the salinity PCE.

6.1.3.10.6 North Bay Aqueduct

6.1.3.10.6.1 PCE 1: Physical Habitat (Spawning Substrate)

Operation of the NBA would not modify the spawning substrate PCE for Delta Smelt.

6.1.3.10.6.2 PCE 2: Water (Quality)

Diversions to the NBA could produce a localized effect on otherwise suitable water quality by increasing susceptibility of larval Delta Smelt to entrainment by the NBA; however, as previously noted in Individual-Level and Population-Level Effects sections, such effects would be similar between the NAA and PA.

6.1.3.10.6.3 PCE 3: River Flow (Facilitating Movement)

As with PCE 2, diversions to the NBA could produce a localized effect on flow in Barker Slough which could increase susceptibility of larval Delta Smelt to entrainment by the NBA. Such effects would be similar between the NAA and PA.

6.1.3.10.6.4 PCE 4: Salinity (Low Salinity Zone)

The small size of the diversions to the NBA would produce minimal changes to the low salinity zone and, as shown in the analysis of fall rearing abiotic habitat for juvenile Delta Smelt, there would be little difference between NAA and PA in the low salinity zone extent as indexed by the fall abiotic habitat index, because of overall management of exports in the Delta.

6.1.3.10.7 Other Facilities

6.1.3.10.7.1 Contra Costa Canal Rock Slough Intake

6.1.3.10.7.1.1 PCE 1: Physical Habitat (Spawning Substrate)

Operation of the Rock Slough intake would not modify the spawning substrate PCE for Delta Smelt.

6.1.3.10.7.1.2 PCE 2: Water (Quality)

Diversions to the Rock Slough intake could produce a localized effect to otherwise suitable water quality by increasing susceptibility of Delta Smelt to entrainment; however, as previously noted in Section 6.1.3.9.1, *Contra Costa Canal Rock Slough Intake*, Rock Slough generally has low habitat quality for Delta Smelt.

6.1.3.10.7.1.3 PCE 3: River Flow (Facilitating Movement)

As with PCE 2, diversions by the Rock Slough intake could produce a localized effect on flow in Rock Slough which could increase susceptibility of larval Delta Smelt to entrainment. Modeled diversions during April and May were greater under the PA, although the no-fill and no-diversion periods discussed in Section 6.1.3.9.1, *Contra Costa Canal Rock Slough Intake*, are intended to minimize the potential for effects to Delta Smelt and other listed species and adverse modification of critical habitat.

6.1.3.10.7.1.4 PCE 4: Salinity (Low Salinity Zone)

The small size of the diversions to the Rock Slough intake would produce minimal changes to the low salinity zone and, as shown in the analysis of fall rearing abiotic habitat for juvenile Delta Smelt, there would be little difference between NAA and PA in the low salinity zone extent as indexed by the fall abiotic habitat index, because of overall management of exports in the Delta.

6.1.3.10.7.2 Clifton Court Forebay Aquatic Weed Control Program

6.1.3.10.7.2.1 PCE 1: Physical Habitat (Spawning Substrate)

Spawning substrate would not be adversely modified by herbicide treatment and is unlikely to be adversely modified by mechanical removal of aquatic weeds. Any effects on spawning substrate in Clifton Court Forebay are not considered important, given that the water quality PCE is severely modified by the risk of entrainment, with low prospects of survival to any successfully spawned Delta Smelt.

6.1.3.10.7.2.2 PCE 2: Water (Quality)

As described for motile life stages such as migrating adult Delta Smelt in Section 6.1.3.7.2, *Clifton Court Forebay Aquatic Weed Control Program*, water quality effects would not be expected from herbicide treatment because there would not be a temporal overlap in treatment (July-August) with Delta Smelt occurrence (December-June). The potential for adverse modification of this PCE because of mechanical removal of aquatic weeds (e.g., injury from contact with cutting blades) may be offset to some extent 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.

6.1.3.10.7.2.3 PCE 3: River Flow (Facilitating Movement)

The Clifton Court Forebay Aquatic Weed Control Program would not modify river flows that facilitate movement of Delta Smelt life stages.

6.1.3.10.7.2.4 PCE 4: Salinity (Low Salinity Zone)

The Clifton Court Forebay Aquatic Weed Control Program would not modify the extent or location of low salinity zone nursery habitat.

6.1.4 Effects of Conservation Measures on Delta Smelt

6.1.4.1 Tidal and Channel Margin Habitat Restoration

6.1.4.1.1 Migrating Adults (December-March)

6.1.4.1.1.1 Individual-Level Effects

Construction at habitat restoration sites would be undertaken during approved in-water work windows (summer/fall) and therefore would not affect individual migrating adult Delta Smelt. To the extent that individual Delta Smelt encounter restoration sites (e.g., when occupying nearshore areas during ebb tides of upstream migrations; Bennett and Burau 2015), the restoration is intended to 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 zooplankton prey or increasing subtidal habitat diversity. As suggested for the Lower Yolo Ranch Restoration Project (National Marine Fisheries Service 2014), potential adverse effects to migrating adult Delta Smelt at habitat restoration sites under construction include degraded water quality (e.g., liberation of contaminants 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.

6.1.4.1.1.2 Population-Level Effects

The intention of habitat restoration projects is to improve habitat conditions so the population-level effect on migrating adult Delta Smelt, if there is one, should be beneficial.

6.1.4.1.2 Spawning Adults (February-June)

6.1.4.1.2.1 Individual-Level Effects

As with migrating adult Delta Smelt, construction at habitat restoration sites would be undertaken during approved in-water work windows (summer/fall) and therefore individual spawners would not be affected by construction per se. Should restored habitat include suitable holding and spawning microhabitat for Delta Smelt (the latter being hypothesized to be sandy shallow areas, per Bennett [2005]), completed restoration projects may provide greater spawning opportunities to individual adult Delta Smelt than NAA; they may also increase feeding opportunities if zooplankton prey production increases. As with migrating adults, there may be water quality and predation risks associated with habitat restoration that could result in some adverse effects to individual fish.

6.1.4.1.2.2 Population-Level Effects

The intention of habitat restoration projects is to improve habitat conditions so the population-level effect on spawning adult Delta Smelt, if there is one, should be beneficial.

6.1.4.1.3 Eggs/Embryos (Spring: ~March–June)

6.1.4.1.3.1 Individual-Level Effects

As stated above, construction at habitat restoration sites would be undertaken during approved in-water work windows (summer/fall) and therefore would not affect eggs/embryos in spring. When construction is completed, and if suitable spawning microhabitat was successfully provided, individual Delta Smelt may spawn eggs at the site, producing a positive individual impact.

6.1.4.1.3.2 Population-Level Effects

The intention of habitat restoration projects is to improve habitat conditions so the population-level effect on Delta Smelt eggs/embryos, if there is one, should be beneficial.

6.1.4.1.4 Larvae/Young Juveniles (Spring: ~March–June)

6.1.4.1.4.1 Individual-Level Effects

It is anticipated that habitat restoration work would occur during a late spring/summer/fall work window (June through October) (see Section 3.4.4.1, *Tidal Wetland Restoration*, in Chapter 3), so there would be limited potential for effects of construction on individual Delta Smelt larvae using the temporal definition applied in this effects analysis. The types of effects described for juvenile Delta Smelt could occur for larval Delta Smelt occurring near construction of habitat restoration.

6.1.4.1.4.2 Population-Level Effects

The intention of habitat restoration projects is to improve habitat conditions so the population-level effect on Delta Smelt larvae/young juveniles, if there is one, should be beneficial.

6.1.4.1.5 Juveniles (Summer/Fall: ~July–December)

6.1.4.1.5.1 Individual-Level Effects

Habitat restoration projects intended to ultimately benefit Delta Smelt have to be located where Delta Smelt are likely to occur. Thus, there is the potential for adverse effects on individuals during construction. Juveniles are the only Delta Smelt life stage that would be affected by construction at habitat restoration sites, on the basis of temporal overlap with the summer/fall in-water work windows. As with other life stages, there would be long-term positive effects once habitat restoration is complete. Potential short-term adverse effects from tidal habitat restoration are exemplified by those described as potential effects for the Lower Yolo Tidal Restoration Project (National Marine Fisheries Service 2014). To the extent practicable, grading and excavation of marsh plains and tidal channels would be done prior to excavation of levee perimeter notches, to minimize adverse effects on juvenile Delta Smelt. Excavation of levee perimeter notches to allow tidal exchange could result in several effects to juvenile Delta Smelt: temporary loss of aquatic and riparian habitat (e.g., increasing predation potential because of reduced cover, reduced substrate for prey, and increased water temperature); degraded water quality from contaminants liberated from soils and increased suspended sediment which could affect fish directly if in very high concentration, as well as affecting prey availability; heavy machinery noise resulting in fish being inhibited from movements near the work areas, and possibly being startled away from work areas and therefore becoming more susceptible to predation as a result; direct strikes to fish from construction equipment performing notch excavation; and stranding of fish within dewatered areas (e.g., within cofferdams) that may be required during construction. However, as shown for the Lower Yolo Tidal Restoration Project,

such potential adverse effects can be minimized by construction techniques such as not operating heavy machinery from the water; limiting construction to only the small areas necessary to restore tidal connections; limiting work to low tide and daylight hours; and installing sheet pile exclusion barriers with vibratory hammers.

6.1.4.1.5.2 Population-Level Effects

The intention of habitat restoration projects is to improve habitat conditions so the population-level effect on juvenile Delta Smelt, if there is one, should be beneficial.

6.1.4.2 Localized Reduction of Predatory Fishes to Minimize Predator Density at North and South Delta Export Facilities

As described in Appendix 3.F, *General Avoidance and Minimization Measures*, localized reduction of predatory fishes is proposed to occur at the NDD and Clifton Court Forebay using physical reduction methods, including boat electrofishing, hook-and-line fishing, passive capture by net or trap (e.g., gillnetting, hoop net, fyke trap), and active capture by net (e.g., beach seine). The goal of this measure is to reduce predation on juvenile salmonids occurring at the north Delta and south Delta export facilities, and as such would be focused on the winter/spring period (~December-June) when juvenile salmonids are migrating through the Delta. As described in the predation effects assessments for Delta Smelt at the north Delta (Section 6.1.3.2.3, *Predation at the North Delta Export Facilities*) and south Delta (Section 6.1.3.3.2, *Predation* at the *South Delta Export Facilities*, this conservation measure could also potentially reduce predation on Delta Smelt, but predator removal in CCF has no meaningful capacity to impact Delta Smelt and if Delta Smelt numbers at the NDD are very low (as described above), predator removal from in front of the NDD fish screens will also have no meaningful impact.

6.1.4.2.1 Migrating Adults (December-March)

6.1.4.2.1.1 Individual-Level Effects

The methods that could be used to minimize the local abundance of predatory fish at the NDD and Clifton Court Forebay would have some potential to adversely affect migrating adult Delta Smelt. The main effect perhaps being startling of individuals during gear deployment (which could ironically increase predation susceptibility, assuming predators in the vicinity are not also startled) or injure fish if they contacted nets trying to escape through the mesh. Capture of adult Delta Smelt by hook-and-line fishing would not occur, and passive or active capture methods involving traps or nets would involve mesh sizes through which Delta Smelt would be able to escape. Electrofishing gear would be set to target fish of the size likely to be predators on juvenile salmonids and as such would have lesser impact on Delta Smelt than large-bodied fish because at a given voltage gradient, total body voltage increases with length, resulting in greater potential to capture larger fish without effects to smaller fish (Reynolds and Kolz 2012). As described in the predation effects assessments for Delta Smelt at the north Delta (Section 6.1.3.2.3, *Predation at the North Delta Export Facilities*) and south Delta (Section 6.1.3.3.2, *Predation* at the *South Delta Export Facilities*), to the extent that predatory fish density reduction is successful, it could reduce predation on Delta Smelt adults occurring near the NDD and in Clifton Court Forebay.

6.1.4.2.1.2 Population-Level Effects

As previously described in the analysis of entrainment and impingement at the NDD (Section 6.1.3.2, *North Delta Exports*), it is anticipated that very low numbers of migrating adult Delta Smelt would occur near the NDD, so predator removal in front of the NDD fish screens would be expected to have no meaningful effect on migrating adult Delta Smelt at the population level. In addition, the survival of Delta Smelt reaching the south Delta fish facilities is likely to be very low, so predator removal in CCF has no meaningful capacity to affect the Delta Smelt population.

6.1.4.2.2 Spawning Adults (February-June)

6.1.4.2.2.1 Individual-Level Effects

The analysis presented in Section 6.1.4.2.1.1, *Individual-Level Effects,* for migrating adult Delta Smelt would also apply to spawning adults.

6.1.4.2.2.2 Population-Level Effects

As previously described in the analysis of entrainment and impingement at the NDD (Section 6.1.3.2, *North Delta Exports*) and discussed for migrating adults, it is anticipated that very low numbers of spawning adult Delta Smelt would occur near the NDD, so predator removal in front of the NDD fish screens would be expected to have no meaningful effect on spawning adult Delta Smelt at the population level. In addition, the survival of Delta Smelt reaching the south Delta fish facilities is likely to be very low, so predator removal in CCF has no meaningful capacity to affect the Delta Smelt population

6.1.4.2.3 Eggs/Embryos (Spring: ~March–June)

6.1.4.2.3.1 Individual-Level Effects

If Delta Smelt spawned in Clifton Court Forebay, the survival of the progeny once they hatched would be likely to be close to zero. The proposed predator removal tactics are designed to catch larger piscivorous fishes and not the small fishes and shrimp that likely comprise the major predators of Delta Smelt eggs. The capture techniques generally are not anticipated to catch eggs attached to sandy substrates. Thus, there is unlikely to be an effect on individual Delta Smelt eggs.

6.1.4.2.3.2 Population-Level Effects

The lack of effects on individual eggs/embryos from predator reduction would result in no population-level effects on this life stage. Larvae/Young Juveniles (Spring: ~March–June)

6.1.4.2.3.3 Individual-Level Effects

The biggest known predator of Delta Smelt larvae is inland (a.k.a. Mississippi) silverside (Baerwald *et al.* 2012). This fish is the same size as Delta Smelt and therefore will not be vulnerable to the methods proposed to catch large piscivorous fishes. Therefore it is unlikely that there would be an effect on individual larval and young juvenile Delta Smelt from predator capture.

6.1.4.2.3.4 Population-Level Effects

Adverse population-level effects to larval/young juvenile Delta Smelt from predatory fish reduction would not occur because of the limited prospect of individual-level effects, the small

proportion of the population likely to occur near the NDD, and the low probability of individuals occurring in Clifton Court Forebay surviving the salvage process.

6.1.4.2.4 Juveniles (Summer/Fall: ~July-December)

6.1.4.2.4.1 Individual-Level Effects

The December-June period in which predator reduction activities are proposed to be focused essentially does not overlap the period of occurrence of juvenile Delta Smelt, so the types of effects noted for other life stages are unlikely.

6.1.4.2.4.2 Population-Level Effects

The lack of temporal overlap of this life stage with predator reduction activities means that there would be no population-level effect.

6.1.4.3 Georgiana Slough Nonphysical Fish Barrier

As described in Appendix 3.F, *General Avoidance and Minimization Measures*, the Georgiana Slough Nonphysical Fish Barrier (NPB) would consist of an NPB to reduce the likelihood of Sacramento River-origin juvenile salmonids entering the interior Delta through Georgiana Slough. Based on a recent evaluation of different technology to achieve this goal, a bioacoustic fish fence (BAFF) appears to offer more potential than a floating fish guidance structure (FFGS) for this location (DWR 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[20] because the focus for protection is surface-oriented juvenile salmonids, but the BAFF consists of acoustic deterrence stimuli broadcast from loudspeakers and contained within a bubble curtain that is illuminated with strobe lights (to allow the fish to orient away from the sound stimulus better), whereas the FFGS is a floating series of metal plates that deters fish based on them seeing the barrier and sensing the change in flow. Whereas the pilot studies of these technologies and their construction occurred in winter/spring, for the PA construction and removal would be done outside the main period of juvenile salmonid occurrence (November/December-June).

6.1.4.3.1 Migrating Adults (December-March)

6.1.4.3.1.1 Individual-Level Effects

Individual Delta Smelt migrating upstream via Georgiana Slough or the Sacramento River would not be affected by the construction of this NPB because construction would occur before any smelt moved this far upstream. The operational effects could include enhanced risk of predation near the NPB, as they include in-water structures that predatory fish may use as ambush habitat, and the NPB is designed to startle fish to cause them to change their course (particularly the BAFF, with its acoustic deterrence). However, there was no evidence from acoustic tracking that juvenile salmonids were being preyed upon at higher rates near the BAFF compared to sites farther away in 2011 and 2012, and little evidence from acoustic tracking of predators that they occupied areas near the BAFF more frequently than other areas (DWR 2012, 2015a). Indeed, the

[20] In the case of the BAFF, the top half of the water column (~10–12 feet); in the case of the FFGS, 5 feet for the 2014 pilot study because of lower water levels caused by drought conditions, whereas 10 feet would be possible with greater river flow.

2011 and 2012 BAFF pilot studies provided evidence that predatory fish were deterred by the BAFF,[21] with general evidence for increasing avoidance over time for all species combined, although some species may have become conditioned to the BAFF over time and therefore would not have been deterred. Studies of the 2014 FFGS have not been completed to address these topics. Migrating adult Delta Smelt encountering the NPB could be dissuaded from moving further upstream or startled 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[22], they would be able to swim under/around the FFGS, or under the BAFF. Further, there is no known reason that Delta Smelt need to move beyond this junction to spawn. Most fish spawn in places distant from the junction of Georgiana Slough and the Sacramento River.

6.1.4.3.1.2 Population-Level Effects

Few Delta Smelt are known to spawn in the Sacramento River and Georgiana Slough where the NPB will be located. There should be little if any population impact of this proposed salmonid fish conservation measure.

6.1.4.3.2 Spawning Adults (February–June)

6.1.4.3.2.1 Individual-Level Effects

The potential effects to spawning adult Delta Smelt from NPB would be similar to those noted for migrating adult Delta Smelt. However, these effects would be less likely to occur because spawning adult Delta Smelt would not be undergoing the broad-scale movements of migrating adults and therefore would have less potential to encounter the NPBs.

6.1.4.3.2.2 Population-Level Effects

As described for migrating adult Delta Smelt, few Delta Smelt are known to spawn in the Sacramento River and Georgiana Slough where the NPB will be located. There should be little if any population impact of this proposed salmonid fish conservation measure.

6.1.4.3.3 Eggs/Embryos (Spring: ~March–June)

6.1.4.3.3.1 Individual-Level Effects

Delta smelt eggs/embryos would not overlap the construction or removal periods of the NPB and there would be no potential for adverse individual-level effects from operations.

6.1.4.3.3.2 Population-Level Effects

The lack of individual-level effects from the NPB on eggs/embryos means there would be no population-level effect.

6.1.4.3.4 Larvae/Young Juveniles (Spring: ~March–June)

6.1.4.3.4.1 Individual-Level Effects

Larval/young juvenile Delta Smelt moving down the Sacramento River could encounter the NPB. Given their weak swimming abilities, they may be subject to near-field hydraulic effects

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

[22] The BAFF pilot studies in 2011 and 2012 blocked the entire entrance to Georgiana Slough, 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.

such as slight alterations of direction in response to changes in flows, and possibly injury when contacting the structures associated with the NPB.

6.1.4.3.4.2 Population-Level Effects

Few Delta Smelt are known to spawn in the Sacramento River and Georgiana Slough where the NPB will be located, resulting in few larvae/young juveniles in the area. There should be little if any population impact of this proposed salmonid fish conservation measure.

6.1.4.3.5 Juveniles (Summer/Fall: ~July-December)

6.1.4.3.5.1 Individual-Level Effects

The Delta Smelt juvenile life stage would be the only part of the life cycle that would have the potential to experience adverse effects to individuals from construction and removal of the NPB. Any pile-driving that would occur would be done with a vibratory hammer, which would minimize the potential for injury and probably limit adverse effects by deterring fish from the construction site. In-water work would be performed consistent with the biological opinions for the pilot implementations of the BAFF (U.S. Fish and Wildlife Service 2011b) and FFGS (U.S. Fish and Wildlife Service 2014). As with adults, altered behavior and locally elevated predation could occur.

6.1.4.3.5.2 Population-Level Effects

Few juvenile Delta Smelt are known to rear in the Sacramento River and Georgiana Slough where the NPB will be located. There should be little if any population impact of this proposed salmonid fish conservation measure.

6.1.4.4 Effects of Conservation Measures on Delta Smelt Critical Habitat

6.1.4.4.1 PCE 1: Physical Habitat (Spawning Substrate)

Although minimal, if any, effects to spawning substrate are anticipated, restoration of tidal habitat and channel margin habitat would have the potential to offset losses in spawning substrate.

As described above for effects to eggs/embryos, substrate-disturbing localized predatory fish reduction methods (e.g., beach seining) would have the potential to affect the spawning substrate PCE. However, such methods would only seem to be feasible in Clifton Court Forebay and not near the NDD (because of the deep-water habitat and steeply sloping banks in the vicinity), and effects on spawning substrate in Clifton Court Forebay are not considered important, given that the water quality PCE is severely modified by the risk of entrainment, with low prospects of survival to any successfully spawned Delta Smelt.

Implementation of a NPB at Georgiana Slough would have minimal effects on Delta Smelt spawning substrate, which most likely would be limited to piles driven into the substrate, or anchoring of associated structures.

6.1.4.4.2 PCE 2: Water (Quality)

Construction-related effects to water quality (e.g., increases in suspended sediment during earth-moving activities) would of similar nature to construction related effects described above, but would be limited in duration, would occur during work windows to minimize exposure of Delta

Smelt, and minimized with standard AMMs. Therefore there would not be effects on the water quality PCE.

Sediment disturbance and releases of contaminants (e.g., fuel spills) during construction/removal activities of NPB would have the potential to result in effects on the water quality PCE (e.g., by liberating contaminants), but the implementation of standard AMMs and the limited duration of the work would minimize effects on this PCE, as concluded for the pilot projects (U.S. Fish and Wildlife Service 2011b, 2014).

6.1.4.4.3 PCE 3: River Flow (Facilitating Movement)

None of the conservation measures would affect river flow.

6.1.4.4.4 PCE 4: Salinity (Low Salinity Zone)

None of the conservation measures would affect salinity.

6.1.5 Effects of Monitoring Activities

As described in Section 3.4.9.2.4 of Chapter 3, effectiveness monitoring for fish would consist of a combination of continuation of existing monitoring authorized under the 2008/2009 BiOps (*i.e.*, principally salvage and larval smelt monitoring at the south Delta export facilities), as well as additional monitoring of the NDD (principally entrainment and impingement monitoring). Entrainment monitoring at the NDD would consist of sampling entrained fish behind the fish screens with a fyke net (see Table 3.4-5 in Chapter 3); impingement monitoring methods are not specified at this time, but on the basis of existing monitoring (e.g., Freeport Regional Water Authority intake's fish screen), would be likely to consist of visual observation by diver survey or acoustic imaging camera. Other monitoring activities that are part of the PA would be unlikely to affect Delta Smelt and are not discussed here. Existing monitoring activities that would inform operations of the PA (e.g., trawl and seines surveys by DFW and USFWS) are not part of the PA. Although monitoring activities at restoration sites have not been determined, they are not expected to include in-water work with any potential to harm Delta Smelt or any other listed fishes.

6.1.5.1 Migrating Adults (December-March)

6.1.5.1.1 Individual-Level Effects

As discussed in Section 6.1.3.2.1.1, *Migrating Adults (December-March*) for the NDD, the NDD fish screens would exclude migrating adult Delta Smelt from entrainment, so there would be no effect from entrainment monitoring at the NDD. If impingement monitoring were to consist of visual observation by diver survey, there would be minor potential for individual migrating adult Delta Smelt occurring immediately adjacent to the fish screens to be startled and leave the immediate area if encountering the divers; there would be no effect if conducting observations with an acoustic imaging camera. At the south Delta export facilities, salvage of migrating adult Delta Smelt would be done in the same way under NAA and PA. Individual migrating adult Delta Smelt collected during sampling of salvaged fish would die; however, as shown in Section 6.1.3.3.1.1, entrainment at the south Delta export facilities is expected to be lower under the PA than NAA, therefore any effects to individual Delta Smelt from salvage monitoring would be lower under the PA than NAA.

6.1.5.1.2 Population-Level Effects

Given the low percentage of the migrating adult Delta Smelt population expected to be near the NDD (Section 6.1.3.2.2.1.2, *Population-Level Effects*), any effects of impingement monitoring at the NDD would be inconsequential at the population level. South Delta exports salvage monitoring also would be expected to have essentially no population-level effect, given that only a subsample of fish would be collected, entrainment would be limited (and would be less under the PA than NAA), and that for the SWP, the main source of mortality (pre-screen loss) occurs before salvage sampling. Given that monitoring informs adjustments to operations to protect migrating adult Delta Smelt, the ultimate net effect of monitoring should be positive to the population.

6.1.5.2 Spawning Adults (February-June)

6.1.5.2.1 Individual-Level Effects

The potential effects of monitoring on individual spawning adult Delta Smelt would be similar to those effects noted for migrating adult Delta Smelt (*i.e.*, principally the lethal take during south Delta salvage monitoring), although spawning adults would be less likely to be sampled during monitoring activities if primarily holding near spawning sites.

6.1.5.2.2 Population-Level Effects

As discussed for migrating adult Delta Smelt, there would be essentially no population-level effects of monitoring on spawning adult Delta Smelt.

6.1.5.3 Eggs/Embryos (Spring: ~March-June)

6.1.5.3.1 Individual-Level Effects

As noted for other potential effects of the PA, the demersal and adhesive nature of Delta Smelt eggs/embryos means that they would not affected by the monitoring proposed under the PA.

6.1.5.3.2 Population-Level Effects

The lack of individual-level effects from monitoring of the PA on Delta Smelt eggs/embryos means that there would be no population-level effects.

6.1.5.4 Larvae/Young Juveniles (Spring: ~March-June)

6.1.5.4.1 Individual-Level Effects

At the NDD, entrainment sampling behind the fish screens would result in lethal take of individual larval and young juvenile Delta Smelt that are small enough to pass through the screens. These fish might otherwise survive passage to the Intermediate Forebay or the north cell of the reconfigured Clifton Court Forebay. Entrainment surveys of young smelt at the south Delta export facilities would also result in lethal take of any sampled larval or young juvenile Delta Smelt, and would occur under NAA and PA.

6.1.5.4.2 Population-Level Effects

Any collections of larval or young juvenile Delta Smelt during entrainment monitoring at the NDD or south Delta export facilities would have no effect at the population level because these fish would die anyway, either immediately (through injury during passage through conveyance infrastructure) or subsequently (e.g., if surviving and growing in Clifton Court Forebay, they

would be expected to either die from predation or from excessive water temperatures in the summer).

6.1.5.5 Juveniles (Summer/Fall: ~July-December)

6.1.5.5.1 Individual-Level Effects

Effects to juvenile Delta Smelt would be as discussed for migrating adult Delta Smelt in terms of the potential to be lethally taken during salvage monitoring at the south Delta export facilities; however, as discussed in Section 6.1.3.3.1.5, *Juveniles: (Summer/Fall: July-December)*, few juvenile Delta Smelt would be expected to occur at this time. Less south Delta exports under the PA than NAA would results in this being less of an effect. It is unlikely that monitoring of impingement potential at the NDD would be undertaken during the summer/fall, given the periods of occurrence of listed fishes, so there would be no effect from diver surveys.

6.1.5.5.2 Population-Level Effects

As discussed in the individual-level effects, the minimal temporal and spatial overlap of juvenile Delta Smelt with south Delta salvage monitoring means that there would be no population-level effect on juvenile Delta Smelt from monitoring.

6.1.5.6 Effects of Monitoring Activities on Delta Smelt Critical Habitat

6.1.5.6.1 PCE 1: Physical Habitat (Spawning Substrate)

There would be no effect of monitoring on the physical habitat PCE.

6.1.5.6.2 PCE 2: Water (Quality)

There would be no effect of monitoring on the water PCE.

6.1.5.6.3 PCE 3: River Flow (Facilitating Movement)

There would be no effect of monitoring on the river flow PCE.

6.1.5.6.4 PCE 4: Salinity (Low Salinity Zone)

There would be no effect of monitoring on the salinity PCE.

6.1.6 Cumulative Effects on Delta Smelt

Cumulative effects include the effects of future state, tribal, local, or private actions that are reasonably certain to occur in the action area (50 CFR 402.02). Future Federal actions that are unrelated to the PA are not considered in this section because they require separate consultation pursuant to Section 7 of the ESA. A list of specific projects considered for the cumulative effects analysis is included as Appendix 5.G, *Projects Considered for Cumulative Effects Analysis for the Conveyance Section 7 Biological Assessment*.

6.1.6.1 Water Diversions

Water diversions for irrigated agriculture, municipal and industrial use, and managed wetlands are found throughout the Delta, and many of them remain unscreened. Depending on the size, location, and season of operation, these unscreened diversions have the potential to entrain and kill many life stages of aquatic species, including Delta Smelt. However, the vast majority of

private unscreened diversions in the Delta are small pipes in large channels that do not operate every day of the year. As a result, even where they do regularly co-occur with these diversions, Delta Smelt appear to have low vulnerability to entrainment (Nobriga *et al.* 2004). Most of the 370 water diversions operating in Suisun Marsh are likewise unscreened (Herren and Kawasaki 2001). However the two major Suisun Marsh distribution systems, both part of the SWP, divert most of the water into the marsh that is subsequently redistributed further by the many smaller diversions. Of the two SWP distribution systems, Roaring River is screened while Morrow Island is not. Delta smelt entrainment into the Morrow Island Distribution system is very low due to high salinity in western Suisun Marsh (Enos *et al.* 2007); the effects of these systems on Delta Smelt was analyzed in Section 6.1.3.7, *Suisun Marsh Facilities.*

New municipal water diversions in the Delta are routinely screened per biological opinions. Private irrigation diversions in the Delta are mostly unscreened but the total amount of water diverted onto Delta farms has remained very stable for decades (Culberson *et al.* 2008) so the cumulative impact should remain similar to baseline. Ongoing non-Federal diversions of water within the action area (e.g., municipal and industrial uses, as well as diversions through intakes serving numerous small, private agricultural lands) are not likely to entrain very many Delta Smelt based on the results of a study by Nobriga *et al.* (2004). Nobriga *et al.* reasoned that the littoral location and low-flow operational characteristics of these diversions reduced their risk of entraining Delta Smelt. A study of the Morrow Island Distribution System by DWR produced similar results, with one demersal species and one species that associates with structural environmental features, together accounting for 97–98% of entrainment; only one Delta Smelt was observed to be entrained during the 2 years of the study (Enos *et al.* 2007).

6.1.6.2 Agricultural Practices

Farming occurs throughout the Delta adjacent to waterways used by Delta Smelt. Agricultural practices introduce nitrogen, ammonium, and other nutrients into the watershed, which then flow into receiving waters, adding to other inputs such as wastewater treatment (Lehman *et al.* 2014); however, wastewater treatment provides the bulk of ammonium loading, for example (Jassby 2008). Stormwater and irrigation discharges related to both agricultural and urban activities contain numerous pesticides and herbicides that may negatively affect Delta Smelt reproductive success and survival rates (Dubrovsky *et al.* 1998; Kuivila *et al.* 2004; Scholz *et al.* 2012). Discharges occurring outside the action area that flow into the action area also contribute to cumulative effects of contaminant exposure.

6.1.6.3 Increased Urbanization

The Delta Protection Commission's Economic Sustainability Plan for the Delta reported an urban 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 6.1-48 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 6.1-48. 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
Sources: California Department of Finance 2012.					

Table 6.1-49 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 6.1-49. Delta Communities Population, 2000 and 2010

Community	2000	2010	Average Annual Growth Rate 2000–2010
Contra Costa County			
Incorporated Cities and Towns			
Antioch	90,532	102,372	1.3%
Brentwood	23,302	51,481	12.1%
Oakley	25,619	35,432	3.8%
Pittsburg	56,769	63,264	1.1%
Small or Unincorporated Communities			
Bay Point	21,415	21,349	-0.0%
Bethel Island	2,252	2,137	-0.5%
Byron	884	1,277	4.5%
Discovery Bay	8,847	13,352	5.1%
Knightsen	861	1,568	8.2%
Sacramento County			
Incorporated Cities and Towns			
Isleton	828	804	-0.3%
Sacramento	407,018	466,488	1.5%
Small or Unincorporated Communities			
Courtland	632	355	-4.4%
Freeport and Hood	467	309[a]	-3.4%
Locke	1,003	Not available	—
Walnut Grove	646	1,542	13.9%
San Joaquin County			
Incorporated Cities and Towns			
Lathrop	10,445	18,023	7.3%
Stockton	243,771	291,707	2.0%
Tracy	56,929	82,922	4.6%
Small or Unincorporated Communities			
Terminous	1,576	381	-7.6%
Solano County			
Incorporated Cities and Towns			
Rio Vista	4,571	7,360	6.1%
Yolo County			
Incorporated Cities and Towns			
West Sacramento	31,615	48,744	5.4%
Small or Unincorporated Communities			
Clarksburg	681	418	-3.9%

Sources: U.S. Census Bureau 2000; U.S. Census Bureau 2011.
[a] Freeport had a population of 38; Hood had a population of 271.

Increases in urbanization and housing developments can impact habitat by altering watershed characteristics, and changing both water use and stormwater runoff patterns. Increased growth will place additional burdens on resource allocations, including natural gas, electricity, and water, as well as on infrastructure such as wastewater sanitation plants, roads and highways, and public utilities. Some of these actions will not require Federal permits and thus will not undergo review through the Section 7 consultation process.

Adverse effects on Delta Smelt and their critical habitat may result from urbanization-induced point and non-point source chemical contaminant discharges within the action area. These contaminants include, but are not limited to, ammonia and free ammonium ion, numerous pesticides and herbicides, and oil and gasoline product discharges. Increased urbanization also is expected to result in increased recreational activities in the region.

6.1.6.4 Waste Water 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 the magnitude 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 total ammonia nitrogen) 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. A study by Werner *et al.* in 2008 concluded that ammonia concentrations present in the Sacramento River below the SRWTP are not acutely toxic to 55-day-old Delta Smelt. However, based on information provided by EPA (1999) and other related studies, it is possible that concentrations below the SRWTP may be chronically toxic to Delta Smelt and other sensitive fish species (Werner *et al.* 2010). In 2010 the same group conducted three exposure experiments to measure the effect concentration of SRWTP effluent. No significant effects of effluent on the survival of larval Delta Smelt or rainbow trout was found. More recent studies (which used concentrations of ammonia higher than typically experienced by Delta Smelt) have shown that Delta Smelt that are exposed to ammonia exhibit membrane destabilizations. This results in increased membrane permeability and increased susceptibility to synergistic effects of multi-contaminant exposures (Connon *et al.* 2009; Hasenbein *et al.* 2014). Results are unclear at this time as to what the effect of ammonia exposure is on Delta smelt, and research is ongoing. EPA published revised national recommended ambient water quality criteria for the protection of aquatic life from the toxic effects of ammonia in 2013. Studies are ongoing to further determine the effect of ammonia on Delta Smelt and other fish populations. The Freeport location of the SRCSD discharge places it upstream of the confluence of Cache Slough and the mainstem Sacramento River, a location just upstream of where Delta Smelt have been observed to congregate in recent years during the

spawning season. The potential for exposure of a substantial fraction of Delta Smelt spawners to elevated ammonia levels has heightened the importance of this investigation.

In addition to concerns about direct toxicity of ammonia to Delta Smelt, another important concern is that ammonium inputs have suppressed diatom blooms in the Delta and Suisun Bay, thereby reducing the productivity in the Delta Smelt food web. The IEP MAST Team (2015: 71) provided the following summary: "Dugdale *et al.* (2007) and Wilkerson *et al.* (2006) found that high ammonium concentrations prevented the formation of diatom blooms but stimulated flagellate blooms in the lower estuary. They propose that this occurs because diatoms preferentially utilize ammonium in their physiological processes even though it is used less efficiently and at high concentrations ammonium can prevent uptake of nitrate (Dugdale *et al.* 2007). Thus, diatom populations must consume available ammonium before nitrate, which supports higher growth rates, can be utilized or concentrations of ammonium need to be diluted. A recent independent review panel (Reed *et al.* 2014) found that there is good evidence for preferential uptake of ammonium and sequential uptake of first ammonium and then nitrate, but that a large amount of uncertainty remains regarding the growth rates on ammonium relative to nitrate and the role of ammonium in suppressing spring blooms." The IEP MAST Team (2015: 71-72) further discussed this issue as follows: "Glibert (2012) analyzed long-term data (from 1975 or 1979 to 2006 depending on the variable considered) from the Delta and Suisun Bay and related changing forms and ratios of nutrients, particularly changes in ammonium, to declines in diatoms and increases in flagellates and cyanobacteria. Similar shifts in species composition were noted by Brown (2009), with loss of diatom species, such as *Thalassiosira* sp., an important food for calanoid copepods, including *Eurytemora affinis* and *Sinocalanus doerri* (Orsi 1995). More recently, Parker *et al.* (2012) found that the region where blooms are suppressed extends upstream into the Sacramento River to the SRWTP, the source of the majority of the ammonium in the river (Jassby 2008). Parker *et al.* (2012) found that at high ambient ammonium concentrations, river phytoplankton cannot efficiently take up any form of nitrogen including ammonium, leading to often extremely low biomass in the river. A study using multiple stable isotope tracers (Lehman *et al.* 2014) found that the cyanobacteria *M. aeruginosa* utilized ammonium, not nitrate, as the primary source of nitrogen in the central and western Delta. In 2009, the ammonia concentration in effluent from SRWTP was reduced by approximately 10%, due to changes in operation (K. Ohlinger, Sacramento Regional County Sanitation District, personal communication). In spring 2010 unusually strong spring diatom blooms were observed in Suisun Bay that co-occurred with low ammonia concentrations (Dugdale *et al.* 2013)."

Ammonia discharge concerns have also been expressed with respect to the City of Stockton Regional Water Quality Control Plant, but its remoteness from the parts of the Estuary frequented by Delta Smelt and its recent upgrades suggest that it is more a potential issue for migrating salmonids than for Delta Smelt.

6.1.6.5 Other Activities

Other future, non-Federal actions within the action area that are likely to occur and may adversely affect Delta Smelt and their critical habitat include: the dumping of domestic and industrial garbage that decreases water quality; oil and gas development and production that may affect aquatic habitat and may introduce pollutants into the water; and state or local levee maintenance that may also destroy or adversely affect habitat and interfere with natural, long-