4 Analysis of Take

California Endangered Species Act (CESA) defines *take* as hunting, pursuing, catching, capturing, or killing a listed species, or the attempt of any such act (California Fish and Game Code Section 86). California Department of Fish and Wildlife (CDFW) incidental take permit (ITP) regulations require an analysis of whether and to what extent the project or activity could result in the taking of the covered species, and the impacts of the proposed taking on the species (14 California Code of Regulations [CCR] 783.2(a)(5) and 783.2(a)(6)). This chapter provides this analysis for each of the covered species, and also for Mason's lilaeopsis, in accordance with the requirements of 14 CCR § 786.9 *Take of Rare Plants*. Permit regulations also require an analysis of whether the activities covered by an ITP would jeopardize the continued existence of the species (14 CCR 783.2(a)(7)). A jeopardy analysis is provided for each species; this analysis evaluates the species' capability to survive and reproduce, and any adverse impacts of the taking on those capabilities in light of the following.

- Known population trends (described in Chapter 2, *Covered Species*)
- Known threats to the species (described in Chapter 2, *Covered Species*)
- Reasonably foreseeable impacts on the species from other related projects and activities.

Based on available information, the applicant, the California Department of Water Resources (DWR) believes the CESA-listed species discussed in this permit application occupy or potentially occur in the project area and that the proposed project may result in incidental take of these species.

The take analysis for each species first describes the expected effects and estimated take on the species from the proposed project. Proposed project effects are discussed separately for permanent effects, temporary effects, and construction-related mortality. Next, the analysis describes the potential effects outside the project footprint and effects from ongoing activities such as project operations or maintenance. Finally, the analysis provides a summary of the expected take of the covered species, the impacts of the taking, a cumulative effects analysis, and a jeopardy analysis. The methods used to conduct these analyses for longfin smelt are presented in Appendix 4.A *Longfin Smelt Quantitative Analyses*, and methods used for terrestrial species are described in Appendix 4.B *Terrestrial Impact Analysis Methods*. Methods used for the Delta Smelt and for Chinook salmon are referred to in the text describing those analyses. Finally, the information used to conduct the cumulative effects analyses is presented in Appendix 4.C *Information to Support Cumulative Effects Analysis*.

The analysis of the effects of the Proposed Project on fish and aquatic resources is influenced by numerous factors related to the complexity of the ecosystem, changes within the system (e.g., climate change and species population trends), and the imprecision of operational controls and resolution in modeling tools. These factors are further complicated by the scientific uncertainty about some fundamental aspects of aquatic species life history and how these species respond to changes in the system, as well as sometimes competing points of view on the interpretation of biological and physical data within the scientific community. This is the case with respect to the importance of South Delta operations (Head of Old River barrier, Delta Cross Channel Gates, OMR), Rio Vista flow parameters, operations of the North Delta diversions, and spring and fall X2, as each still has a high degree of scientific uncertainty. Table 4.0-1 summarizes the major areas of scientific uncertainty along with a bibliography of the scientific literature that supports that uncertainty and competing views.

In light of this uncertainty, the operational criteria for the Proposed Project has been conservatively developed based on professional judgment borne out of precautionary principles – uncertainty resolved in a manner promoting higher flows and/or restricting pumping by the SWP and CVP, as compared to current regulatory requirements. This approach is reflected in the effects analysis. Also, it is important to note that the operational parameters were developed, in large part, as part of a proposed habitat conservation plan for the purpose of contributing to the recovery of listed and nonlisted covered species.

The uncertainty described in the take analysis regarding the hypotheses underlying many of the analyses, as well as the modeling approaches themselves, will be investigated as part of the Collaborative Science and Adaptive Management Program ("CSAMP"). By reducing scientific uncertainty, the CSAMP is intended to improve decision-making to ensure the effects of operations of the Proposed Project on state-listed species are fully mitigated.

The CSAMP process has already initiated studies relevant to current SWP-CVP operations, and those initial studies and assessments of scientific uncertainty will continue to inform future adaptive management. Other sources of information will also be drawn upon during the development of future investigations. For example, the BDCP contains examples of the types of scientific uncertainty that the CSAMP process will address. (See BDCP, Chapter 5, Effects Analysis, particularly the Delta Smelt and Longfin Smelt decision tree sections, and green sturgeon.) The Delta Science Program has also convened several expert review panels and their reports raise issues of scientific uncertainty relevant to SWP-CVP operations. Those reports include, but are not limited to, the Long-term Operations Biological Opinions Annual Science Reviews ("LOBO reviews"), Workshop on Delta Outflows and Related Stressors, Panel Summary Report (2014), Workshop on the Interior Delta Flows and related Stressors Panel Summary Report (2014) and Fishes and Flows in the Sacramento-San Joaquin Delta: Strategic Science Needs (2015). As our scientific understanding matures, there will be new questions raised regarding the potential effects of the SWP-CVP, the life cycle of the species and habitat requirements, and the impacts of other environmental stressors, which will be incorporated into the CSAMP process.

Table 4.0-1 Summary of Scientific Uncertainty and Bibliography

<table>
<tr><th>Analytical Method and/or Underlying Assumptions</th><th>Scientific Uncertainty

[which includes, but is not limited to, gaps in scientific understanding, areas of investigation with inconclusive results, and disagreement between experts.]</th></tr>
<tr><td>Delta Smelt:
Entrainment</td><td>There is scientific uncertainty associated with the environmental factors that affect Delta Smelt entrainment, accuracy of methods used to estimate entrainment, and population level significance of past and current entrainment. Scientific uncertainty is currently being addressed through the CSAMP process, which is a process that will inform both the implementation of current and future BiOps. The CSAMP adaptive management team has formulated a workplan that identifies a number of key questions and possible investigative approaches on the issue of entrainment. (See CSAMP Table. Appendix 6.A., p. 6.A-5, Quantitative Methods for Biological Assessment of Delta Smelt, below.) The CSAMP workplan provides information regarding the specific areas of scientific uncertainty under “key questions.”
<table>
<tr><th>Key Questions</th><th>Possible Investigative Approaches</th></tr>
<tr><td>What factors affect adult delta smelt entrainment during and after winter movements to spawning areas?
a. How should winter “first flush” be defined for the purposes of identifying entrainment risk and managing take of delta smelt at the south Delta facilities?
b. What habitat conditions (e.g., first flush, turbidity, water source, food, time of year) lead to adult delta smelt entering and occupying the central and south Delta?</td><td>Summarization of environmental and fish distribution/abundance data (e.g., FMWT, SKT).
Multivariate analyses and modeling (e.g., 3D particle tracking) to examine whether fall conditions affect winter distribution.
Completion of First Flush Study analyses.
The Delta Conditions Team (DCT) is currently developing a scope of work to use turbidity modeling to examine various “first flush” conditions, expected entrainment risks, and potential preventative actions that could be taken to reduce entrainment, consistent with key question (a). The DCT could also conduct analyses to address key question (b).</td></tr>
<tr><td>What are the effects of entrainment on the population?
a. What is the magnitude (e.g., % of population) of adult and larval entrainment across different years and environmental conditions?
b. How do different levels of entrainment for adults and larvae affect population dynamics, abundance, and viability?</td><td>a. Application of different models (e.g., individual based models, life history) to estimate proportional entrainment.
A direct approach to addressing question (a) has been proposed by Kimmerer 2008, as modified in 2011. This or a derivative approach should be explored as a means to directly estimate the proportional entrainment that has occurred in recent years. Apply to as much of historical record as possible.
b. Application of different models (e.g., IBM, life history, population viability analysis [PVA]) to simulate effects on population dynamics, abundance, and variability.</td></tr>
<tr><td>How many adult delta smelt and larval/post-larval delta smelt are entrained by the water projects?</td><td>Workshop or expert panel review.
Testing of new field methodologies such as SmeltCAM.
Gear efficiency and expanded trawling experiments.
Evaluation of alternative models to estimate abundance, distribution and entrainment.</td></tr>
</table>
</td></tr>
</table>

Analytical Method and/or Underlying Assumptions	**Scientific Uncertainty** ***[which includes, but is not limited to, gaps in scientific understanding, areas of investigation with inconclusive results, and disagreement between experts.]***	
	What conditions prior to movement to spawning areas affect adult delta smelt entrainment? Is there a relationship between delta smelt distribution and habitat conditions (e.g., turbidity, X2, temperature, food) during fall and subsequent distribution (and associated entrainment risk) in winter?	Summarization of environmental and fish distribution/abundance data (e.g., FMWT, SKT). Multivariate analyses and modeling (e.g., 3D particle tracking) to examine whether fall conditions affect winter distribution. Completion of first flush study analyses.
	What factors affect larval and post-larval delta smelt entrainment? a. How does adult spawning distribution affect larval and post-larval entrainment? b. What conditions (e.g., first flush, spawning distribution, turbidity, water source, food, time of year) lead to larvae and post-larvae occupying the central and south Delta?	Summarization of environmental and fish distribution/abundance data. Statistical analysis and modeling (e.g. 3D PTM) of effects of adult distribution (e.g., SKT) on larval (e.g., 20 mm) distributions. Summarization of environmental and fish distribution/abundance data (e.g., 20 mm). Multivariate analyses/modeling to identify conditions promoting occupancy of central and south Delta.
	What new information would inform future consideration of management actions to optimize water project operations while ensuring adequate entrainment protection for delta smelt? a. Can habitat conditions be managed during fall or early winter to prevent or mitigate significant entrainment events? b. Should habitat conditions (including OMR) be more aggressively managed in some circumstances as a preventative measure during the upstream movement period (e.g., following first flush) to reduce subsequent entrainment?	Synthesis of available information and study results by CAMT Entrainment Team, designated expert panel, or both. Consultation with regulatory agencies and operators about the feasibility of different actions.
	Source: Collaborative Adaptive Management Team (2014).	
Delta Smelt: Entrainment	The Delta Smelt entrainment analysis is based on a regression of point estimates from Kimmerer *et al*. 2008. This analysis is uncertain because Kimmerer *et al*. 2008 has broad confidence intervals. A regression of data with large confidence intervals adds additional uncertainty to an already uncertain analysis.	

Analytical Method and/or Underlying Assumptions	**Scientific Uncertainty** ***[which includes, but is not limited to, gaps in scientific understanding, areas of investigation with inconclusive results, and disagreement between experts.]***
Delta Smelt: Entrainment	Kimmerer's (2008) original estimates of entrainment loss had large confidence limits, which Kimmerer *et al*.(2008:24) noted could be reduced by additional sampling. Since Kimmerer's paper was published, it has been recognized that turbidity plays a major role in the salvage of delta smelt, particularly in the adult stage (Grimaldo et al.2009). Thus, some of the uncertainty alluded to above is caused by the lack of turbidity as a predictor in Kimmerer's model. In addition, Miller *et al*. (2011) assessed the explicit and implicit assumptions of Kimmerer's estimation methods and surmised that for estimates of adult proportional entrainment, there were eight assumptions of which three may have biased the estimates upward, one may have estimated the bias downward, and the remainder would not have resulted in bias. For larval-juvenile entrainment, Miller *et al*. (2011) suggested that of 10 assumptions made by Kimmerer *et al*. (2008), eight would have resulted in upward bias and two would not have resulted in bias. Miller (2011) suggested methodological adjustments for four of the assumptions that could have resulted in bias of adult and juvenile proportional entrainment estimates, but was not able to quantify adjustments for eight of the potential assumptions leading to (upward) bias. In response to the quantifiable biases suggested by Miller (2011), Kimmerer (2011) concurred with one (leading to a downward adjustment of his adult loss estimates by 24% [by multiplying by 0.76]; see detail below in Section 6.A.3.1.1, *Adults*) and rejected the others. A number of assumptions that may introduce upward bias remain unresolved and contribute to uncertainty in the estimates. At this time, there is no reliable way to forecast future turbidity, and therefore, the assumption is made that, on average, or across years, relative adult entrainment risk for comparison across model scenarios can be reasonably reflected using predictions of Old and Middle River (OMR) flow based on the USFWS (2008) equation. Similarly, it is assumed that the relative risk of larval-juvenile entrainment in the south Delta can be characterized by using predictions of X2 and OMR flow per the equation developed by USFWS (2008). However, these assumptions are uncertain.
Delta Smelt: Entrainment	It is unknown if the current level and/or historic entrainment had a population level effect. For example, Kimmerer 2008 estimated combined historic life stage entrainment could have been between 0-40%. However, Kimmerer at p. 25 also concluded that: "Although the upper bound of this range represents a substantial loss, the effect of this loss is complicated by subsequent variability in survival. If this variability is uncorrelated with entrainment losses, then these losses will contribute little to the variability in fall abundance index. The simpliest way to evaluate this is by regression of fall midwater trawl index on winter-spring export flow, but this relationship is contaminated by the downward step change in abundance in approximately 1981-1982, together with the long-term upward trend in export flow (mainly up to the mid-1970s, see Kimmerer 2004). Including this step in a regression model eliminates the effect of export flow on the fall midwater trawl index (coefficient= -1.5 $\pm$ 2.4, 95% CL, 36 df). It seems unlikely that the downward step change was due to the earlier increase in export flow; furthermore, despite substantial variability in export flow in years since 1982, no effect of export

<table>
<tr><th>Analytical Method and/or Underlying Assumptions</th><th>Scientific Uncertainty

[which includes, but is not limited to, gaps in scientific understanding, areas of investigation with inconclusive results, and disagreement between experts.]</th></tr>
<tr><td></td><td>flow on subsequent midwater trawl abundance is evident.
This is not to dismiss the rather large proportional losses of delta smelt that occur in some years; rather, it suggest that these losses have effects should be calculated rather than inferred from correlative analyses….”
Kimmerer 2008 goes on to explain that there is an approximately 50-fold variation in summer-fall Delta Smelt survival, therefore export effects are difficult to identify and suggests that past entrainment events could have been episodic in nature. Kimmerer further acknowledges that toxic contaminants, predation and other stressors could improve the status of Delta Smelt, but entrainment management is also important even though the effects of exports are “relatively small.”</td></tr>
<tr><td>Delta Smelt:
Fall X2</td><td>There is scientific uncertainty associated with the definition of Delta Smelt habitat and the identification of factors that could be driving summer and fall abundance. Scientific uncertainty is currently being addressed through the CSAMP process. As previously noted in the description of analyses related to south Delta entrainment, the CAMT has the mission of working to develop a robust science and adaptive management program through the CSAMP that will inform both the implementation of the current BiOps and future BiOps. This adaptive management team has formulated a workplan that identifies a number of key questions and possible investigative approaches to the issue of fall outflow management (Table CSAMP_fall; Collaborative Adaptive Management Team 2014), BA Appendix 6A, p. 6.A-19). The CSAMP workplan provides information regarding the specific areas of scientific uncertainty under “key questions.”
<table>
<tr><th>Key Questions</th><th>Possible Investigative Approaches</th></tr>
<tr><td>Are there biases in the IEP survey data? How should the survey data be utilized if biases do exist?</td><td>Convene a workshop to discuss possible survey problems and identify opportunities to address in 2014 with existing data.
Consider ongoing work and approaches of Emilio Laca. Many of these issues have been proposed by FWS to be addressed through a package of gear efficiency and smelt distribution studies; however, that package includes extensive field work, and some elements have timelines extending beyond the remand period.</td></tr>
<tr><td>Under what circumstances does survival in the fall affect subsequent winter abundance?</td><td>Quantitatively determine the contribution of delta smelt survivorship in the fall to inter-annual population variability Review available lifecycle models for applicability.</td></tr>
<tr><td>Under what circumstances do environmental conditions in the fall season contribute to determining the subsequent abundance of delta smelt?</td><td>Investigate the relationship between fall outflow and the relative change in delta smelt abundance using univariate and multivariate and available historic data. Related to wor undertaken in the Management, Analysis, and Synthesis Team (MAST) report, which examined pairs of dry and we years in 2005/6 and 2010/11.
Also explore effects occurring through other avenues (e.g. growth or fecundity).</td></tr>
<tr><td>How much variability in tidal, daily, weekly,</td><td>Hydrological modeling tools to determine the prospective locations of X2 in the fall under circumstances with and</td></tr>
</table></td></tr>
</table>

Analytical Method and/or Underlying Assumptions	Scientific Uncertainty *[which includes, but is not limited to, gaps in scientific understanding, areas of investigation with inconclusive results, and disagreement between experts.]*

and monthly fluctuations in fall X2 is attributable to water project operations?	without project operations. An analysis of historical data will also be carried out to examine outflow during periods when the projects were required to meet specific outflow requirements, to evaluate the degree of control that has been possible at various time scales. See work addressing this issue by: Grossinger, Hutton, and a paper by Cloern and Jassby (2012)
Under what circumstances is survival of delta smelt through the fall related to survival or growth rates in previous life stages?	Compare delta smelt survival during the fall to both survival in prior seasons and to fork length at the end of the summer/start of the fall. New data are being collected as part of the Fall Outflow Adaptive Management Plan (FOAMP). Consider individual-based modeling (IBM).
Does outflow during the fall have significant effects on habitat attributes that may limit the survival and growth of delta smelt during the fall?	There may be competing approaches that will be simultaneously pursued. One is to develop graphs and conduct univariate and multivariate analyses involving survival ratios and growth rates. Test whether month-to-month declines in abundance or growth during the fall is greater when X2 is located further east. See also the analytical approach in MAST report, work by Kimmerer, Burnham & Manly.
Can an index based on multiple habitat attributes provide a better surrogate for delta smelt habitat than one based only on salinity and turbidity?	Review approaches in existing literature. There may be competing approaches that will be simultaneously pursued, depending on expert advice. One possible approach is to develop suitability index curves and combine geometrically to create a habitat quality index. Utilize data from areas where delta smelt are frequently observed to assess habitat quality. See work by Burnham, Manly, and Guay.
Under what conditions (e.g., distribution of the population, prey density, contaminants) do fall operations have significant effects on survival?	Utilizing relationships identified in the above studies, simulate how changes in project operations may influence survival of delta smelt during the fall.
Source: Collaborative Adaptive Management Team (2014)	

Analytical Method and/or Underlying Assumptions	**Scientific Uncertainty** ***[which includes, but is not limited to, gaps in scientific understanding, areas of investigation with inconclusive results, and disagreement between experts.]***
Delta Smelt: Fall X2	Various peer-reviewed studies have statistically examined linkages between salinity (often indexed by X2) and indices of Delta Smelt abundance or survival. The first analysis was Feyrer *et al.* (2007), concluding that Delta Smelt abundance in summer was positively related to prior fall abundance, and negatively related to prior fall water conductivity. This analysis has been questioned, primarily because the linear equation used in the analysis was not based on an established biological model and predicted the same change in summer abundance for the same change in Fall X2 no matter what the initial FMWT abundance. Feyrer *et al.* 2011 created an abiotic index based on the analysis of Delta Smelt occupancy at different values of conductivity and Secchi depth, Feyrer concluded that his abiotic index was negatively correlated with X2, meaning that as X2 moved downstream in the fall, his abiotic index grew larger. Manly *et al*. 2014 raised questions about how to interpret Feyrer *et al*. 2011, arguing that cross correlations between conductivity, Secchi depth, and geographical location made it impossible to determine whether conductivity is the driver of Delta smelt distribution. MacNally *et al.* (2010) found no evidence for a relationship between fall X2 and Delta Smelt abundance. Thomson et al. (2010) found no evidence for a relationship between fall X2 and Delta Smelt abundance. Miller *et al*. (2012) found that neither fall X2 not the volume of suitable fall habitat (with suitability based on salinity, water clarity, and temperature) were able to explain additional variability in trends in Delta Smelt fall-to-fall survival, beyond direct factors included in a best regression model. Kimmerer *et al*. (2013) at p. 15 concluded that, "…our use of salinity as the only variable that defines habitat is clearly inadequate…Given the difficulty in determining the controls on the delta smelt population, it is not surprising that such a simple descriptor is inadequate for this species."
Delta Smelt: Migration during first flush	The BA describes a life history of Delta Smelt as part of the entrainment analysis that assumes that the majority of the Delta Smelt population migrates into the interior Delta to spawn, making them susceptible to entrainment as they migrate past or into areas in the proximity of the south Delta pumping facilities. However, there are other studies that suggest a different life history where the population spreads out in all directions following first flush as the area with suitable habitat conditions expands. (Merz *et al.* (2011), Murphy and Hamilton (2013).) This alternative life history hypothesis would suggest that the species vulnerability to entrainment during the first flush is less than assumed in the BA as only a portion of the Delta Smelt population would be potentially susceptible to entrainment.
Green Sturgeon: Delta Outflow Relationship	NMFS hypothesizes that relationships between white sturgeon year class index and Delta outflow may also be applicable to green sturgeon. Unlike white sturgeon, there is no correlation between winter-spring X2 and green sturgeon species abundance. Moreover, there is reason to believe that green sturgeon do not respond to flow similarly to white sturgeon as the life histories of the two species are quite different. For example, as BDCP Chapter 5, at p. 447 explains, white sturgeon spend the majority of their lives in brackish portions of the estuary in deep water, although a small number of individuals dwell in the ocean…," while, "Green sturgeon adults spend extended periods of time within the ocean making long migrations as far north as southern Alaska and as far south as Ensenada, Mexico." Even for white sturgeon, however, the biological mechanism underlying the observed winter-spring X2-FMWT abundance correlation is unknown, meaning that the environmental factor that could actually be driving abundance (and the correlation) is unknown.

Analytical Method and/or Underlying Assumptions	**Scientific Uncertainty** ***[which includes, but is not limited to, gaps in scientific understanding, areas of investigation with inconclusive results, and disagreement between experts.]***
Sturgeon: Entrainment	There is little monitoring data available regarding the size of the green sturgeon population therefore the population level effects of any change in project operations is unknown. As explained above, it should be acknowledged that green sturgeon spend a significant period of their life history in the ocean. Salvage in the south Delta facilities is low.
Salmonids: Channel Velocity (DSM2-HYDRO)	It is generally recognized that salmonids likely detect instantaneous velocity rather than "net flow." (See e.g., Monismith *et al.* 2014, p. 3.) However, there is significant uncertainty in the interpretation of the modeled velocity results as there have been no studies in the Delta that investigate how salmonids in the riverine and tidal areas of the Delta respond to changes in velocity in terms of changes in behavior and/or survival (e.g., potential delays in migration or selection of migration pathways). It is unknown what magnitude of change in velocity is biologically significant, particularly within the tidal Delta where tidal velocities can be quite large. It is similarly unknown if the modeled changes in the BA are reported on a time-step that is the most biologically relevant.
In-Delta Temperature modeling	Kimmerer 2004 at pp. 19-20 noted that the water temperature in the San Francisco Estuary depends mainly on air temperature, and that even in the Delta the relationship between air and water temperature is only slightly affected by freshwater inflow. Kimmerer (2004) suggested that water temperature at Freeport could be cooled up to about 3°C by high Sacramento River flows, but only by flood events that are in excess of flows that can the sustained by the SWP-CVP.
Salmonids: Entry into Interior Delta from the Sacramento River	Juvenile salmonids may enter the interior Delta from the mainstem of the Sacramento River through junctions such as Georgiana Slough and the Delta Cross Channel. South Delta CVP-SWP export operations do not significantly affect flow or velocity north of the San Joaquin River. The lack of evidence of south Delta export related changes in Sacramento River flow is also reflected in studies of out-migrating juvenile survival. South Delta exports do not significantly affect fish routing from the Sacramento River into the Delta. As Cavallo *et al.* 2015 concluded: "There was no evidence of a significant 'pulling' of fish off of the main stem routes at the range of diversions examined, likely because the magnitude of tidal flow swamps out most of the diversion (and inflow) signal. Fish will enter distributary routes regardless of management of inflows and diversions." And, "Diversions had little effect on predicted fish routing into the interior Delta at Georgiana Slough." At the same time, Cavallo *et al*. 2015 did identify a relationship between the number of juvenile out-migrating salmonids entering the interior Delta with increasing flow through channels like Georgianna Slough and the Delta Cross Channel. There is greater flow through these channels with decreasing inflows. The BA models project related changes in flow at north Delta junctions. However, the BA does not account for the number of salmon potentially present at north Delta flow junctions so it is unknown the extent that salmon would actually be entrained in the interior Delta over the range of operations. It is unknown if the modeled changes in flow would result in statistically significant changes in salmonid entrainment in the interior Delta. There is reason to believe that changes in the rate of

Analytical Method and/or Underlying Assumptions	**Scientific Uncertainty** ***[which includes, but is not limited to, gaps in scientific understanding, areas of investigation with inconclusive results, and disagreement between experts.]***
	entrainment in the interior Delta would not be significant as Perry et al. 2012 estimated that total through-Delta survival would only increase by 2-7% if all routes into the interior Delta were blocked.
Salmonids: Assumed relationship between Sacramento River flow and out-migrating juvenile salmonid survival (Delta Passage Model)	Perry 2010 results are that juvenile salmonid survival increases with outflows between approximately 10,000 cfs – 20,000 cfs. Perry's analysis was based on a small sample size using data for the years 2006-2008. Subsequently, Perry et al. 2012 evaluated flow-survival relationships for the years 2009-2010. Perry et al. 2012 at p. 1 concluded that survival did not continue to improve at flows exceeded approximately 20,000 ft^3/s stating: "Population-level survival through the Delta S_{Delta} ranged from 0.374 (SE=0.040 to 0.0524 (SE= 0.034) among releases. Although river flows for the February release groups were substantially higher (20,000-40,000 ft^3 /s at Freeport) than for the December release groups (about 10,000 ft^3/s). S_{Delta} [Survival] did not differ considerably between release groups." Perry et al. 2012 at p. 23 indicated contrary findings as there was less than expected differences in salmon survival between release groups relative to the differences in river flows experienced by each release group, therefore adding uncertainty as to the strength of the previously observed flow relationship. There is weak evidence of south Delta export effect on survival of out-migrating juvenile salmonids. Newman and Brandes (2009) found a high probability of a negative export effect on survival, but when compared against models with and without an export effect, the other models explained the observed data just as well. As the Delta Science Program's 2012 LOBO review concluded, "…fish entrainment into the interior Delta was not related to the pumping operation…," and, "..results of tagging studies to date (through the 2012 study) show little correlation between operations and fish movement…."
Salmonids: Assumed relationship between San Joaquin River flow and/or south Delta projects exports, and survival of out-migrating juvenile salmonids in the south Delta.	It has been generally thought that the San Joaquin River route had the greatest juvenile out-migrating salmonid survival but that conclusion is uncertain as in recent years survival has been greatest for salmonids traveling through the salvage facilities at the federal pumping facilities. (Buchanan et al. 2013.) Newman 2008 analyzed the effects of south Delta pumping facilities on out-migrating juvenile salmonids. Newman concluded that south Delta export pumping had no significant negative effect on out-migrating salmonid survival, and may even have a positive effect, which is counter-initiative. This out-come could potentially be explained by the comparatively favorable survival for salmonids going through the federal south Delta pumping facilities. Kjelson 1989 and others (including Newman 2008) identified a relationship between San Joaquin River flow and out-migrating salmonid survival. In recent years, however, the previously observed relationships have not continued to be observed as salmonid survival has not increased even in high flow years, like 2006 and 2011.

Analytical Method and/or Underlying Assumptions	Scientific Uncertainty *[which includes, but is not limited to, gaps in scientific understanding, areas of investigation with inconclusive results, and disagreement between experts.]*
Salmonids: Significance of current levels of entrainment	The existing salvage of winter-run salmon is a small fraction of the permitted incidental take. Even though the method of calculating the current level of incidental take is associated with uncertainty, it is unlikely that current salvage is having a statistically significant effect on the species. As Anderson et al. 2014 observed, even if the 2014 winter-run salmon JPE overestimated the total population by a factor of three, the actual take was only 4% of the annual take limit, so it is unlikely that current levels of salvage at the south Delta facilities are jeopardizing the species.
Salmonids: Effectiveness of the Head of Old River Barrier (HORB)	The Delta Science Program's 2012 LOBO review of the performance of the RPAs considered HORB operations. They concluded that the relative survival of smolts in Old and Middle River versus the San Joaquin River flow is about the same supporting, a conclusion that the HORB is ineffective at increasing survival. The LOBO panel at pp. 30-31 identified several reasons why the effects of the HORB may be detrimental to smolt survival, stating: "There are several reasons one could reasonably speculate that the effects of the HORB are detrimental to survival of smolts. Given that the VAMP acoustic tag study results have indicated that Chinook salmon survival through the Delta is substantially greater via the shortest river segments to the holding tank would seem the best option for protecting out-migrating salmonid smolts. The HORB inhibits passage along one of the shortest routes to the holding tanks from the upper San Joaquin watershed. Also, the HORB increases negative Old and Middle River flows and potential opportunities for smolts to become entrained along routes in the southern Delta where survival is considerably lower. Also, it has simply been assumed that the HORB does not result in enhanced mortality on smolts as was shown to occur with the non-physical barrier tested in previous years. All of the calculations and recalculations of route-specific mortality of acoustic tagged smolts that resulted in increasing the number of entrained smolts required to trigger real-time decisions for adjusting water operations were all based on the assumption that the HORB was not associated with increased mortality from predation and other factors. Lacking evidence to the contrary, it is difficult to conclude that the HORB provided equal or greater protection for smolts."

4.1 Take of Delta Smelt

Take estimation is based upon the likelihood of physical injury or mortality to individuals of Delta smelt. It is not possible to predict the number of individuals that would be subject to such take; in general, that would be a density-dependent phenomenon, e.g., with more fish subject to take in years when the population was relatively high in the project area. Instead, the risk of take is assessed through proxies such as the area of habitat affected, the duration of impact pile driving, or the probability of a contaminant release. Each section of the take analysis identifies the mechanisms by which take could occur and the probability that take would occur. If that probability is substantial, so that some individuals are likely to suffer mortality, then factors influencing the magnitude of take are detailed; typically these include take minimization measures, as well as the take proxies mentioned above. Mitigation is described (in Chapter 5

Mitigation) that is proportionate to the take, so as to show full mitigation for the take. The take analysis considers mechanisms of take for which authorization is needed (such as, conveyance facility construction and operations), as well as mechanisms of take for which authorization is not here requested (such as, maintenance activities or construction of mitigation sites) or is not needed (such as, CVP operations, cumulative effects, or climate change), because all such mechanisms are considered in determining whether the proposed project (PP) is likely to jeopardize Delta smelt.

The potential effects of the PP[1] on Delta Smelt are evaluated in this section for construction, maintenance, operations, mitigation measures, and monitoring activities. 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). 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 will 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 baseline (the no action alternative [NAA]) and PP could be made.

Scientific uncertainty exists with respect to the potential effects of the PP on Delta Smelt. As described in Section 6.1 *Collaborative Science and Adaptive Management Program*, the Collaborative Science and Adaptive Management Program will help to address scientific uncertainty by guiding the development and implementation of scientific investigations and monitoring for both permit compliance and adaptive management, and applying new information and insights to management decisions and actions.

The take analysis concludes with an analysis of potential for jeopardy, which considers the PP in the context of cumulative effects.

4.1.1 Construction Effects

4.1.1.1 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. 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 (Appendix 3.G *Geotechnical Exploration Plan—Phase 2*). Site-specific studies will investigate

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

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 an in-water work window extending from August 1 through 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 will not 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*).

Restricting in-water drilling to an August 1 to October 31 work window will effectively avoid the periods when Delta Smelt may be present in the areas of the proposed geotechnical activities. Therefore, no direct effects on Delta Smelt are anticipated. Geotechnical activities in open water may affect 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 will be negligible due to the small areas and nature of disturbance resulting from installation and removal of the casings, and the general lack of physical features at the proposed sites that are thought to be preferred by Delta Smelt for spawning (discussed in Section 4.1.1.2 *North Delta Diversions*, Section 4.1.1.3 *Barge Landings*, Section 4.1.1.4 *Head of Old River Gate*, and Section 4.1.1.5 *Clifton Court Forebay*). Consequently, with implementation of the proposed in-water work window and AMMs, geotechnical exploration is not likely to cause incidental take of Delta Smelt.

4.1.1.2 North Delta Diversions

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 Project*). Each intake can divert a maximum of 3,000 cfs of Sacramento 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 Intermediate Forebay (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 Project*.

Construction activities that could potentially affect Delta Smelt include the following in-water activities: cofferdam installation, 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 will 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 Diversions (NDDs), 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 each intake is projected to take approximately 4 to 5 years. In the first year of construction, cofferdams will be installed in the Sacramento River to isolate the majority of work area from the river during the remaining years of construction. The cofferdams will become permanent components of the intake structure. 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, 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 a June 1 through October 31 in-water construction window when Delta Smelt are least likely to occur in the project area. It is also assumed that periodic maintenance dredging will be needed to maintain appropriate flow conditions and will occur only during the approved in-water work window.

During the in-water construction period, a total of approximately 5.6 acres of shallow water habitat will be permanently[2] affected by construction activities. These impacts include 0.4 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. In addition, the 5.6-acre estimate includes potential suspended sediment effects 1,000 feet downstream of each intake (a total of 1.9 acres of

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

shallow water habitat; see Section 4.1.1.2.1.2 *Spawning Adults*). The impacts to shallow water habitat will be mitigated at a 5:1 ratio, for a total of 28 acres. Permanent modifications of nearshore habitat due to the presence of these structures will encompass a total of 1.02 linear miles of shoreline. At each intake, between 1.6 and 3.1 acres of river area will be located within the cofferdams during construction.

4.1.1.2.1 Turbidity and Suspended Sediment

Construction activities that disturb the riverbed and banks within the footprints of the NDD 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 a June 1 through October 31 in-water work window, at which time Delta Smelt are least likely to occur in the project area. In addition to limiting activities to the in-water work window, the following AMMs will be implemented 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: 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 NDD construction will be isolated from the Sacramento River and will not result in the discharge of sediment to the river with implementation of AMMs and best management practices related to land-based construction activities.

Construction-related turbidity and suspended sediment may occur during winter and spring due to increased erosion and mobilization of sediment in runoff from disturbed levee surfaces. However, with the timing restrictions on in-water activities and implementation of the proposed erosion and sediment control measures (Appendix 3.F *General Avoidance and Minimization Measures,* AMM4) and other BMPs to ensure the effectiveness of these measures (Appendix 3.F *General Avoidance and Minimization Measures,* AMM2 *Construction Best Management Practices and Monitoring*), no adverse water quality effects are anticipated during this period.

4.1.1.2.1.1 Migrating Adults (December–March)

The timing of in-water work (June 1 through October 31) will avoid the Delta Smelt adult migration season. Therefore, there will be no effect on migrating adults from temporary increases in turbidity and suspended sediment, and no population-level effects are expected.

4.1.1.2.1.2 Spawning Adults (February–June)

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 strongly reduced at 250 NTU (Hasenbein *et al.* 2013). This finding is consistent with monitoring data showing that Delta Smelt are often captured in turbidities between 10 and 50 NTU (Feyrer *et al.* 2007).

During in-water work at the NDDs, turbidity and suspended sediment levels in the river are anticipated to exceed ambient river levels in the immediate vicinity of construction activity, creating turbidity plumes that may extend several hundred feet downstream. The National Marine Fisheries Service (NMFS) (2008) reviewed observations of turbidity plumes during installation of riprap for bank protection projects along the Sacramento River and concluded that visible plumes will be limited to a fraction 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 will not adversely affect Delta Smelt based on the general association and feeding responses of Delta Smelt to turbidity (Hasenbein *et al.* 2013). However, under the assumption that there could be some effect up to 1,000 feet downstream from each intake, this will result in 1.9 acres of impact to shallow water habitat (which is included in the overall 5.6 acres of shallow water habitat impact from the NDD; see Section 4.1.1.2 *North Delta Diversions*). This will be mitigated at a 5:1 ratio (Table 5.4-1).

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 appears to provide little or no suitable habitat thought to be preferred by Delta Smelt for spawning; the reach is dominated by steep levee slopes, existing riprap, and low quantities of riparian and aquatic vegetation. Thus, the reach likely does not support appreciable spawning by Delta Smelt.

Spawning adults may be present in the vicinity of the intakes during February through June. Thus, the timing of in-water construction (June 1 through October 31) will avoid most of the spawning season (i.e., January through June, with a maximum 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 NDD area is low; Delta Smelt presence is most likely during the primary winter and spring migration and spawning periods. For example, during April and May, 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 percent of the mean densities collected downstream of these locations (Section 4.1.3, *Operations Effects*). The expectation that a small proportion of migrating adults will near the intake sites during construction and operation of these facilities is also supported by the results of a DSM2-PTM analysis (described in ICF International [2016], Appendix 6.A *Quantitative Methods for Biological Assessment of Delta Smelt*, Section 6.A.2.1 *Migrating Adult*

Movement Upstream [DSM2-PTM]). Thus, the potential effects of increased turbidity and suspended sediment associated with construction work will be limited to that small proportion of the population that may be present in the project 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.

4.1.1.2.1.3 Eggs/Embryos (Spring: March–June)

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 will be at risk of burial by the deposition of suspended sediment generated by in-water construction activities.

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

4.1.1.2.1.4 Larvae/Young Juveniles (Spring: March–June)

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.

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

4.1.1.2.1.5 Juveniles (Summer/Fall: July–December)

Juvenile Delta Smelt rear downstream of the proposed intake locations in the summer and fall and therefore are unlikely to be affected by increased turbidity and suspended sediment during in-water construction activities. No population-level effects are expected.

4.1.1.2.2 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. Potential effects of contaminants on fish include direct injury and mortality (e.g., damage to gill tissue causing asphyxiation) or delayed effects on growth and survival (e.g., increased stress or reduced feeding), depending on the type of contaminant, extent of the spill, and exposure concentrations. The risk of such effects is highest during in-water construction activities, including cofferdam installation, dredging, and barge operations, because of the proximity of construction equipment to the Sacramento River. Implementation of Appendix 3.F *General Avoidance and Minimization Measures*, AMM5 *Spill Prevention, Containment, and Countermeasure Plan* and AMM14 *Hazardous Materials Management* will minimize the potential for contaminant spills and guide rapid and effective response in the case of inadvertent spills of hazardous materials. With implementation of these and other required construction BMPs (e.g., AMM3 *Stormwater Pollution Prevention Plan*), the risk of contaminant spills or discharges to the Sacramento River from in-water or upland sources will be effectively minimized.

Contaminants may also enter the aquatic environment through the disturbance, resuspension, or discharge of contaminated soil and sediments from construction sites. Sediments act as a sink or source of contaminant exposure depending on local hydrologic conditions, habitat type, and frequency of disturbance. Sediment is a major sink for more persistent chemicals that have been introduced into the aquatic environment, with most organic and inorganic anthropogenic chemicals and waste materials accumulating in sediment (Ingersoll et al. 1995). 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.

Resuspension of contaminated sediments may have adverse effects on fish that encounter sediment plumes or come into contact with deposited or newly exposed sediment. Suspended sediment can also adversely affect fish by causing localized increases in chemical oxygen demand in waters in or near plumes. 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 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).

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

4.1.1.2.2.1 Migrating Adults (December–March)

The timing of in-water construction activities (June 1–October 31) will avoid the Delta Smelt adult migration season, minimizing exposure risk for migrating adults. With implementation of pollution prevention and erosion and sediment control AMMs, there is little risk of exposure of migrating adults to contaminants. Due to the low magnitude of risk, no population-level effects are expected.

Spawning Adults (February–June)Based on the timing of in-water construction activities (June 1–October 31), spawning adults in the vicinity of the NDDs will be subject to direct exposure to contaminant spills or sediment-borne contaminants (i.e., through exposure to turbidity plumes). Exposure risk will occur only in June. Implementation of pollution prevention and erosion and sediment control AMMs will minimize this risk.

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 pollution control and erosion and sediment control AMMs.

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

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 will be minimal, individual eggs could suffer adverse effects if directly exposed to contaminant spills or sediment-borne contaminants during construction. Implementation of pollution prevention and erosion and sediment control AMMs will minimize this risk throughout the construction period.

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

4.1.1.2.2.3 Larvae/Young Juveniles (Spring: ~March–June)

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. Implementation of pollution prevention and erosion and sediment control AMMs will minimize this risk throughout the construction period.

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

4.1.1.2.2.4 Juveniles (Summer/Fall: ~July–December)

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. Due to the low magnitude of risk, no population-level effects are expected.

4.1.1.2.3 Underwater Noise

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

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.

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

Dual interim criteria have been established to provide guidance for assessing the potential for injury of fish resulting from pile driving noise (Fisheries Hydroacoustic Working Group 2008) (Table 4.1-1). 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 4.1-1. 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 will 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.

Table 4.1-2 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 Project*. This analysis considers only those pile driving activities that could generate noise levels sufficient to exceed the interim injury thresholds in the Sacramento River or other waters potentially supporting listed fish species. These activities include impact pile driving in open water, in cofferdams adjacent to open water, or on land within 200 feet of open water. For cofferdam sheet piles, it is assumed that approximately 70 percent of the length of each pile can be driven using vibratory pile driving, with impact driving used to finalize pile placement. For the intake structure foundation piles, the current design assumes the use of impact pile driving only. However, some degree of attenuation is expected assuming that the cofferdams can be fully dewatered. Therefore, predictions are shown for two scenarios, one in which dewatering results in a 5 dB reduction in reference noise levels, and one in which no attenuation is possible (no dewatering or other forms of attenuation). All computed distances over which pile driving sounds are expected to exceed the injury and behavioral thresholds assume an unimpeded sound propagation path. However, site conditions such as major channel bends and other in-water structures can reduce these distances by impeding the propagation of underwater sound waves.

Table 4.1-2. Extent, Timing, and Duration of Pile Driving Noise Levels Predicted to Exceed the Interim Injury and Behavioral Thresholds at the North Delta Intakes

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)	Construction Season	Timing of Pile Driving	Duration of Pile Driving (days)
Intake 2						
Cofferdam	30	2,814	13,058	Year 8	Jun–Oct	42
Foundation (no attenuation)	46	3,280	32,800	Year 9	Jun–Oct	19
Foundation (with attenuation)	20	1,522	15,226	Year 9	Jun-Oct	19
Intake 3						
Cofferdam	30	2,814	13,058	Year 7	Jun–Oct	42
Foundation (no attenuation)	46	3,280	32,800	Year 8	Jun–Oct	14
Foundation (with attenuation)	20	1,522	15,226	Year 8	Jun-Oct	14
Intake 5						
Cofferdam	30	2,814	13,058	Year 5	Jun–Oct	42
Foundation (no attenuation)	46	3,280	32,800	Year 6	Jun–Oct	19
Foundation (with attenuation)	20	1,522	15,226	Year 6	Jun-Oct	19

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

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

Sound monitoring data collected during similar types of pile driving operations indicate that single-strike peak SPLs exceeding the interim injury thresholds are expected to be limited to areas within 30 feet of the cofferdam sheet piles and 20-46 feet of the intake foundation piles, depending on whether cofferdams can be dewatered (Table 4.1-2).

Based on a cumulative (daily) threshold of 187 dB SEL, the risk of injury is calculated to extend up to 5,628 feet (2,814 x 2) during installation of the cofferdams and 6,560 feet (3,280 x 2) during installation of the foundation piles (3,044 feet if the cofferdams can be dewatered) assuming an unimpeded propagation path.[3] The predictions in Table 4.1-2 apply to one intake location; the current construction schedule indicates that pile driving in a given year will occur at one intake only with the exception of Year 8 in which cofferdam installation at Intake 2 may coincide with foundation pile installation at intake 3 (Appendix 3.D *Construction Schedule for*

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

the Proposed Project). In this case, there would be no overlap in the potential noise impact areas although fish migrating through the action area could be exposed to pile driving noise within two reaches totaling 12,188 feet. Based on the estimated duration of pile driving activities, such conditions could occur for up to 14 days based on the duration of foundation pile installation.

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

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

4.1.1.2.3.1 Migrating Adults (December–March)

The timing of in-water construction activities (June 1–October 31) will avoid the Delta Smelt adult migration season. There will be no risk of exposure of migrating adults to impact pile driving noise. In the absence of such risk, no population-level effects are expected.

4.1.1.2.3.2 Spawning Adults (February–June)

Restricting impact pile driving to June 1–October 31 will avoid most of the Delta Smelt spawning season, but potential for exposure of spawning adults will occur in June. Adults occur in the north Delta and farther upstream but results from various surveys and general life history information suggest that the proportion of the population seasonally occupying the project area is low and most likely to be present during the December through May, when no in-water work will occur. Some potential exists for adults to occur in the project 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 project area, the potential for exposure of Delta Smelt to pile driving noise is low. Potential exposure of the population to pile driving noise will be minimized through 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.

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

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 due to the absence of suitable spawning substrates in the vicinity of the NDDs, any individual eggs in the vicinity of the intake sites will be unable to avoid prolonged exposure to pile driving noise, resulting in adverse effects on survival, development, or viability.

Based on the small proportion of spawning adults in the project area at the time of pile driving operations and expected low utilization of the affected reaches by spawning adults due to the absence of suitable spawning substrates in the vicinity of the NDDs, any mortality of eggs or embryos due to pile driving noise will not affect population abundance. 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.

4.1.1.2.3.4 Larvae/Young Juveniles (Spring: ~March–June)

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 will 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.

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 will represent a very 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.

4.1.1.2.3.5 Juveniles (Summer/Fall: ~July–December)

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. Thus, no population-level effects are expected.

4.1.1.2.4 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 will 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.

4.1.1.2.4.1 Migrating Adults (December–March)

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, and no population-level effects are expected.

4.1.1.2.4.2 Spawning Adults (February–June)

Although present in low numbers, spawning adults may be present in the project area in June and subject to stranding in cofferdams. Adults may move away from active construction areas, but some risk of stranding will exist as long as the affected areas are accessible to fish. Fish rescue and salvage activities using accepted fish collection methods can minimize stranding losses but can also result in injury or mortality due to potential stress and injury associated with various capture and handling methods. However, these effects are typically minor and can often be avoided with appropriate training.

Population-level effects will be negligible because of the low densities of adults that may be present in the project area during cofferdam installation, low utilization of the intake sites by spawning adults, and implementation of fish rescue and salvage activities.

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

Based on the low utilization of the intake sites by spawning adults (due to the absence of suitable spawning substrates in the vicinity of the NDDs), there is little or no risk of stranding of Delta Smelt eggs or embryos. Due to the low stranding risk, no population-level effects are expected.

4.1.1.2.4.4 Larvae/Young Juveniles (Spring: ~March–June)

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.

Population-level effects will 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.

4.1.1.2.4.5 Juveniles (Summer/Fall: ~July–December)

Juvenile Delta Smelt rear downstream of the proposed intake sites in the summer and fall and therefore are unlikely to be stranded in cofferdams. Due to the low stranding risk, no population-level effects are expected.

4.1.1.2.5 Direct Physical Injury

During construction of the NDDs, 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. Besides the June 1–October 31 work window, the potential for injury of listed fish species will 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*).

4.1.1.2.5.1 Migrating Adults (December–March)

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.

4.1.1.2.5.2 Spawning Adults (February–June)

Due to the absence of suitable spawning substrates in the vicinity of the NDDs, spawning adults are only likely to be present if moving towards upstream spawning sites. Such fish comprise a very small fraction of the spawner population. Spawning adults may be present in very small numbers in June and therefore subject to injury. Although adults may 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. Population-level effects will be negligible because of the low densities of adults that may be present in the project area during in-water construction.

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

Based on low utilization of the affected reaches by spawning adults (due to the absence of suitable spawning substrates in the vicinity of the NDDs), there is little or no risk of injury of Delta Smelt eggs or embryos. No population-level effects are expected.

4.1.1.2.5.4 Larvae/Young Juveniles (Spring: ~March–June)

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. Population-level effects will 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.

4.1.1.2.5.5 Juveniles (Summer/Fall: ~July–December)

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. No population-level effects are expected.

4.1.1.2.6 Loss or Alteration of Habitat

Construction of the north Delta intakes will result in permanent loss or alteration of aquatic habitat in areas where Delta Smelt could occur. 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[4] 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

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

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 affect a total of 1.02 linear miles of shoreline.

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

4.1.1.2.6.1 Migrating Adults (December–March)

The NDDs are located 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. For the small proportion of the population that may migrate past these sites, these changes will impair adult passage and subject adults to an elevated risk of predation as they attempt to pass the construction sites.

The loss of low-velocity shoreline areas and increased predation risk at the intake construction sites may 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 of fish 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 will remain unaffected) or spawning areas (e.g., returning downstream to spawn). Due to the small proportion of the population that migrates and spawns in the reaches upstream of the intake site, any population-level effects will be small.

4.1.1.2.6.2 Spawning Adults (February–June)

There is little or no spawning habitat for Delta Smelt 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 will have little or no effect on spawning site selection or spawning success of adults.

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 will have a negligible population-level effect because of the small proportion of the population spawning in the project area, low utilization of the intake sites by spawning adults, and negligible contribution of this habitat to the overall spawning capacity of the upper estuary.

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

Based on the small proportion of the population spawning in the project 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. Population-level effects will be negligible.

4.1.1.2.6.4 Larvae/Young Juveniles (Spring: ~March–June)

Delta Smelt larvae and young 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, these structures likely do not provide beneficial habitat for these small predators, which may be susceptible to the same larger predators that consume adult Delta Smelt. Therefore, elevated predation on Delta Smelt larvae is unlikely.

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 will be small based on the small proportion of the population occurring in or upstream of the project area.

4.1.1.2.6.5 Juveniles (Summer/Fall: ~July–December)

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. No population-level effects are expected.

4.1.1.3 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 RTM. A total of seven barge landings are proposed (Appendix 3.A *Map Book for the Proposed Project*) at the following locations:

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

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

Major construction elements of this action include barge landing construction, levee clearing and armoring (as necessary), and barge operations. The barge landings will be constructed over a period of 2 years. Each landing will consist of a dock supported by steel piles. Each landing will occupy an overwater area of up to 0.34 acre (300 by 50 feet) and will obstruct 5-9 percent of the total channel widths at each proposed location. Any clearing and armoring of the levee necessary to provide access and protect the levee from wave erosion is included within the footprint estimate (30 acres total) for barge landings.

Construction of the barge landings will result in permanent impacts to a total of up to 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 Delta Smelt spawning substrate potentially affected by construction are not currently available. Each landing will be in use for the duration of construction activities (5-6 years) at each TBM shaft site and other construction sites (e.g., north Delta intakes) as needed. Each landing will be removed at the completion of construction.

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

4.1.1.3.1 Turbidity and Suspended Sediment

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

Potential turbidity and sediment impacts on Delta Smelt and other listed species will be minimized by restricting in-water construction activities to August 1 through October 31 at most locations[5]. To protect aquatic habitat and listed fish species at the barge landings and along the barge transport routes, the barge operations plan (Appendix 3.F *General Avoidance and Minimization Measures*, AMM7) will require barges and towing vessels to comply with standard navigation and operating rules to avoid or minimize physical disturbances and water quality impacts in the navigable waterways of the Delta. Where avoidance is not possible, the plan will include provisions to minimize effects as described in Appendix 3.F *General Avoidance and Minimization Measures*, Section 3.F.2.7.4 *Environmental Training* and Section 3.F.2.7.5 *Dock Approach and Departure Protocol*. Other AMMs that are proposed to avoid or minimize potential turbidity, suspended sediment, and other water quality impacts include *Worker Awareness Training; Construction Best Management Practices and Monitoring; Stormwater Pollution Prevention Plan (SWPPP); Erosion and Sediment Control Plan; Spill Prevention, Containment, and Countermeasure Plan (SPCCP); Hazardous Material Management Plan; and Disposal and Reuse of Spoils, Reusable Tunnel Material, and Dredged Material* (Appendix 3.F *General Avoidance and Minimization Measures*).

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

4.1.1.3.1.1 Migrating Adults (December–March)

The timing of in-water construction at the barge landings (August 1–October 31) will avoid the Delta Smelt adult migration season. However, barge operations will continue year-round for 5-6 years following construction, potentially increasing the frequency of wave-induced erosion and associated increases in nearshore turbidity and suspended sediment levels along the barge transport routes. Based on the general association and responses of Delta smelt to turbidity (see Section 4.1.1.2.1), no adverse effects on migrating adults are expected. In addition, such disturbances will be minimized by implementing the barge operations plan (Appendix 3.F *General Avoidance and Minimization Measures,* AMM7), which includes specific measures to minimize bed scour, bank erosion, loss of submerged and emergent vegetation, and disturbance of benthic communities. No population-level effects are expected.

4.1.1.3.1.2 Spawning Adults (February–June)

The timing of in-water construction at the barge landings (August 1–October 31) will avoid the Delta Smelt spawning season. Therefore, spawning adults will be unaffected by increases in turbidity and suspended sediment during construction of the barge landing sites. However, it is possible that the deposition of suspended sediment generated by construction activities could degrade potential spawning habitat through burial of suitable substrates, if such habitat occurs near barge landing sites. Because Delta Smelt are generally found in the west Delta and Cache Slough/Liberty Island area during spring and summer, most of the population will be unaffected by potential degradation of spawning habitat at the barge landing sites. Furthermore, potential adverse effects of sedimentation on physical habitat (spawning substrate) will be minimized by

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

siting the barge landings on levees with steep, riprapped banks and deep nearshore areas that lack shallow water areas suitable for spawning.

Because barges will be operating year-round for 5-6 years along a number of routes within the Delta and estuary, increases in the frequency of wave-induced erosion and associated increases in nearshore turbidity and suspended sediment levels could directly affect spawning adults and habitat. Based on the general association and responses of Delta smelt to turbidity (see Section 4.1.1.2.1), no adverse effects on spawning adults are expected. Increases in turbidity and suspended sediment in nearshore areas could adversely affect spawning habitat but such effects will be minimized by implementing the barge operations plan (Appendix 3.F *General Avoidance and Minimization Measures*, AMM7), which includes specific measures to minimize bed scour, bank erosion, loss of submerged and emergent vegetation, and disturbance of benthic communities. Furthermore, potential effects on the overall quantity and quality of spawning habitat in the Delta will be minimal because increases in barge traffic levels are predicted to average only 7.5 trips per day over the entire project area and primarily affect the channels of the east and south Delta (where much of the barge activity will be focused). No population-level effects are expected.

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

In-water construction activities at the barge landings will occur between August 1 and October 31, and therefore will not affect eggs/embryos. Year-round operation of barges could increase suspended sediment along nearshore areas along the barge routes, resulting in potential adverse effects on spawning habitat and burial of eggs/embryos. However, as discussed above, no population-level effects are expected based on the small incremental increase in barge traffic levels and implementation of the barge operations plan.

4.1.1.3.1.4 Larvae/Young Juveniles (Spring: ~March–June)

The timing of in-water work at the barge landing (August 1–October 31) will avoid the primary months when Delta Smelt larvae and young juveniles may be present at the barge landing sites. Based on the general association and responses of Delta smelt to turbidity (see Section 4.1.1.2.1), no adverse effects associated with increases in turbidity and suspended sediment along the barge traffic routes are expected.

4.1.1.3.1.5 Juveniles (Summer/Fall: ~July–December)

Juvenile Delta Smelt rear downstream of the barge landing sites in the summer and fall and therefore will be unaffected by increases in turbidity and suspended sediment during in-water construction activities. Based on the general association and responses of Delta smelt to turbidity (see Section 4.1.1.2.1), no adverse effects associated with increases in turbidity and suspended sediment during year-round barge operations are expected.

4.1.1.3.2 Contaminants

Construction and operation 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 and operation of the barge landings will be similar to that described previously (Section 4.1.1.2 *North Delta Diversions*), due to the proximity of construction activities and barge operations to the waters of the Delta. Implementation of Appendix 3.F *General Avoidance and Minimization Measures,* AMM5 *Spill Prevention, Containment, and Countermeasure Plan*, AMM8 *Barge Operations Plan*, and AMM14 *Hazardous Materials Management* will minimize the potential for introduction of contaminants into surface waters and guide rapid and effective response in the case of inadvertent spills of hazardous materials. These AMMs include the use of watertight forms and other containment structures to prevent spills or discharge of raw concrete, wash water, and other contaminants from entering surface waters and other sensitive habitats during casting of the barge decks and other overwater activities. With implementation of these and other required construction BMPs (e.g., AMM 3 *Stormwater Pollution Prevention Plan*), the risk of contaminant spills or discharges to Delta waters from in-water and overwater sources will be effectively minimized.

Contaminants may also enter the aquatic environment through disturbance, resuspension, or discharge of contaminated soil and sediments from construction sites. As described in Section 4.1.1.2 *Contaminants*, sediments act as a sink or source of contaminant exposure and resuspension of contaminated sediments may have adverse effects on fish that encounter sediment plumes or come into contact with newly exposed sediment. In addition to direct exposure, contaminated sediments can adversely affect fish through accumulation of contaminants in the food web. Because the barge landings will be constructed on Delta waterways adjacent to major agricultural islands, these sites are more likely to contain agricultural-related toxins such as copper and organochlorine pesticides, which can cause acute (lethal) toxicity in aquatic organisms at high concentrations, or chronic (sublethal) effects at lower concentrations which reduces the organism’s health and may lessen survival over time.

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

4.1.1.3.2.1 Migrating Adults (December–March)

The potential effects of contaminants on Delta Smelt were discussed previously (Section 4.1.1.2.2). The timing of in-water construction activities (August 1–October 31) will avoid the Delta Smelt adult migration season. Therefore, migrating adults will not be subject to direct exposure to contaminant spills or sediment-born contaminants during construction of the barge landing sites. Some risk will exist year-round at the barge landing sites and along the barge transport routes but implementation of proposed pollution prevention, erosion and sediment control, and barge operations AMMs will minimize this risk.

During the 5-6 years of barge operations, potential increases in mobilization of contaminants in nearshore sediments subjected to wave-induced erosion caused by passing barges could adversely affect migrating adults but such effects will be minimized by implementing the barge operations plan (Appendix 3.F *General Avoidance and Minimization Measures,* AMM7), which includes specific measures to minimize bed scour, bank erosion, loss of submerged and emergent vegetation, and disturbance of benthic communities. Furthermore, potential increases in contaminant levels in Delta waters subject to increased barge traffic will be minimal because increases in barge traffic levels are predicted to average only 7.5 trips per day over the entire project area. No population-level effects are expected.

4.1.1.3.2.2 Spawning Adults (February–June)

The timing of in-water construction at the barge landing (August 1–October 31) will avoid the Delta Smelt spawning season. Therefore, spawning adults will not be subject to direct exposure to contaminant spills or sediment-born contaminants during construction of the barge landing sites. As discussed above, an increased risk of exposure to contaminants will exist year-round at the barge landing sites and along the barge transport routes but implementation of proposed pollution prevention, erosion and sediment control, and barge operations AMMs will minimize this risk. No population-level effects are expected.

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

In-water construction activities at the barge landings will occur between August 1 and October 31, and therefore will avoid the Delta Smelt spawning and incubation period. Therefore, Delta Smelt eggs/embryos will not be subject to direct exposure to contaminant spills or sediment-born contaminants during construction of the barge landing sites. As discussed above, an increased risk of exposure to contaminants will exist year-round at the barge landing sites and along the barge transport routes but implementation of proposed pollution prevention, erosion and sediment control, and barge operations AMMs will minimize this risk. No population-level effects are expected.

4.1.1.3.2.4 Larvae/Young Juveniles (Spring: ~March–June)

The timing of in-water construction at the barge landing (August 1–October 31) will avoid the primary months when Delta Smelt larvae/young juveniles may be present at the barge landing sites. Therefore, larvae/young juvenile will not be subject to direct exposure to contaminant spills or sediment-born contaminants during construction of the barge landing sites. As discussed above, an increased risk of exposure to contaminants will exist year-round at the barge landing sites and along the barge transport routes but implementation of proposed pollution prevention, erosion and sediment control, and barge operations AMMs will minimize this risk. No population-level effects are expected.

4.1.1.3.2.5 Juveniles (Summer/Fall: ~July–December)

Juvenile Delta Smelt rear downstream of the proposed barge landings 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. As discussed above, an increased risk of exposure to contaminants will exist year-round along the barge transport routes (which may include summer and fall rearing areas) but implementation of proposed pollution prevention, erosion and sediment control, and barge operations AMMs will minimize this risk. No population-level effects are expected.

4.1.1.3.3 Underwater Noise

As discussed in Section 4.1.1.2.3, impact pile driving can produce underwater noise levels of sufficient intensity and duration to cause injury to fish. Currently, it is estimated that each barge landing will require vibratory and/or impact driving of 107 steel pipe piles (24-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 is expected to occur over a period of 2 days at each barge landing.

Based on the general timing and abundance of Delta Smelt in the east and south Delta, restriction of pile driving activities to August 1 through October 31 will avoid the primary months when Delta Smelt may be present at the barge landing sites. In addition, as described in Section 4.1.1.2.3, 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.

4.1.1.3.3.1 Migrating Adults (December–March)

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

4.1.1.3.3.1 Spawning Adults (February–June)

Based on the timing of pile driving operations at the barge landings (August 1–October 31) and the general timing and abundance of Delta Smelt in the east and south delta, spawning adults will not be exposed to pile driving noise.

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

Pile driving at the barge landings will occur between August 1 and October 31, and therefore will not affect eggs/embryos.

4.1.1.3.3.3 Larvae/Young Juveniles (Spring: ~March–June)

Pile driving at the barge landings will occur between August 1 and October 31, and therefore will not affect larvae/young juveniles.

4.1.1.3.3.4 Juveniles (Summer/Fall: ~July–December)

Juvenile Delta Smelt rear downstream of the proposed barge landing sites in summer and fall and therefore will not be affected by pile driving noise.

4.1.1.3.4 Fish Stranding

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

4.1.1.3.5 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 Delta. Potential mechanisms include fish being crushed by falling rock (riprap), impinged by piles, or struck or entrained by vessels or propellers. Physical injury of fish may also occur as a result of propeller entrainment and shoreline disturbances (e.g., dewatering) associated with year-round operation of barges within the Delta channels used by barges to transport construction equipment and materials between the loading and unloading facilities.

In addition to the proposed in-water work window (August 1-October 31), the potential for injury of listed fish species during construction of the barge landings will 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*). To protect aquatic habitat and listed fish species, the barge operations plan (AMM7) will require barges and towing vessels to comply with standard navigation and operating rules to avoid or minimize physical disturbances and water quality impacts in the navigable waterways of the Delta. Where avoidance is not possible, the plan will include provisions to minimize effects as described in Appendix 3.F *General Avoidance and Minimization Measures*, Section 3.F.2.7.4 *Environmental Training* and Section 3.F.2.7.5 *Dock Approach and Departure Protocol*.

4.1.1.3.5.1 Migrating Adults (December–March)

The timing of in-water construction activities (August 1–October 31) will avoid the Delta Smelt adult migration season. Therefore, migrating adults will not be subject to direct physical injury during construction of the barge landings. However, barge operations will continue year-round for 5-6 years following construction, potentially affecting migrating adults at the barge landings and in the Delta channels used to transport construction equipment and materials between the barge loading and unloading facilities. Potential effects include direct injury or mortality of fish from entrainment by tug boat propellers. There are few direct observations of fish being seriously injured or killed by boat traffic (Rosen and Hales 1980; Gutreuter et al. 2003), although there is general agreement that juveniles and adults are less susceptible to injury than early life stages (eggs and larvae) because of their greater swimming ability and resistance to shear stresses caused by propellers (Morgan et al. 1976; Holland 1986; Killgore et al. 2001; Wolter and Arlinghaus 2003).

No information exists on the potential for vessel interactions with Delta Smelt or other Delta fishes. Although implementation of the barge operations plan (AMM7) is expected to minimize potential interactions, the frequency of such interactions with migrating adults may increase and result in an elevated risk of injury. However, an average increase of 7.5 trips per day over the entire action area, and the relatively low densities of adults in the east and south Delta (where much of the barge activity will be focused), suggests that any increases in injury will be small. No population-level effects are expected.

4.1.1.3.5.2 Spawning Adults (February–June)

The timing of in-water construction activities (August 1–October 31) will avoid the Delta Smelt spawning season. However, as discussed above for migrating adults, year-round operation of barges at the barge landings and along the barge transport routes could result in direct injury of Delta Smelt. Spawning adults may less vulnerable to direct interactions with vessels because of their presumed utilization for shallow areas or shoal habitat for spawning although such areas may be more sensitive to disturbances (e.g., wave scour, dewatering) caused by the passage of barges and towing vessels. However, no population-level effects are expected because of the low utilization of the east and south Delta channels by spawning adults, the small incremental increases in barge traffic levels, and implementation of the barge operations plan (see Section 4.1.1.3.1.2 *Spawning Adults*).

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

The timing of in-water construction activities (August 1–October 31) will avoid the Delta Smelt spawning and incubation season. However, similar to spawning adults, eggs/embryos will be relatively vulnerable to shoreline disturbances (propeller wash, wave scour) associated with year-round barge operations at the barge landing sites and along the transport routes. However, no population-level effects are expected because of the low utilization of the east and south Delta by spawning adults, the small incremental increases in barge traffic levels, and implementation of the barge operations plan (see Section 4.1.1.3.1.2 *Spawning Adults*).

4.1.1.3.5.4 Larvae/Young Juveniles (Spring: ~March–June)

The timing of in-water work at the barge landing (August 1–October 31) will avoid the primary months when Delta Smelt larvae and young juveniles may be present at the barge landing sites. However, as discussed above for migrating adults, year-round operation of barges at the barge landings and along the barge transport routes could result in direct injury of larvae and young juveniles. Delta smelt larvae and early juveniles may be particularly vulnerable to injury because of their limited swimming ability and sensitivity to shear stresses caused by propellers. However, population-level effects will be negligible based on the small proportion of adults that spawn in the east and south Delta (and resulting low densities of larvae/young juveniles), the small incremental increases in barge traffic levels, and implementation of the barge operations plan (see Section 4.1.1.3.1.2 *Spawning Adults*).

4.1.1.3.5.5 Juveniles (Summer/Fall: ~July–December)

Juvenile Delta Smelt rear downstream of the proposed barge landings in the summer and fall and therefore are unlikely to be injured by construction activities at the barge landing sites. As discussed above, an increased risk of injury will exist year-round along the barge transport routes (which may include summer and fall rearing areas) but population-levels effects are expected to be negligible because of the small incremental increases in barge traffic levels and implementation of the barge operations plan (see Section 4.1.1.3.1.2 *Spawning Adults*).

4.1.1.3.6 Loss or Alteration of Habitat

Construction of the barge landings will result in temporary and permanent losses or alteration of aquatic habitat in several channels of the east and south Delta that could be occupied by 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 that will return to baseline levels following cessation of construction activities.

Construction of all barge landings will result in permanent impacts to up to 22.4 acres of tidal perennial aquatic habitat (approximately 3.2 acres per landing). At each site, approximately 0.34 acres of tidal perennial aquatic habitat will be covered by the dock. During construction, and continuing during year-round 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, 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 will also implement Appendix 3.F *General Avoidance and Minimization Measures*, AMM7 *Barge Operations Plan*, which includes specific measures to minimize bed scour, bank erosion, loss of submerged and emergent vegetation, and disturbance of benthic communities. Unavoidable impacts to 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.

4.1.1.3.6.1 Migrating Adults (December–March)

Although affecting a small proportion of the population, migrating adults may be subject to an elevated risk of predation as they pass the barge landing sites because of potential increases in predator habitat. The presence of in-water and overwater structures (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. Increased predation risk at the barge landing sites will potentially result in increased mortality of migrating adults. Based on the small proportion of the Delta Smelt population spawning in the east and south Delta, the population-level effect is expected to be small.

4.1.1.3.6.2 Spawning Adults (February–June)

Construction of the barge landings and subsequent barge operations will result in loss or alteration of nearshore areas and potential loss of degradation of Delta Smelt spawning habitat at the barge landing sites and in the Delta channels used by the barges to transport equipment and materials between the loading and unloading facilities. Because the barge landings will likely be sited in areas with steep, riprapped levees and deep nearshore areas, the potential for use 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 will not likely alter spawning habitat use or spawning success of adults in these areas. Year-round barge operations following construction will result in increased disturbance of nearshore areas along the barge transport routes which could affect the suitability of these areas for spawning. However, no population-level effects are expected because of the low utilization of the east and south Delta channels by spawning adults, the small incremental increases in barge traffic levels, and implementation of the barge operations plan (see Section 4.1.1.3.1.2 *Spawning Adults*).

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

Based on the small proportion of the population spawning in the project area and expected low utilization of the barge landing sites by spawning adults, there is little risk of adverse effects on eggs or embryos during construction of the barge landings. Year-round barge operations following construction will result in increased disturbance of nearshore areas along the barge transport routes which could affect the suitability of these areas for spawning. However, no population-level effects are expected because of the low utilization of the east and south Delta channels by spawning adults, the small incremental increases in barge traffic levels, and implementation of the barge operations plan (see Section 4.1.1.3.1.2 *Spawning Adults*).

4.1.1.3.6.4 Larvae/Young Juveniles (Spring: ~March–June)

Delta Smelt larvae and early juveniles migrating from upstream spawning areas to estuarine rearing areas (e.g., in the low salinity zone) 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. Even if larvae and juveniles are subject to elevated predation rates as they pass the construction sites, the population-level effect will be small based on the small proportion of the population potentially present near barge landing sites.

4.1.1.3.6.5 Juveniles (Summer/Fall: ~July–December)

Juvenile Delta Smelt rear downstream of the proposed barge landing sites (e.g., in the low salinity zone and in the Cache Slough/Sacramento Deep Water Ship Channel Area) in the summer and fall and therefore are unlikely to be affected by losses or alteration of habitat during construction. No population-level effects are expected.

4.1.1.4 Head of Old River Gate

An operable 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 in Old River approximately 400 feet downstream of the junction of Old River with the San Joaquin River (Appendix 3.A *Map Book for the Proposed Project*). The gate will be 210 feet long and 30 feet wide, with a top elevation of +15 feet (Appendix 3.C *Conceptual Engineering Report*, Volume 2, Sheets 11, 12, and 13), and include seven bottom-hinged gates, fish passage structure, boat lock, control building, boat lock operator's building, and communications antenna.

Additional details on the design, construction methods, and proposed construction schedule for the HOR gate are described in Chapter 3 *Proposed Project*.

Construction of the HOR gate will take 2 years. The HOR gate will be constructed in two phases using cofferdams to isolate and dewater half the channel during the first phase and the other half during the second phase. All in-water construction work, including cofferdam installation, riprap placement, dredging, and barge operations, will be restricted to August 1-October 31 to minimize or avoid potential effects on 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 will 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.

4.1.1.4.1 Turbidity and Suspended Sediment

In-water construction activities will 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 will not result in the discharge of sediment to the river. Water pumped from the cofferdams will be treated, removing all sediment using settling basins or Baker tanks, and returned to the river. 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.

4.1.1.4.1.1 Migrating Adults (December–March)

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

4.1.1.4.1.2 Spawning Adults (February–June)

The timing of in-water construction activities (August 1–October 31) 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.

Most of the Delta Smelt population is distributed downstream of the proposed HOR gate (Moyle 2002). Available monitoring data suggest that adult Delta Smelt occur in very low numbers near the HOR gate. Over 2,300 beach seine samples[6] 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[7] 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 will have negligible population-level effects.

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

The timing of in-water construction activities (August 1–October 31) will avoid the Delta Smelt incubation season. Therefore, there will be no direct effects on eggs/embryos from temporary increases in turbidity and suspended sediment. 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, no population-level effects are anticipated because of the timing of in-water construction activities, low proportion of the population utilizing the project area, and low quality of spawning habitat in the vicinity of the HOR gate.

4.1.1.4.1.4 Larvae/Young Juveniles (Spring: ~March–June)

The timing of in-water construction activities (August 1-October 31) will avoid the downstream migration period of Delta Smelt larvae/young juveniles. Therefore, there will be no effect on Delta smelt larvae/young juveniles from temporary increases in turbidity and suspended sediment.

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[6] 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.

[7] 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.

4.1.1.4.1.5 Juveniles (Summer/Fall: ~July–December)

Juvenile Delta Smelt rear downstream of the proposed HOR gate in the summer and fall and therefore will not be affected by increased turbidity and suspended sediment during in-water construction activities.

4.1.1.4.2 Contaminants

Construction of the HOR gate 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 potentially hazardous materials will be similar to that described for the NDDs (Section 4.1.1.2.2 *Contaminants*) due to the proximity of construction activities to the waters of the Delta. Implementation of the following AMMs will minimize the potential for introduction of contaminants into surface waters and guide rapid and effective response in the case of inadvertent spills of hazardous materials: AMM1 *Worker Awareness Training; Construction Best Management Practices and Monitoring;* AMM 3*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* (Appendix 3.F *General Avoidance and Minimization Measures*).

Contaminants can also enter the aquatic environment through disturbance, resuspension, or discharge of contaminated soil and sediments from construction sites. As described in Section 4.1.1.2.2 *Contaminants*, sediments act as a sink or source of contaminant exposure, and resuspension of contaminated sediments may have adverse effects on fish that encounter sediment plumes or come into contact with deposited or newly exposed sediment. In addition to direct exposure, contaminated sediments can adversely affect fish through accumulation of contaminants in the food web.

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

4.1.1.4.2.1 Migrating Adults (December–March)

The timing of in-water construction activities (August 1–October 31) 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 will exist throughout the construction period. No population-level effects are expected.

4.1.1.4.2.2 Spawning Adults (February–June)

The timing of in-water construction activities (August 1-October 31) 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 will exist throughout the construction period. No population-level effects are expected.

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

The timing of in-water construction activities (August 1-October 31) 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 will exist throughout the construction period. No population-level effects are expected.

4.1.1.4.2.4 Larvae/Young Juveniles (Spring: ~March–June)

The timing of in-water construction activities (August 1-October 31) 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 will exist throughout the construction period. No population-level effects are expected.

4.1.1.4.2.5 Juveniles (Summer/Fall: ~July–December)

Juvenile Delta Smelt rear downstream of the proposed HOR gate in the summer and fall and therefore are unlikely to be affected by contaminant spills or sediment-borne contaminants during construction of the intakes. No population-level effects are expected.

4.1.1.4.3 Underwater Noise

Impact pile driving at the HOR gate will potentially produce underwater noise levels of sufficient intensity and duration to injure or kill fish. Currently, it is estimated that HOR gate construction will entail installation of 550 temporary sheet piles (275 piles per season) to construct the cofferdams and 100 14-inch steel pipe or H-piles (50 piles per season) to construct the foundation. Based on an installation rate of 15 piles per day, pile driving will occur on 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.

4.1.1.4.3.1 Migrating Adults (December–March)

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

4.1.1.4.3.2 Spawning Adults (February–June)

The timing of impact pile driving activities (August 1–October 31) will avoid the Delta Smelt spawning season. There will be no risk of exposure of spawning adults to impact pile driving noise.

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

The timing of impact pile driving activities (August 1–October 31) will avoid the Delta Smelt incubation season. There will be no risk of exposure of eggs or embryos to impact pile driving noise.

4.1.1.4.3.4 Larvae/Young Juveniles (Spring: ~March–June)

The timing of impact pile driving activities (August 1–October 31) will avoid the downstream migration period of Delta Smelt larvae and early juveniles. There will be no risk of exposure of larvae or early juveniles to impact pile driving noise.

4.1.1.4.3.5 Juveniles (Summer/Fall: ~July–December)

4.1.1.4.3.5.1 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. No population-level effects are expected.

4.1.1.4.4 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 will 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 will 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 juveniles may be present.

4.1.1.4.4.1 Migrating Adults (December–March)

The timing of cofferdam construction (August 1–October 31) will avoid the Delta Smelt adult migration season. There will be no risk of stranding of migrating adults.

4.1.1.4.4.2 Spawning Adults (February–June)

The timing of cofferdam construction (August 1–October 31) will avoid the Delta Smelt spawning season. There will be no risk of stranding of spawning adults.

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

The timing of cofferdam construction (August 1–October 31) will avoid the Delta Smelt incubation season. There will be no risk of stranding of eggs or embryos.

4.1.1.4.4.4 Larvae/Young Juveniles (Spring: ~March–June)

The timing of cofferdam construction (August 1–October 31) will avoid the downstream migration period of Delta Smelt larvae and early juveniles. There will be no risk of stranding of larvae or early juveniles.

4.1.1.4.4.5 Juveniles (Summer/Fall: ~July–December)

Juvenile Delta Smelt rear downstream of the HOR gate in summer and fall and therefore are unlikely to be stranded in the cofferdams. No population-level effects are expected.

4.1.1.4.5 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 will 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 juveniles may be present. In addition to the proposed work window, the potential for injury of listed fish species will be minimized to the extent practicable by limiting the duration of in-water construction activities and implementing 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* (Appendix 3.F *General Avoidance and Minimization Measures*).

4.1.1.4.5.1 Migrating Adults (December–March)

The timing of in-water construction activities (August 1–October 31) will avoid the Delta Smelt adult migration season. There will be no risk of injury of migrating adults.

4.1.1.4.5.2 Spawning Adults (February–June)

The timing of in-water construction activities (August 1–October 31) will avoid the Delta Smelt spawning season. There will be no risk of injury of spawning adults.

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

The timing of in-water construction activities (August 1–October 31) will avoid the Delta Smelt incubation season. There will be no risk of injury of eggs or embryos.

4.1.1.4.5.4 Larvae/Young Juveniles (Spring: ~March–June)

The timing of in-water construction activities (August 1–October 31) will avoid the downstream migration period of Delta Smelt larvae and early juveniles. There will be no risk of injury of larvae or early juveniles.

4.1.1.4.5.5 Juveniles (Summer/Fall: ~July–December)

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.

4.1.1.4.6 Loss or Alteration of Habitat

Construction of the HOR gate will result in temporary and permanent losses or alteration of aquatic habitat in Old River. Temporary effects of construction activities on water quality 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. These parameters will 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* (Appendix 3.F *General Avoidance and Minimization Measures*) to protect listed fish, wildlife, and plant species, and other sensitive natural communities. These BMPs include a number of measures to limit the extent of disturbance of aquatic and riparian habitat during construction, and, following construction, to restore temporarily disturbed areas to pre-construction conditions. All construction and site restoration BMPs will be subject to an approved construction and post-construction monitoring plan to ensure their effectiveness. DWR will offset unavoidable impacts to habitat through on-site and/or off-site mitigation, including the purchase of conservation credits at an approved conservation bank.

4.1.1.4.6.1 Migrating Adults (December–March)

Migrating Delta Smelt adults may be subject to potential delays in migration and increased predation as they attempt to pass the cofferdams during the two-year construction period. Cofferdams that constrict the flow to half the channel’s width will 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. 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 will be limited to a very small proportion of the population, resulting in negligible effects on the total spawning stock of Delta Smelt.

4.1.1.4.6.2 Spawning Adults (February–June)

Loss or alteration of aquatic habitat within the footprints of the cofferdams, riprapped banks, and dredged channel areas will reduce the amount of shallow water habitat potentially available to spawning adults. Under baseline conditions, 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. Little or no potential spawning habitat will be affected by construction of HOR gate and thus there is little likelihood of adverse effects on spawning adults. No population-level effects are expected.

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

Based on the lack of preferred spawning habitat for Delta Smelt, the potential for adverse effects on eggs and embryos is negligible. No population-level effects are expected.

4.1.1.4.6.4 Larvae/Young Juveniles (Spring: ~March–June)

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. 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 will likely be limited to a very small proportion of the population, resulting in negligible effects on juvenile and adult recruitment.

4.1.1.4.6.5 Juveniles (Summer/Fall: ~July–December)

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. No population-level effects are expected.

4.1.1.5 Clifton Court Forebay

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

In-water construction activities, including pile driving, dredging, riprap placement, and barge operations, will be conducted over a 5-month period each year (July 1-November 30). Pile driving operations include the installation of an estimated 10,294 temporary sheet piles to construct the cofferdams for the embankments and divider wall, and 2,160 14-inch diameter concrete or steel pipe piles to construct the siphon at the NCCF outlet. A total of 4 construction seasons will be required to complete pile driving operations based on the estimated duration of pile installation.

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

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

4.1.1.5.1 Turbidity and Suspended Sediment

In-water construction at CCF will result in elevated turbidity and suspended sediment levels in CCF and Old River. The principal sources of increased turbidity and suspended sediment are dredging, cofferdam construction (sheet pile installation and removal), levee clearing and grading, and riprap placement. Minor increases in turbidity and suspended sediment in CCF and Old River are also expected during construction of the CCPP, embankments, outlet canal and siphons, SSCF intake structure, and North CCF (NCCF) emergency spillway. All other sediment-disturbing activities within cofferdams, dewatered areas of the forebay (NCCF), upland areas, or non-fish-bearing waters that 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 will be minimized by restricting all in-water construction activities to July 1-November 30, limiting the duration of these activities to the extent practicable, and implementing 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,* and AMM6 *Disposal and Reuse of Spoils, Reusable Tunnel Material, and Dredged Material* (Appendix 3.F *General Avoidance and Minimization Measures*).

Dredging of CCF will result in the suspension of large volumes of sediment and potential secondary effects on water quality, including potential re-suspension of contaminants and reductions in dissolved oxygen levels associated with the decomposition of vegetation and organic material in disturbed sediments. In addition to implementing the AMMs listed above, DWR will 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 will 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 percent of total surface area of CCF). 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 (SAP), compliance with NPDES and SWRCB water quality requirements during dredging activities, and compliance with applicable in-water work windows established by CDFW, NMFS, and USFWS.

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.

4.1.1.5.1.1 Migrating Adults (December–March)

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

4.1.1.5.1.2 Spawning Adults (February–June)

Based on potential individual-level effects of elevated turbidity and suspended sediment on Delta Smelt (see Section 4.1.1.2 *North Delta Diversions*), it is generally concluded that the levels of turbidity and suspended sediment generated by in-water construction activities will not adversely affect Delta Smelt. Furthermore, any effects on Delta Smelt will be minimized by the timing of in-water construction activities (July 1–November 30), which avoids 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). Thus, no population-level effects are anticipated.

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

Based on the timing of in-water construction activities (July 1–November 30) and low probability of successful spawning of Delta Smelt, eggs/embryos are not likely to be affected by increases in turbidity and suspended sediment from in-water construction activities. No population-level effects are expected.

4.1.1.5.1.4 Larvae/Young Juveniles (Spring: ~March–June)

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. No population-level effects are expected.

4.1.1.5.1.5 Juveniles (Summer/Fall: ~July–December)

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

4.1.1.5.2 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 will be similar to that described for the NDDs (Section 4.1.1.2.2 *Contaminants*) due to the proximity of construction activities to the waters of the Delta. Implementation of the following AMMs will minimize the potential for introduction of contaminants into surface waters and guide rapid and effective response in the case of inadvertent spills of hazardous materials: 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* (Appendix 3.F *General Avoidance and Minimization Measures*).

Contaminants can also enter the aquatic environment through disturbance, resuspension, or discharge of contaminated soil and sediments from construction sites. As described in Section 4.1.1.2.2 *Contaminants*), sediments act as a sink or source of contaminant exposure, and resuspension of contaminated sediments may have adverse effects on fish that encounter sediment plumes or come into contact with deposited or newly exposed sediment. In addition to direct exposure, contaminated sediments can adversely affect fish through accumulation of contaminants in the food web.

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. 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 project area.

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

4.1.1.5.2.1 Migrating Adults (December–March)

The timing of in-water construction activities (July 1-November 30) will avoid the Delta Smelt adult migration season and potential direct exposure of migrating adults to potential spills and resuspension of contaminated sediments. However, the presence of newly exposed sediment and resuspension of sediments by currents and wind-driven mixing could increase exposure of spawning adults at other times of the year. This risk will be minimized by implementing the proposed pollution prevention and erosion and sediment control AMMs. Because of the low likelihood of survival of Delta Smelt in CCF, construction-related increases in contaminant exposure are not likely to have measurable population-level effects.

4.1.1.5.2.2 Spawning Adults (February–June)

The timing of in-water construction activities (July 1–November 30) will minimize the potential for direct exposure of spawning adults to contaminants resulting from potential spills and resuspension of contaminated sediments. Adults may be present in CCF in July although the numbers of adults are expected to be very low based on salvage records. However, the presence of newly exposed sediment and resuspension of sediments by currents and wind-driven mixing could increase exposure of spawning adults at other times of the year. This risk will be minimized by implementing the proposed pollution prevention and erosion and sediment control AMMs. Because of the low likelihood of survival of Delta Smelt in CCF, construction-related increases in contaminant exposure are not likely to have measurable population-level effects.

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

The timing of in-water construction activities (July 1–November 30) will minimize the potential for direct exposure of eggs/embryos to contaminants resulting from potential spills and resuspension of contaminated sediments, although the presence of newly exposed sediment and resuspension of sediments by currents and wind-driven mixing could increase exposure of eggs/embryos at other times of the year. This risk will be minimized by implementing the proposed pollution prevention and erosion and sediment control AMMs. Because of the low likelihood of survival of Delta Smelt in CCF, construction-related increases in contaminant exposure are not likely to have measurable population-level effects.

4.1.1.5.2.4 Larvae/Young Juveniles (Spring: ~March–June)

The timing of in-water construction activities (July 1-November 30) will minimize the potential for direct exposure of larvae/young juveniles to contaminants resulting from potential spills and resuspension of contaminated sediments during construction activities, although the presence of newly exposed sediment and resuspension of sediments by currents and wind-driven mixing could increase exposure of larvae/young juveniles at other times of the year. This risk will be minimized by implementing the proposed pollution prevention and erosion and sediment control AMMs. Because of the low likelihood of survival of Delta Smelt in CCF, construction-related increases in contaminant exposure are not likely to have measurable population-level effects.

4.1.1.5.2.5 Juveniles (Summer/Fall: ~July–December)

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. No population-level effects are expected.

4.1.1.5.3 Underwater Noise

As discussed in Section 4.1.1.2.3 *Underwater Noise*, impact pile driving can produce underwater noise levels of sufficient intensity and duration to cause injury to fish. Pile driving information for CCF is available for the embankments, divider wall, siphon at NCCF outlet, and siphon at Byron Highway (Appendix 3.E *Pile Driving Assumptions for the Proposed Project*). Pile driving operations include the installation of an estimated 10,294 temporary sheet piles to construct the cofferdams for the embankments and divider wall, and 2,160 14-inch diameter concrete or steel pipe piles to construct the siphon at the NCCF outlet. Pile driving for the siphon under Byron Highway is not addressed in the following analysis because all pile driving will be conducted on land and more than 200 feet from water potentially containing listed fish species. A total of 4 construction seasons will likely be required to complete pile driving operations based on the estimated duration of pile installation (Appendix 3.D *Construction Schedule for the Proposed Project*).

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

Table 4.1-3 presents the extent, timing, and duration of pile driving noise levels predicted to exceed the interim injury and behavioral thresholds during installation of cofferdam sheet piles for the embankments and divider wall, and the structural piles for the NCCF siphon based on application of the NMFS spreadsheet model and the assumptions presented in Appendix 3.E *Pile Driving Assumptions for the Proposed Project*. For cofferdam sheet piles, it is assumed that approximately 70 percent of the length of each pile can be driven using vibratory pile driving, with impact driving used to finalize pile placement. For the NFFC siphon piles, the current design assumes the use of impact pile driving only. However, some degree of attenuation is expected assuming that the cofferdams can be fully dewatered. Therefore, predictions are shown for two scenarios, one in which dewatering results in a 5 dB reduction in reference noise levels, and one in which no attenuation is possible.

Table 4.1-3. Extent, Timing, and Duration of Pile Driving Noise Levels Predicted to Exceed the Interim Injury and Behavioral Thresholds at CCF.

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

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

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

Sound monitoring data collected during similar types of pile driving operations indicate that single-strike peak SPLs exceeding the interim injury thresholds are expected to be limited to areas within 30 feet of the cofferdam sheet piles and 20-46 feet of the NCCF siphon piles (Table 4.1-3). Based on a cumulative (daily) threshold of 183 dB, the risk of injury is calculated to extend 2,814 feet away from the source piles during installation of cofferdam sheet piles and 1,774 feet during installation of the NCCF siphon piles (823 feet if the cofferdams can be dewatered).[8] Based on a threshold of 150 dB RMS, the potential for behavioral effects is calculated to extend 13,058 and 9,607 feet (4,458 if the cofferdams can be dewatered), respectively. Such exposures will occur over a period of up to 72 days (36 days per season) during installation of the NCCF siphon piles (second and third years of construction activities at CCF), 86 days during cofferdam construction for the divider wall (year 4), and 85 days during cofferdam construction for the embankments (year 5).

4.1.1.5.3.1 Migrating Adults (December–March)

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

4.1.1.5.3.2 Spawning Adults (February–June)

Based on the general timing and abundance of Delta Smelt inferred from salvage and fish monitoring data, (see Section 4.1.1.5.1.2 *Spawning Adults*), restriction of impact pile driving in CCF to July 1-November 30 will minimize potential exposure of spawning adults to potentially harmful underwater noise levels. 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 measurable population-level effects.

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

Based on the general timing and abundance of Delta Smelt inferred from salvage and fish monitoring data, restriction of impact pile driving in CCF to July 1-November 30 will minimize potential exposure of eggs/embryos to potentially harmful underwater noise levels. 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 will be low, individual eggs or embryos will be unable to avoid prolonged exposure to pile driving noise. However, any adverse effects on individual eggs or embryos will 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, potential injury or mortality of eggs/embryos from pile driving noise is unlikely to have measurable population-level effects.

4.1.1.5.3.4 Larvae/Young Juveniles (Spring: ~March–June)

Based on the general timing and abundance of Delta Smelt inferred from salvage and fish monitoring data, restriction of impact pile driving in CCF to July 1-November 30 will minimize potential exposure of larvae/young juveniles to potentially harmful underwater noise levels. No measurable population-level effects will occur because of the low likelihood of survival of larvae and juveniles in CCF.

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

4.1.1.5.3.5 Juveniles (Summer/Fall: ~July–December)

Juvenile Delta Smelt rear downstream of CCF in the summer and fall and therefore are unlikely to be affected by pile driving noise. No population-level effects are expected.

4.1.1.5.4 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 identify appropriate procedures for excluding fish from the construction zones, where feasible, and procedures for collecting, holding, handling, and release for all in-water activities with the potential to entrap fish. All fish rescue and salvage operations will be conducted under the guidance of a qualified fish biologist. The biologist, in consultation with a designated agency biologist, will determine the appropriate fish collection and relocation methods based on site-specific conditions and construction methods. Collection methods may include seines, dip nets, and electrofishing if permitted.

4.1.1.5.4.1 Migrating Adults (December–March)

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

4.1.1.5.4.2 Spawning Adults (February–June)

Small numbers of spawning adults may be present in CCF and Old River in July. Although adults may avoid active construction areas, it is assumed that some adults may be unable to avoid or escape from areas enclosed by cofferdams or silt curtains 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. It will be impractical or infeasible to rescue fish from large, deep areas surrounded by silt curtains in CCF. However, it may be possible to exclude fish from active dredging areas in CCF by deploying silt curtains in a manner that directs fish away from the silt curtains and prevents fish from re-entering these areas during dredging operations. Fish rescue operations at NCCF prior to dewatering will require special considerations given its large surface area and highly variable depths.

Based on the small proportion of spawning adults that may be present during cofferdam and silt curtain installation (July 1–November 30), and the low likelihood of survival of larvae and juveniles in CCF, potential injury or mortality of spawning adults from stranding is expected to have no measurable population effects..

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

Because eggs and embryos are immobile and attached to substrate or other structures during incubation, they are susceptible to stranding and subsequent injury or mortality from construction activities within cofferdams and silt curtains. Based on the small proportion of adults potentially spawning in CCF in 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 is expected to have no measurable population effects.

4.1.1.5.4.4 Larvae/Young Juveniles (Spring: ~March–June)

Delta Smelt larvae and young 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. Based on the low likelihood of survival for Delta Smelt in CCF, stranding of larvae and early juveniles in cofferdams or silt curtains is expected to have no measurable population effects.

4.1.1.5.4.5 Juveniles (Summer/Fall: ~July–December)

Juvenile Delta Smelt rear downstream of CCF in summer and fall and therefore are unlikely to be exposed to in-water construction activities. No population-level effects are expected.

4.1.1.5.5 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 will 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*).

4.1.1.5.5.1 Migrating Adults (December–March)

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

4.1.1.5.5.2 Spawning Adults (February–June)

Spawning adults may be present in low numbers in CCF and Old River in July and therefore subject to injury during in-water construction activities. Although adults may 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. Based on the small proportion of spawning adults that may be present during the in-water construction season (July 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 are expected to have no measurable population effects..

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

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. Based on the small proportion of adults potentially spawning in CCF during the in-water construction season (July 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 are expected to have no measurable population effects.

4.1.1.5.5.4 Larvae/Young Juveniles (Spring: ~March–June)

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. Based on the low likelihood of survival for Delta Smelt in CCF, potential losses of larvae or early juveniles due to direct injury or mortality from in-water construction activities are expected to have no measurable population effects.

4.1.1.5.5.5 Juveniles (Summer/Fall: ~July–December)

Juvenile Delta Smelt rear downstream of CCF in summer and fall and therefore are unlikely to be exposed to in-water construction activities. No population-level effects are expected.

4.1.1.5.6 Loss or Alteration of Habitat

Dredging and expansion of CCF and construction of the new water conveyance facilities at CCF will result in long-term or permanent impacts on aquatic habitat. Dredging, cofferdam installation, levee armoring, and barge operations will affect an estimated 1,932 acres of tidal perennial aquatic habitat (Appendix 3.A *Map Book for the Proposed Project,* sheets 11 and 12) 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 will 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 (Appendix 3.A *Map Book for the Proposed Project,* sheets 11 and 12). 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* (Appendix 3.F *General Avoidance and Minimization Measures*) to protect listed fish, wildlife, and plant species, and other sensitive natural communities. These BMPs include a number of measures to limit the extent of disturbance of aquatic and riparian habitat during construction, and, following construction, to restore temporarily disturbed areas to pre-construction conditions. All construction and site restoration BMPs will be subject to an approved construction and post-construction monitoring plan to ensure their effectiveness. Compensation for unavoidable impacts on aquatic habitat in CCF is not proposed because CCF is not considered suitable habitat for Delta Smelt.

4.1.1.5.6.1 Migrating Adults (December–March)

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 will 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.

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 of habitat for 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 will be no measurable effect on spawning success or recruitment of larvae and juveniles to the adult population.

4.1.1.5.6.2 Spawning Adults (February–June)

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 will 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. 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 effects will occur.

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

The modification of physical habitat in CCF and Old River will 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. In consideration of this low habitat quality, no population-level effects are expected.

4.1.1.5.6.4 Larvae/Young Juveniles (Spring: ~March–June)

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 will be negligible because of the low likelihood of survival of larvae that may be produced in this region of the Delta. In consideration of this low habitat quality, no population-level effects are expected.

4.1.1.5.6.5 Juveniles (Summer/Fall: ~July–December)

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. No population-level effects are expected.

4.1.2 Maintenance Effects

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

4.1.2.1 North Delta Diversions

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. Major equipment repairs and overhauls will 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. In-river dredging is expected to occur every 2-3 years on average. A dredging plan describing specific maintenance dredging activities will be developed prior to dredging activities. AMMs 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).

All in-water maintenance activities will 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*).

4.1.2.1.1 Migrating Adults (December–March)

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

4.1.2.1.2 Spawning Adults (February–June)

As described in Section 4.1.1 *Construction Effects,* 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.

Spawning adults may be present 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 Section 4.1.1 *Construction Effects*, exposure of the population to maintenance activities will 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 will be negligible.

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

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. Population-level effects will be negligible based on the low potential for exposure of spawning adults described above.

4.1.2.1.4 Larvae/Young Juveniles (Spring: ~March–June)

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 will avoid or minimize exposure of larvae and early juveniles to potential water quality impacts or other hazards, this life stage, if present, will be unable to avoid active work areas and will therefore be susceptible to the hazards of in-water maintenance activities.

Population-level effects will 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*.

4.1.2.1.5 Juveniles (Summer/Fall: ~July–December)

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

4.1.2.2 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). All in-water maintenance activities will be conducted within the same work windows proposed for in-water construction activities (August 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*).

4.1.2.2.1 Migrating Adults (December–March)

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

4.1.2.2.2 Spawning Adults (February–June)

The timing of in-water maintenance activities (August 1–October 31) will avoid the Delta Smelt spawning season and direct exposure of spawning adults to these activities. 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. Based on the discussion in Section 4.1.1 *Construction Effects,* exposure of the population to temporary and long-term effects of maintenance activities on aquatic habitat will be limited by the small proportion of adults that spawn in the east and south Delta, the low quality of spawning habitat at preferred sites for the barge landings, and implementation of the AMMs described in Appendix 3.F *General Avoidance and Minimization Measures*.

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

The timing of in-water maintenance activities (August 1–October 31) will avoid the Delta Smelt incubation season and direct exposure of eggs/embryos to these activities. Potential adverse effects associated with habitat modification from dredging and other in-water maintenance activities will have a negligible effect on population abundance based on the small proportion of adults that spawn in the east and south Delta, the low quality of spawning habitat at preferred sites for the barge landings, and implementation of the AMMs described in Appendix 3.F *General Avoidance and Minimization Measures*.

4.1.2.2.4 Larvae/Young Juveniles (Spring: ~March–June)

The timing of in-water maintenance activities (August 1–October 31) will avoid the primary months when Delta Smelt larvae and young juveniles may be present at the barge landing sites. Therefore, there will be no direct effects of maintenance activities on larvae/young juveniles. Potential adverse effects associated with habitat modification from dredging and other in-water maintenance activities will have a negligible effect on population abundance based on the small proportion of adults that spawn in the east and south Delta and implementation of the AMMs described in Appendix 3.F *General Avoidance and Minimization Measures*.

4.1.2.2.5 Juveniles (Summer/Fall: ~July–December)

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

4.1.2.3 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. 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 will be performed as part of levee maintenance. All in-water maintenance activities will be conducted within the same work window proposed for in-water construction activities (August 1 to 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*).

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

4.1.2.3.1 Migrating Adults (December–March)

The timing of in-water maintenance activities (August 1–October 31) will avoid the Delta Smelt adult migration season. Therefore, there will be no direct effects of maintenance activities on migrating adults. Potential adverse effects associated with habitat modification from dredging and other in-water maintenance activities will have a negligible effect on population abundance based on the small proportion of adults that spawn in the east and south Delta and implementation of the AMMs described in Appendix 3.F *General Avoidance and Minimization Measures*.

4.1.2.3.2 Spawning Adults (February–June)

The timing of in-water maintenance activities (August 1–October 31) will avoid the Delta Smelt spawning season. Therefore, there will 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 that are periodically disturbed by dredging or levee repair activities.

As described in Section 4.1.1 *Construction Effects*, 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 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 will have negligible population-level effects.

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

The timing of in-water maintenance activities (August 1–October 31) will avoid the Delta Smelt incubation season. Therefore, there will be no direct effects of maintenance activities on eggs and embryos. Population-level effects will be negligible based on the potential for exposure of spawning adults and habitat described above.

4.1.2.3.4 Larvae/Young Juveniles (Spring: ~March–June)

The timing of in-water maintenance activities (August 1–October 31) will avoid the potential occurrence of Delta Smelt larvae/young juveniles within the vicinity of the HOR gate. Therefore, there will be no direct effects of maintenance activities on larvae/young juveniles. Potential adverse effects associated with habitat modification from dredging and other in-water maintenance activities will have a negligible effect on population abundance based on the small proportion of adults that spawn in the east and south Delta and implementation of the AMMs described in Appendix 3.F *General Avoidance and Minimization Measures*.

4.1.2.3.5 Juveniles (Summer/Fall: ~July–December)

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

4.1.2.4 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, there will be no need for additional dredging of NCCF and SCCF over the first 50 years following construction. All in-water maintenance activities will be conducted within the same work window proposed for in-water construction activities (July 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*).

4.1.2.4.1 Migrating Adults (December–March)

The timing of in-water maintenance activities (July 1–November 30) will avoid the Delta Smelt adult migration season. Therefore, there will be no direct effect on migrating adults. Based on the discussion in Section 4.1.1.5.6. *Alteration or Loss of Habitat*, potential adverse effects associated with habitat modification from dredging and other in-water maintenance activities will have a negligible effect on population abundance based on the small proportion of adults that spawn in the east and south Delta, the low survival of Delta Smelt in CCF, and implementation of the AMMs described in Appendix 3.F *General Avoidance and Minimization Measures*.

4.1.2.4.2 Spawning Adults (February–June)

Based on the general timing and abundance of Delta Smelt inferred from salvage and fish monitoring data, (see Section 4.1.1.5.1.2 *Spawning Adults*), restriction of in-water maintenance activities in CCF and Old River to July 1 to November 30, and implementation of the AMMs described in Appendix 3.F *General Avoidance and Minimization Measures* will minimize the potential for direct exposure of spawning adults to water quality, noise, and other in-water disturbances associated with these activities. As discussed in Section 4.1.1.5.6 *Alteration or Loss of Habitat*, potential adverse effects associated with habitat modification from dredging and other in-water maintenance activities will have a negligible effect on population abundance based on the small proportion of adults that spawn in the east and south Delta, the low quality of existing habitat, and low survival of Delta Smelt in CCF.

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

Based on the general timing and abundance of Delta Smelt inferred from salvage and fish monitoring data, (see Section 4.1.1.5.1.2 *Spawning Adults*), restriction of in-water maintenance activities in CCF and Old River to July 1 to November 30, will minimize the potential for direct exposure of eggs/embryos to water quality, noise, and other in-water disturbances associated with these activities. As discussed above, habitat modifications resulting from in-water maintenance activities will have a negligible effect on population abundance.

4.1.2.4.4 Larvae/Young Juveniles (Spring: ~March–June)

Based on the general timing and abundance of Delta Smelt inferred from salvage and fish monitoring data, (see Section 4.1.1.5.1.2 *Spawning Adults*), restriction of in-water maintenance activities in CCF and Old River to July 1 to November 30 will minimize the potential for direct exposure of larvae/young juvenile to water quality, noise, and other in-water disturbances associated with these activities. As discussed above, habitat modifications resulting from in-water maintenance activities will have a negligible effect on population abundance.

4.1.2.4.5 Juveniles (Summer/Fall: ~July–December)

Juvenile Delta Smelt rear downstream of CCF in summer and fall and therefore are unlikely to be affected by habitat modifications resulting from in-water maintenance activities. No population-level effects are expected.

4.1.3 Operations Effects

4.1.3.1 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 PP 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.

4.1.3.2 North Delta Exports

The reach of the Sacramento River where the NDDs are proposed to be built is considered to be near the northern limit of where Delta Smelt occur. Surveys conducted within the Sacramento River near the proposed NDD locations indicate few Delta Smelt are ever found in the vicinity. On one occasion, the species has been found as far upstream as Knights Landing (Vincik and Julienne 2012), demonstrating the potential for entrainment and impingement of Delta Smelt at the proposed NDDs. For the effects analysis here presented, 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 4.1-1). Summed catch data for these locations were then compared to other survey locations, which were designated as downstream sites. The beach seine data may not sample Delta Smelt well because of the pelagic nature of the species (i.e., generally occurring farther from shore), so additional data from Kodiak trawling was considered. Data considered for the intake reach include the USFWS Sacramento River trawl location at Sherwood Harbor, as well as the DFW Spring Kodiak Trawl (SKT) survey station in the Sacramento River at Ryde. The remaining SKT stations were considered as downstream comparison stations, and were grouped into geographic areas, described further below. 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 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 4.1.3.5 *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.

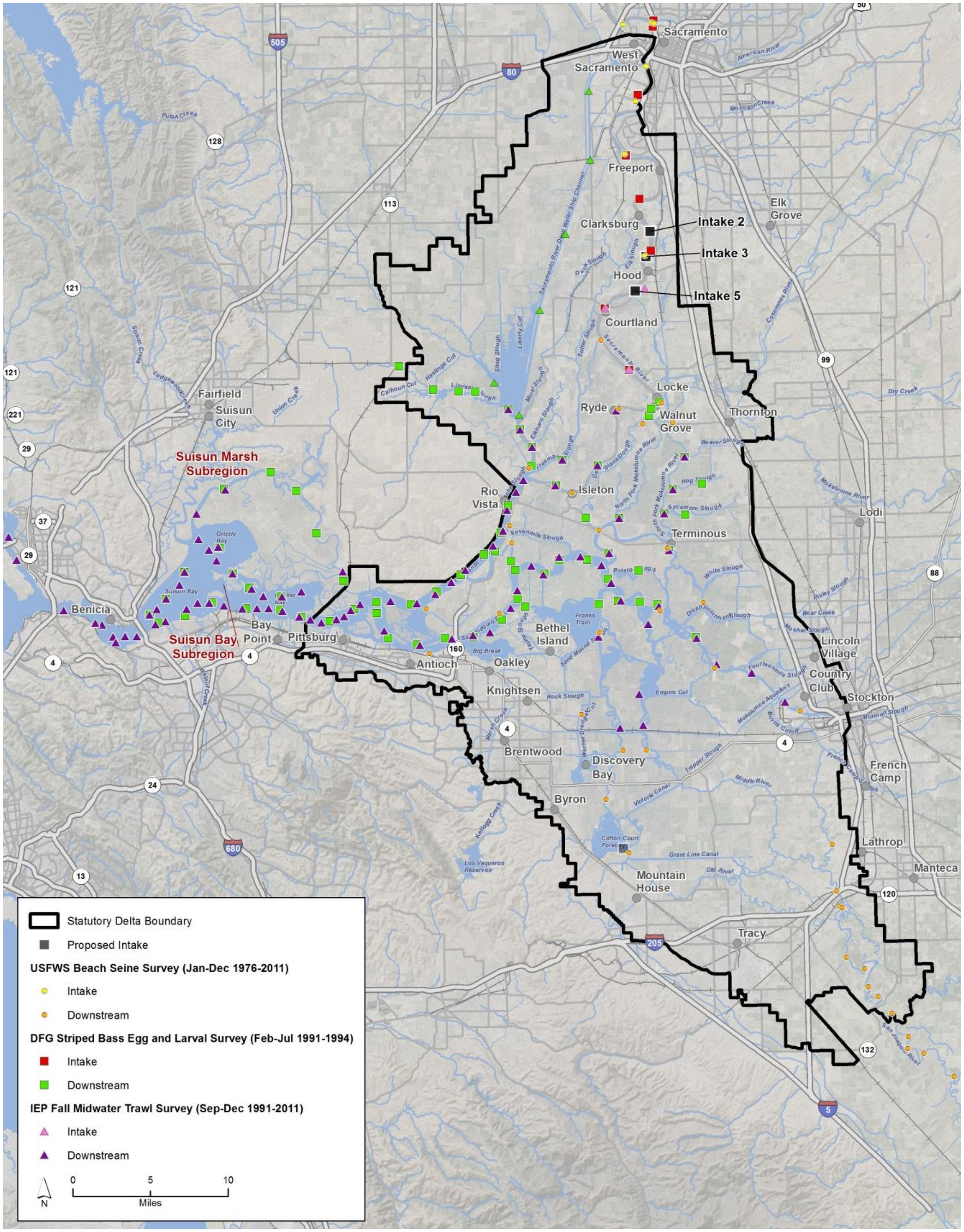


Figure 4.1-1. Survey Station Locations Used to Assess the Potential Presence of Delta Smelt Near the Proposed North Delta Diversions

4.1.3.2.1 Entrainment

4.1.3.2.1.1 Migrating Adults (December–March)

Based on Delta Smelt body depth to body length ratios and using the screening effectiveness analysis (described in ICF International [2016], 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 will prevent Delta Smelt larger than around 20-21 mm SL (standard length) 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 will be no entrainment of individual adult Delta Smelt. As there will be no individual-level adverse effect, there will also be no population-level adverse effect to migrating adult Delta Smelt from entrainment at the NDD.

4.1.3.2.1.2 Spawning Adults (February–June)

As described for migrating adult Delta Smelt, the proposed NDD screen mesh of 1.75 mm will prevent Delta Smelt greater than around 20-21 mm SL from being entrained. Therefore, there will be no adverse effect to individual spawning adult Delta Smelt. In the absence of any individual-level adverse effect, there will be no population-level adverse effect to spawning adult Delta Smelt from entrainment at the NDD.

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

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 will not be subject to entrainment and there will be no individual-level adverse effect. In the absence of any individual-level adverse effect, there will be no population-level adverse effect from the NDD with respect to entrainment.

4.1.3.2.1.4 Larvae/Young Juveniles (Spring: ~March–June)

As noted for adult Delta Smelt, based on Delta Smelt body depth to body length ratios (ICF International [2016], 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 will exclude Delta Smelt greater than around 20-21 mm SL (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 4.1.3.2.2 *Impingement and Screen Contact*.

The Freeport Regional Water Authority's water intake is the most closely 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 PP'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 (*vs.*, 3,000 cfs for each NDD intake), and the fish screen panels are 9.92 feet wide by 10.71 feet tall (*vs.* 15.6 feet wide by 12.5 to 17.0 feet tall for the NDD screens), with a total of 16 fish screens (*vs.* 66 to 90 screens at each of the NDD intakes). 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 percentage of river flow diverted by the intakes, with the risk increasing as higher percentages 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 percentage of flow diverted, by dividing the NDD flow by the Sacramento River flow at Freeport. The percentage of flow diverted by the NDD increases as bypass flow constraints decrease: in wet years, the median percentage of flow diverted ranged from 7 percent in April (range 0 percent to 15 percent) to 32 percent in June (range 7–38 percent); in contrast, in critical years, the median percentage of flow diverted ranged from 3 percent in April (range 0 percent to 6 percent) to 6 percent in June (range 6 percent to 8 percent) (Table 4.1-4). Thus, the risk to individual fish will be lower in drier years and the risk will be lower in April and May than in March or June.

Table 4.1-4. Summary Statistics of CalSim-Modeled Average Monthly North Delta Diversion as a Percentage of Sacramento River at Freeport Flows for the Proposed Project

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%

4.1.3.2.1.4.1 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 4.1-5), 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, the months when (as shown previously) the lowest percentage of Sacramento River water will be diverted by the NDD (Table 4.1-6). Accordingly, any adverse population-level effect from entrainment by the NDD will be small.

It is not possible to provide a precise estimate of the percentage 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 percent 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 4.1-1; 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 percent of larvae could occur in the NDD reach. If 10 percent of water was diverted, this suggests that the order of magnitude of population-level larval entrainment from the NDD will be considerably less than 0.1 percent (and closer to 0.01 percent). Mean estimates of potential March–June larval population-level entrainment by the NDD using a DSM2-PTM analysis (described in ICF International [2016], Appendix 6.A *Quantitative Methods for Biological Assessment of Delta Smelt*, Section 6.A.3.2), ranged from <0.1 percent in critical years to nearly 0.2 percent in other water year types (see further discussion in Section 4.1.3.3.1 *Entrainment* 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 is expected to be higher than in the Sacramento River, which may have upwardly biased these estimates.

Further perspective on the percentage of the Delta Smelt population that could occur near the NDD was provided by a DSM2-PTM analysis incorporating movement into the upper 10 percent of the water column during flood tides, to simulate the upstream migration of adult Delta Smelt; as described in more detail in Section 4.1.3.2.2.1 *Migrating Adults*, this analysis also provided evidence that a very low percentage of the Delta Smelt population (migrating adults, and therefore their progeny) will occur near the NDD, as no particles originating downstream were entrained at the NDD (or moved upstream of Isleton; Table 4.1-5, indicating that there is no hydraulic reason to expect significant fractions of the Delta Smelt population to reach the NDDs.

Table 4.1-5. Number of Delta Smelt Larvae Collected and Catch per Cubic Meter during the CDFW Striped Bass Egg and Larval Survey in the Project 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.

4.1.3.2.1.5 Juveniles (Summer/Fall: ~July–December)

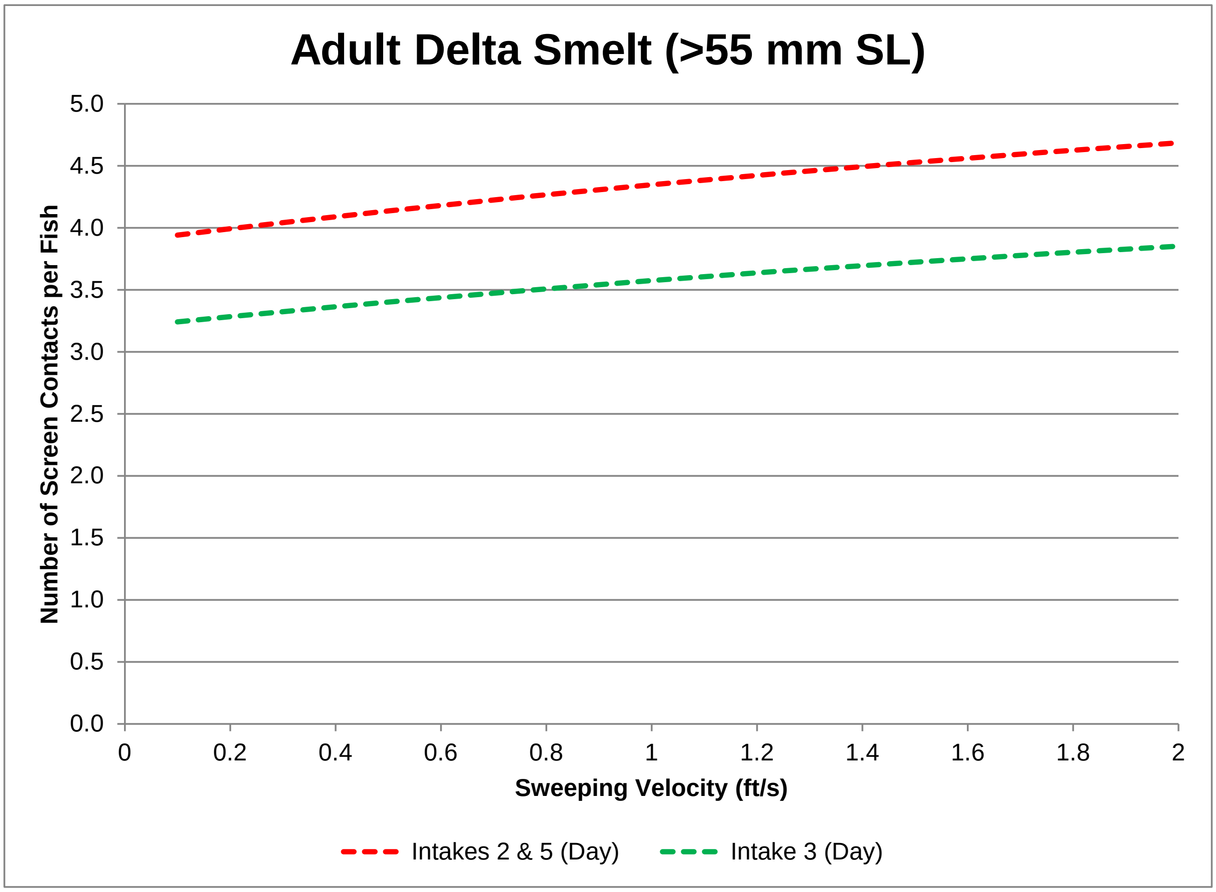
As described for adult Delta Smelt, the proposed NDD screen mesh of 1.75 mm will prevent Delta Smelt larger than around 20-21 mm SL from being entrained, and therefore will allow juvenile Delta Smelt to avoid entrainment but not necessarily impingement. There will be no adverse effect to individual juvenile Delta Smelt from entrainment. Based on the lack of effect to individual juvenile Delta Smelt, there will not be an adverse population-level effect from entrainment at the NDD to Delta Smelt juveniles.

4.1.3.2.2 Impingement and Screen Contact

4.1.3.2.2.1 Migrating Adults (December–March)

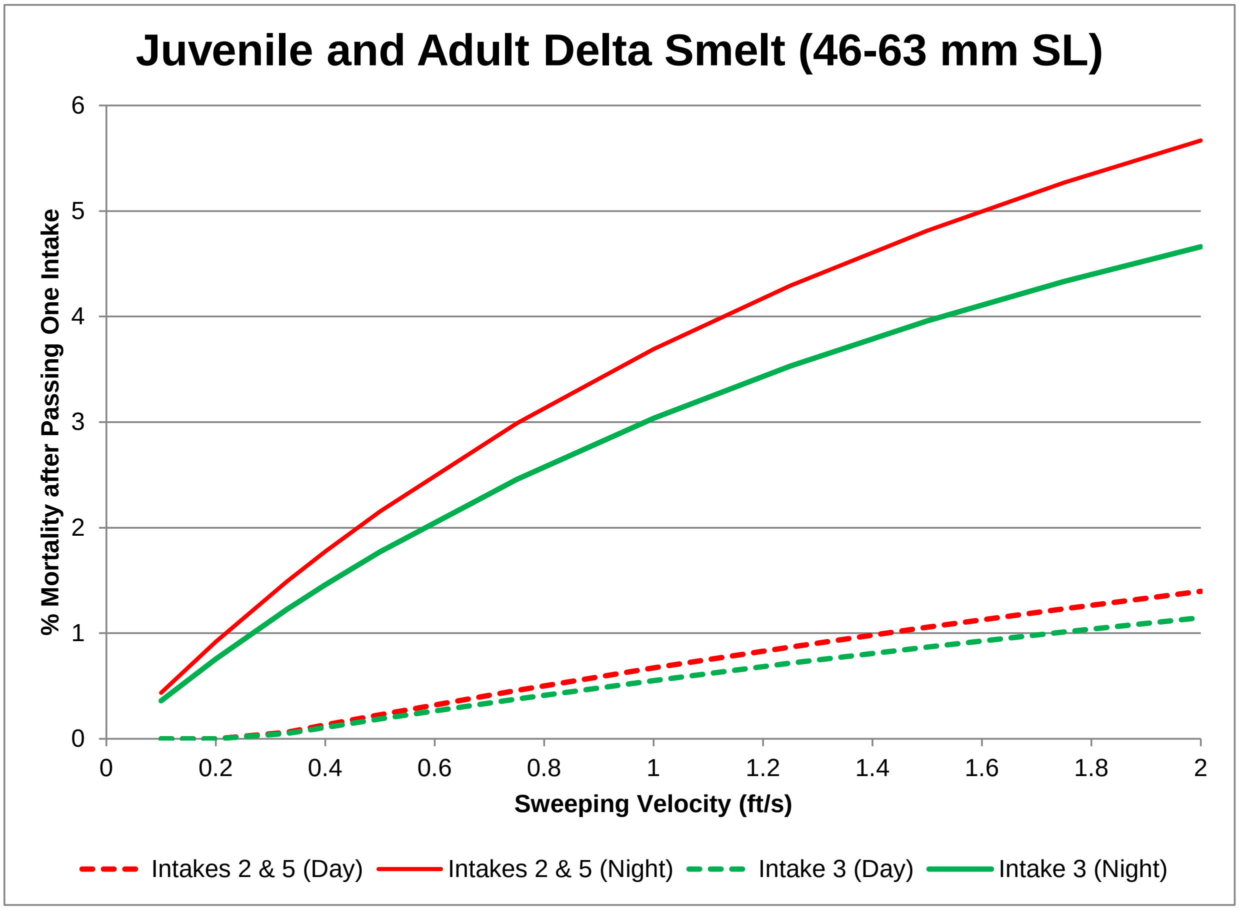
As noted in Chapter 3 *Description of the Proposed Project*, the NDD will be operated such that approach velocity is consistent with recommendations for Delta Smelt (0.2 ft/s). However, there remains the potential that Delta Smelt larger than the minimum screenable size of ~20-21 mm SL could contact 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 ICF International [2016], Appendix 5.A *CALSIM Methods and Results*, Section 5.A.5.2.4.9 *North Delta Diversion Bypass Flows*; also see ICF International [2016], Appendix 5.B *DSM2 Modeling and Results*, Section 5.B.2.3.5 *North Delta Diversion Operations*) 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 4.1.3.2.2.1 *Migrating Adults*) 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 will be operating (*i.e.*, the typical tidal surfing behavioral conceptual model [Bennett and Burau 2015] will 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 migrate along the left bank of the river where the NDD will 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 ICF International (2016, Appendix 6.A *Quantitative Methods for Biological Assessment of Delta Smelt*, Section 6.A.2.3.1.1 *Adult Delta Smelt (Number of Screen Contacts)* and Section 6.A.2.3.1.2 *Juvenile and Adult Delta Smelt (Percentage Mortality)*), two of the methods were based on an assessment methodology undertaken as part of the BDCP Fish Facilities Technical Team planning effort. From these analyses, it is estimated that adult Delta Smelt passing one of the NDD screens—moving against the flow, *i.e.*, in an upstream direction, based on the laboratory studies—will contact the screen 3 to 5 times, and that there will be little variation in this estimate across a wide range of sweeping velocity (Figure 4.1-2). In addition, application of the relationships from the laboratory studies show that mortality is estimated to be 1 percent 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 percent at sweeping velocity above 1.5 ft/s if encountered at night (Figure 4.1-3). A third analysis (ICF International [2016], 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)*) 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 will successfully pass the fish screens at the lowermost of the 3 proposed intakes 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 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 NDDs will be situated, and of those, only the ones encountering the intake screens at the river margins where the on-bank intakes will be sited.

Figure 4.1-2. 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 will be situated, and of those, only the ones encountering the intake screens at the river margins where the on-bank intakes will be sited.

Figure 4.1-3. 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 will 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 percent of approach velocity measurements did not exceed the target design approach velocity of 0.2 ft/s, although the facility was operating at 85 percent 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 percentage (4 percent) of fish will do so. If successfully passing one intake and remaining near the left bank, the remaining Delta Smelt will 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 will 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.

4.1.3.2.2.1.1 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 SL. The proportion of Delta Smelt ≥60 mm FL collected in the reach of the Sacramento River where the proposed intakes will be situated averaged slightly below 20 percent 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 4.1-6). Seine data do indicate that adult Delta Smelt occur in low numbers in the reach of the river where the proposed north Delta intakes will be sited.

Additional consideration of the distribution of Delta Smelt was provided by examining Kodiak trawl data from the intake reach (as represented by the USFWS trawl location at Sherwood Harbor and the SKT station at Ryde) and downstream areas (the remaining SKT stations; Figure 4.1-4). It is acknowledged that the locations of Sherwood Harbor (~river mile 55) and Ryde (~river mile 24) are quite far upstream and downstream from the proposed NDD locations (~river miles 38–41), and that the Ryde sampling intensity is low (once per month), but these data may be more representative of Delta Smelt distribution than the seine surveys because of the open-water nature of the species[9]. Kodiak trawl data were examined for January–March to reflect the period of overlap between the USFWS and DFW surveys, and no size restriction was placed in the summary of the data because the gear captures principally adult Delta Smelt. Sherwood Harbor data for 2002–2016 showed that during January–March Delta Smelt were caught infrequently in each year (0 percent–5 percent of trawls), with low mean density (0.00–0.08 fish per 10,000 m^3 trawled) (Table 4.1-7). The same was true at Ryde, for which Delta Smelt were only caught in 2005 and never again in 2006–2016 (Table 4.1-8). In contrast, the density and frequency of occurrence in the more "core" (sensu IEP MAST Team 2015) Delta Smelt habitat was greater: in the lower Sacramento River, the mean annual density during 2002–2016 was 0.32–27.23 fish per 10,000 m^3 with frequency of occurrence 22–78 percent; in the north Delta, mean density was 0.43–55.18 fish per 10,000 m^3 with frequency of occurrence 22–73 percent; in the Confluence/Honker Bay area, mean density was 0.08–21.48 fish per 10,000 m^3 with frequency of occurrence 6–73 percent; in the Suisun Marsh/Grizzly Bay area, mean density was 0.49–58.82 fish per 10,000 m^3 with frequency of occurrence 25–79 percent, and in the lower San Joaquin River, mean density was 0.19–15.86 fish per 10,000 m^3 with frequency of occurrence 7–87 percent (Table 4.1-8). The low density and frequency of occurrence at Ryde and Sherwood Harbor was of similar or lower magnitude to density and frequency of occurrence in the East/South Delta, Napa River, and West Suisun Bay.

[9] As discussed further later in the analysis, however, Delta Smelt may need to use the margins of the river channel more in riverine areas; this may make them more susceptible to capture by seines in the vicinity of the NDD.

The Kodiak trawl data support the general conclusion that because 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 percent of the water column during flood tides (*i.e.* modeled tidal surfing behavior), to simulate the upstream migration of adult Delta Smelt (described in ICF International [2016], Appendix 6.A *Quantitative Methods for Biological Assessment of Delta Smelt,* Section 6.A.2.1). This analysis also provided evidence that a very low proportion of the migrating adult Delta Smelt population will 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[10]; Table 4.1-9). Therefore tidal migration upstream toward the NDD will not be enhanced by the PP.

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 (ICF International [2016], 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 8 percent. If for the sake of argument, 1 percent of all adult Delta Smelt attempt to pass one or more of the NDDs, the population loss will be 8 percent of 1 percent, which is 0.08 percent or about eight of every 10,000 fish. As described in ICF International (2016, 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)*), 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 will be expected that a smaller fraction of the population will 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 are summarized in Table 4.1-6, but these are challenging to compare quantitatively because, as described in ICF International (2016, 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 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

[10] A breakdown of the fates of particles by geographic subregion is also provided in ICF International [2016], Appendix 6.A *Quantitative Methods for Biological Assessment of Delta Smelt,* Section 6.A.2.1.2.

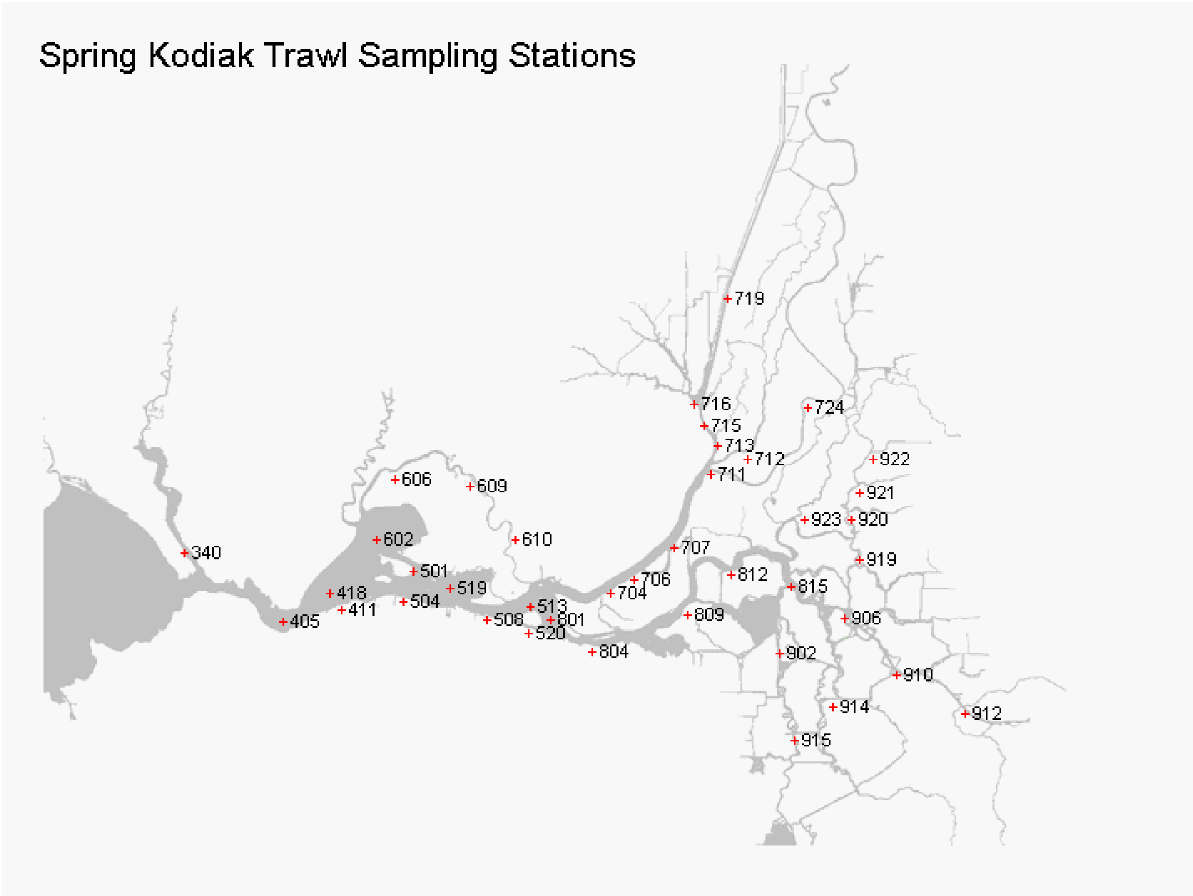
the river along its east bank if they choose to do so. Thus, the loss of low-velocity shoreline and increase in shoreline water velocity along the river's east (left) bank that will occur as a result of the NDD fish screens will have an impact to Delta Smelt habitat because it will alter the capacity of the fish to ascend the river along its east bank. As discussed above, the overall magnitude of this potential effect on individual Delta Smelt will 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 will not affect Delta Smelt at a population level. Nevertheless, in recognition that that there potentially will be reduced access to ESA-designated critical habitat near and upstream of the NDD, it is proposed to restore 245 acres of shallow water habitat as compensation for the estimated extent of this type of habitat that may be less accessible upstream of the NDD. Of the 245 acres, 108 acres must be sandy beach spawning habitat (a 3:1 mitigation ratio for the estimated 36 acres of such habitat that would be affected). See additional discussion in Section 4.1.6.3.1 *North Delta Diversions*.

Table 4.1-6. Number of Delta Smelt (≥60 mm Fork Length) Collected and Catch per Seine during USFWS Beach Seine Sampling in the Project 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
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

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					
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.).



Source: http://www.dfg.ca.gov/delta/data/skt/skt_stations.asp.

Figure 4.1-4. Locations of Spring Kodiak Trawl Sampling Stations.

Table 4.1-7. Density and Frequency of Occurrence of Delta Smelt in Kodiak Trawls at Sherwood Harbor (January–March).

Year	Number of Trawls	Density (Number Per 10,000 m3 ± S.D.)	Frequency of Occurrence
2002	324	0.01 (± 0.10)	1%
2003	328	0.07 (± 0.34)	4%
2004	267	0.00 (± 0.00)	0%
2005	369	0.01 (± 0.11)	1%
2006	327	0.00 (± 0.00)	0%
2007	411	0.00 (± 0.00)	0%
2008	372	0.00 (± 0.06)	0%
2009	372	0.00 (± 0.00)	0%
2010	332	0.00 (± 0.07)	0%
2011	342	0.00 (± 0.00)	0%
2012	383	0.08 (± 0.40)	5%
2013	381	0.00 (± 0.00)	0%

Year	Number of Trawls	Density (Number Per 10,000 m3 ± S.D.)	Frequency of Occurrence
2014	520	0.04 (± 0.28)	3%
2015	380	0.00 (± 0.00)	0%
2016	340	0.00 (± 0.00)	0%
Source: Speegle (pers. comm.) and https://www.fws.gov/lodi/juvenile_fish_monitoring_program/data_management/Sacramento_Trawls_CHN_&_POD_Species_2012-2016.xlsx. Accessed: September 14, 2016.			

Table 4.1-8. Density and Frequency of Occurrence of Delta Smelt in Spring Kodiak Trawls (January–March).

Area	Year	Number of Trawls	Density (Number Per 10,000 m^3 ± S.D.)	Frequency of Occurrence
Confluence/ Honker Bay (stations 501, 504, 508, 513, 519, 520)	2002	18	3.79 (± 6.71)	44%
	2003	18	3.43 (± 5.06)	56%
	2004	18	2.81 (± 4.35)	61%
	2005	18	2.39 (± 4.77)	56%
	2006	18	1.90 (± 2.61)	56%
	2007	18	3.12 (± 6.65)	28%
	2008	18	2.21 (± 3.05)	50%
	2009	18	1.70 (± 5.75)	17%
	2010	18	1.10 (± 1.82)	33%
	2011	18	0.47 (± 1.30)	17%
	2012	15	21.48 (± 41.37)	73%
	2013	18	0.77 (± 1.58)	28%
	2014	18	1.26 (± 3.69)	17%
	2015	18	0.18 (± 0.52)	11%
	2016	18	0.08 (± 0.33)	6%
East/South Delta (stations 902, 906, 910, 912, 914, 915, 919, 920, 921, 922, 923)	2002	30	1.09 (± 2.13)	27%
	2003	30	0.57 (± 1.86)	13%
	2004	28	1.85 (± 6.27)	29%
	2005	33	0.20 (± 0.68)	9%
	2006	33	0.24 (± 0.62)	15%
	2007	33	0.00 (± 0.00)	0%
	2008	33	0.06 (± 0.32)	3%
	2009	32	0.06 (± 0.34)	3%
	2010	33	0.00 (± 0.00)	0%
	2011	33	0.16 (± 0.54)	9%
	2012	33	0.00 (± 0.00)	0%
	2013	33	0.05 (± 0.29)	3%
	2014	33	0.06 (± 0.33)	3%
	2015	32	0.06 (± 0.34)	3%
	2016	33	0.00 (± 0.00)	0%

Area	Year	Number of Trawls	Density (Number Per 10,000 m^3 ± S.D.)	Frequency of Occurrence
Lower Sacramento River (stations 704, 706, 707)	2002	9	7.88 (± 12.57)	67%
	2003	9	11.78 (± 18.84)	78%
	2004	9	14.57 (± 18.75)	67%
	2005	9	10.19 (± 13.87)	78%
	2006	9	0.32 (± 0.65)	22%
	2007	9	9.58 (± 15.51)	56%
	2008	9	13.87 (± 31.49)	56%
	2009	9	27.23 (± 47.87)	67%
	2010	9	5.54 (± 5.87)	67%
	2011	9	4.53 (± 6.43)	67%
	2012	9	11.25 (± 11.95)	67%
	2013	9	4.23 (± 7.38)	33%
	2014	9	4.19 (± 5.87)	78%
	2015	9	7.44 (± 13.48)	56%
	2016	9	0.68 (± 1.68)	22%
Lower San Joaquin River (stations 801, 804, 809, 812, and 815)	2002	15	10.00 (± 15.03)	80%
	2003	15	3.66 (± 6.18)	53%
	2004	15	15.86 (± 19.84)	87%
	2005	15	0.88 (± 1.72)	27%
	2006	15	0.59 (± 1.09)	27%
	2007	15	0.91 (± 2.43)	13%
	2008	15	0.45 (± 0.78)	27%
	2009	15	0.92 (± 2.34)	20%
	2010	15	0.45 (± 1.75)	7%
	2011	15	0.28 (± 0.58)	20%
	2012	15	2.88 (± 4.75)	47%
	2013	15	2.32 (± 5.28)	27%
	2014	15	1.80 (± 3.82)	33%
	2015	15	1.89 (± 4.61)	27%
	2016	15	0.19 (± 0.51)	13%
North Delta (stations 711, 712, 713, 715, 716, and 719)	2002	15	8.85 (± 17.88)	60%
	2003	15	26.69 (± 36.42)	73%
	2004	15	0.43 (± 0.78)	27%
	2005	17	8.78 (± 14.49)	59%
	2006	18	4.53 (± 8.61)	39%
	2007	18	8.27 (± 18.85)	44%
	2008	18	12.55 (± 23.48)	61%
	2009	20	27.92 (± 90.15)	25%

Area	Year	Number of Trawls	Density (Number Per 10,000 m^3 ± S.D.)	Frequency of Occurrence
	2010	20	11.62 (± 33.90)	60%
	2011	18	27.58 (± 82.40)	56%
	2012	20	55.18 (± 106.58)	60%
	2013	22	18.34 (± 33.39)	36%
	2014	18	6.50 (± 16.28)	67%
	2015	19	1.44 (± 3.38)	32%
	2016	18	0.68 (± 1.71)	22%
Napa River (station 340)	2002	3	0.45 (± 0.79)	33%
	2003	3	0.00 (± 0.00)	0%
	2004	3	0.47 (± 0.82)	33%
	2005	3	1.46 (± 2.53)	33%
	2006	3	13.86 (± 4.87)	100%
	2007	2	0.00 (± 0.00)	0%
	2008	2	0.00 (± 0.00)	0%
	2009	3	0.00 (± 0.00)	0%
	2010	3	0.00 (± 0.00)	0%
	2011	3	0.00 (± 0.00)	0%
	2012	2	1.10 (± 1.55)	50%
	2013	3	0.00 (± 0.00)	0%
	2014	3	0.00 (± 0.00)	0%
	2015	3	0.00 (± 0.00)	0%
	2016	3	0.00 (± 0.00)	0%
Ryde (station 724)	2005	2	0.47 (± 0.67)	50%
	2006	3	0.00 (± 0.00)	0%
	2007	3	0.00 (± 0.00)	0%
	2008	3	0.00 (± 0.00)	0%
	2009	3	0.00 (± 0.00)	0%
	2010	3	0.00 (± 0.00)	0%
	2011	3	0.00 (± 0.00)	0%
	2012	2	0.00 (± 0.00)	0%
	2013	2	0.00 (± 0.00)	0%
	2014	2	0.00 (± 0.00)	0%
	2015	2	0.00 (± 0.00)	0%
	2016	2	0.00 (± 0.00)	0%

Area	Year	Number of Trawls	Density (Number Per 10,000 m^3 ± S.D.)	Frequency of Occurrence
Suisun Marsh/Grizzly Bay (stations 602, 606, 609, and 610)	2002	12	76.39 (± 97.59)	67%
	2003	12	10.30 (± 15.12)	67%
	2004	12	58.82 (± 91.67)	75%
	2005	12	29.04 (± 50.51)	75%
	2006	12	7.17 (± 11.48)	58%
	2007	12	15.17 (± 23.92)	67%
	2008	12	1.40 (± 1.77)	42%
	2009	14	13.31 (± 29.31)	64%
	2010	12	15.83 (± 25.30)	58%
	2011	14	12.08 (± 21.13)	79%
	2012	11	27.03 (± 31.44)	64%
	2013	13	11.51 (± 15.32)	77%
	2014	12	20.71 (± 42.22)	58%
	2015	12	4.21 (± 7.84)	58%
	2016	12	0.49 (± 0.92)	25%
West Suisun Bay (stations 405, 411, and 418)	2002	9	1.60 (± 1.27)	78%
	2003	9	2.00 (± 4.06)	33%
	2004	9	0.50 (± 1.51)	11%
	2005	9	0.47 (± 1.42)	11%
	2006	9	1.07 (± 0.89)	67%
	2007	9	0.00 (± 0.00)	0%
	2008	9	0.22 (± 0.66)	11%
	2009	9	0.00 (± 0.00)	0%
	2010	9	0.20 (± 0.60)	11%
	2011	9	0.00 (± 0.00)	0%
	2012	6	0.44 (± 1.09)	17%
	2013	9	0.00 (± 0.00)	0%
	2014	9	0.00 (± 0.00)	0%
	2015	9	0.00 (± 0.00)	0%
	2016	9	0.00 (± 0.00)	0%

Source: ftp://ftp.dfg.ca.gov/Delta%20Smelt/SKT.mdb. Accessed: September 14, 2016.

Table 4.1-9. 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	PP	PP vs. NAA	NAA	PP	PP vs. NAA	NAA	PP	PP vs. NAA	NAA	PP	PP vs. NAA	NAA	PP	PP vs. NAA	NAA	PP	PP vs. NAA	NAA	PP	PP vs. NAA
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 PP.

4.1.3.2.2.2 Spawning Adults (February–June)

Presumably the risk to adult Delta Smelt from impingement at the NDD will 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 will be as described for migrating adults.

4.1.3.2.2.2.1 Population-Level Effects

As with migrating adults during December–March, in some years, the catch per unit effort of adult (≥60 mm) Delta Smelt from beach seines 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 4.1-10). 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. The Kodiak trawl data previously described for migrating adults also indicate that most Delta Smelt are well downstream of the proposed NDD (Table 4.1-7; Table 4.1-8). 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 will not affect spawning adult Delta Smelt at a population level.

Table 4.1-10. Number of Delta Smelt (≥60 mm Fork Length) Collected and Catch per Seine during USFWS Beach Seine Sampling in the Project 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

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					
1995	134	355	5	10	0.33	0.04	0.03
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.).

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

As noted for entrainment, Delta Smelt eggs and embryos are demersal and adhesive, and so will not be subject to impingement; thus there will be no adverse population-level effects from the NDD with respect to impingement.

4.1.3.2.2.4 Larvae/Young Juveniles (Spring: ~March–June)

Delta Smelt larvae and young juveniles that are large enough (>20-21 mm SL) to be excluded from entrainment by the NDD screens will 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 SL; 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 will be greater than for larger Delta Smelt, for which mortality was estimated to be up to ~6 percent of the small number of fish passing each of the intakes during the night at the highest sweeping velocity.

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

4.1.3.2.2.5 Juveniles (Summer/Fall: ~July–December)

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

Survey data and the opinions of numerous experts that have sampled the Delta extensively[11] 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 4.1-11); 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 4.1-12). Therefore, it is concluded that the population-level effects of impingement at the NDD will usually be near zero

[11] 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 4.1-11. 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 4.1-12. Number of Juvenile Delta Smelt (<60 mm Fork Length) Collected and Catch per Seine during USFWS Beach Seine Sampling in the Project 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.).

4.1.3.2.3 Predation at the North Delta Diversions

4.1.3.2.3.1 Migrating Adults (December–March)

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 will present 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 NDDs 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[12]. As discussed in Section 4.1.1.2.6 *Loss or Alteration of Habitat*, riprap used in association with the intakes could result in increased predator habitat and predation risk. The potential adverse effect to individual migrating adult Delta Smelt from predation at the NDD will be minimal at the population level because, as discussed previously for impingement and screen contact, a very small proportion of the Delta Smelt population will occur near the NDDs.

4.1.3.2.3.2 Spawning Adults (February–June)

To the extent that spawning adult Delta Smelt occur near the NDDs, 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 have limited risk of predation at the NDDs.

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

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

Following Bennett (2005), it is generally thought that egg/embryo habitat for Delta Smelt consists of shallow sandy areas, which will not occur at the NDDs. Therefore, there will be no effects on individual eggs or embryos, and no adverse population effect..

4.1.3.2.3.4 Larvae/Young Juveniles (Spring: ~March–June)

To the extent that the NDDs 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 NDDs will provide beneficial habitat, as presumably these small predators will be susceptible to the same larger predators that could consume adult Delta Smelt. Therefore, elevated predation on Delta Smelt larvae is unlikely. However, 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 percent) percentage of the population occurring near the NDD; see more detailed discussion in the analysis of the effects of entrainment.

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

4.1.3.2.3.5 Juveniles (Summer/Fall: ~July–December)

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

4.1.3.3 South Delta Exports

4.1.3.3.1 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 4.1-13), 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, but 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 CCF ranged from about 90 percent to 100 percent for adults and nearly 100 percent for juveniles during a recent study (Castillo *et al.* 2012)[13].

[13] 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) as well.

Table 4.1-13. 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	U.S. Fish and Wildlife Service (2011a)
Identification protocols	Identified from subsamples, then expanded in salvage estimates	Not identified	Identified from subsamples, then expanded in salvage estimates	U.S. Fish and Wildlife Service (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; entrainment can be characterized as a sporadically significant influence on Delta Smelt population dynamics. Kimmerer (2008) estimated that annual entrainment of the Delta Smelt population (adults and their progeny combined) ranged from approximately 10 to 60 percent per year from 2002–2006. Major population 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.*

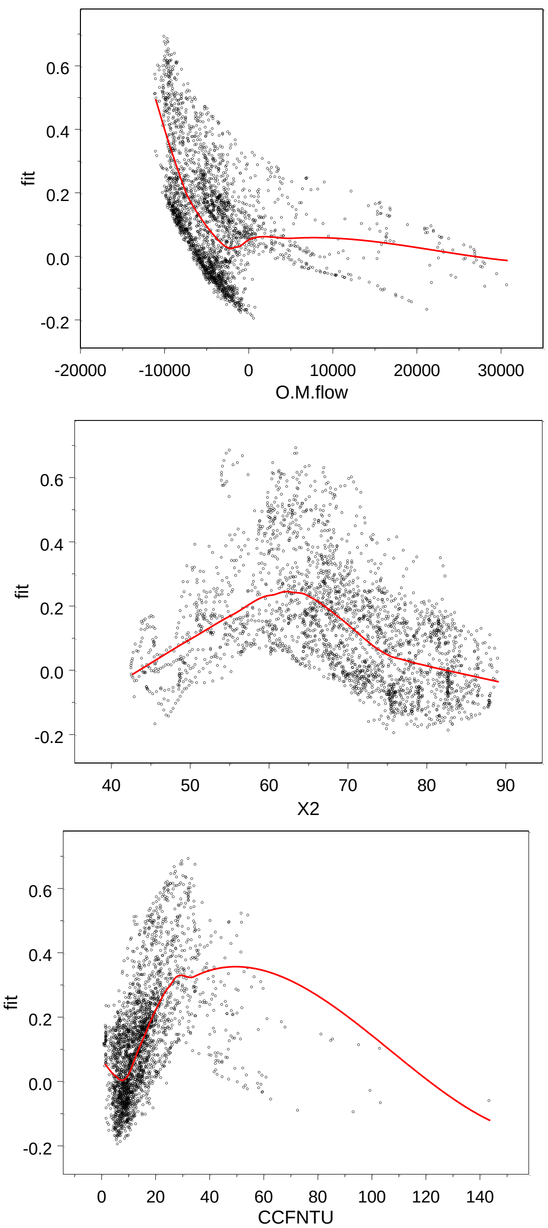
2010; Maunder and Deriso 2011[14]; Miller *et al.* 2012). However, this is an area of scientific debate with some researchers finding that entrainment (or water diversions during the time period when entrainment would be of concern) may affect population dynamics (Rose *et al.* 2013b; Thomson *et al.* 2010). The RPA actions related to south Delta entrainment in the U.S. Fish and Wildlife Service (2008) and National Marine Fisheries Service (2009) BiOps have reduced the potential for entrainment loss since 2008–2009.

4.1.3.3.1.1 Migrating Adults (December–March)

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 4.1-5. 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 4.1-5 shows that even when X2 and 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 4.1-5).

[14] 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.



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

Figure 4.1-5. 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 CCF (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 (U.S. Fish and Wildlife Service 2015b).[15]

Under the PP, OMR flows will be less negative than under the NAA during the months of concern for adult Delta Smelt (Figure 4.1-6, Figure 4.1-7, Figure 4.1-8, Figure 4.1-9; also see ICF International [2016], Appendix 5.A *CALSIM Methods and Results*, Table 5.A.6-25 and Figures 5.A.6-25-1 to 5.A.6-25-19). As described in Section 3.3.2.2 *Operational Criteria for South Delta CVP/SWP Export Facilities,* the OMR flow requirements will be those of U.S. Fish and Wildlife Service (2008) and National Marine Fisheries Service (2009) until completion of the NDD, after which the newly proposed criteria will generally improve OMR flows more in wetter years under the PP compared to the existing BiOps; provided, that the research and results of the Collaborative Science and Adaptive Management program (described in Chapter 6 *Monitoring*) show these criteria are necessary to avoid jeopardy of any endangered or threatened species or to prevent the destruction or adverse modification of ESA-designated critical habitat for those species. Real-time management of entrainment risk will also occur (if needed), in a manner similar to the existing Smelt Working Group process. Therefore individual Delta Smelt will be less susceptible to entrainment under the PP than under the NAA. This is analyzed at the population level in the next section.

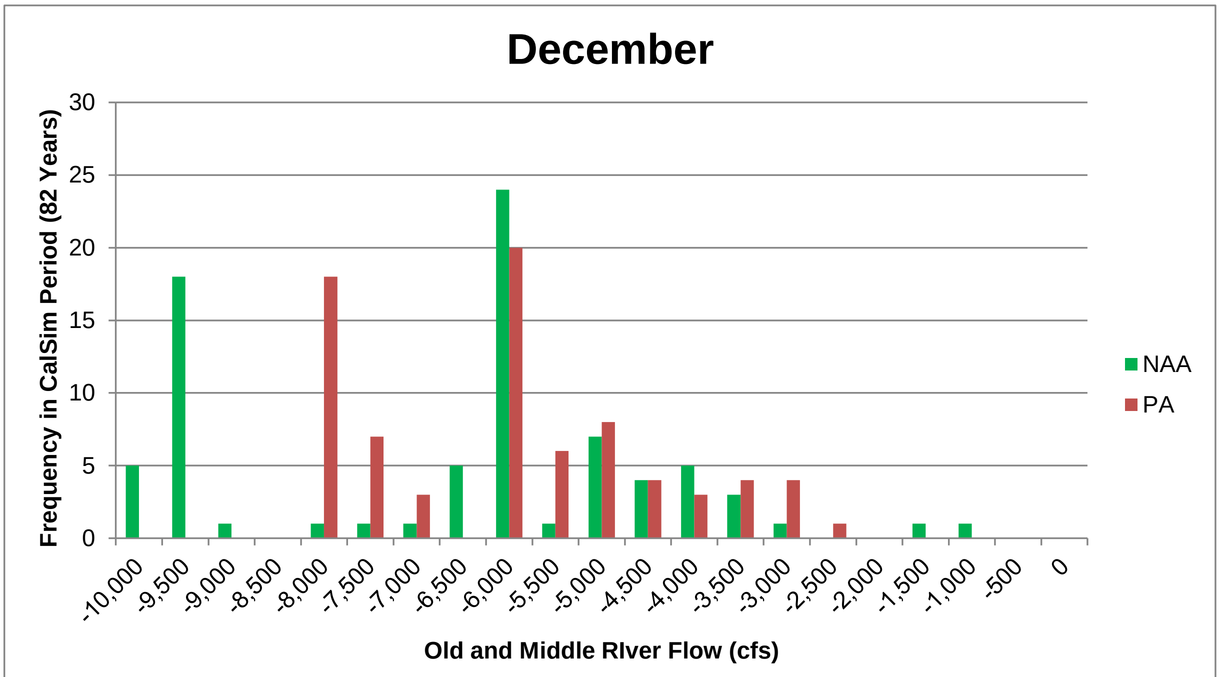


Figure 4.1-6. Frequency of December Old and Middle River Flows in Water-Year 1922–2003 Period Simulated with CalSim

[15] 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.

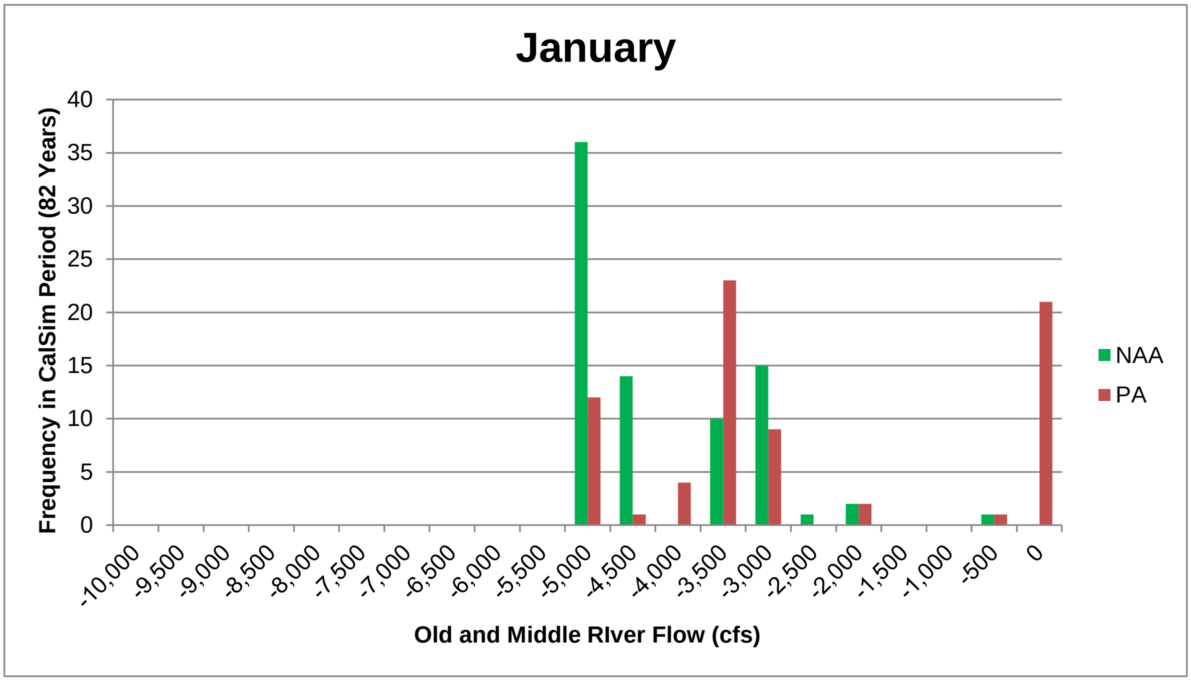


Figure 4.1-7. Frequency of December Old and Middle River Flows in Water-Year 1922–2003 Period Simulated with CalSim

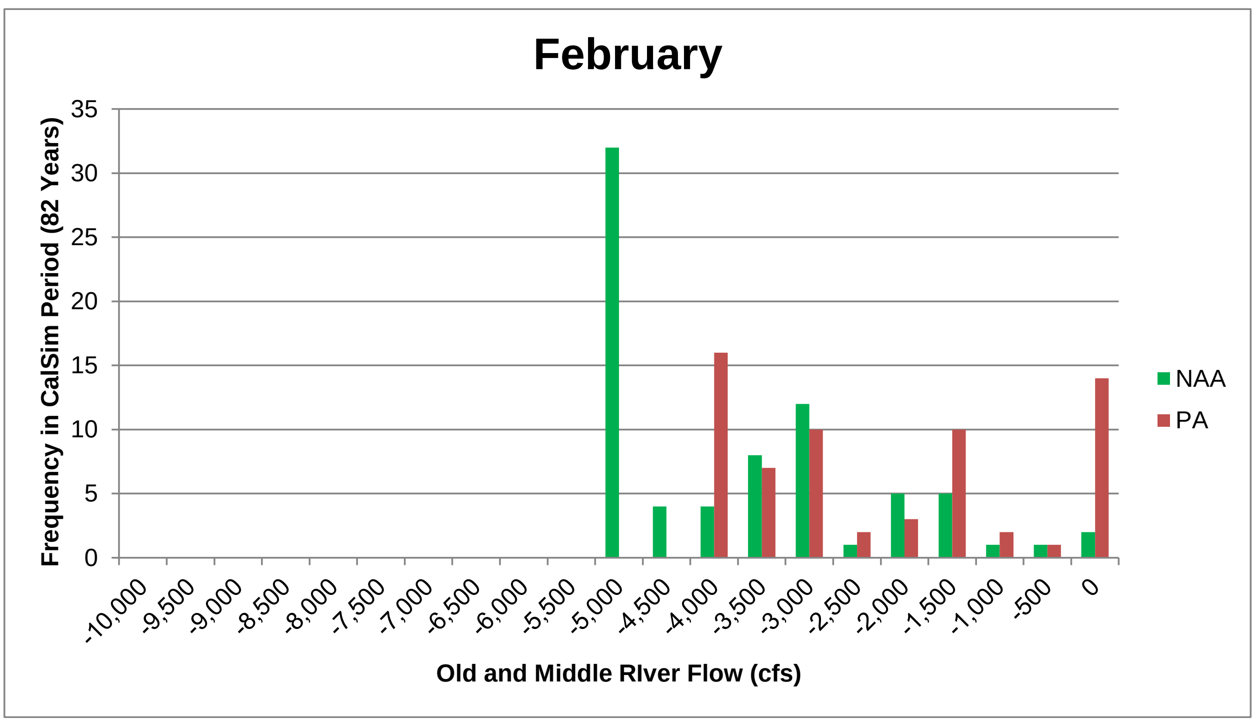


Figure 4.1-8. Frequency of February Old and Middle River Flows in Water-Year 1922–2003 Period Simulated with CalSim

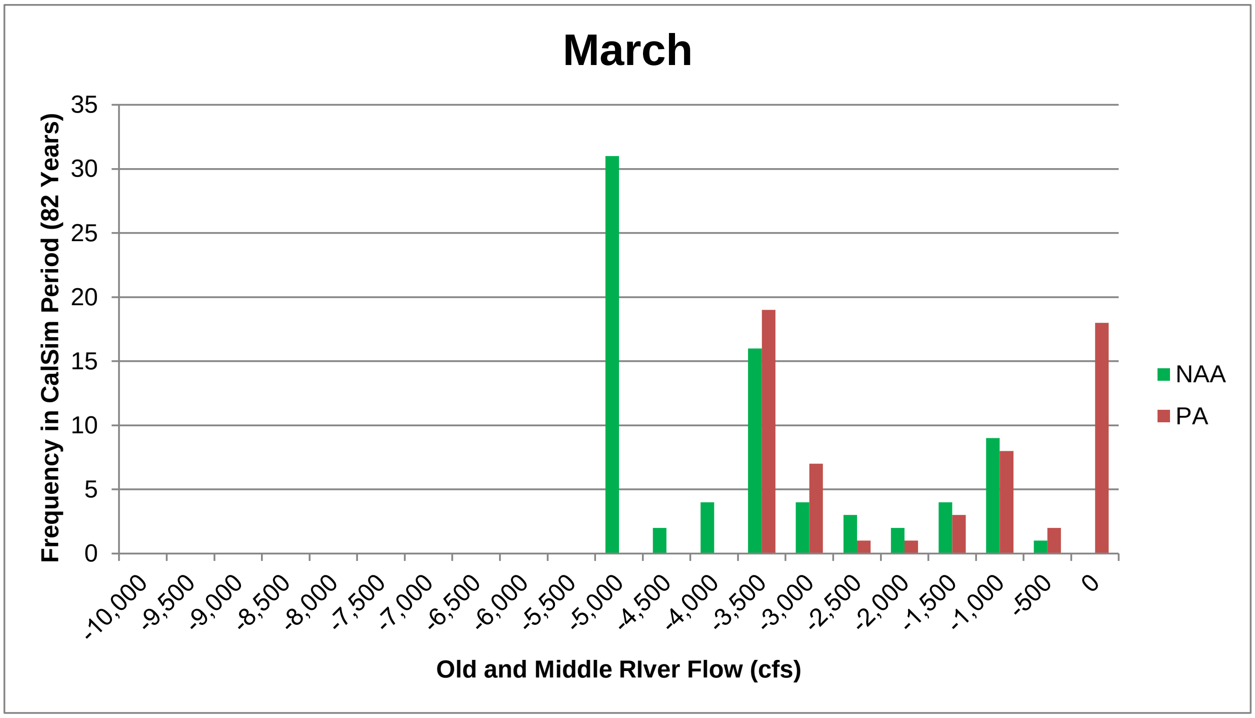


Figure 4.1-9. Frequency of March Old and Middle River Flows in Water-Year 1922–2003 Period Simulated with CalSim

4.1.3.3.1.1.1 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 percentage loss as a function of historical OMR flows, for example), because of the difficulty in forecasting turbidity and abundance. For this effects analysis, the percentage entrainment of adult Delta Smelt was estimated using OMR flow predictions derived from CalSim II model outputs (U.S. Fish and Wildlife Service 2008; ICF International 2016, Appendix 6.A *Quantitative Methods for Biological Assessment of Delta Smelt*, Section 6.A.3.1). As noted in ICF International (2016, Appendix 6.A *Quantitative Methods for Biological Assessment of Delta Smelt*), although much of the variability in percentage 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 PP.

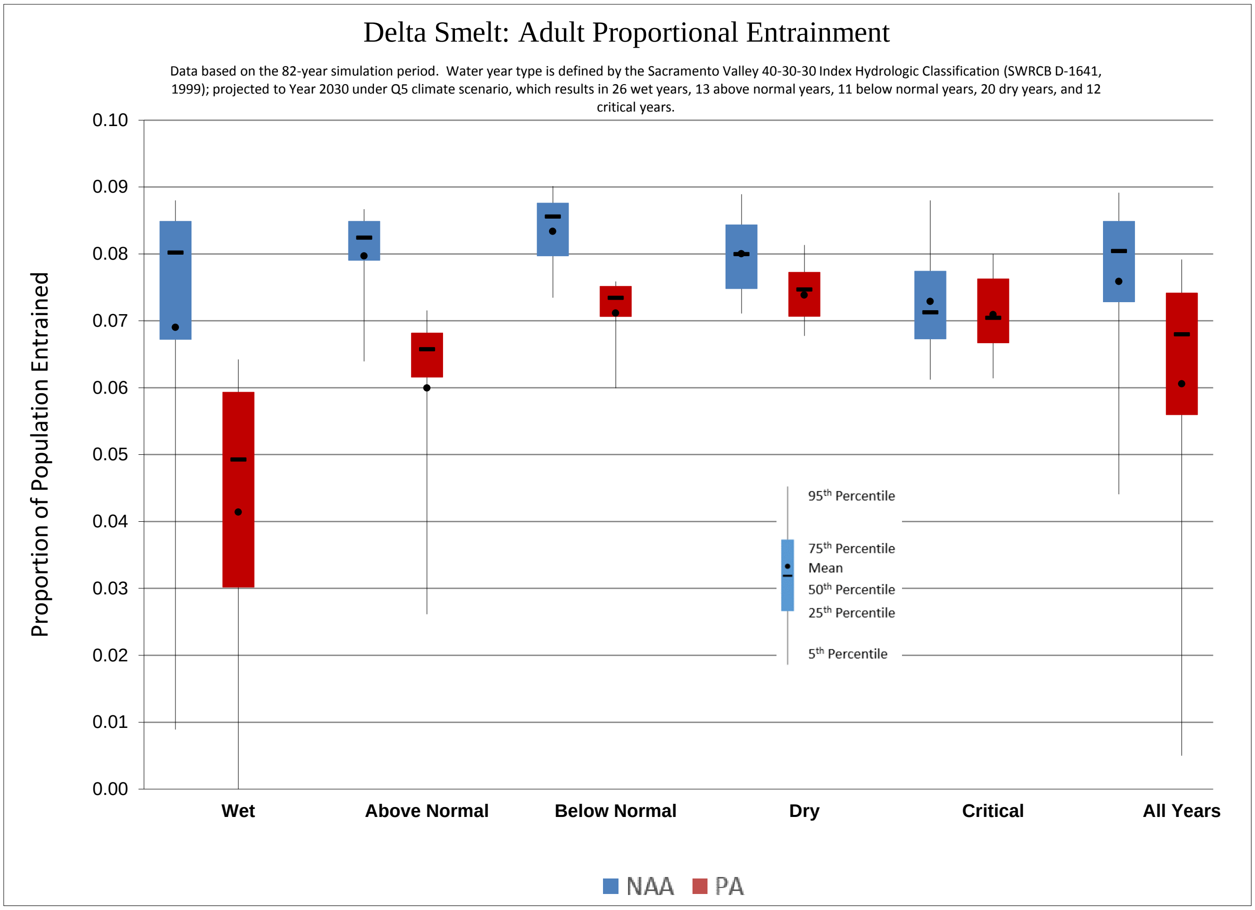
The analysis indicates that percentage entrainment loss of adult Delta Smelt will be lower under the PP than NAA, with variable differences when the results are summarized by water year type (Table 4.1-14; Figure 4.1-10). In drier years, the need to maintain suitable bypass flows in the Sacramento River 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 PP in south Delta exports and entrainment loss of adult Delta Smelt. The U.S. Fish and Wildlife Service (2008) and National Marine Fisheries Service (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 could be appreciably lessened under the PP. Note, however, that there is appreciable uncertainty in the magnitude of the potential difference between NAA and PP, because there is considerable variability that is left unexplained by the regression equation, resulting in broad prediction intervals (Figure 4.1-11).

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 percent of samples from 2002–2009 [Merz *et al.* 2011]; ~22 percent 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 PP, as illustrated by the previously mentioned USFWS proposal for the 2016 incidental take limit calculation.

Table 4.1-14. Mean Estimated Annual Percentage 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 Project (PP), Based on the Percentage Entrainment Regression

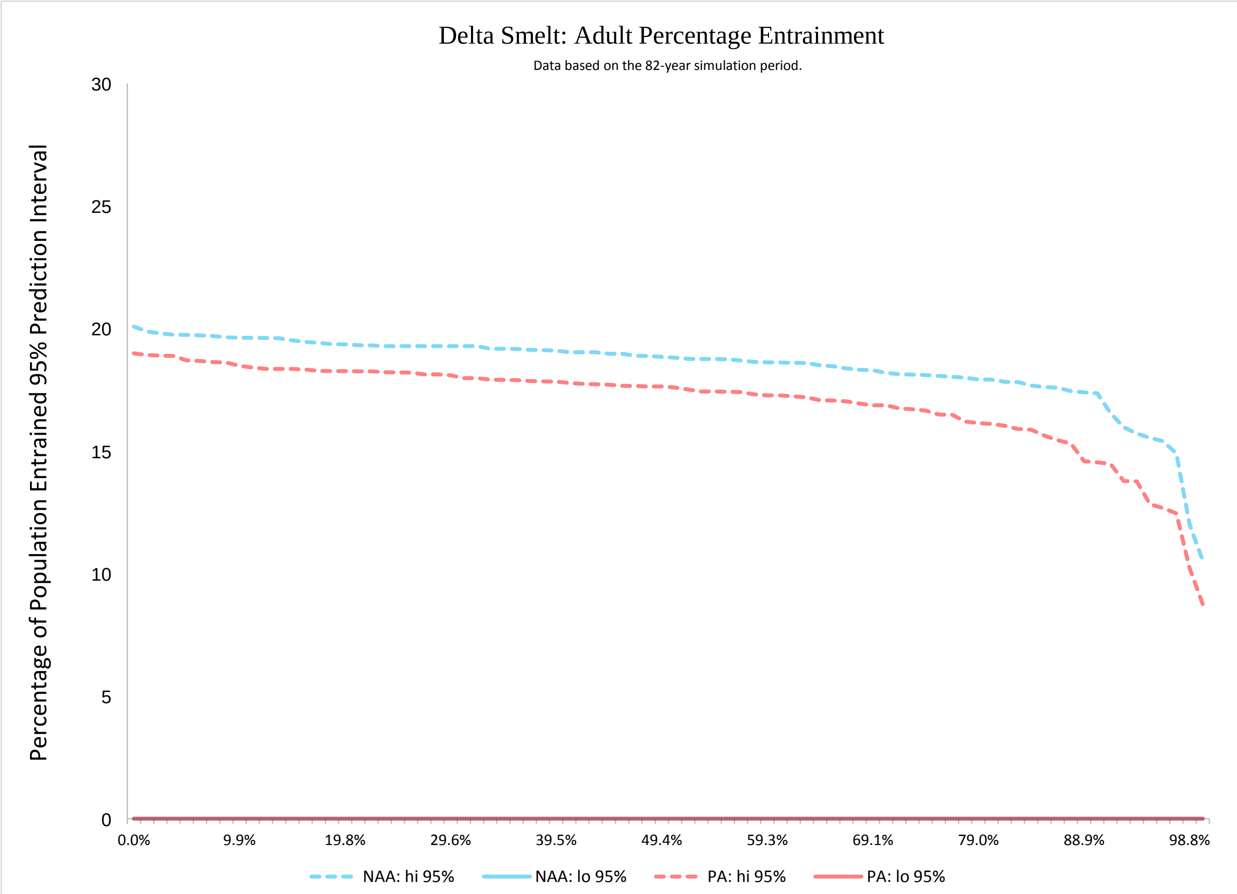
Water Year Type	NAA	PP	PP vs. NAA[1]
All	7.39	5.94	-1.45 (-20%)
Wet	6.73	4.11	-2.62 (-39%)
Above Normal	7.75	5.89	-1.87 (-24%)
Below Normal	8.10	6.95	-1.15 (-14%)
Dry	7.79	7.20	-0.59 (-8%)
Critical	7.11	6.92	-0.19 (-3%)

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



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

Figure 4.1-10. Box Plots of Adult Delta Smelt Percentage , Grouped by Water Year Type



Note: Data are sorted by mean estimate, with only 95% prediction intervals shown. The lower bound of the 95% prediction interval is zero in all cases (following adjustment from negative values; see Section 6.A.3.1 *Percentage Loss Equations* in ICF International (2016, Appendix 6.A *Quantitative Methods for Biological Assessment of Delta Smelt*).

Figure 4.1-11. Exceedance Plot of Adult Delta Smelt Percentage Entrainment

4.1.3.3.1.2 Spawning Adults (February–June)

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 PP suggest that entrainment risk will be reduced throughout the spawning season regardless of nuances about adult behavior and movements.

Under the assumption that spawning adults generally are not undergoing broad-scale migrations,[16] there would not be an adverse population-level effect of entrainment from south

[16] For example, the longer, tidally-facilitated migrations from the low salinity zone to upstream spawning areas, as occurs with migrating adults (Sommer et al. 2011; Bennett and Burau 2015). As noted in Section 4.1.3.3.1.1, entrainment can occur even with positive OMR flows, suggesting some level of non-tidal movement (which is also suggested by the occurrence in the Sacramento River near the proposed NDD; Section 4.1.3.2.2.1), although for this analysis it is assumed that spawning adults have completed the main period of movement (migration).

Delta exports to this life stage, but the persistently less negative OMR flows predicted for the PP suggest that percentage 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.

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

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

4.1.3.3.1.4 Larvae/Young Juveniles (Spring: ~March–June)

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 SL. 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).

U.S. Fish and Wildlife Service (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 U.S. Fish and Wildlife Service (2008) and National Marine Fisheries Service (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 PP, individual larval/juvenile Delta Smelt will be susceptible to entrainment at the south Delta export facilities. The analysis presented below focuses on the population-level effect, by examining the percentage of the population that could be entrained under PP and NAA.

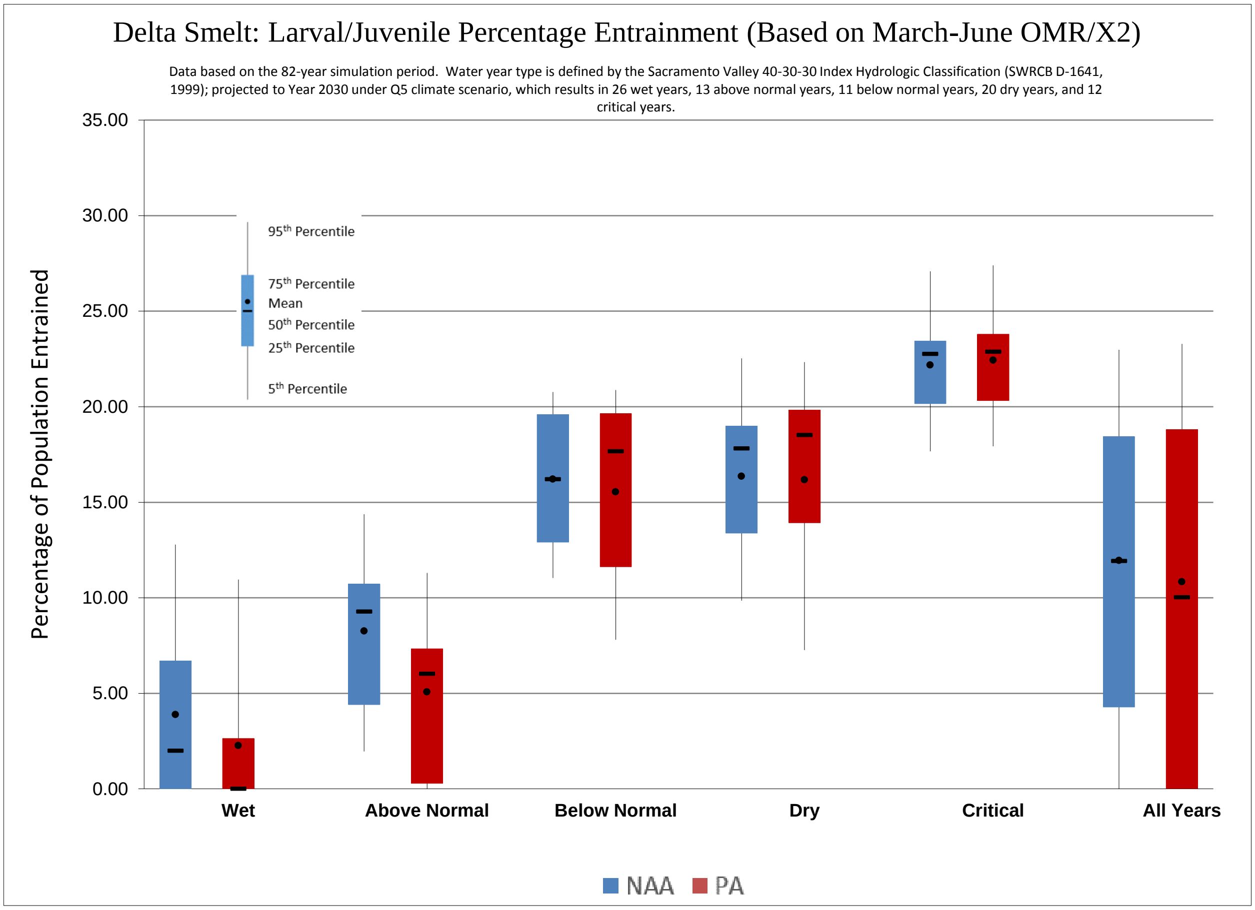
4.1.3.3.1.4.1 Population-Level Effects

For this effects analysis, two approaches were used to estimate entrainment effects on larval/young juvenile Delta Smelt. First, percentage entrainment loss regression equations similar to those used by the U.S. Fish and Wildlife Service (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 (ICF International [2016], 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 percentage entrainment of larval/juvenile Delta Smelt will tend to be very similar under the PP and the NAA (Table 4.1-15, Table 4.1-16, Figure 4.1-12, Figure 4.1-13; Figure 4.1-14; Figure 4.1-15). A tendency for somewhat larger entrainment estimates under the PP in drier years reflects OMR flows that may be less under the PP; this is explored further in relation to DSM2-PTM results. The NAA and PP had quite broad prediction intervals, which were overlapping across all exceedance values (Figure 4.1-13; Figure 4.1-15), as also illustrated when plotting the results as time series (Figure 4.1-16; Figure 4.1-17). As noted in the independent review panel report for the working draft BA, it is possible that the true annual values could lie near the bottom boundary of the prediction interval for PP and near the top boundary of the prediction interval for NAA (Simenstad et al. 2016). This would result in greater differences than suggested by the comparison of annual mean values. By the same rationale, it is also possible that the true annual values could lie near the top boundary of the prediction intervals for both PP and NAA, in which case the differences would be more similar to the differences between means.

Table 4.1-15. Mean Annual Percentage 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 Project (PP), Based on the Percentage Entrainment Regression Using Mean March–June Old and Middle River Flows and X2.

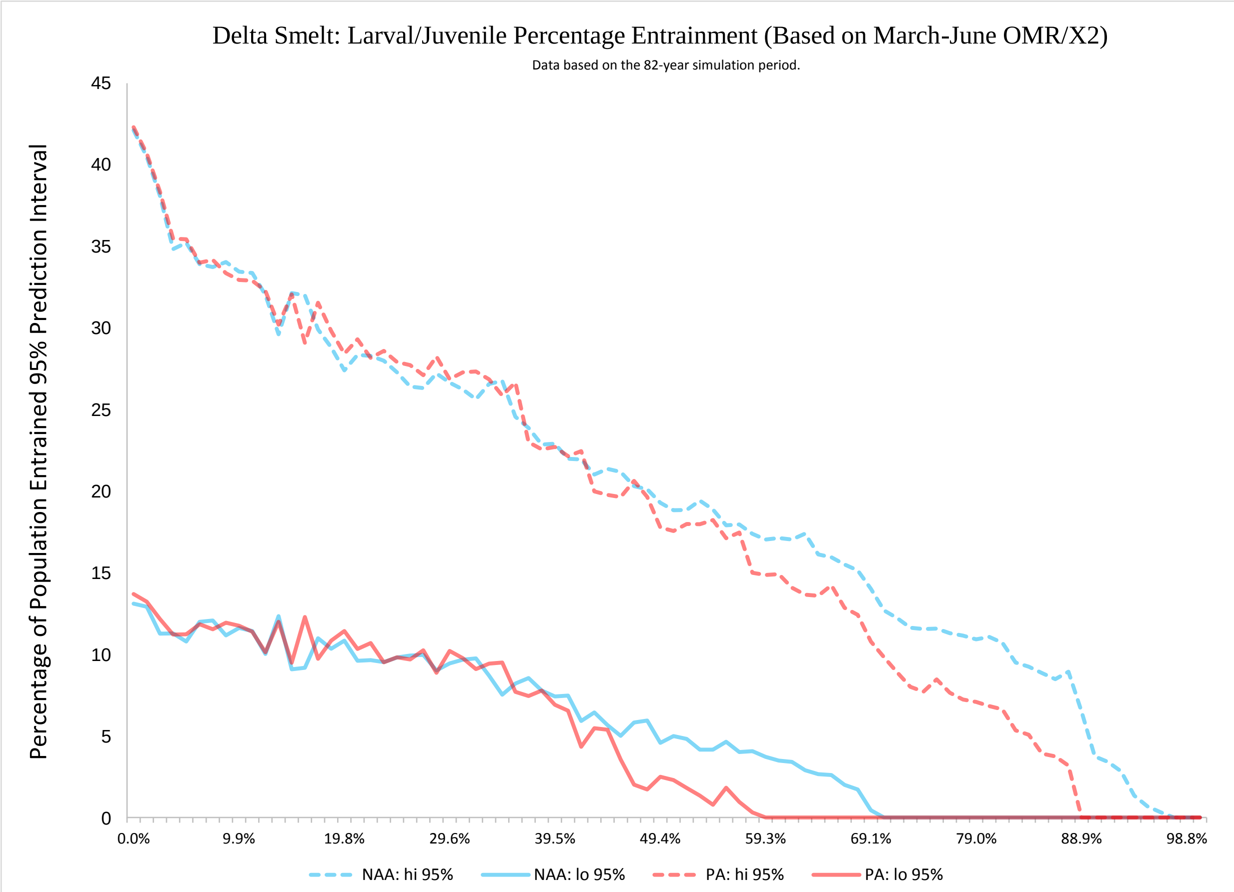
Water Year Type	NAA	PP	PP vs. NAA[1]
All	11.95	10.83	-1.12 (-9%)
Wet	3.89	2.26	-1.63 (-42%)
Above Normal	8.26	5.07	-3.18 (-39%)
Below Normal	16.20	15.54	-0.66 (-4%)
Dry	16.36	16.17	-0.19 (-1%)
Critical	22.18	22.43	0.25 (1%)

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



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

Figure 4.1-12. Box Plots of Larval/Juvenile Delta Smelt Percentage Entrainment), Grouped by Water Year Type, Based on Mean March–June Old and Middle River Flows and X2



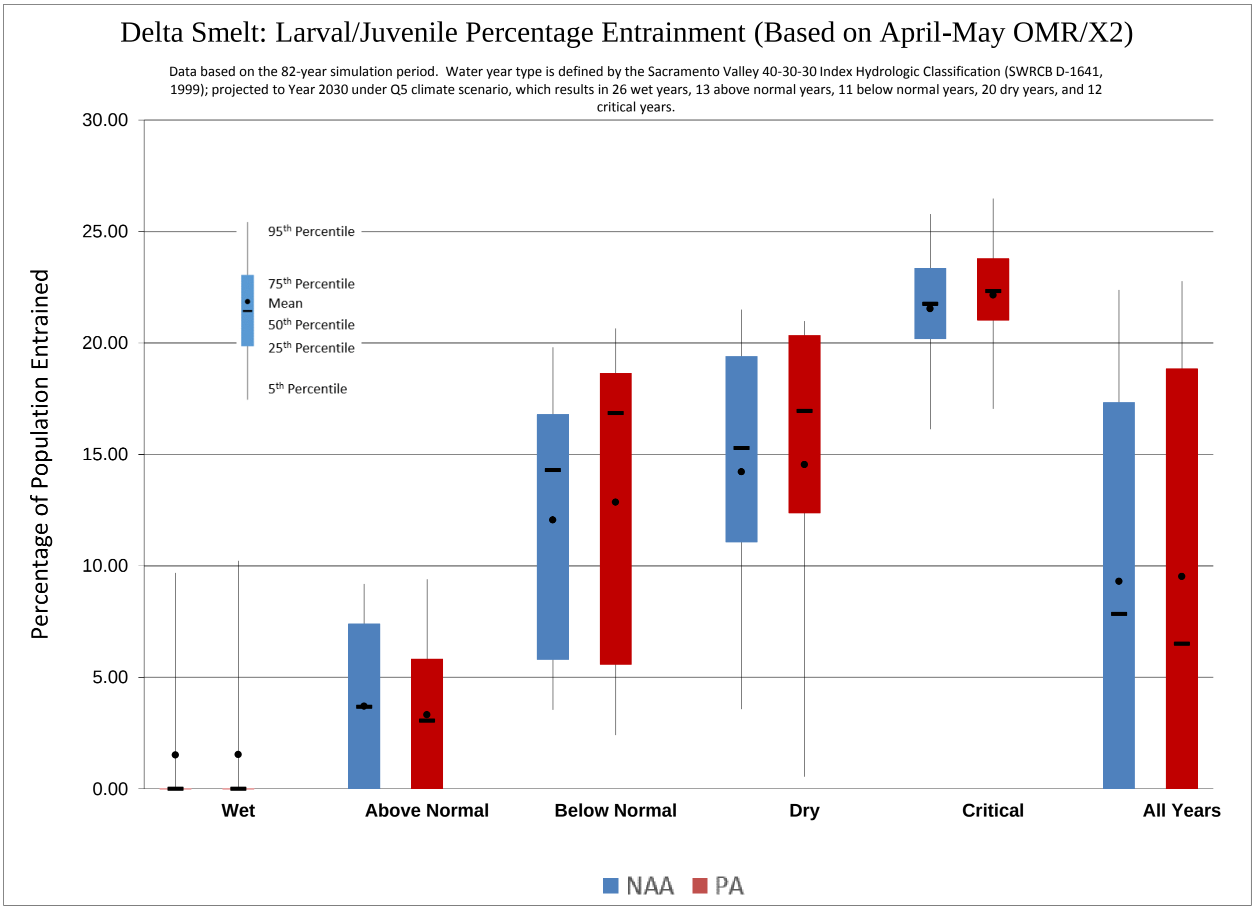
Note: Data are sorted by mean estimate, with only 95% prediction intervals shown. When necessary, the lower bound of the 95% prediction is adjusted to zero from negative values (see Section 6.A.3.1 *Percentage Loss Equations* in ICF International (2016, Appendix 6.A *Quantitative Methods for Biological Assessment of Delta Smelt*)).

Figure 4.1-13. Exceedance Plot of Larval/Juvenile Delta Smelt Percentage Entrainment, Based on Mean March–June Old and Middle River Flows and X2

Table 4.1-16. Mean Annual Percentage 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 Project (PP), Based on the Percentage Entrainment Regression Using Mean April–May Old and Middle River Flows and X2.

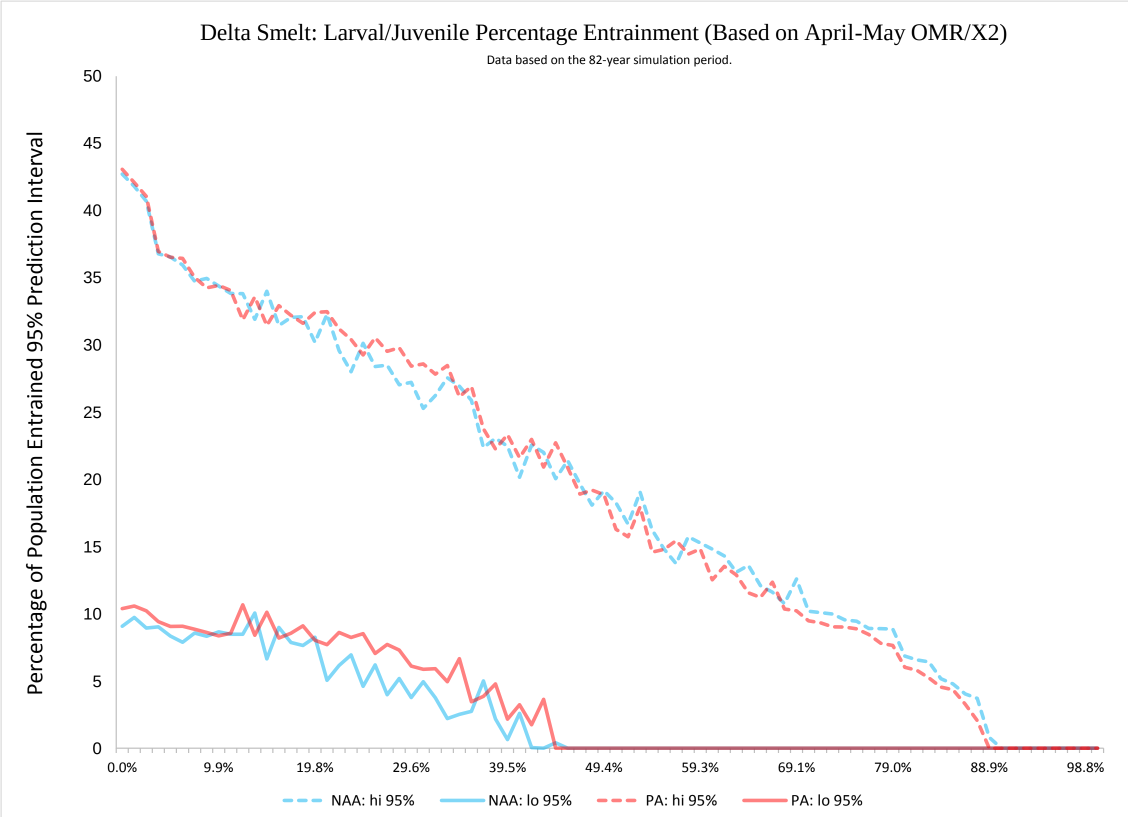
Water Year Type	NAA	PP	PP vs. NAA[1]
All	9.31	9.53	0.22 (2%)
Wet	1.52	1.54	0.02 (2%)
Above Normal	3.71	3.32	-0.38 (-10%)
Below Normal	12.06	12.86	0.80 (7%)
Dry	14.22	14.54	0.33 (2%)
Critical	21.54	22.15	0.61 (3%)

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



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

Figure 4.1-14. Box Plots of Larval/Juvenile Delta Smelt Percentage Entrainment Grouped by Water Year Type, Based on Mean April–May Old and Middle River Flows and X2



Note: Data are sorted by mean estimate, with only 95% prediction intervals shown. When necessary, the lower bound of the 95% prediction is adjusted to zero from negative values (see Section 6.A.3.1 Percentage Loss Equations in ICF International (2016, Appendix 6.A *Quantitative Methods for Biological Assessment of Delta Smelt*).

Figure 4.1-15. Exceedance Plot of Larval/Juvenile Delta Smelt Percentage Entrainment, Based on Mean April–May Old and Middle River Flows and X2

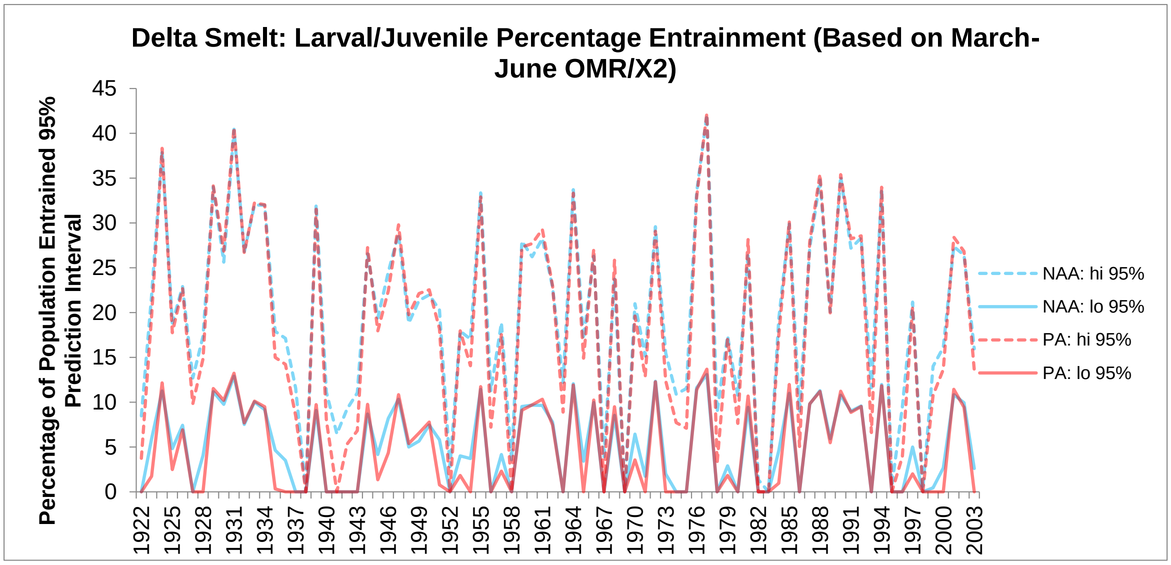


Figure 4.1-16. Time Series of 95% Prediction Interval Larval/Juvenile Delta Smelt Percentage Entrainment, Based on Mean March-June Old and Middle River Flows and X2.

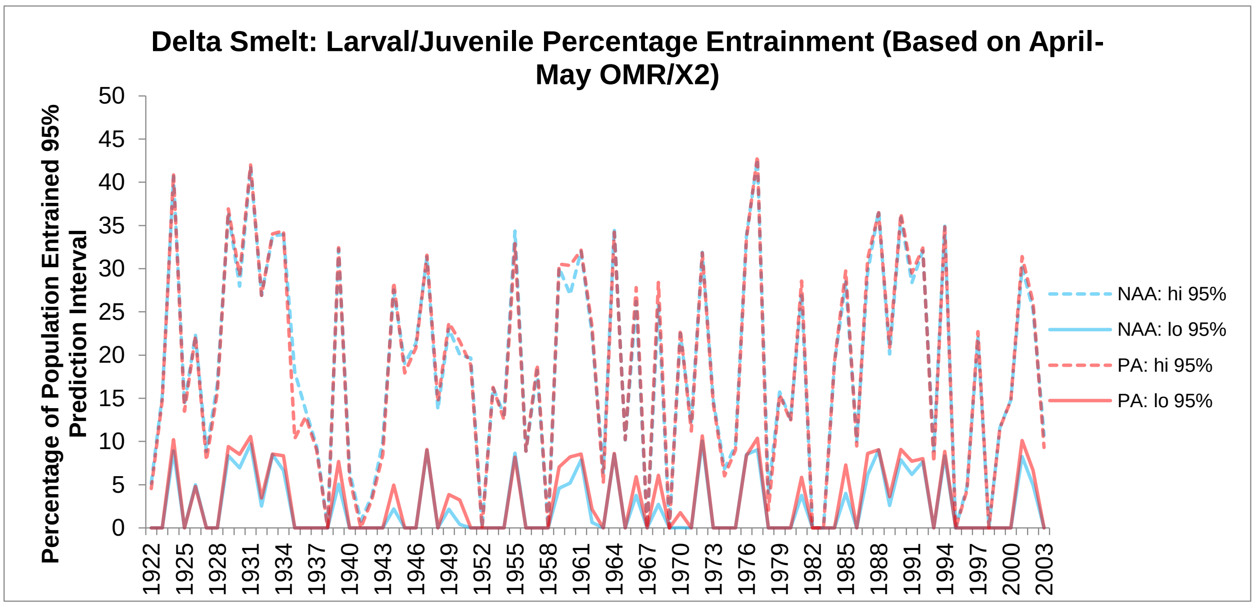


Figure 4.1-17. Time Series of 95% Prediction Interval Larval/Juvenile Delta Smelt Percentage Entrainment, Based on Mean April-May Old and Middle River Flows and X2.

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 U.S. Fish and Wildlife Service (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 percentage 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 ICF International (2016, 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 at SWP or CVP diversions in the Delta).

As described in ICF International (2016, Appendix 6.A *Quantitative Methods for Biological Assessment of Delta Smelt,* Section 6.A.3.2), 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 PP, then this could affect the absolute value of the entrainment predictions, but not their relative differences. Second, there are no 20-mm Survey stations upstream from the NDD, so the NDD received the same weighting of particles as downstream stations in the north Delta: from the 1995-2011 20-mm Survey data, the mean percentage at each of these stations was 2.7 percent (range 0 percent to nearly 10 percent).

The percentage of Delta Smelt larvae assumed to occur downstream of the Delta decreased as water years became drier (Table 4.1-17), 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 suggest that, accounting for the four main SWP and CVP entrainment locations in the Delta, there will be less entrainment under the PP than NAA, averaged over the March–June period, in wetter years; whereas in drier years, there will be little to no difference between PP and NAA. However, there are important differences by month (Table 4.1-17; Figure 4.1-18, Figure 4.1-19, Figure 4.1-20, Figure 4.1-21, Figure 4.1-22, Figure 4.1-23, Figure 4.1-24, and Figure 4.1-25). Total entrainment is driven by trends in south Delta entrainment, which, when examined month by month, suggested that under the PP 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 PP and NAA across water year types matches the general pattern observed in the percentage entrainment regression analysis for March–June (Table 4.1-18) and April–May (Table 4.1-19). The relatively greater entrainment under PP 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 percentage of larvae in the central and south Delta in drier years (ICF International [2016], 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 PP in April and May (ICF International [2016], Appendix 5.A *CALSIM Methods and Results*, Table 5.A.6-26), which means that the influences of the NAA and PP on larval distribution will be broadly similar. Further exploration of the effect of the HOR gate on OMR flows is provided in Section 4.A.3.2 *Results* of Appendix 4.A *Longfin Smelt Quantitative Analyses*.

The percentage of particles entrained at the NDD under the PP always averaged well below 1 percent (Table 4.1-17); 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 4.1.3.2.1.4 *Larvae/Young Juveniles,* extrapolation of catch density in the egg and larval survey suggests that a small percentage (perhaps ~0.25 percent) 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 4.1.3.2.2.1 *Migrating Adults*). 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[17] to reflect lower occurrence than the other locations in the Cache Slough and North Delta area (see ICF International [2016], Appendix 6.A *Quantitative Methods for Biological Assessment of Delta Smelt,* Table 6.A-5) gave considerably lower entrainment at the NDD under PP (water-year-type means of 0.00-0.01 percent in March–May, and 0.03-0.05 percent in June) than with the unadjusted original values, but only slightly less of a relative difference between NAA and PP in total entrainment: for example, in April, the mean total entrainment was 18 percent greater under PP in wet years (compared to 22 percent without the adjustment), 1 percent greater under PP in above normal years (compared to 2 percent without the adjustment), 35 percent greater under PP in above normal years (compared to 37 percent without the adjustment), 22 percent greater under PP in dry years (compared to 22 percent without the adjustment), and 13 percent greater under PP in above normal years (compared to 14 percent without the adjustment).

For the DSM2-PTM analysis described here for larval/juvenile Delta Smelt, there is little difference in entrainment at the NBA, reflecting similar operations under the PP and NAA (Table 4.1-17).

The results of the DSM2-PTM modeling do not incorporate real-time management that will occur under both the NAA and PP, incorporating the latest information gained from the results of coordinated monitoring and research under the Collaborative Science and Adaptive Management

[17] 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.

Program about fish distribution and other factors that 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 4.1.3.4 *Head of Old River Gate Operations.*

Table 4.1-17. 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	PP	PP vs. NAA[2]	NAA	PP	PP vs. NAA[2]	NAA	PP	PP vs. NAA[2]	NAA	PP	PP vs. NAA[2]	NAA	PP	PP 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 project (PP) than under the no action alternative (NAA).

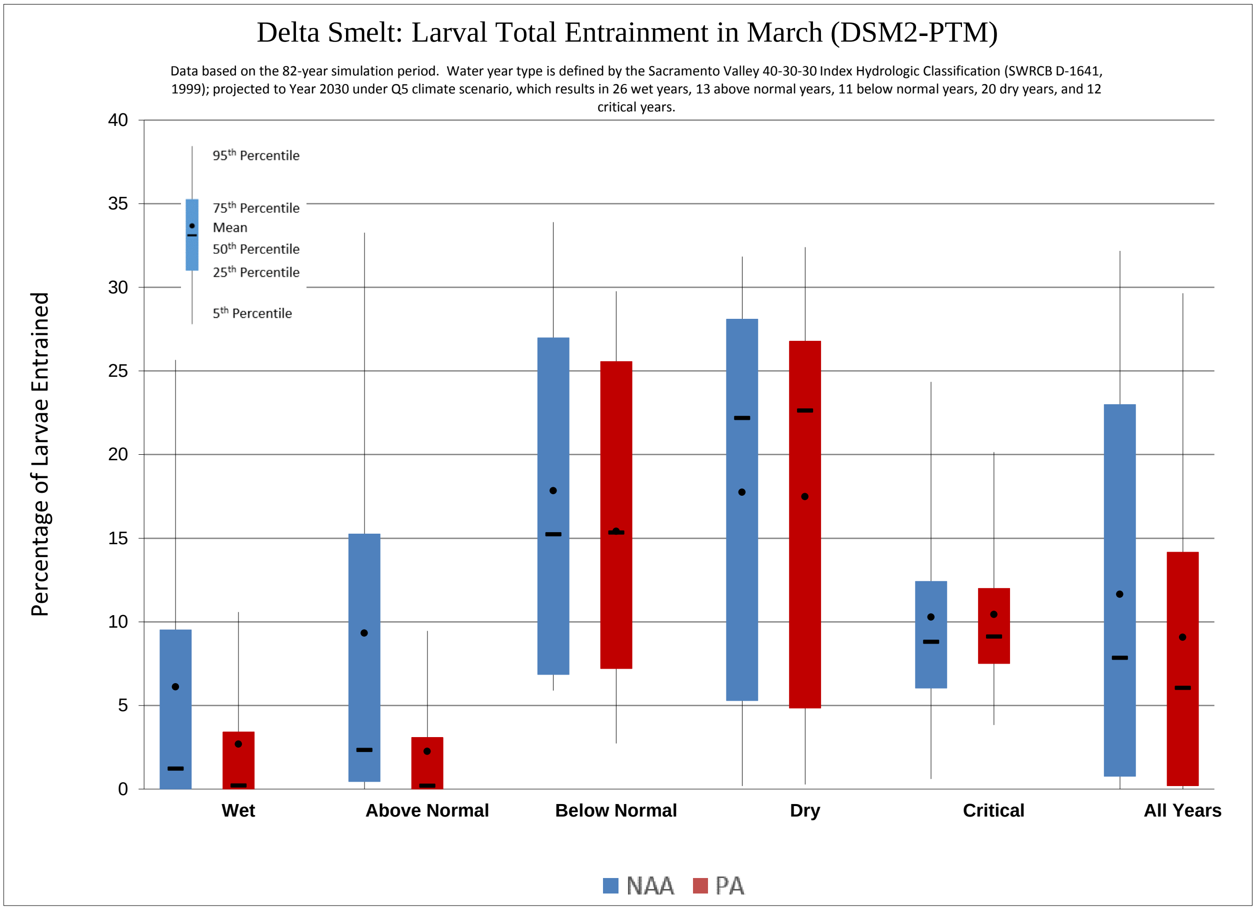


Figure 4.1-18. Box Plot of Percentage of Particles Representing Delta Smelt Larvae Entrained over 30 Days into Clifton Court Forebay (State Water Project), Jones Pumping Plant (Central Valley Project), the North Delta Diversion, and the North Bay Aqueduct Barker Slough Pumping Plant, Grouped by Water Year Type, from DSM2 Particle Tracking Modeling of March 1922–2003

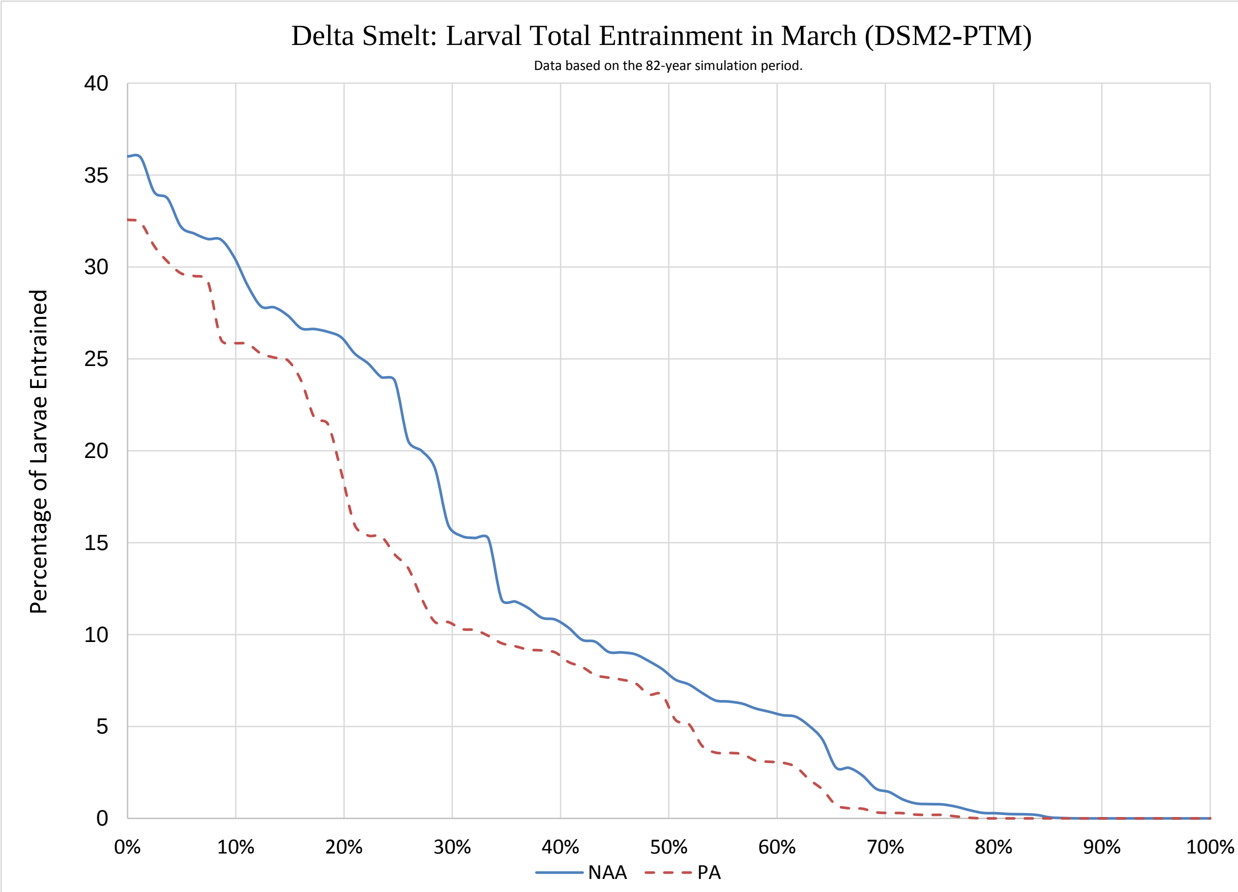


Figure 4.1-19. Exceedance Plot of Percentage of Particles Representing Delta Smelt Larvae Entrained over 30 Days into Clifton Court Forebay (State Water Project), Jones Pumping Plant (Central Valley Project), the North Delta Diversion, and the North Bay Aqueduct Barker Slough Pumping Plant, Grouped by Water Year Type, from DSM2 Particle Tracking Modeling of March 1922–2003

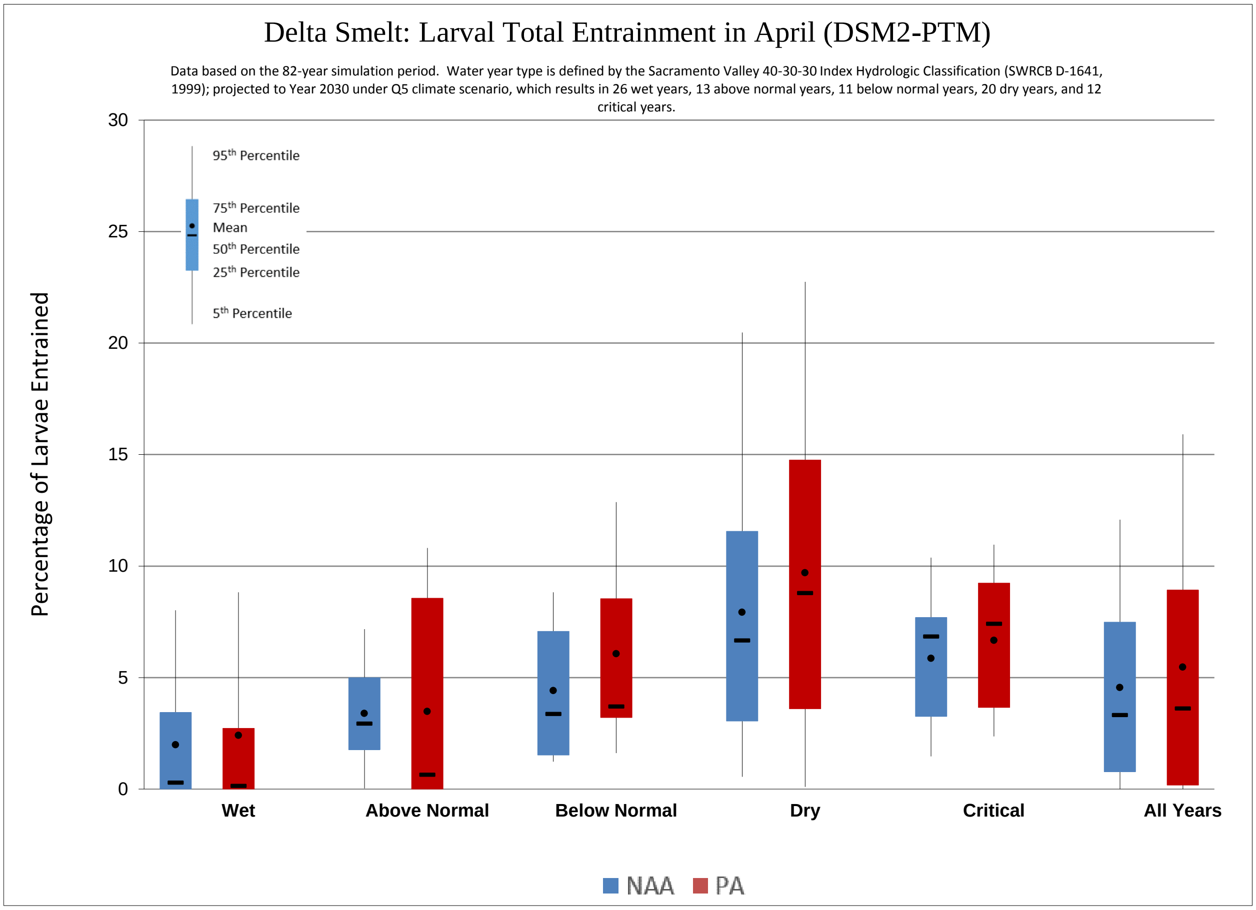


Figure 4.1-20. Box Plot of Percentage of Particles Representing Delta Smelt Larvae Entrained over 30 Days into Clifton Court Forebay (State Water Project), Jones Pumping Plant (Central Valley Project), the North Delta Diversion, and the North Bay Aqueduct Barker Slough Pumping Plant, Grouped by Water Year Type, from DSM2 Particle Tracking Modeling of April 1922–2003

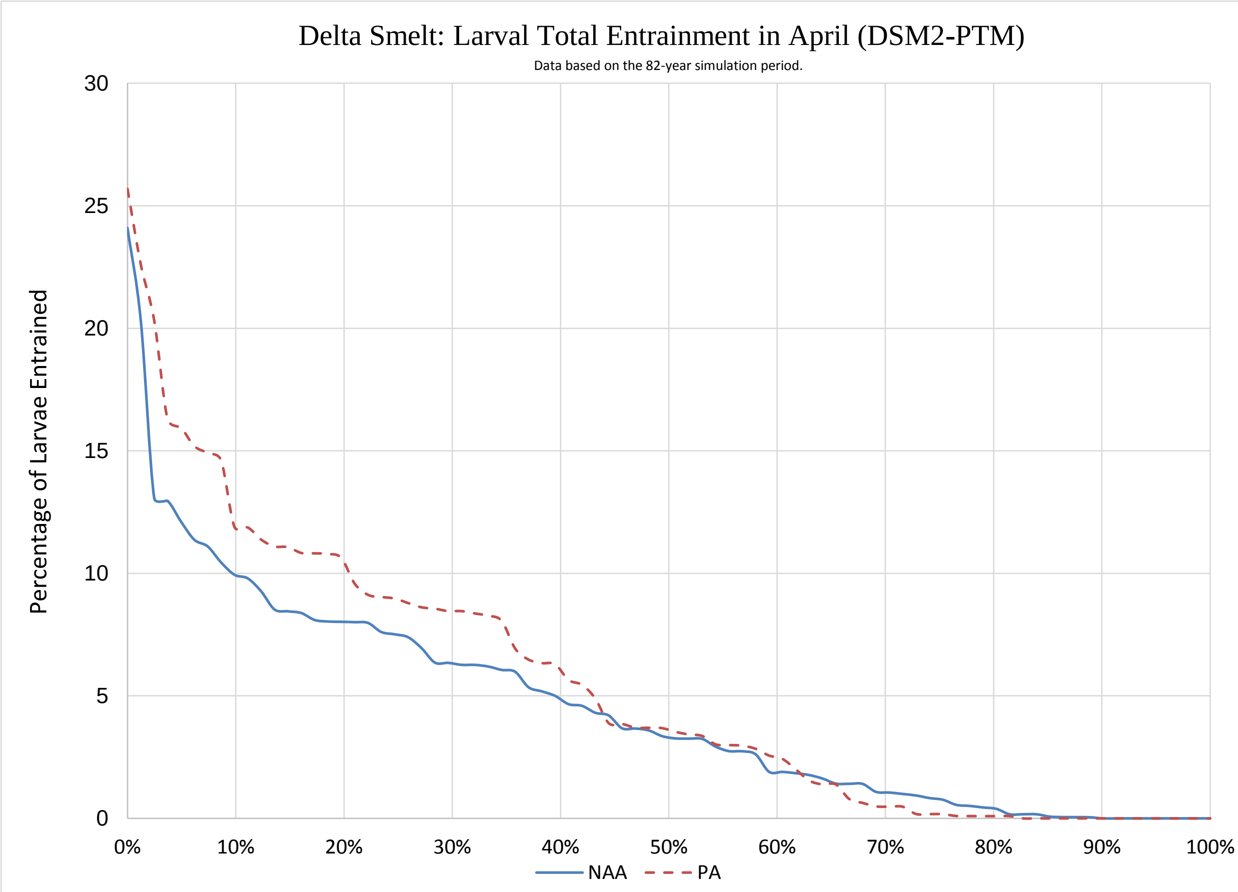


Figure 4.1-21. Exceedance Plot of Percentage of Particles Representing Delta Smelt Larvae Entrained over 30 Days into Clifton Court Forebay (State Water Project), Jones Pumping Plant (Central Valley Project), the North Delta Diversion, and the North Bay Aqueduct Barker Slough Pumping Plant, Grouped by Water Year Type, from DSM2 Particle Tracking Modeling of April 1922–2003

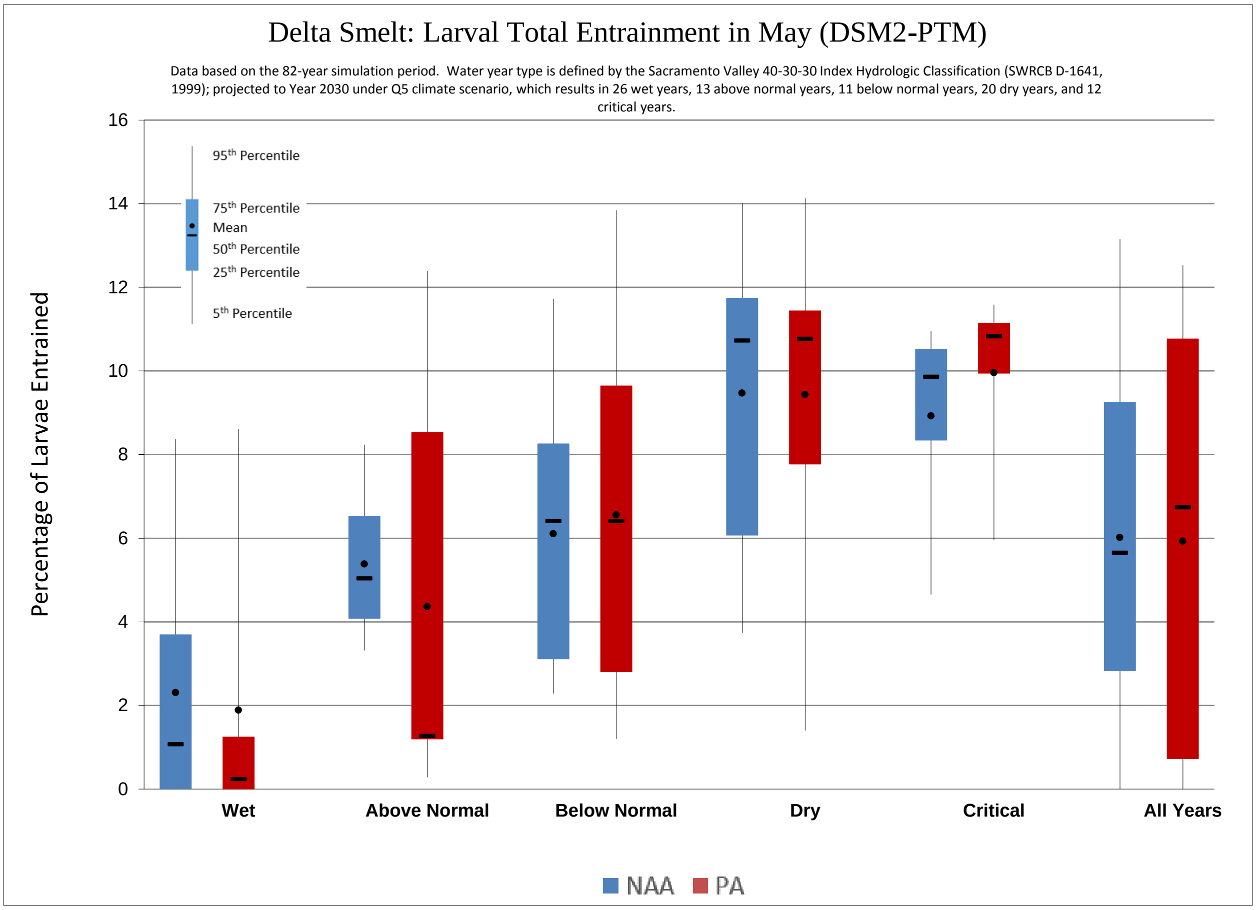


Figure 4.1-22. Box Plot of Percentage of Particles Representing Delta Smelt Larvae Entrained over 30 Days into Clifton Court Forebay (State Water Project), Jones Pumping Plant (Central Valley Project), the North Delta Diversion, and the North Bay Aqueduct Barker Slough Pumping Plant, Grouped by Water Year Type, from DSM2 Particle Tracking Modeling of May 1922–2003

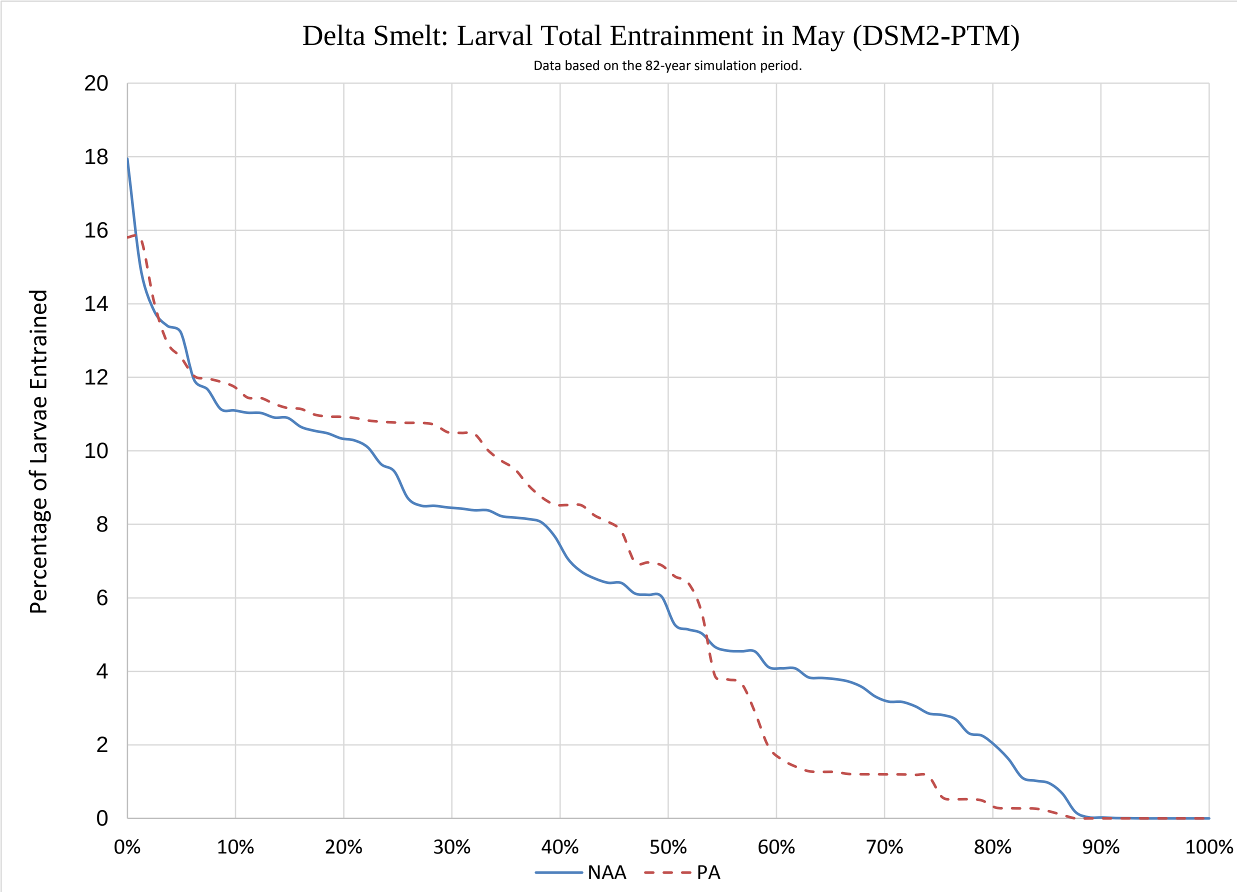


Figure 4.1-23. Exceedance Plot of Percentage of Particles Representing Delta Smelt Larvae Entrained over 30 Days into Clifton Court Forebay (State Water Project), Jones Pumping Plant (Central Valley Project), the North Delta Diversion, and the North Bay Aqueduct Barker Slough Pumping Plant, Grouped by Water Year Type, from DSM2 Particle Tracking Modeling of May 1922–2003

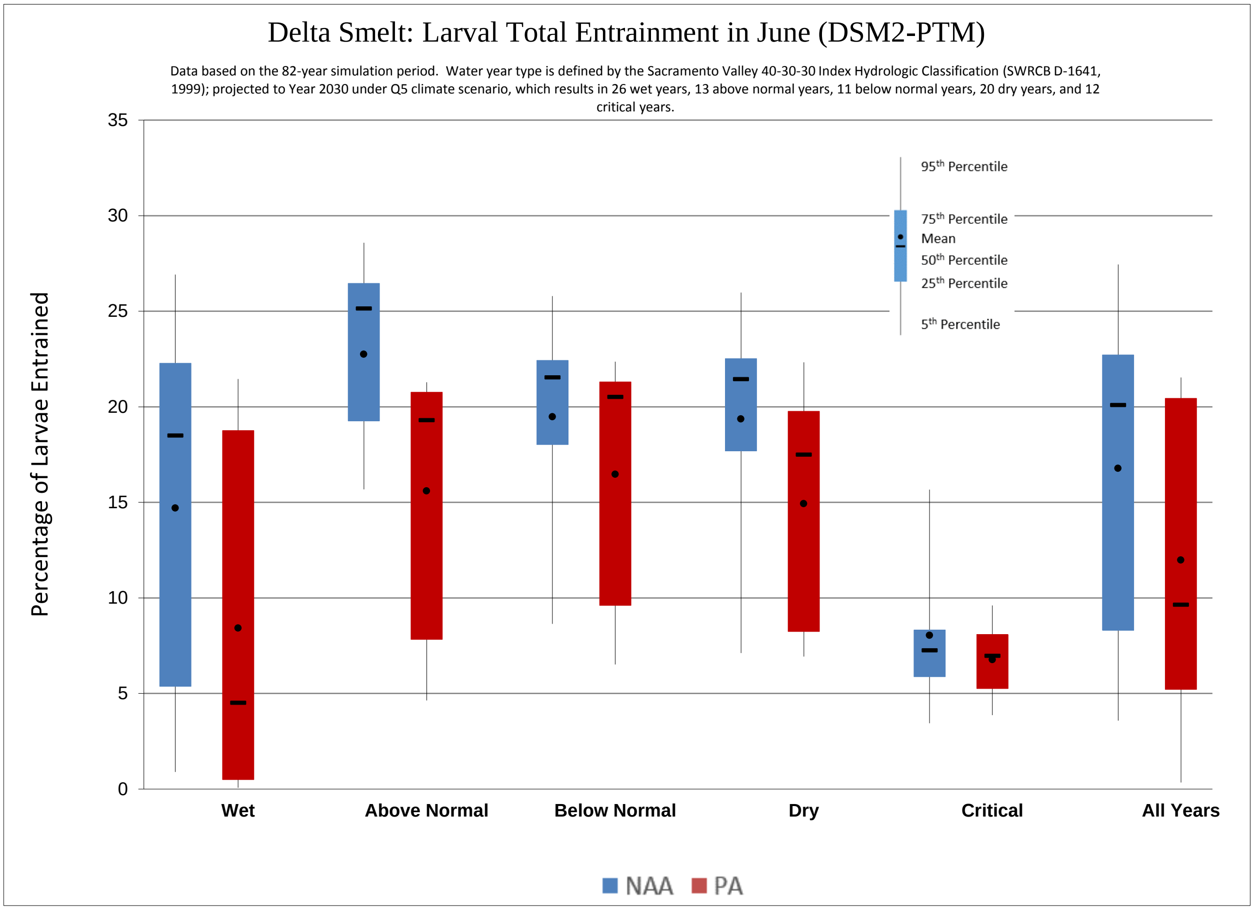


Figure 4.1-24. Box Plot of Percentage of Particles Representing Delta Smelt Larvae Entrained over 30 Days into Clifton Court Forebay (State Water Project), Jones Pumping Plant (Central Valley Project), the North Delta Diversion, and the North Bay Aqueduct Barker Slough Pumping Plant, Grouped by Water Year Type, from DSM2 Particle Tracking Modeling of June 1922–2003

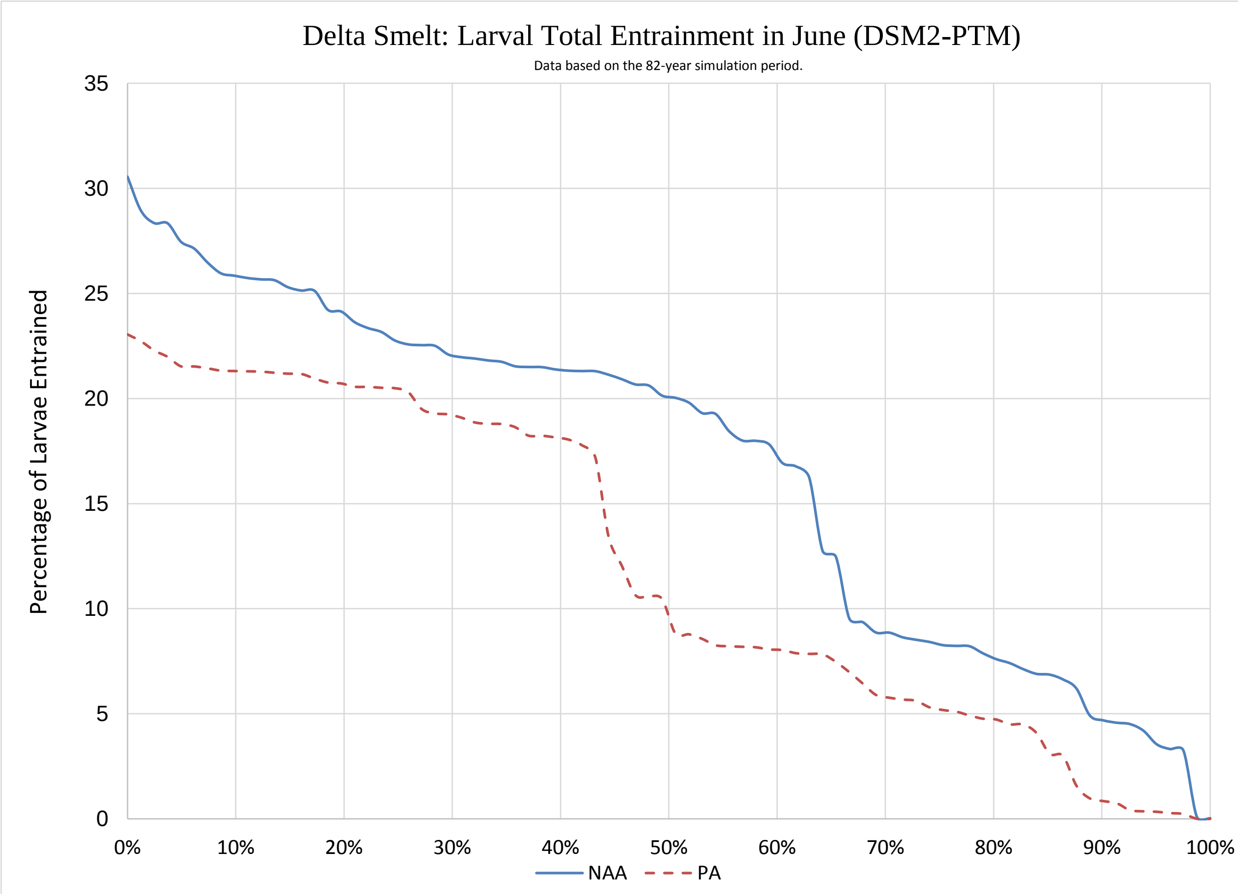


Figure 4.1-25. Exceedance Plot of Percentage of Particles Representing Delta Smelt Larvae Entrained over 30 Days into Clifton Court Forebay (State Water Project), Jones Pumping Plant (Central Valley Project), the North Delta Diversion, and the North Bay Aqueduct Barker Slough Pumping Plant, Grouped by Water Year Type, from DSM2 Particle Tracking Modeling of June 1922-2003

Table 4.1-18. Comparison of Trends in Delta Smelt Larval Entrainment Loss at the South Delta Export Facilities from the March–June Percentage Entrainment Regression and DSM2-PTM Results for March–June (Monthly Mean).

Water Year Type	Percentage Entrainment Regression[1]			DSM2-PTM Results (% Entrained at South Delta Only)		
	NAA	PP	PP vs. NAA[2]	NAA	PP	PP vs. NAA[1]
Wet	3.89	2.26	-1.63 (-42%)	5.09	2.48	-2.61 (-51%)
Above Normal	8.26	5.07	-3.18 (-39%)	8.94	4.95	-3.98 (-45%)
Below Normal	16.20	15.54	-0.66 (-4%)	9.76	8.73	-1.03 (-11%)
Dry	16.36	16.17	-0.19 (-1%)	11.92	10.97	-0.94 (-8%)
Critical	22.18	22.43	0.25 (1%)	7.05	7.06	0.01 (0%)

Note:
1 Negative values indicate lower entrainment loss under the proposed project (PP) than under the no action alternative (NAA).

Table 4.1-19. Comparison of Trends in Delta Smelt Larval Entrainment Loss at the South Delta Export Facilities from the April–May Percentage Entrainment Regression and DSM2-PTM Results for April–May (Monthly Mean).

Water Year Type	Percentage Entrainment Regression[1]			DSM2-PTM Results (% Entrained at South Delta Only)		
	NAA	PP	PP vs. NAA[2]	NAA	PP	PP vs. NAA[1]
Wet	1.52	1.54	0.02 (2%)	0.97	0.92	-0.05 (-5%)
Above Normal	3.71	3.32	-0.38 (-10%)	2.72	2.12	-0.59 (-22%)
Below Normal	12.06	12.86	0.80 (7%)	2.97	3.93	0.96 (32%)
Dry	14.22	14.54	0.33 (2%)	6.80	7.56	0.76 (11%)
Critical	21.54	22.15	0.61 (3%)	6.21	7.08	0.88 (14%)

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

4.1.3.3.1.5 Juveniles (Summer/Fall: ~July–December)

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, U.S. Fish and Wildlife Service (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 CCF 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).

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

4.1.3.3.2 Predation at the South Delta Export Facilities

4.1.3.3.2.1 Migrating Adults (December–March)

The previously presented analyses of entrainment effects of the PP on migrating adult Delta Smelt at the south Delta export facilities incorporated predation loss, e.g., prescreen losses across CCF when estimating a percentage 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 4.1-13). Thus, a lower entrainment risk to individual Delta Smelt under the PP in relation to NAA, should decrease mortality rates experienced by the adult stock[18]. Given that a measurable proportion of the migrating adult Delta Smelt population can be lost to entrainment and associated predation, lower entrainment under PP should translate into lower overall adult mortality, compared to NAA.

4.1.3.3.2.2 Spawning Adults (February–June)

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).

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 PP should translate into lower overall adult mortality, compared to NAA.

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

As noted for entrainment at the south Delta export facilities, Delta Smelt eggs and embryos are demersal and adhesive and will 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 PP relative to NAA.

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

4.1.3.3.2.4 Larvae/Young Juveniles (Spring: ~March–June)

As summarized in Table 4.1-13, 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 percentage loss estimates described above, which were based on estimates from Kimmerer (2008). There is no additional effect to analyze under this impact mechanism.

4.1.3.3.2.5 Juveniles (Summer/Fall: ~July–December)

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

4.1.3.4 Head of Old River Gate Operations

4.1.3.4.1 Migrating Adults (December–March)

The potential for effects at the HOR gate is similar to the effects described for the south Delta Temporary Barriers Project (TBP), as previously noted by U.S. Fish and Wildlife Service (2008: 225-226). Unlike the rock barrier currently used in some years, however, HOR gate operations will 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), will be undertaken to limit adverse effects to Delta Smelt. U.S. Fish and Wildlife Service (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 U.S. Fish and Wildlife Service (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 will 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.

Over 2,300 beach seine samples[19] 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[20] from 1994 to 2011 resulted in the capture of 44 Delta Smelt, principally during March–June. As described above in the analysis of effects on individuals, 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.

4.1.3.4.2 Spawning Adults (February–June)

The effects to spawning adults are assumed to be the same as those described above for migrating individuals (Section 4.1.3.4.1 *Migrating Adults*).

4.1.3.4.3 Eggs/Embryos (Spring: March–June)

As noted for other potential effects of the PP, Delta Smelt eggs and embryos are demersal and adhesive, and so the potential hydrodynamic effects of the HOR gate will not result in adverse effects to individuals or to Delta Smelt populations.

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[19] 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.

[20] 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.

4.1.3.4.4 Larvae/Young Juveniles (Spring: March–June)

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 PP does not indicate that there will be a consistent decrease in the percentage entrainment of larval and small juvenile Delta Smelt, in part because of the modeling assumption about the frequency of HOR gate closures during spring.

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 from the structures themselves.

4.1.3.4.5 Juveniles (Summer/Fall: ~July–December)

Effects to individual juvenile Delta Smelt from HOR gate operations will be similar to those for adult Delta Smelt, in terms of potential for broad-scale and local 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 impacts from the structures themselves.

4.1.3.5 Habitat Effects

4.1.3.5.1 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 U.S. Fish and Wildlife Service (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 U.S. Fish and Wildlife Service (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 PP and this section compares results for PP versus NAA using the abiotic habitat index of Feyrer *et al.* (2011); there is scientific debate and uncertainty regarding this method (described in ICF International [2016], Appendix 6.A *Quantitative Methods for Biological Assessment of Delta Smelt*). Year-around summaries of X2 are provided in ICF International (2016, 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]).

4.1.3.5.1.1 Juveniles (Fall: ~September–December)

As described by U.S. Fish and Wildlife Service (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. U.S. Fish and Wildlife Service (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 U.S. Fish and Wildlife Service (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*, the fall X2 action from the U.S. Fish and Wildlife Service (2008) BiOp has also been proposed to be included in the PP, provided 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 ESA-designated critical habitat for those species. Thus, no meaningful difference in fall abiotic habitat index is expected. To confirm this, a quantitative examination of the PP effects on abiotic habitat suitability was undertaken based on the abiotic habitat index method of Feyrer *et al.* (2011) (ICF International [2016], 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 PP emphasizes that there will be little difference in fall outflow management under the PP in all water year types, relative to NAA (Table 4.1-20; Figure 4.1-26 and Figure 4.1-27), as a result of the inclusion of the same water operations criteria for fall X2[21].

The independent review panel report for the working draft BA recommended that the more recent analysis of Bever et al. (2016) be adapted to assess the potential effects of the PP in relation to the NAA (Simenstad et al. 2016). Bever et al. (2016) found that in addition to salinity and water clarity, low current speed is also an important component of fall abiotic habitat for juvenile Delta Smelt. The independent review panel recommended that the abiotic station index of Bever et al. (2016) be modified to include only salinity and current speed, given that water clarity is not readily modeled. Such an analysis is not included herein for two main reasons.

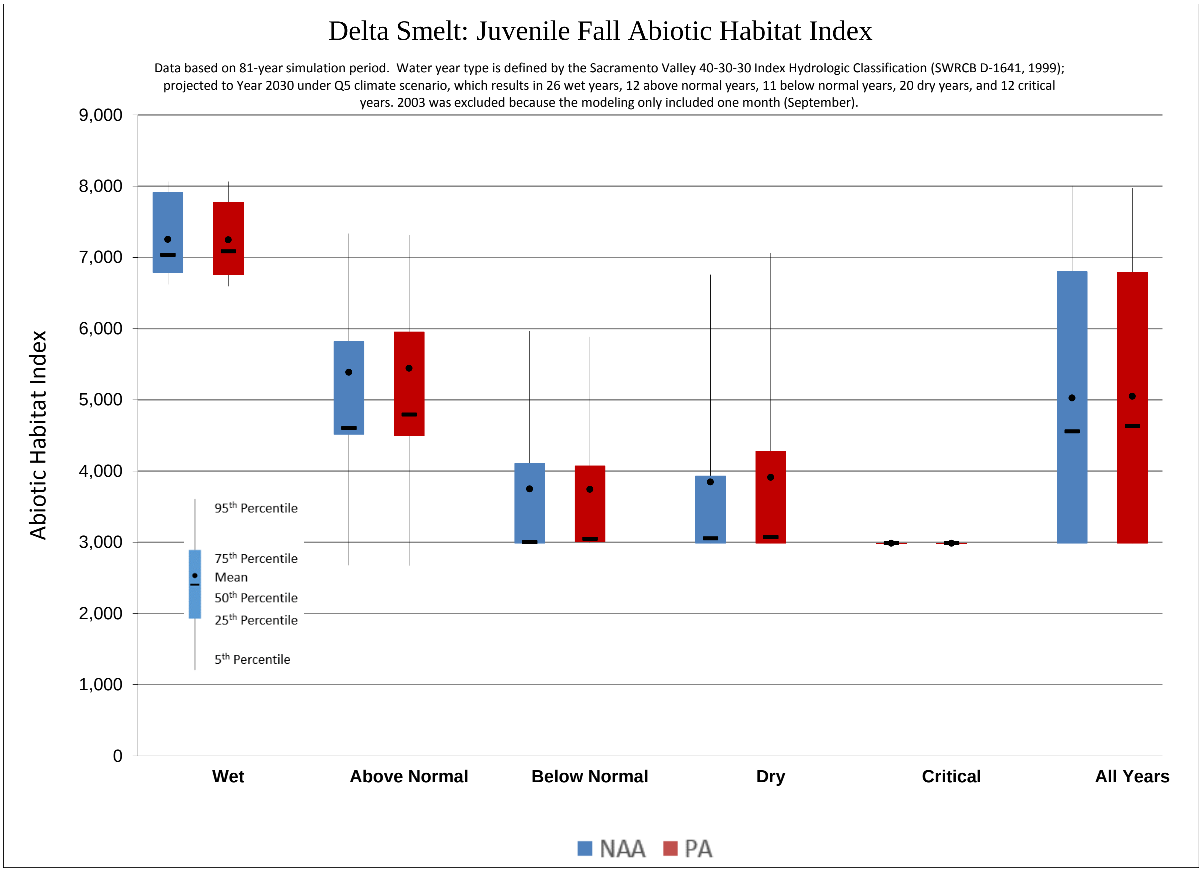
[21] The independent review panel report for the working draft BA noted—with respect to predictions based on regressions equations incorporating uncertainty, e.g., for prediction intervals such as those shown in Figure 6.1-24—that it is possible that the true annual values could lie near the bottom boundary of the prediction interval for PP and near the top boundary of the prediction interval for NAA (Simenstad et al. 2016). However, in this case, given that water operations in the fall have the same criteria for fall X2, it is expected that the abiotic habitat index would be similar between NAA and PP, as suggested by the mean values.

First, the inclusion of fall X2 water operations criteria for both the NAA and PP results in little difference in expected abiotic habitat, as illustrated above for the method based on Feyrer et al. 2011. Second, the additional abiotic variable highlighted by Bever et al. (2016) as an important component of habitat is current speed, which would be essentially unaffected by operations, even if operations were markedly different; see Figure 11D-F of Bever et al. (2016). This is because of the considerable tidal influences on current speed in the low salinity areas of greatest importance to Delta Smelt, e.g., during a typical summer tidal cycle, the flow near Pittsburg can vary from 330,000 cfs upstream to 340,000 cfs downstream.[22]

Table 4.1-20. Mean Fall Abiotic Habitat Index, Based on the Method of Feyrer *et al.* (2011).

Water Year Type	NAA	PP	PP vs. NAA[1]
All	4,977	4,995	18 (0%)
Wet	7,131	7,126	-6 (0%)
Above Normal	5,366	5,406	40 (1%)
Below Normal	3,723	3,725	2 (0%)
Dry	3,822	3,889	67 (2%)
Critical	2,994	2,977	-17 (-1%)

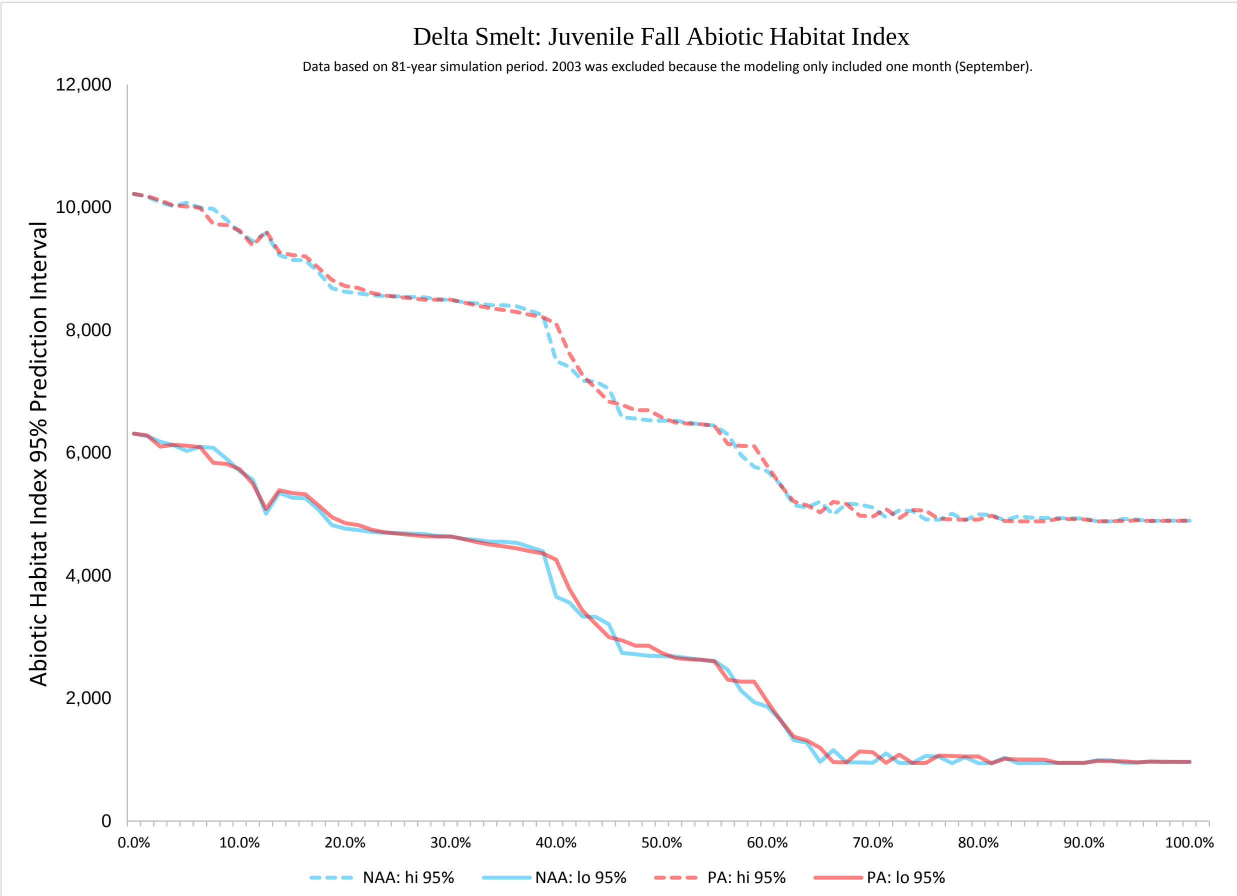
Note:
[1] Negative values indicate lower abiotic habitat index under the proposed project (PP) than under the no action alternative (NAA).



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

22 http://baydeltaoffice.water.ca.gov/DeltaAtlas/03-Waterways.pdf. Accessed: July 13, 2016.

Figure 4.1-26. Box Plot of Mean Fall Abiotic Habitat Index, Grouped by Water Year Type, Based on the Method of Feyrer *et al.* (2011)



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

Figure 4.1-27. Exceedance Plot of Mean Fall Abiotic Habitat Index, Based on the Method of Feyrer *et al.* (2011).

4.1.3.5.2 Water Temperature

As noted in the take analysis for Chinook salmon (Section 4.3 *Take of Winter-Run Chinook Salmon* and Section 4.4 *Take of Spring-Run Chinook Salmon*), 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. U.S. Fish and Wildlife Service (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 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 PP with respect to dual conveyance means that it is prudent to investigate whether water temperature would differ between the NAA and the PP, and if so, why. To do this, DSM2-QUAL modeling was undertaken to predict water temperatures for the NAA and PP 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 ICF International (2016, Appendix 5.B *DSM2 Methods and Results*, Attachment 5.B.A.4 *DSM2 Temperature Modeling*), with results in ICF International (2016, Appendix 5.B *DSM2 Methods and Results,* Section 5.B.5 *DSM2 Results*). 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 ICF International (2016, Appendix 5.B *DSM2 Methods and Results,* Attachment 5.B.A.4 *DSM2 Temperature Modeling*), 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.

4.1.3.5.2.1 Migrating Adults (December–March)

From examination of exceedance plots of Rio Vista mean water temperatures (ICF International [2016], Appendix 5.B *DSM2 Methods and Results,* Figure 5.B.5.40-1), the only discernible differences in water temperature were in March, and these were small differences (~0.1°C greater under PP). At Prisoners Point (ICF International [2016], Appendix 5.B *DSM2 Methods and Results*, Figure 5.B.5.41-1), 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 PP were modeled, these were during a relatively cool part of the year and therefore would not affect migrating adults in that portion of the Delta.

From examination of exceedance plots of Rio Vista mean water temperatures (ICF International [2016], Appendix 5.B *DSM2 Methods and Results,* Figure 5.B.5.40-1), there were no discernible differences in water temperature (maximum "differences" were well within model noise, e.g., ~0.1°C greater under PP in March). At Prisoners Point (ICF International [2016], Appendix 5.B *DSM2 Methods and Results,* Figure 5.B.5.41-1), 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.

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

4.1.3.5.2.2 Spawning Adults (February–June)

As described previously for migrating adult Delta Smelt, there might be slightly greater water temperatures under PP 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 California Department of Fish and Wildlife Spring Kodiak Trawling Data at: 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).

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 will affect egg supply. As described above, it is uncertain whether the PP will actually affect water temperature in the Delta, but if it does, that effect will be very minor and very localized. Thus, it is unlikely that project effects on water temperature will translate into a population-level effect on Delta Smelt. Air temperature is generally the main driver on water temperature in the Delta, as shown by detailed temperature modeling that does not include the effects of flow and has higher correspondence with observed temperatures than DSM2-QUAL estimates (Wagner *et al.* 2011).

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

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 will be little if any difference in temperature between NAA and PP 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 PP will be slightly closer toward optimum hatching temperature than under NAA (ICF International [2016], Appendix 5.B *DSM2 Methods and Results,* Figure 5.B.5.41-1), whereas in May, temperatures under PP 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 PP could give a 0.5-day shorter incubation time for Delta Smelt occurring in the lower San Joaquin River.

The slightly greater Prisoners Point water temperature under PP 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 will 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 is a lower proportion of the population than occurs in the north Delta. As previously noted, air temperature will remain the main driver on water temperature in the Delta (Wagner *et al.* 2011), and the differences between PP and NAA scenarios are very small.

4.1.3.5.2.4 Larvae/Young Juveniles (Spring: ~March–June)

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 PP 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 (ICF International [2016], Appendix 5.B *DSM2 Methods and Results*, Figures 5.B.5.41-3 to 5.B.5.41-6; although as noted previously, it is not appropriate to examine more than general patterns when comparing the NAA and PP scenarios).

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 will 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 may be subject to slightly higher water temperatures. However, as previously noted, air temperature will remain the main driver on water temperature in the Delta and flow effects will be of minor importance (Wagner *et al.* 2011).

4.1.3.5.2.5 Juveniles (Summer/Fall: ~July–December)

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 will be similar or slightly warmer under the PP 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 percent years indicated about 0.1–0.2°C greater temperature under the PP (ICF International [2016], Appendix 5.B *DSM2 Methods and Results*, Figure 5.B.5.40-1 and Figure 5.B.5.41-1)

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).

4.1.3.5.3 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 percent 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 NDDs will 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. California Department of Water Resources and U.S. Bureau of Reclamation (2013) presented 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 California Department of Water Resources and U.S. Bureau of Reclamation [2013], Appendix 5.C *Flow, Passage, Salinity, and Turbidity*, Section 5C.D.3). For the present effects analysis of the PP, 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 percent (range: 5–15 percent) of combined sediment load entering the Delta from combined inflow at Freeport and the Yolo Bypass will be removed by the NDDs. Considering only the Sacramento River load at Freeport, it was estimated that a mean of 11 percent (range: 7–16 percent) of sediment load will be removed by the NDDs. If this sediment, some of which will be collected in the sedimentation basins (described in Section 3.2.2 *North Delta Diversions*) 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 PP; based on the estimates by Wright and Schoellhamer (2005), sediment removal by the south Delta export facilities in 1999-2002 averaged around 2 percent 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 PP (NDD exports, also less south Delta exports than NAA) will be appreciably greater than sediment removal under NAA. As described in Section 3.2.10.6 *Dispose Spoils*, 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 will mitigate the effects of sediment removal by the NDD.

4.1.3.5.3.1 Migrating Adults (December–March)

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 4.1-21), removal of sediment by the NDD may have limited adverse effects on individual Delta Smelt because the transparency of inflowing Sacramento River water would not change 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.

Following from this consideration of individual-level effects, population-level adverse effects on migrating adult Delta Smelt from sediment removal by the NDDs 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 NDDs 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 4.1-21. 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: U.S. Geological Survey (2015)	

4.1.3.5.3.2 Spawning Adults (February–June)

Given the timing of the upstream migration in the often high-flow winter months, during which suspended sediment concentration is greatest (Table 4.1-21), removal of sediment by the NDDs may have limited adverse effects on individual Delta Smelt because the transparency of inflowing Sacramento River would not change 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 to mitigate the effects of sediment removal by the NDDs.

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 above, proposed sediment reintroduction will mitigate any effects of sediment removal by the NDDs.

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

Increases in water clarity during the latter parts of spring when river inflow's suspended sediment concentration goes down (Table 4.1-21) 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 will mitigate any effects of sediment removal by the NDDs.

As noted for spawning Delta Smelt, the population-level impacts 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 above, proposed sediment reintroduction will mitigate any effects of sediment removal by the NDDs.

4.1.3.5.3.4 Larvae/Young Juveniles (Spring: ~March–June)

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 the proposed sediment reintroduction plan will mitigate any effects of sediment removal by the NDDs.

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 above, proposed sediment reintroduction will mitigate any effects of sediment removal by the NDDs.

4.1.3.5.3.5 Juveniles (Summer/Fall: ~July–December)

Occurrence of juvenile Delta Smelt during the low-flow time of year when suspended sediment concentration in inflow is at a minimum (Table 4.1-21) 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 the proposed sediment reintroduction plan will mitigate any effects of sediment removal by the NDDs.

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 above, proposed sediment reintroduction will mitigate any effects of sediment removal by the NDD.

4.1.3.5.4 Entrainment of Food Web Materials

As highlighted by Arthur *et al.* (1996), Jassby and Cloern (2000) and Jassby *et al.* (2002), and the U.S. Fish and Wildlife Service (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 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 at the same time (*e.g.*, clam grazing and ammonium inhibition of per capita diatom growth rates). Entrainment of phytoplankton and zooplankton by the south Delta export facilities generally will be somewhat less under the PP compared to NAA, but the NDDs will add a new source of loss along the Sacramento River. This impact 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, scaled up to the volume of the Delta). The methods for this analysis are presented in ICF International (2016, Appendix 6.A *Quantitative Methods for Biological Assessment of Delta Smelt*, Section 6A.4.2). This analysis is essentially an approximation of phytoplankton carbon load that could be entrained by the NDDs. Factors that could offset any potential effects to Delta Smelt include the *in situ* productivity of phytoplankton carbon within the Delta, which may be large, and reduced entrainment of phytoplankton carbon by the south Delta export facilities under the PP. These factors, which vary substantially by water year type, are discussed qualitatively in the analysis.

Median (50^{th} percentile) estimates of phytoplankton carbon load entrained by the NDDs ranged from around 0.2 metric tons/day in April and May (5^{th} to 95^{th} percentile ranges were 0.01 to 1.8 metric tons/day) to 1.6 metric tons/day in February (5^{th} to 95^{th} percentile range 0.13 to 5.7 metric tons/day) (Table 4.1-22). 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 4.1-23). Thus, the percentage of Delta phytoplankton carbon biomass estimated to be entrained by the NDDs ranges from 0.0 percent based on the 5^{th} percentile of entrained load estimates at the NDDs during several months up to 12 percent at the 95^{th} percentile load estimate combined with the minimum biomass estimate in December (Table 4.1-24). The median estimates of total fraction of phytoplankton biomass removed by the NDDs ranged from 0.5 percent to 2 percent per month when compared to minimum Delta phytoplankton carbon biomass estimates, down to 0.1 percent to 1 percent when compared to maximum Delta phytoplankton carbon biomass estimates. On the basis of the 95th percentiles, it appears that the NDDs will seldom if ever entrain more than 5 percent of the Delta's standing stock of phytoplankton in any given month.

Table 4.1-22. 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 4.1-23. 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 4.1-24. 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 NDDs 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 NDDs will 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 PP 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 percent less under PP in January to 70 percent less in October; only in December (12 percent less under the PP) were the differences not close to half or more (ICF International [2016], 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 percent (Jassby *et al.* 2002)[23]. It is anticipated that the overall long-term 50 percent reduction in south Delta exports will increase the loading of relatively productive San Joaquin River water to the western Delta and Suisun Bay (Table 4.1-25) and therefore should offset some or all of the loss attributable to the NDDs, and perhaps could even provide a net beneficial effect.

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

Table 4.1-25. 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	PP	PP vs. NAA	NAA	PP	PP vs. NAA	NAA	PP	PP vs. NAA	NAA	PP	PP vs. NAA	NAA	PP	PP vs. NAA
Jan	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 PP and NAA: total Delta exports on average (1922–2003) would be somewhat greater under PP (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 PP than NAA in September–November; similar in April–May and August; and generally lower under PP than NAA in the remaining months, to varying degrees (ICF International [2016], 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 percent. However, the timing of differences in exports in relation to different life stages and location of exports is important, and consideration should also be made of *in situ* productivity 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.

4.1.3.5.4.1 Migrating Adults (December–March)

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 will most likely fall between no effect and some immeasurably small impact on growth rates of individual fish.

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.

4.1.3.5.4.2 Spawning Adults (February–June)

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 will most likely fall between no effect and some immeasurably small impact on growth rates of individual fish.

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.

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

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

4.1.3.5.4.4 Larvae/Young Juveniles (Spring: ~March–June)

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 percent to over 5 percent of phytoplankton carbon in the Delta could be entrained by the NDD in March–June (Table 4.1-24). 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.

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 acts 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 percent at the higher end 95th percentile (Table 4.1-23). 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 NDDs 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 4.1-25).

4.1.3.5.4.5 Juveniles (Summer/Fall: ~July–December)

The empirical evidence for food limitation during the juvenile 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 percent of phytoplankton standing stock could be entrained by the NDDs (95th percentile for high end estimates; Table 4.1-24). 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.

The reduction in prey available for juvenile Delta Smelt because of NDD exports could 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.

4.1.3.5.5 Microcystis

The toxic cyanobacterium, *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)[24]. 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 PP scenarios, which introduces some uncertainty to the results.

The potential effects of PP 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 4.1.3.5.2 *Water Temperature*) and DSM2-PTM for estimates of residence time (ICF International [2016], 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 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 PP 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[25]. This analysis suggested that flow conditions conducive to *Microcystis* bloom occurrence will tend to occur less frequently under the PP 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 percent in October to 98 percent in August, whereas for PP, the range was from 9 percent of years in October to 99 percent of years in August (Table 4.1-26). In neither the NAA nor the PP scenario were mean monthly flows below

[24] 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.

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

the range noted for *Microcystis* occurrence, whereas for PP there were substantially more years above the range than for NAA. The results reflected greater mean QWEST flows under the NAA compared to PP, with monthly means under the PP 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 PP than NAA.

Table 4.1-26. 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				PP			
	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 PP would result in less Sacramento River flow compared to NAA, as reflected in the examination of QRIO (Table 4.1-27). The percentage of years within the range at which *Microcystis* has been noted to occur ranged from 59 percent in September to 89 percent in August under NAA, compared to a range from 48 percent in September to 96 percent in July for PP (Table 4.1-27). 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.* (2013: 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 PP than NAA in July (0 percent, compared to 10 percent under NAA), September (0 percent, compared to 29 percent under NAA), and November (10 percent, compared to 16 percent 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 PP than NAA. However, this is presently not an area of intense *Microcystis* blooms and if it remains sufficiently turbid in the future, it is expected that current conditions will continue[26].

[26] As previously described in Section 4.1.3.5.3 *Sediment Removal (Water Clarity)*, there is the potential for removal of suspended sediment by the NDD and reduced water clarity, which would be minimized by sediment reintroduction. Long-term increases in water clarity in the future could affect *Microcystis* potential for occurrence, irrespective of the PP, although this is uncertain.

Table 4.1-27. 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					PP			
	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 PP on hydraulic residence time are highest. The effects of the PP 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 percentage changes in residence time (e.g., locations near the NDDs) and regions with comparatively long residence times typically had moderate to low percentage changes in residence time (Table 4.1-28 through Table 4.1-48). Differences between NAA and PP 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 4.1-28. Summary Statistics of Residence Time (Days) in the Upper Sacramento River Subregion from DSM2-PTM.

Percentile	July			August			September			October			November		
	NAA	PP	PP vs. NAA	NAA	PP	PP vs. NAA	NAA	PP	PP vs. NAA	NAA	PP	PP vs. NAA	NAA	PP	PP vs. NAA
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 4.1-29. Summary Statistics of Residence Time (Days) in the Sacramento River Near Ryde Subregion from DSM2-PTM.

Percentile	July			August			September			October			November		
	NAA	PP	PP vs. NAA	NAA	PP	PP vs. NAA	NAA	PP	PP vs. NAA	NAA	PP	PP vs. NAA	NAA	PP	PP vs. NAA
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 4.1-30. Summary Statistics of Residence Time (Days) in the Sacramento River Ship Channel Subregion from DSM2-PTM.

Percentile	July			August			September			October			November		
	NAA	PP	PP vs. NAA	NAA	PP	PP vs. NAA	NAA	PP	PP vs. NAA	NAA	PP	PP vs. NAA	NAA	PP	PP vs. NAA
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 4.1-31. Summary Statistics of Residence Time (Days) in the Cache Slough and Liberty Island Subregion from DSM2-PTM.

Percentile	July			August			September			October			November		
	NAA	PP	PP vs. NAA	NAA	PP	PP vs. NAA	NAA	PP	PP vs. NAA	NAA	PP	PP vs. NAA	NAA	PP	PP vs. NAA
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 4.1-32. Summary Statistics of Residence Time (Days) in the Sacramento River Near Rio Vista Subregion from DSM2-PTM.

Percentile	July			August			September			October			November		
	NAA	PP	PP vs. NAA	NAA	PP	PP vs. NAA	NAA	PP	PP vs. NAA	NAA	PP	PP vs. NAA	NAA	PP	PP vs. NAA
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 4.1-33. Summary Statistics of Residence Time (Days) in the Lower Sacramento River Subregion from DSM2-PTM.

Percentile	July			August			September			October			November		
	NAA	PP	PP vs. NAA	NAA	PP	PP vs. NAA	NAA	PP	PP vs. NAA	NAA	PP	PP vs. NAA	NAA	PP	PP vs. NAA
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 4.1-34. Summary Statistics of Residence Time (Days) in the Lower San Joaquin River Subregion from DSM2-PTM.

Percentile	July			August			September			October			November		
	NAA	PP	PP vs. NAA	NAA	PP	PP vs. NAA	NAA	PP	PP vs. NAA	NAA	PP	PP vs. NAA	NAA	PP	PP vs. NAA
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 4.1-35. 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	PP	PP vs. NAA	NAA	PP	PP vs. NAA	NAA	PP	PP vs. NAA	NAA	PP	PP vs. NAA	NAA	PP	PP 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 4.1-36. Summary Statistics of Residence Time (Days) in the San Joaquin River at Prisoners Point from DSM2-PTM.

Percentile	July			August			September			October			November		
	NAA	PP	PP vs. NAA	NAA	PP	PP vs. NAA	NAA	PP	PP vs. NAA	NAA	PP	PP vs. NAA	NAA	PP	PP vs. NAA
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 4.1-37. 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	PP	PP vs. NAA	NAA	PP	PP vs. NAA	NAA	PP	PP vs. NAA	NAA	PP	PP vs. NAA	NAA	PP	PP 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 4.1-38. Summary Statistics of Residence Time (Days) in the Disappointment Slough Subregion from DSM2-PTM.

Percentile	July			August			September			October			November		
	NAA	PP	PP vs. NAA	NAA	PP	PP vs. NAA	NAA	PP	PP vs. NAA	NAA	PP	PP vs. NAA	NAA	PP	PP vs. NAA
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 4.1-39. Summary Statistics of Residence Time (Days) in the San Joaquin River Near Stockton Subregion from DSM2-PTM.

Percentile	July			August			September			October			November		
	NAA	PP	PP vs. NAA	NAA	PP	PP vs. NAA	NAA	PP	PP vs. NAA	NAA	PP	PP vs. NAA	NAA	PP	PP vs. NAA
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 4.1-40. Summary Statistics of Residence Time (Days) in the Mildred Island Subregion from DSM2-PTM.

Percentile	July			August			September			October			November		
	NAA	PP	PP vs. NAA	NAA	PP	PP vs. NAA	NAA	PP	PP vs. NAA	NAA	PP	PP vs. NAA	NAA	PP	PP vs. NAA
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 4.1-41. Summary Statistics of Residence Time (Days) in the Holland Cut Subregion from DSM2-PTM.

Percentile	July			August			September			October			November		
	NAA	PP	PP vs. NAA	NAA	PP	PP vs. NAA	NAA	PP	PP vs. NAA	NAA	PP	PP vs. NAA	NAA	PP	PP vs. NAA
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 4.1-42. Summary Statistics of Residence Time (Days) in the Franks Tract Subregion from DSM2-PTM.

Percentile	July			August			September			October			November		
	NAA	PP	PP vs. NAA	NAA	PP	PP vs. NAA	NAA	PP	PP vs. NAA	NAA	PP	PP vs. NAA	NAA	PP	PP vs. NAA
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 4.1-43. Summary Statistics of Residence Time (Days) in the Rock Slough and Discovery Bay Subregion from DSM2-PTM.

Percentile	July			August			September			October			November		
	NAA	PP	PP vs. NAA	NAA	PP	PP vs. NAA	NAA	PP	PP vs. NAA	NAA	PP	PP vs. NAA	NAA	PP	PP vs. NAA
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 4.1-44. Summary Statistics of Residence Time (Days) in the Old River Subregion from DSM2-PTM.

Percentile	July			August			September			October			November		
	NAA	PP	PP vs. NAA	NAA	PP	PP vs. NAA	NAA	PP	PP vs. NAA	NAA	PP	PP vs. NAA	NAA	PP	PP vs. NAA
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 4.1-45. Summary Statistics of Residence Time (Days) in the Middle River Subregion from DSM2-PTM.

Percentile	July			August			September			October			November		
	NAA	PP	PP vs. NAA	NAA	PP	PP vs. NAA	NAA	PP	PP vs. NAA	NAA	PP	PP vs. NAA	NAA	PP	PP vs. NAA
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 4.1-46. Summary Statistics of Residence Time (Days) in the Victoria Canal Subregion from DSM2-PTM.

Percentile	July			August			September			October			November		
	NAA	PP	PP vs. NAA	NAA	PP	PP vs. NAA	NAA	PP	PP vs. NAA	NAA	PP	PP vs. NAA	NAA	PP	PP vs. NAA
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 4.1-47. 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	PP	PP vs. NAA	NAA	PP	PP vs. NAA	NAA	PP	PP vs. NAA	NAA	PP	PP vs. NAA	NAA	PP	PP 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 4.1-48. Summary Statistics of Residence Time (Days) in the Upper San Joaquin River Subregion from DSM2-PTM.

Percentile	July				August				September				October				November		
	NAA	PP	PP vs. NAA		NAA	PP	PP vs. NAA		NAA	PP	PP vs. NAA		NAA	PP	PP vs. NAA		NAA	PP	PP vs. NAA
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%)

4.1.3.5.5.1 Migrating Adults (December–March)

Microcystis blooms occur during the summer and early fall so there will be no effect on migrating adult Delta Smelt during the winter months. As there will be no adverse effect to individual migrating adult Delta Smelt from *Microcystis*, there will likewise be no adverse population-level effect.

4.1.3.5.5.2 Spawning Adults (February–June)

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, or to harm the population of spawning adult Delta Smelt.

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

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.

4.1.3.5.5.4 Larvae/Young Juveniles (Spring: ~March–June)

There is some potential overlap in timing between larval life stages of Delta Smelt and *Microcystis* blooms. This impact is addressed in the discussion of the juvenile stage which has most of the seasonal overlap with blooms. Due to the very limited potential effects to individual larval/young juvenile Delta Smelt, there will be minimal population-level adverse effects to this life stage.

4.1.3.5.5.5 Juveniles (Summer/Fall: ~July–December)

As discussed in Section 4.1.3.5.2 *Water Temperature*, climate change is likely to increase summer water temperature but it is not clear whether the PP will change water temperature. The warming climate may however increase the length of the viable growing season for *Microcystis* blooms and that effect will interact with PP-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 PP (see previous discussion of timing shifts for spawning Delta Smelt), which will 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 PP generally would give somewhat less potential for *Microcystis* to occur in that area, relative to the NAA; under the PP, a greater percentage of years were above the range of flows at which *Microcystis* has occurred. Therefore, under the PP, 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).

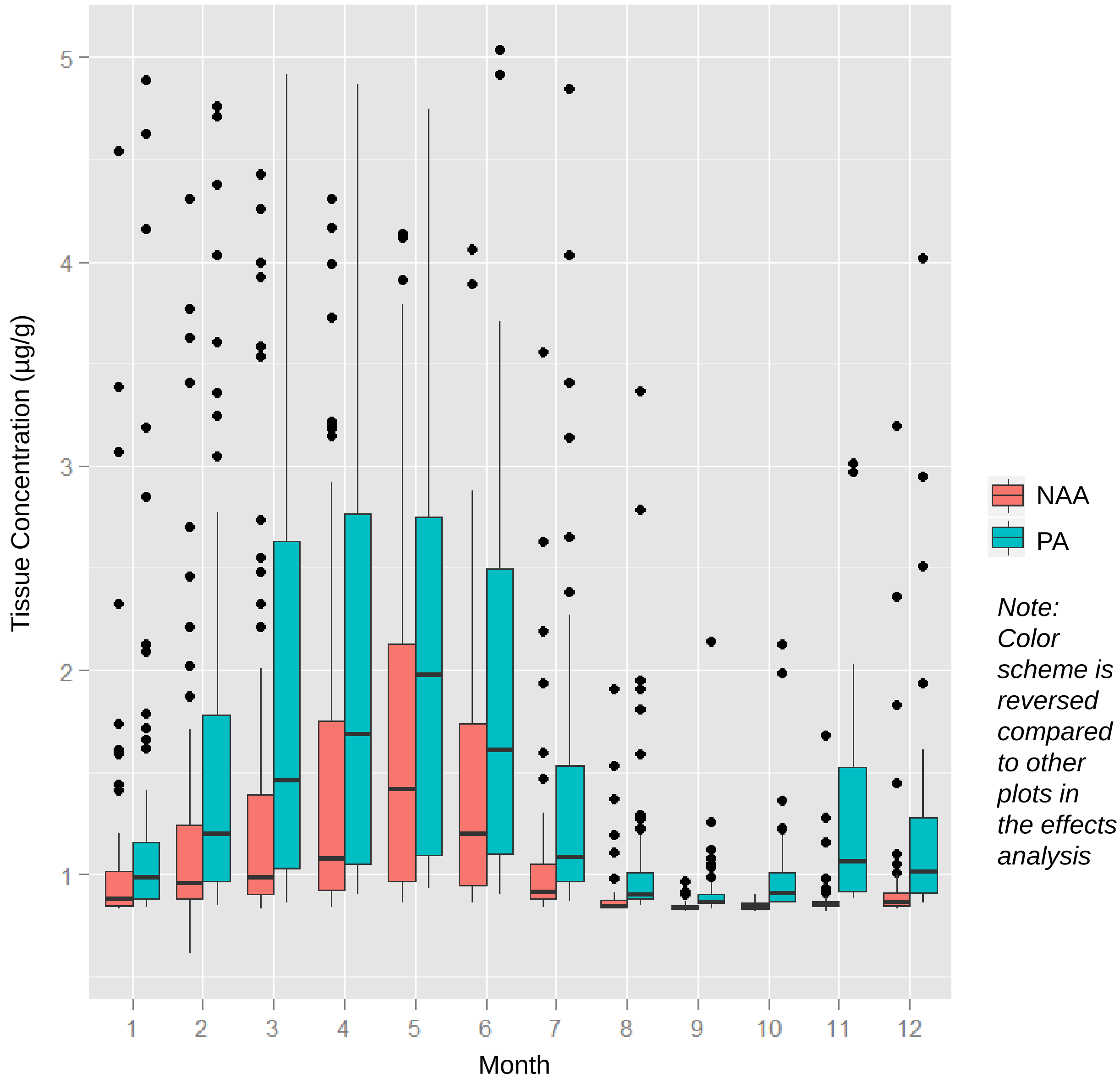
Most of the Delta Smelt population is not distributed in the southern Delta during the summer and fall because the water is too warm and too clear (Feyrer *et al.* 2007; Nobriga *et al.* 2008). Therefore, the Delta Smelt population does not overlap the peak of the *Microcystis* bloom in space and time. 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 will be less potential for *Microcystis* occurrence under the PP. 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 will be from the south Delta, with any additional allowable exports 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 will 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.

4.1.3.5.6 Selenium

The increase in the proportion of San Joaquin River water entering the Delta because of less south Delta exports under the PP would be expected to increase the selenium concentration in Delta water. The potential for this change to affect Delta Smelt through body deformities resulting from feeding on contaminated prey was investigated using the results of DSM2 volumetric fingerprinting estimates, Delta water source selenium input concentrations, conversions of water selenium concentration to particulate selenium concentration, and trophic transfer factors to estimate the concentration of selenium from Delta Smelt copepod prey to Delta Smelt tissue (see Section 6.A.4.4 *Selenium* in ICF International [2016], Appendix 6.A *Quantitative Methods for Biological Assessment of Delta Smelt*). As described in Section 6.A.4.4.4 *Modeling Assumptions*, this analysis has a number of assumptions leading to uncertainty in the results, including that the selenium toxicity threshold for Sacramento splittail (7.2 µg/g selenium whole-body tissue concentration) is representative of Delta Smelt, and the uncertainty around the concentration of selenium in the diet that results in toxic effects.

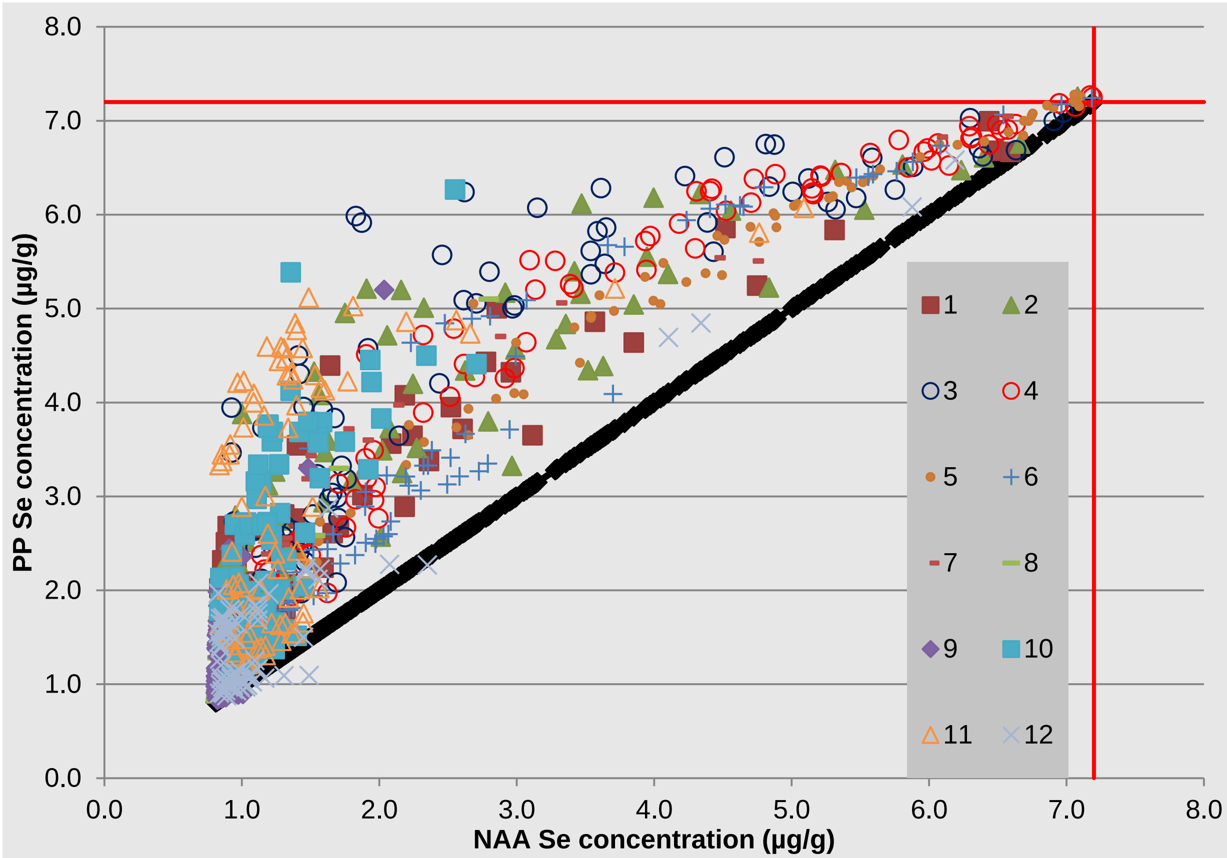
Monthly mean predicted Delta Smelt selenium tissue concentrations showed high variability at the five sites that were examined (San Joaquin River at Prisoners Point, Cache Slough at Ryer Island, Sacramento River at Emmaton, San Joaquin River at Antioch, and Suisun Bay at Mallard Island). The monthly selenium tissue concentrations were elevated in the PP relative to the NAA, sometimes as much as doubling the tissue concentrations compared to the NAA. However, even in those instances, the concentrations almost always remained well below the comparative effects threshold of 7.2 µg/g. Prisoners Point was the only one of the 5 sites at which tissue concentrations ever exceeded the chosen threshold of 7.2 µg/g. Because the predicted tissue concentrations are strongly influenced by the proportion of San Joaquin River water (see Table 6.A-12 in Section 6.A.4.4.1 *Selenium Concentrations in Water* in ICF International [2016], Appendix 6.A *Quantitative Methods for Biological Assessment of Delta Smelt*), data from Prisoners Point at a K_d of 6000 (higher bioavailable selenium) represent a conservative high end of selenium exposure to Delta Smelt from the PP.

Selenium concentration in Delta Smelt tissue at Prisoners Point had a broad peak from March through June (Figure 4.1-28), the months when the fraction of San Joaquin River water was often highest at those sites. Exceedance occurred in 7 out of 992 months (0.7 percent) and only when using the high bioavailable selenium estimate (high K_d) (Figure 4.1-29). The relatively small number of exceedances for the PP occurred primarily in the months of March, April, and May, where predicted NAA selenium tissue concentrations were observed to be close or at threshold exceedance. Based upon the modeling results, the PP is expected to increase San Joaquin River water contribution to 5 sites relevant to Delta Smelt. It is reasonable to conclude that there will be an increase in selenium bioavailability and potential for elevated tissue concentrations in Delta Smelt. However, based on modeled Delta Smelt tissue concentrations and the selected selenium toxicity threshold value, the PP is unlikely to increase tissue concentrations significantly enough to result in detrimental effects to Delta Smelt. The results are discussed in the following sections by life stage.



Note: Plot only includes mean responses and does not consider model uncertainty. ‘PA’ refers to the Proposed Project.

Figure 4.1-28. Box Plot of Predicted Monthly Mean Delta Smelt Tissue Selenium Concentration at Prisoners Point, Based on 1922-2003.



Note: Plot only includes mean responses and does not consider model uncertainty. Black diamonds indicate a 1:1 relationship.

Figure 4.1-29. Comparison of Predicted Monthly Mean Delta Smelt Tissue Selenium Concentration at Prisoners Point for NAA and PP Scenarios, In Relation to the 7.2-µg/g Effects Threshold (Red Line).

4.1.3.5.6.1 Migrating Adults (December-March)

As illustrated in the foregoing analysis, the selenium concentration in migrating adult Delta Smelt would be expected to increase somewhat during the December-March period (Figure 4.1-28). However, the potential to exceed the assumed detrimental threshold of 7.2-µg/g selenium whole-body tissue concentration would be limited spatially (San Joaquin River at Prisoner’s Point) and in very few years (Figure 4.1-29), resulting in a very low potential for population-level effects.

4.1.3.5.6.2 Spawning Adults (February-June)

Similar to migrating adults, the selenium concentration in spawning adult Delta Smelt (assuming similar rates of selenium transfer as to other motile life stages; see Hung et al. 2014 for discussion of cessation of feeding in females prior to spawning, coupled with greater feeding leading to spawning) would be expected to increase somewhat during the December-March period (Figure 4.1-28). However, the potential to exceed the assumed detrimental threshold of 7.2- µg/g selenium whole-body tissue concentration would be limited spatially (San Joaquin River at Prisoner’s Point) and in very few years during spring (Figure 4.1-29) resulting in a very low potential for population-level effects.

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

Eggs/embryos would not be feeding and therefore would not be exposed to selenium directly. To the extent that selenium is passed from female Delta Smelt to the eggs, the eggs/embryos would have greater selenium under the PP than NAA. However, as previously described for spawning adults, the incidence of exceedance of the 7.2-µg/g selenium whole-body tissue concentration threshold for spawning adults is extremely limited spatially and temporally, suggesting the likelihood of negative effects for eggs/embryos to also be extremely limited. There is, however, uncertainty in the extent to which selenium could be transferred from female Delta Smelt to their eggs.

Reflecting the potential for extremely limited individual-level effects, it is concluded that the population-level effects on eggs/embryos would also be extremely limited, although there is uncertainty in the extent to which selenium could be transferred from female Delta Smelt to their eggs.

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

As illustrated in Figure 4.1-28, the spring months tend to result in the greatest concentrations of selenium in Delta Smelt tissue, as a result of San Joaquin River inflow to the Delta having the greatest contribution to Delta waters in these months (because of south Delta export restrictions and, in the case of the PP, the HOR gate). Young juvenile Delta Smelt (those that are exogenously feeding) therefore would have a greater risk of accumulating selenium under the PP than NAA. However, as previously described, the risk remains very low relative to the 7.2-µg/g selenium whole-body tissue concentration threshold, which is very rarely exceeded (Figure 4.1-29).

Selenium poses some potential for effects to individual Delta Smelt, but the limited spatial extent of the effect (1 of 5 locations) and frequency of occurrence (very few months of the 82 years that were modeled) suggests very little potential for population-level effects.

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

As shown in the Prisoner's Point results broken down by month (Figure 4.1-29), the juvenile Delta Smelt tissue concentration during July–December would be greater under PP than NAA, but well below the 7.2-µg/g selenium whole-body tissue concentration threshold. This indicates the potential for detrimental effects on juvenile Delta Smelt from selenium during these months is extremely low.

4.1.3.6 Delta Cross Channel

Although the Delta Cross Channel is a CVP facility, its operations are relevant to the PP and it is operated consistent with the COA. The PP proposes no changes to DCC operational criteria.

4.1.3.6.1 Migrating Adults (December–March)

U.S. Fish and Wildlife Service (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 will 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 PP (ICF International [2016], Appendix 5.A *CALSIM Methods and Results*, Table 5.A.6-31). Therefore any individual-level or population-level effects on adult Delta Smelt (e.g., flow cues for migration) would be similar between NAA and PP.

4.1.3.6.2 Spawning Adults (February–June)

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 will be limited potential for DCC operations to affect individual spawning adults, which presumably will be much less limited in terms of movements and may be holding near spawning locations. Any effect would be very similar for NAA and PP (ICF International [2016], Appendix 5.A *CALSIM Methods and Results*, Table 5.A.6-31).

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

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

Given that the DCC's principal effects will be on the motile life stages of Delta Smelt (by changing flows in Delta channels), the demersal and adhesive egg/embryo life stage will not be affected by DCC operations, and there will be no population-level effects.

4.1.3.6.4 Larvae/Young Juveniles (Spring: ~March–June)

U.S. Fish and Wildlife Service (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 4.1.3.3.1.4 *Larvae/Young Juveniles*). There would be little to no difference in DCC operations between NAA and PP, with the DCC only being open for an average of 5 days more under PP in June of wet years (ICF International [2016], Appendix 5.A *CALSIM Methods and Results*, Table 5.A.6-31).

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

4.1.3.6.5 Juveniles (Summer/Fall: ~July–December)

Given that the main effect of DCC operations will be to change the quantity of Sacramento River flow entering the interior Delta (central/south Delta), there will 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 PP (see Section 4.1.3.3.1.4, *Larvae/Young Juveniles (Spring: March–June)*). This is because of several operational criteria described in ICF International (2016, Appendix 5.A *CALSIM Methods and Results*, Section 5.A.5.1.4.2). The CalSim modeling showed that in September of ~20 percent of years, sufficient water was exported by the NDD that the 25,000-cfs threshold for closure of the DCC is not exceeded, whereas it is exceeded under the NAA in the same years and results in closure of the DCC more than under PP (ICF International [2016], Appendix 5.A *CALSIM Methods and Results*, Table 5.A.6-31). Additionally, in October–November, reservoir releases later in the year under the NAA triggered the 7,500-cfs Sacramento River at Wilkins Slough threshold assumed to coincide with juvenile salmon migration into the Delta, which resulted in a greater number of days with DCC closed under NAA. Last, the DCC may also have been open more under the PP to maintain water quality conditions per D-1641 (Rock Slough salinity standard). However, given that most juvenile Delta Smelt would be in the low-salinity zone or in the Cache Slough area during this time period, any effects would be limited; the extent and location of the low-salinity zone would not differ between NAA and PP during September–December, as shown in the analysis of abiotic habitat for juvenile Delta Smelt (Section 4.1.3.5.1.1 *Juveniles*).

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

4.1.3.7 Suisun Marsh Facilities[27]

4.1.3.7.1 Suisun Marsh Salinity Control Gates

4.1.3.7.1.1 Migrating Adults (December–March)

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 U.S. Fish and Wildlife Service (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). U.S. Fish and Wildlife Service (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 PP, based on the December–March flows in Montezuma Slough just upstream of the SMSCG being similar (see ICF International [2016], Appendix 5.B *DSM2 Modeling and Results*, Table 5.B.5-29).

U.S. Fish and Wildlife Service (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 U.S. Fish and Wildlife Service (2008: 219), operations to meet D-1641 will limit such

[27] The independent review panel report for the working draft BA recommended that the water-distribution system within Suisun Marsh be qualitatively assessed for its potential influence on the salinity, current speed, and turbidity within the high-abundance area for Delta Smelt (Simenstad et al. 2016). The analysis included herein considers the main aspects of the Suisun Marsh facilities that were identified to be of relevance to Delta Smelt by USFWS (2008). Although further analysis of the type recommended by the independent review panel report is possible, such an analysis is not included herein because of the overall similarity in Suisun Marsh facility operations between the NAA and PP.

potential effects; these operations will be undertaken under both NAA and PP, and are reflected in there being little meaningful difference between NAA and PP in X2 during December–March (see ICF International [2016], Appendix 5.A *CALSIM Methods and Results*, Table 5.A.6-29).

Given that the SMSCG is 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 above, any effects would be similar between NAA and PP.

4.1.3.7.1.2 Spawning Adults (February–June)

Spawning adult Delta Smelt will be less susceptible to the effects of the SMSCG than migrating adult Delta Smelt because they will 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 U.S. Fish and Wildlife Service (2008: 218) could occur. Any such effects would be similar for NAA and PP based on the February–June flows in Montezuma Slough just upstream of the SMSCG being similar (see ICF International [2016], Appendix 5.B *DSM2 Modeling and Results*, Table 5.B.5-29).

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 will be minimal population-level effects on spawning adult Delta Smelt from the SMSCG. In any case,the magnitude of any effects would be similar for the NAA and PP.

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

Operation of the SMSCG will not affect Delta Smelt eggs/embryos, which as previously noted are demersal and adhesive.

4.1.3.7.1.4 Larvae/Young Juveniles (Spring: ~March–June)

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 PP based on the March–June flows in Montezuma Slough just upstream of the SMSCG being similar (see ICF International [2016], Appendix 5.B *DSM2 Modeling and Results,* Table 5.B.5-29).

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 PP 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 small and would not differ between NAA and PP.

4.1.3.7.1.5 Juveniles (Summer/Fall: ~July–December)

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 PP based on the July–December flows in Montezuma Slough just upstream of the SMSCG being similar (see ICF International [2016], Appendix 5.B *DSM2 Modeling and Results*, Table 5.B.5-29). As described for migrating adult Delta Smelt, U.S. Fish and Wildlife Service (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 4.1.3.5.1.1 *Juveniles* illustrated that X2 and the low salinity zone would be similar between NAA and PP, reflecting adherence of both scenarios to the U.S. Fish and Wildlife Service (2008) BiOp RPA requiring fall X2 management.

The relatively few days (10 to 20) which the SMSCG might be operated, coupled with SWP/CVP management of X2 for juvenile Delta Smelt fall rearing habitat per the U.S. Fish and Wildlife Service (2008) BiOp RPA, suggests that there will be minimal population-level effects of the SMSCG on juvenile Delta Smelt, and that these would not differ between NAA and PP.

4.1.3.7.2 Roaring River Distribution System

4.1.3.7.2.1 Migrating Adults (December–March)

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 will be minimal. Accordingly, the RRDS will have no population-level effects on migrating adult Delta Smelt.

4.1.3.7.2.2 Spawning Adults (February–June)

As with migrating adult Delta Smelt, the screens on the RRDS intake will minimize any potential adverse effects to individual spawning adult Delta Smelt. There will be essentially no population-level effects from the RRDS on spawning adult Delta Smelt.

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

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 will not be subject to entrainment.

4.1.3.7.2.4 Larvae/Young Juveniles (Spring: ~March–June)

Based on the RRDS screen specifications and applying the methods used for the NDD (ICF International [2016], 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[28] 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.

Any population-level effects on larval/young juvenile Delta Smelt from the RRDS that do occur would be similar between NAA and PP, and will represent a continuation of existing operations; as previously noted, flows in Montezuma Slough as a result of SMSCG operations would be similar for NAA and PP. Entrainment risk into RRDS appears limited, given that DSM2-PTM

[28] 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.

modeling for the California Department of Fish and Game (2009) longfin smelt incidental take permit application did not observe any particles entering RRDS. Therefore, the population-level effect of the RRDS will be minimal.

4.1.3.7.2.5 Juveniles (Summer/Fall: ~July–December)

As with migrating adult Delta Smelt, the screens on the RRDS intake will minimize any potential adverse effects to individual juvenile Delta Smelt. There will be minimal, if any, population-level effects from the RRDS on juvenile Delta Smelt.

4.1.3.7.3 Morrow Island Distribution System

4.1.3.7.3.1 Migrating Adults (December–March)

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 will 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.

The population-level effects of the MIDS to migrating adult Delta Smelt will be minimal, if any, given that entrainment is only expected to occur in wet years. Any entrainment under the PP would also be likely to occur under the NAA, given that operations of the MIDS will not be changing (see ICF International [2016], Appendix 5.B, *DSM2 Modeling and Results*, Tables 5.B.5-31, 5.B.5-32, and 5.B.5-33).

4.1.3.7.3.2 Spawning Adults (February–June)

As with migrating adult Delta Smelt, spawning adults will only be susceptible to entrainment at the MIDS in wet years. The population-level effects of the MIDS to spawning adult Delta Smelt will be minimal, if any, given that entrainment is only expected to occur in wet years; any entrainment would be similar under NAA and PP.

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

As previously noted, the demersal and adhesive nature of Delta Smelt eggs/embryos means that they will not be subject to entrainment and there will be no individual-level or population-level adverse effects from the MIDS.

4.1.3.7.3.4 Larvae/Young Juveniles (Spring: ~March–June)

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.

As noted by U.S. Fish and Wildlife Service (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 PP (ICF International [2016], Appendix 5.B *DSM2 Modeling and Results*, Tables 5.B.5-31, 5.B.5-32, and 5.B.5-33).

4.1.3.7.3.5 Juveniles (Summer/Fall: ~July–December)

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. Given the absence of juvenile Delta Smelt in entrainment samples at MIDS by Enos *et al.* (2007), the population-level effect of the MIDS will be minimal. Any effect would be similar between NAA and PP.

4.1.3.7.4 Goodyear Slough Outfall

4.1.3.7.4.1 Migrating Adults (December–March)

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.

As discussed previously for MIDS, the available sampling data in the area suggest that migrating adult Delta Smelt will 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 will therefore be likely to occur, with this effect being common to NAA and PP on the basis of similar flows in Goodyear Slough (see ICF International [2016], Appendix 5.B *DSM2 Modeling and Results*, Table 5.B.5-34).

4.1.3.7.4.2 Spawning Adults (February–June)

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.

As discussed for migrating adults, the available information suggests that the population-level effect of the Goodyear Slough outfall will be minimal because of infrequent Delta Smelt occurrence in the area, with the effect not differing between NAA and PP.

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

Eggs/embryos will 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.

As noted for adult Delta Smelt, only a small portion of Delta Smelt eggs/embryos are expected to occur in Goodyear Slough (*i.e.*, possibly only in wet years), so the population-level effects of the Goodyear Slough outfall will be small and similar between NAA and PP.

4.1.3.7.4.4 Larvae/Young Juveniles (Spring: ~March–June)

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.

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 will be expected to occur in Goodyear Slough, at most resulting in small population-level effects that would be similar between NAA and PP.

4.1.3.7.4.5 Juveniles (Summer/Fall: ~July–December)

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.

As concluded for other life stages, only a small portion of Delta Smelt juveniles will be expected to occur in Goodyear Slough, resulting in no more than a small population-level effect that would be similar between NAA and PP.

4.1.3.8 North Bay Aqueduct

4.1.3.8.1 Migrating Adults (December–March)

As noted by U.S. Fish and Wildlife Service (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 will 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 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 PP (see ICF International [2016], Appendix 5.B *DSM2 Modeling and Results*, Table 5.B.5-35), so the potential risk of impingement and predation may also be similar.

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 PP, will greatly limit the potential for adverse effects from the NBA, so population-level effects will be minimal.

4.1.3.8.2 Spawning Adults (February–June)

As with migrating adult Delta Smelt, the Barker Slough pumping plant's fish screen will exclude spawning adult Delta Smelt from entrainment into the NBA, with some potential for impingement and predation that is similar between NAA and PP.

As with migrating adult Delta Smelt, due to 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 PP, population-level effects will be minimal.

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

As previously noted, due to the demersal and adhesive nature of Delta Smelt eggs/embryos they are not be subject to entrainment, so there will be no individual-level or population-level adverse effect from the NBA.

4.1.3.8.4 Larvae/Young Juveniles (Spring: ~March–June)

Larval and young juvenile Delta Smelt could be entrained 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 U.S. Fish and Wildlife Service (2008: 217), a study of a fish screen built to Delta Smelt standards in Horseshoe Bend on the Sacramento River found that over 99 percent of fish were excluded from entrainment, even though most fish were only 15-25 mm long (Nobriga *et al.* 2004); U.S. Fish and Wildlife Service (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.

As previously discussed in Section 4.1.3.3.1.4, *Larvae/Young Juveniles*, the DSM2-PTM analysis of larval Delta Smelt entrainment showed that in general, estimated entrainment at the NBA under the PP and NAA was similar (Table 4.1-16), reflecting the fact that operational criteria do not differ between NAA and PP. Therefore any effects will be similar between scenarios.

4.1.3.8.5 Juveniles (Summer/Fall: ~July–December)

As with adult Delta Smelt, juvenile Delta Smelt will 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 PP (see ICF International [2016], Appendix 5.B *DSM2 Modeling and Results*, Table 5.B.5-35), so the potential risk of impingement and predation may also be similar.

Exclusion of juvenile Delta Smelt by the fish screens at the Barker Slough pumping plant will avoid adverse population-level effects from NBA diversions in terms of entrainment, and generally similar pumping between NAA and PP will limit the potential for near-field predation and impingement risk.

4.1.3.9 Other Facilities

4.1.3.9.1 Contra Costa Canal Rock Slough Intake

Although the Contra Costa Canal Rock Slough Intake is a CVP facility, its operations are relevant to the PP and it is operated consistent with the COA. The PP proposes no changes to operations at the intake.

4.1.3.9.1.1 Migrating Adults (December–March)

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 the National Marine Fisheries Service (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 the National Marine Fisheries Service (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 PP, indicating that the potential for adverse effects to migrating adult Delta Smelt will be similar under the PP compared to NAA. Resolution of the aforementioned issues with screen effectiveness is expected to minimize the potential for any adverse effects to individual migrating adult Delta Smelt.

U.S. Fish and Wildlife Service (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 PP (see discussion in the Individual-Level Effects) suggests that any population-level effect of the Rock Slough intake on migrating adult Delta Smelt will be minimal.

4.1.3.9.1.2 Spawning Adults (February–June)

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 PP 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 PP (see ICF International [2016], Appendix 5.B *DSM2 Modeling and Results*, Table 5.B.5-36). The overall diversions for the Rock Slough intake and the other CCWD intakes on Old River and Middle River do not differ greatly between NAA and PP, suggesting that Rock Slough may have been favored in the modeling of PP for operational reasons, e.g., Old and Middle River flow criteria, for example. This could indicate greater potential for adverse effects to spawning adult Delta Smelt under the PP compared to NAA. However, as noted for migrating adult Delta Smelt, resolution of the aforementioned issues with screen effectiveness will minimize the potential for any adverse effects to individual spawning adult Delta Smelt.

As described for migrating adult Delta Smelt, there will 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).

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

As previously noted, due to the demersal and adhesive nature of Delta Smelt eggs/embryos, they are not subject to entrainment and there will be no individual-level or population-level adverse effects from the Rock Slough intake.

4.1.3.9.1.4 Larvae/Young Juveniles (Spring: ~March–June)

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 is expected to exclude fish of 20-21 mm SL (see Section 4.1.3.2.1.1 *Migrating Adults*, related to the NDD). Modeled pumping of the Rock Slough intake suggested that diversions under the PP generally would be similar to NAA in March and June, but not in April and May, when diversions would be greater under the PP (see ICF International [2016], Appendix 5.B *DSM2 Modeling and Results*, Table 5.B.5-36). The overall diversions for the Rock

Slough intake and the other CCWD intakes on Old River and Middle River do not differ greatly between NAA and PP, suggesting that Rock Slough may have been favored in the modeling of PP for operational reasons, e.g., Old and Middle River flow criteria, for example. Operation of the Rock Slough intake will be included in the no-fill and no-diversion periods associated with all diversions for CCWD, which will minimize the potential for larval entrainment.

As noted by U.S. Fish and Wildlife Service (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 will be very small, particularly in light of the no-fill and no-diversion criteria that are in place to protect listed species during spring.

4.1.3.9.1.5 Juveniles (Summer/Fall: ~July–December)

Potential effects to juvenile Delta Smelt will be similar to those previously discussed for adult Delta Smelt in terms of potential entrainment. Diversions at the Rock Slough intake will be essentially the same under PP as NAA during July–December (see ICF International [2016], Appendix 5.B *DSM2 Modeling and Results,* Table 5.B.5-36), so any entrainment will be similar.

There will 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 (U.S. Fish and Wildlife Service 2008: 217), and abiotic habitat conditions in the summer in the south Delta also are poor for Delta Smelt (Nobriga *et al.* 2008).

4.1.3.9.2 Clifton Court Forebay Aquatic Weed Control Program

4.1.3.9.2.1 Migrating Adults (December–March)

Herbicide treatment of aquatic weeds in CCF in July/August will avoid potential effects to Delta Smelt migrating adults because treatment will occur well after migration is complete. Mechanical removal of aquatic weeds in CCF will occur on an as-needed basis and therefore could coincide with occurrence of migrating adult Delta Smelt. Delta Smelt generally do not occur near aquatic weeds (Ferrari *et al.* 2014), but may occur near 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) might 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.

Given the mixture of potential adverse and beneficial effects from mechanical removal of aquatic weeds in CCF, it is unlikely that there will be a population-level effect on migrating adult Delta Smelt.

4.1.3.9.2.2 Spawning Adults (February–June)

Herbicide treatment of aquatic weeds in CCF in July/August will avoid potential effects to Delta Smelt spawning adults because any spawning adults present in the Forebay will occur earlier in the year. Any mechanical removal effects will be as described for migrating adults.

As described for migrating adults, it is unlikely that there will be a population-level effect on spawning adult Delta Smelt from mechanical removal of aquatic weeds in CCF.

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

Herbicide treatment of aquatic weeds in CCF in July/August will avoid potential effects to Delta Smelt eggs/embryos because eggs/embryos will 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 will avoid eggs/embryos adhering to benthic substrates.

Any population-level adverse effects from physical predator reduction methods at CCF will 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.

4.1.3.9.2.4 Larvae/Young Juveniles (Spring: ~March–June)

As with adults and eggs/embryos, larval/young juvenile Delta Smelt will not temporally overlap the period of herbicide treatment of aquatic weeds in CCF (July–August). Mechanical removal effects may be similar to those noted previously for migrating adult Delta Smelt.

Population-level effects from mechanical removal at CCF will 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.

4.1.3.9.2.5 Juveniles (Summer/Fall: ~July–December)

There will 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 CCF; Delta Smelt that are susceptible to entrainment into CCF are either migrating adults or larvae/young juveniles, and the waters in the Forebay will become too warm for juvenile Delta Smelt by July.

Following from the lack of individual-level effects, there will be no population-level effect on juvenile Delta Smelt.

4.1.4 Mitigation Measure Effects

4.1.4.1 Tidal and Channel Margin Habitat Restoration

4.1.4.1.1 Migrating Adults (December–March)

Construction at habitat restoration sites will occur during an in-water work window to be approved by CDFW, NMFS and USFWS and therefore will 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. 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.

4.1.4.1.2 Spawning Adults (February–June)

As with migrating adult Delta Smelt, construction at habitat restoration sites will occur during an in-water work window to be approved by CDFW, NMFS and USFWS and therefore individual spawners will 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 described in Table 5.4-1 *Summary of Maximum Direct Impact, Proposed Compensation, and Potential Location of Restoration for State Listed Fish Species* in Chapter 5, *Take Minimization and Mitigation Measures*, 273 acres of shallow water tidal habitat restoration is proposed, of which 108 acres would be sandy beach spawning habitat. 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. 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.

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

As stated above, construction at habitat restoration sites will occur during an in-water work window to be approved by CDFW, NMFS and USFWS and therefore will 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. 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.

4.1.4.1.4 Larvae/Young Juveniles (Spring: ~March–June)

Construction at habitat restoration sites will occur during an in-water work window to be approved by CDFW, NMFS and USFWS, so there will be limited potential for effects of construction on individual Delta Smelt larvae. The types of effects described for juvenile Delta Smelt could occur for larval Delta Smelt occurring near construction of habitat restoration. 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.

4.1.4.1.5 Juveniles (Summer/Fall: ~July–December)

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 will be affected by construction at habitat restoration sites, on the basis of temporal overlap with summer/fall in-water work windows to be approved by CDFW, NMFS and USFWS. As with other life stages, there will 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 will 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. 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.

4.1.4.2 Georgiana Slough Nonphysical Fish Barrier

The Georgiana Slough Nonphysical Fish Barrier (NPB) will 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 (California Department of Water Resources 2015b), although these and other options are possibilities. The analysis presented here 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[29] 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 PP construction and removal will be done outside the main period of juvenile salmonid occurrence (November/December–June).

4.1.4.2.1 Migrating Adults (December–March)

Individual Delta Smelt migrating upstream via Georgiana Slough or the Sacramento River will not be affected by the construction of this NPB because construction will occur before any smelt have 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

[29] 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.

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 (California Department of Water Resources 2012, 2015a). Indeed, the 2011 and 2012 BAFF pilot studies provided evidence that predatory fish were deterred by the BAFF,[30] 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 will 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[31], they will 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.

Few Delta Smelt are known to spawn in the Sacramento River and Georgiana Slough where the NPB will be located, resulting in little if any population impact from this proposed salmonid fish conservation measure.

4.1.4.2.2 Spawning Adults (February–June)

The potential effects to spawning adult Delta Smelt from NPB will be similar to those noted for migrating adult Delta Smelt. However, these effects will be less likely to occur because spawning adult Delta Smelt will not be undergoing the broad-scale movements of migrating adults and therefore will have less potential to encounter the NPBs.

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, resulting in little if any population impact from this proposed salmonid fish conservation measure.

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

Delta smelt eggs/embryos will not overlap the construction or removal periods of the NPB and there will be no potential for adverse effects from operations.

4.1.4.2.4 Larvae/Young Juveniles (Spring: ~March–June)

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 such as slight alterations of direction in response to changes in flows, and possibly injury when contacting the structures associated with the NPB.

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

[31] 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.

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 will be little if any population impact from this proposed salmonid fish conservation measure.

4.1.4.2.5 Juveniles (Summer/Fall: ~July–December)

The Delta Smelt juvenile life stage is the only life history stage that has the potential to experience adverse effects to individuals from construction and removal of the NPB. Any pile-driving that will occur will be done with a vibratory hammer, which will minimize the potential for injury. 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.

Few juvenile Delta Smelt are known to rear in the Sacramento River and Georgiana Slough where the NPB will be located, resulting in little if any population impact from this proposed salmonid fish conservation measure.

4.1.5 Monitoring Effects

As described in Section 6.2 *Monitoring and Research Program*, effectiveness monitoring for fish will 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 NDDs (principally entrainment and impingement monitoring). Entrainment monitoring at the NDDs will consist of sampling entrained fish behind the fish screens with a fyke net (see Table 6-2 in Chapter 6, *Monitoring Plan*); impingement monitoring methods are not specified at this time, but on the basis of existing monitoring (e.g., Freeport Regional Water Authority intake's fish screen), will likely consist of visual observation by diver survey or acoustic imaging camera. Other monitoring activities under the PP are unlikely to affect Delta Smelt and are not discussed here. Existing monitoring activities that will inform operations of the PP (e.g., trawl and seines surveys by DFW and USFWS) are not part of the PP. Although monitoring activities at restoration sites have not been determined, they are not expected to include in-water work with any potential to harm Delta Smelt or any other listed fishes.

4.1.5.1 Migrating Adults (December–March)

As discussed in Section 4.1.3.2.1.1 *Migrating Adults* for the NDDs, the NDD fish screens will exclude migrating adult Delta Smelt from entrainment, so there will be no effect from entrainment monitoring at the NDD. If impingement monitoring were to consist of visual observation by diver survey, there 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 will be done in the same way under NAA and PP. Individual migrating adult Delta Smelt collected during sampling of salvaged fish will die; however, as shown in Section 4.1.3.3.1.1 *Migrating Adults*, entrainment at the south Delta export facilities will be lower under the PP than

NAA, therefore any effects to individual Delta Smelt from salvage monitoring will be lower under the PP than NAA.

Given the low percentage of the migrating adult Delta Smelt population expected to be near the NDD (Section 4.1.3.2.2.1 *Migrating Adults*), any effects of impingement monitoring at the NDD will be inconsequential at the population level. South Delta exports salvage monitoring also will have essentially no population-level effect, given that only a subsample of fish will be collected, entrainment will be limited (and will be less under the PP 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 beneficial for the population.

4.1.5.2 Spawning Adults (February–June)

The potential effects of monitoring on individual spawning adult Delta Smelt will 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 will be less likely to be sampled during monitoring activities if primarily holding near spawning sites.

As discussed for migrating adult Delta Smelt, there will be essentially no population-level effects of monitoring on spawning adult Delta Smelt.

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

As noted for other potential effects of the PP, the demersal and adhesive nature of Delta Smelt eggs/embryos means that they will not affected by the monitoring proposed under the PP.

4.1.5.4 Larvae/Young Juveniles (Spring: ~March–June)

At the NDD, entrainment sampling behind the fish screens will 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 CCF. Entrainment surveys of young smelt at the south Delta export facilities will also result in lethal take of any sampled larval or young juvenile Delta Smelt, and will occur under NAA and PP.

Any collections of larval or young juvenile Delta Smelt during entrainment monitoring at the NDD or south Delta export facilities will have no effect at the population level because these fish are unlikely to survive during passage through conveyance infrastructure or, if surviving and growing in CCF, they will either die from predation or from excessive water temperatures in the summer.

4.1.5.5 Juveniles (Summer/Fall: ~July–December)

Effects to juvenile Delta Smelt are comparable to those for migrating adult Delta Smelt in terms of the potential to be lethally taken during salvage monitoring at the south Delta export facilities, except, as discussed in Section 4.1.3.3.1.5 *Juveniles,* few juvenile Delta Smelt will be present at this time. Reduced south Delta exports under the PP compared to NAA further diminishes the potential effect. It is unlikely that monitoring of impingement potential at the NDDs will be undertaken during the summer/fall, given the periods of occurrence of listed fishes, so there will be no effect from diver surveys, and no population-level effects.

4.1.6 Take Analysis

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

4.1.6.1 Effects of Water Facility Construction

Construction has the greatest potential to result in take of Delta Smelt at the NDDs, the temporary barge landings, the Head of Old River gate, and the CCF modifications. Delta smelt are rarely present in the vicinity of the HOR gate (see Section 4.1.1.4, *Head of Old River Gate*), and while often present near the NDDs, this area is outside the species' main range (Section 4.1.1.2, *North Delta Diversions*), so construction of these facilities has substantially less potential to result in take compared to the other facilities named. Construction activities will include cofferdam installation, levee clearing and grading, riprap placement, dredging, and barge operations and could cause turbidity and sedimentation, contaminant spills, underwater noise, fish stranding, direct contact with construction equipment, and loss or alteration of habitat. Underwater noise associated with pile driving, which is needed for construction of all the facilities named, is of concern because of uncertainty in the effectiveness of available mitigation measures for impact driving; however, it is anticipated that most pile driving will be conducted with vibratory methods, which considerably limits the potential for take of Delta Smelt.

Take associated with construction activities will be reduced by restricting construction to in-water work windows when there will generally be less potential for overlap with Delta Smelt life stages. The work windows differ somewhat for the different facilities: June 1 to October 31 for the NDDs; August 1 to October 31 for the barge landings; July 1 to November 30 for the CCF modifications; and August 1 to October 31 for the HOR gate. The overlap of construction at the NDDs with the late spring period (June) results in some potential for take of Delta Smelt.

In addition to restricting construction to periods when Delta Smelt generally will be absent or in lower abundance, take associated with the construction activities will be minimized by using a take minimization measures. The specific take minimization measures that would be implemented to minimize potential take of each of the construction activities and their effects are discussed in Section 4.1.1 *Construction Effects* and are described in detail in Appendix 3.F, *General Avoidance and Minimization Measures.*

Restricting construction activities to work windows will not minimize take resulting from loss and alteration of Delta Smelt habitat. Effects on Delta Smelt habitat are considered permanent because of the species' primarily one-year life cycle (see Table 5.4-1 *Summary of Maximum Direct Impact, Proposed Compensation, and Potential Location of Restoration for State Listed Fish Species* for a summary of these effects associated with each species, at each construction site). With regard to habitat acres affected, construction will result in the loss of 5.6 acres of shallow water habitat at the NDD, 2.9 acres of tidal perennial habitat at the HOR gate, and 22.4 acres of tidal perennial habitat at the barge landings, all of which is considered a permanent loss from the perspective of Delta Smelt, although some of these impacts will cease entirely following construction (for instance, no permanent barge landings are proposed). Much of the habitat affected, especially at the barge landings, HOR gate, and CCF locations, is currently in a degraded condition (e.g., rip-rapped banks), so alteration and loss of this habitat may have little effect on its value for Delta Smelt. However, the creation of new predator habitat at the facilities has the potential result in an increase in predation mortality of Delta Smelt. Take resulting from construction activities and from habitat loss and alteration will be fully mitigated by shallow water and tidal perennial habitat restoration at 5:1 or 3:1 mitigation ratios (depending on the proposed work window), as described in Section 5.4.0.3 *Spatial Extent, Location, and Design of Restoration for Fish Species.* The total area of habitat restoration for full mitigation of water facility construction is 102.7 acres (28 acres of shallow water habitat mitigating for NDD construction; 7.5 acres of tidal perennial habitat mitigating for HOR gate construction; and 67.2 acres of tidal perennial habitat mitigating for barge landing construction).

Overall, the impact of take on Delta Smelt resulting from construction activities will not be substantial because of compliance with work windows designated to avoid or minimize temporal overlap with Delta Smelt, the location of the work (often well outside the species' main range), the many take minimization measures that will be implemented, the low quality of most habitat affected, and the use of habitat restoration to mitigate losses of suitable habitat.

4.1.6.2 Effects of Water Facility Maintenance

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

Regular and unscheduled maintenance will be needed for each of the four principal PP facilities. The maintenance activities with the most potential to result in take of Delta Smelt are dredging and levee maintenance. These activities will be performed during an in-water work window to be approved by CDFW, NMFS, and USFWS. Potential adverse effects will be further minimized by implementing take minimization measures to limit the extent and duration of activities. With implementation of the work windows and take minimization measures, together with the location of the work (often well outside the species' main range), take of Delta Smelt resulting from water facility maintenance activities will be minimal.

4.1.6.3 Effects of Water Facility Operations

Water facility operations have the potential to result in take of Delta Smelt by mechanisms that include entrainment, impingement, catch/capture during salvage at the south Delta export facilities, or by influencing water quality. This section is organized in the same way as Section 4.1.3, *Operations Effects*, in terms of the various subsections discussing effects at different facilities.

4.1.6.3.1 North Delta Diversions

Take at the NDDs could occur as a result of entrainment, impingement/screen contact, and predation, as well as reduced access to upstream spawning habitat. Given the location of the NDDs, the take will affect only a very small proportion of the population (see discussion in Section 4.1.3.2 *North Delta Diversions*). Given the intake screening specifications, only larval Delta Smelt less than 20-21 mm long will be susceptible to entrainment. As discussed in Section 4.1.3.2.1.4.1 *Population-level effects*, rough estimates of the proportion of the larval population that could be within the NDD reach of the Sacramento River (0.25 percent) combined with the rate of water diversion suggests that the population-level larval take by entrainment at the NDDs will be considerably less than 0.1 percent (close to 0.01 percent). Assuming a higher density of larvae in the reach (as done for the DSM2-PTM analysis) would give a greater proportional take (up to nearly 0.2 percent), but as discussed in Section 4.1.3.3.1.4.1 *Population-level effects*, the assumption for the original DSM2-PTM analysis reflected a lack of recent larval density data in the NDD reach; adjustment downward gave estimated larval entrainment considerably less than 0.1 percent. The absolute estimates of entrainment must be treated with caution, but suggest a very low percentage of larval Delta Smelt would be taken; it is possible that with climate change and sea level rise this percentage could increase over time, although this effect is uncertain.

Take of larger (>21 mm long) Delta Smelt could occur by impingement and screen contact, resulting in injury and subsequent mortality. Based on laboratory studies, the number of screen contacts and mortality would increase as sweeping velocity increased (Figures 4.1-2 and 4.1-3), and mortality would increase at night compared to during the day (Figure 4.1-3). It is possible that there could be take of Delta Smelt near the NDD from predation, particularly as Delta Smelt may be more susceptible to predation due to injury from screen contact/impingement, and also because the in-water structure provided by the NDD may provide favorable habitat for predators. As previously discussed, any such take will be limited to a small proportion of the population. NDD screen design and operations criteria will minimize the potential take of Delta Smelt at the NDD.

The NDD could also result in take of Delta Smelt by reducing the probability of access to upstream shallow water habitat, including sandy beach spawning habitat, by creating a relatively high-velocity nearshore habitat on the left bank of the Sacramento River at the NDD that would be challenging for upstream migrating adult Delta Smelt to pass with active swimming; 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 (see Section 4.1.3.2.2.1). This effect will be fully mitigated by restoring 245 acres of shallow water habitat as compensation for the estimated extent of this type of habitat that may be less accessible upstream of the NDD. Of the 245 acres, 108 acres must be sandy beach spawning habitat (a 3:1 mitigation ratio for the estimated 36 acres of such habitat that would be affected; see Table 5.4-1 *Summary of Maximum Direct Impact, Proposed Compensation, and Potential Location of Restoration for State Listed Fish Species*).

4.1.6.3.2 South Delta Exports

Take at the south Delta export facilities will occur as a result of entrainment, predation, and salvage. Salvage is generally regarded as resulting in high mortality, but relatively high survival of adult Delta Smelt can occur during collection, handling, transport, and release when adult Delta Smelt are salvaged during cool temperature conditions (Morinaka 2013); however, high pre-screen predation loss reduces the usefulness of catch/capture during salvage as a means of limiting take.

In the years since the U.S. Fish and Wildlife Service (2008) BiOp was issued, take (salvage) of Delta Smelt at the south Delta export facilities has ranged from 0 to 260 fish for adults, and from 0 to 2,155 for juveniles (Table 4.1-49). Take in each year has been less than the take limit authorized to avoid jeopardy to Delta Smelt; the percentage of authorized take has ranged from 0 percent to around 75 percent for adults and juveniles. Authorized take is a function of the prior fall midwater trawl (FMWT) index. Predictions of absolute take for the PP are challenging to make because it is unknown what future population sizes may be. However, the results of the entrainment analyses presented in Section 4.1.3.3.1 *Entrainment* suggest that the levels of take for adult Delta Smelt under the PP should be similar (in drier years) or lower (in wetter years) compared to the NAA; across all years, the average is a 20 percent reduction, ranging from 3 percent less in critical years to 40 percent less in wet years. Given that the authorized take limits from the BiOp are expected to limit adult Delta Smelt loss to around 5 percent of the population (U.S. Fish and Wildlife Service 2008: 387), and the actual take has been lower than the authorized take (averaging 32 percent of authorized take from 2009-2015), the population-level take under the PP is expected to be on the order of 1.3 percent (5 percent authorized take * 0.32 average actual of authorized take * 0.8 PP to NAA entrainment ratio). Note that this is less than the absolute adult Delta Smelt proportional entrainment loss estimated in Section 4.1.3.3.1 *Entrainment*, which underscores the need to consider the entrainment loss estimates in relative terms, for they cannot reflect real-time operational adjustments.

The U.S. Fish and Wildlife Service (2008) BiOp does not indicate the percentage loss of the larval/juvenile population that the authorized take limits are expected to achieve. Actual salvage in 2009-2015 averaged 22 percent of the authorized level. As with the adult Delta Smelt discussed above, the absolute estimates of entrainment loss can be relatively high (e.g., ranging from 2-4 percent in wet years to 22 percent in critical years for the March-June proportional entrainment regressions; Table 4.1-18), but it is expected that real-time operations under the PP, particularly with respect to the consideration of Delta Smelt distribution, OMR flows, and HOR gate operations, will achieve similar levels of take as under NAA.

Table 4.1-49. Authorized and Actual Take (Salvage) of Delta Smelt, Together with Prior Fall Midwater Trawl (FMWT) Index, Water Years 2009-2015.

Water Year	Prior FWMT Index	Adult Delta Smelt			Juvenile Delta Smelt		
		Authorized	Actual	% of Authorized	Authorized	Actual	% of Authorized
2009	23	167	24	14%	1,293	737	57%
2010	17	123	92	75%	955	29	3%
2011	29	210	48	23%	1,630	0	0%
2012	343	2,487	203	8%	19,276	2,155	11%
2013	42	362	260	72%	2,350	1,741	74%
2014	18	155	0	0%	1,007	78	8%
2015	9	196	68	35%	504	4	1%

Sources:
FMWT indices: http://www.dfg.ca.gov/delta/data/fmwt/indices.asp
Authorized and actual salvage:
2009, http://www.dfg.ca.gov/delta/apps/salvage/SalvageExportChart.aspx?Species=3&SampleDate=1%2f1%2f2009&Facility=1 (salvage), with authorized salvage calculated from 7.25*adult salvage and 56.2*juvenile salvage, per the U.S. Fish and Wildlife Service (2008) BiOp;
2010, http://deltacouncil.ca.gov/science-news/pdf/smelt-working-group-report-to-the-independent-review-panel.pdf;
2011, http://deltacouncil.ca.gov/sites/default/files/documents/files/Final_SWG_Report_WY2011.pdf;
2012, http://deltacouncil.ca.gov/sites/default/files/documents/files/secure/LOOAR_2012/bg_mat/SWG/LOOAR_2012_bg_SWG_Report_WY2012.pdf;
2013, http://deltacouncil.ca.gov/sites/default/files/documents/files/SWG_Report_WY2013.pdf;
2014, http://deltacouncil.ca.gov/sites/default/files/2014/10/SWG-Final-Report-Water-Year-2014.pdf;
2015, http://deltacouncil.ca.gov/sites/default/files/2015/10/Final_SWG_WY2015_Report.pdf

4.1.6.3.3 Head of Old River Gate Operations

As described in Section 4.1.3.4 *Head of Old River Gate Operations*, take of Delta Smelt could occur because of HOR gate operations. The extent of take occurring near the HOR gate (e.g., predation due to more suitable predatory fish habitat) cannot be estimated but would likely be very low due to the very low frequency of capture of Delta Smelt in beach seines and trawls in the vicinity (e.g., see Section 4.1.3.4.1.1 *Population-Level Effects*). As previously discussed for south Delta exports, far-field effects of the HOR gate on south Delta hydrodynamics have the potential to affect the risk of entrainment at the south Delta export facilities; it is expected that real-time operations under the PP, particularly with respect to the consideration of Delta Smelt distribution, OMR flows, and other factors (including HOR gate operations) will achieve similar levels of take as under the NAA (see discussion in Section 4.1.6.3.2 *South Delta Exports*).

4.1.6.3.4 Habitat Effects

As described in Section 4.1.3.5 *Habitat Effects,* the combined effects of PP operations have the potential to affect Delta Smelt habitat, which therefore could result in take (primarily indirectly, but potentially directly). It generally is not possible to quantify the extent of this take in terms of number of Delta Smelt or proportion of the population affected. Section 4.1.3.5.1 *Abiotic Habitat* demonstrated that the extent of abiotic habitat (quantity/quality) for juvenile Delta Smelt during the fall rearing period would be similar between PP and NAA, reflecting the inclusion of the U.S. Fish and Wildlife Service (2008) BiOp requirements for fall X2; U.S. Fish and Wildlife Service (2008) determined that this extent of abiotic habitat is necessary to avoid jeopardy to Delta Smelt.

As described in Section 4.1.3.5.2 *Water Temperature*, although air temperature is the primary driver of water temperatures in the Delta, there could be small increases in water temperature as a result of the PP, which could result in greater take for larvae/young juveniles (spring) or juveniles (summer) as a result of factors such as reduced habitat extent, increased metabolic requirements, and greater susceptibility to disease or the effects of contaminants (IEP MAST Team 2015). The primary driver of temperature effects would be climate change, as discussed below in Section 4.1.7.1.7 *Climate Change*.

Sediment removal by the NDD is expected to amount to ~11 percent of the sediment that would otherwise enter the Delta from the Sacramento River (Section 4.1.3.5.3 *Sediment Removal (Water Clarity)*), which could indirectly result in take of Delta Smelt by altering larval feeding success or affecting juvenile habitat extent and distribution. Such take will be mitigated by DWR collaborating 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 (Section 3.2.10.6 *Dispose Spoils*).

Additional indirect take of Delta Smelt could occur because of changes in prey availability caused by the entrainment of food web materials (phytoplankton carbon) by the NDD; however, such changes are estimated to be of low magnitude (seldom more than 5 percent of the standing stock of phytoplankton in any given month) and do not account for *in situ* production and the potential for greater loads of phytoplankton carbon entering the Delta from the San Joaquin River watershed (because of less south Delta exports) (Section 4.1.3.5.4 *Entrainment of Food*

Web Materials). This suggests the potential for take because of entrainment of food web materials is minimal.

The DSM2-PTM-based residence time analysis indicated that because of changes in PP operations relative to NAA operations, *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 (Section 4.1.3.5.5 *Microcystis*); this could result in take of Delta Smelt either directly (toxic effects on Delta Smelt) or indirectly (toxic effects on their prey). As noted in Section 4.1.3.5.5.5 *Juveniles*, there are no published relationships between *Microcystis* and residence time from which to make firm conclusions. As also noted in Section 4.1.3.5.5.5, there is potential to limit the potential for *Microcystis* effects by preferential south Delta export pumping: the modeling undertaken for this analysis assumes that in the summer months (July–September), the first 3,000 cfs of exports will be from the south Delta, with any additional allowable exports 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 will be possible to shift to additional south Delta pumping as opposed to north Delta pumping in order to reduce water residence time, for example. In addition, the analysis presented in Section 4.1.3.5.5 *Microcystis* suggested that based on the published ranges of flows that *Microcystis* occurs at, greater flows in the lower San Joaquin River (QWEST) under the PP generally would give somewhat less potential for *Microcystis* to occur in that area, relative to the NAA; under the PP, a greater percentage of years were above the range of flows at which *Microcystis* has occurred. Therefore, under the PP, take from direct or indirect effects of *Microcystis* could be less in that area. As noted in Section 4.1.3.5.5, on the basis of differences in QRIO flow, therefore, there could be greater potential for *Microcystis* occurrence in the lower Sacramento River under the PP than NAA because of lower net flow in this area compared to 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 of low *Microcystis* will continue.

4.1.6.3.5 Delta Cross Channel

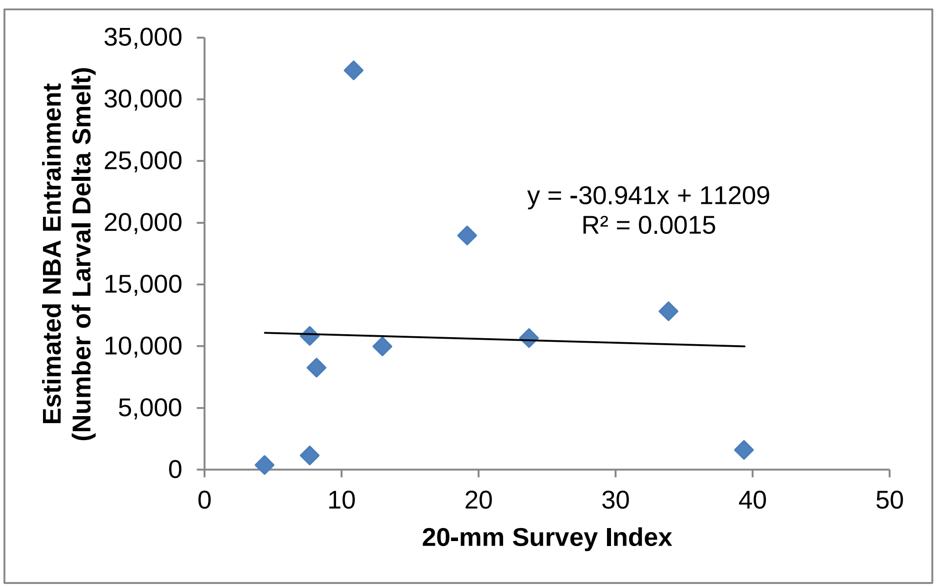
The extent of take of Delta Smelt caused by DCC operations cannot be estimated, but would not be expected to differ between the PP and NAA, given very little difference in the modeled number of days that the DCC would be open (see Section 4.1.3.6 *Delta Cross Channel*).

4.1.6.3.6 Suisun Marsh Facilities

As described in Section 4.1.3.7 *Suisun Marsh Facilities*, there is potential for take of Delta Smelt as a result of entrainment (RRDS and MIDS), predation near facilities (SMSCG), and effects on X2/habitat extent (SMSCG). Take from habitat changes because of SMSCG effects on X2 would be limited because of operations meeting D-1641 criteria, and the PP would include a continuation of the existing operations, resulting in no more than around 10-20 days of operations. Minimal take by entrainment of older Delta Smelt is expected at the MIDS intake on the basis of no observed entrainment during previous studies (2004-2006; Enos et al. 2007), and very little entrainment of larvae is expected based on PTM studies (Culberson et al. 2004). As described in Section 4.1.3.7.2 *Roaring River Distribution System*, the screens on the RRDS intake minimize take of Delta Smelt to entrainment of larvae or smaller juveniles (< 30 mm). There are apparently no monitoring data from which to infer the level of take of larvae; as described in Section 4.1.3.7.2.4 *Larvae/Young Juveniles*, the entrainment risk appears limited given that that DSM2-PTM modeling for the California Department of Fish and Game (2009) longfin smelt incidental take permit application did not observe any particles entering RRDS.

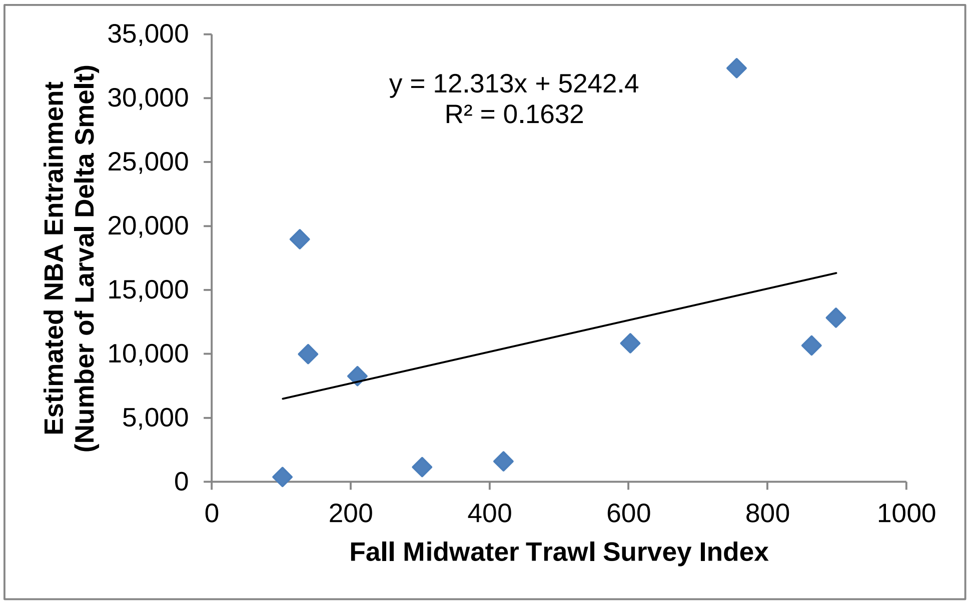
4.1.6.3.7 North Bay Aqueduct

As noted by U.S. Fish and Wildlife Service (2008: 286), take of Delta Smelt at the NBA's Barker Slough Pumping Plant would be difficult to detect because there is no monitoring program sampling on a regular basis, but take would not be expected to be high because of the presence of the fish screens. The DSM2-PTM results gave up to ~2.7 percent of particles representing Delta Smelt larvae being entrained, which reflected the relatively high proportion of Delta Smelt found at 20-mm stations in the vicinity (ICF International 2016: Appendix 6.A *Quantitative Methods for Biological Assessment of Delta Smelt*, Table 6.A-9). Estimates of take of Delta Smelt by entrainment at the NBA during 1995 to 2004 were made in response to the 1995 OCAP biological opinion monitoring requirements by multiplying pumping by the density of larvae at stations in the vicinity. Estimated take by entrainment ranged from 375 larval Delta Smelt in 1995 to 32,323 larval Delta Smelt in 2001 (U.S. Fish and Wildlife Service 2008: 170). These estimates are not closely related to overall indices of Delta Smelt abundance from the 20-mm and fall midwater trawl surveys (Figure 4.1-30 and Figure 4.1-31), although it would be expected that entrainment in the future would be less than previously occurred because of the low abundance of the Delta Smelt population that currently exists relative to the 1995-2004 period for which the NBA estimates were made. U.S. Fish and Wildlife Service (2008: 170-171) noted: "a study of a fish screen in Horseshoe Bend built to delta smelt standards excluded 99.7 percent of fish from entrainment even though most of these were only 15-25 mm long (Nobriga et al. 2004). Thus, the fish screen at NBA may protect many of the delta smelt larvae that do hatch and rear in Barker Slough, so actual entrainment was probably lower" [than estimated from fish density and pumping rates]. Therefore, actual take of Delta Smelt at the NBA under the PP would be similar to the NAA.



Source: U.S. Fish and Wildlife Service (2008: 170); Damon and DuBois (2015).

Figure 4.1-30. Relationship Between Delta Smelt 20-mm Survey Abundance Index and Estimated Entrainment at the North Bay Aqueduct Barker Slough Pumping Plant



Source: U.S. Fish and Wildlife Service (2008: 170); California Department of Fish and Wildlife (2016).

Figure 4.1-31. Relationship Between Delta Smelt Fall Midwater Trawl Abundance Index and Estimated Entrainment at the North Bay Aqueduct Barker Slough Pumping Plant

4.1.6.3.8 Other Facilities

As described by U.S. Fish and Wildlife Service (2008: 286), the take of Delta Smelt at the Contra Costa Canal Rock Slough Intake would be difficult to detect because there is no monitoring program sampling sampling Delta Smelt on a regular basis. U.S. Fish and Wildlife Service (2008: 286) suggested that incidental take is not anticipated to be high because the diversion is at the end of a dead-end slough where Delta Smelt are not usually present. As described in Section 4.1.3.9.1.4 *Larvae/Young Juveniles*, larval fish monitoring found few larval Delta Smelt being entrained at the Rock Slough intake, which suggests that take would be limited, particularly in light of the no-fill and no-diversion criteria that are in place to protect listed species during spring.

The Clifton Court Forebay Aquatic Weed Control Program uses copper-based herbicides in CCF, which could result in injury and mortality of Delta Smelt if they were exposed. However, the herbicide is used during July and August, when few Delta Smelt are expected in CCF (the water will be too warm). Mechanical removal of aquatic weeds may overlap with the occurrence of Delta Smelt in CCF, potentially resulting in injury, but take resulting from mechanical weed removal might be offset by a reduction in abundance of predatory fishes that inhabit the weed mats. The removal of weeds also reduces mortality resulting from smothering of the fish during salvage operations, thereby further offsetting the take.

4.1.7 Analysis of Potential for Jeopardy

4.1.7.1 Cumulative Effects

4.1.7.1.1 Specific Projects and Programs

The projects and programs that have been considered as part of the cumulative analysis have been drawn primarily from California Department of Water Resources, U.S. Bureau of Reclamation, U.S. Fish and Wildlife Service, and National Marine Fisheries Service (2013, Appendix 3D *Defining Existing Conditions, No Action Alternative, No Project Alternative, and Cumulative Impact Conditions*). Those projects and programs that could impact listed fishes in the project area are presented in Appendix 4.C *Information to Support Cumulative Effects Analysis*. The list of past, present and reasonably foreseeable future projects and programs has been evaluated to determine which of these activities may have effects on Delta Smelt. Most of the local, state and federal land use and land management programs that are affecting or will affect the Delta are designed to preserve open space and agricultural lands, and to manage the resources of the area for multiple uses, including agriculture, recreation, fish and wildlife habitat, flood protection and water management. Many of these projects and programs have a conservation or restoration component and thus could ultimately be beneficial to Delta Smelt. Principal among these is California EcoRestore, which was launched by DFW in 2015 and includes advancing (i.e., completing, or breaking ground on) 30,000 acres of fish and wildlife habitat by 2020; of this, 25,000 acres is associated with existing mandates for habitat restoration, pursuant to federal biological opinions, and 5,000 acres is habitat enhancements funded by Proposition 1 grants to local governments, non-profit organizations, and other entities. California EcoRestore has the potential to increase available habitat for occupancy by Delta Smelt, as well as enhancing the lower levels of the food web by restoring tidal natural community functioning.

California's Water Action Plan[32] (issued in 2014 and updated in 2016) is intended to guide the state's path to sustainable water management. Among the key actions with the potential to positively affect Delta Smelt are "Achieve the co-equal goals for the Delta", "Protect and restore important ecosystems", and "Manage and prepare for dry periods". Achievement of the co-equal goals for the Delta includes, among other things (including the PP and EcoRestore), the following important elements:

- "Begin implementation of the Delta Plan
    - "All relevant state agencies will fully participate in the Implementation Committee established by the Delta Stewardship Council and work with the Delta Science Program, the Interagency Ecological Program, and others to implement the Delta Science Plan to enhance water and natural resource policy and management decisions. The Delta Stewardship Council and the Delta Science Program will serve central roles in coordinating and supporting Delta science, with a primary focus on improving water management and ecosystem restoration efforts and informing adaptive management actions. The Delta Science Program will provide grants and direct assistance to support ongoing and emerging science actions.

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32 http://resources.ca.gov/docs/california_water_action_plan/Final_California_Water_Action_Plan.pdf

- "Bay Delta Water Quality Control Plan
  - "The State Water Resources Control Board will complete its update of the Water Quality Control Plan for the Delta and its upstream watersheds. The plan establishes both regulatory requirements and recommended actions. The Board will complete planning activities in the San Joaquin Basin and the southern Delta in 2016. Delta outflow and other flow-related Delta standards will be updated by spring 2018. The Board's action will balance competing uses of water including municipal and agricultural supply, hydropower, fishery protection, recreation, and other uses."

4.1.7.1.2 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 4.1.3.7 *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 diversions of water within the project 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 percent of entrainment; only one Delta Smelt was observed to be entrained during the 2 years of the study (Enos *et al.* 2007).

4.1.7.1.3 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 and Moon 2004; Scholz *et al.* 2012).

Discharges occurring outside the Delta that flow into the project area also contribute to cumulative effects of contaminant exposure.

4.1.7.1.4 Increased Urbanization

The Delta Protection Commission's Economic Sustainability Plan for the Delta reported an urban growth rate of about 54 percent within the statutory Delta between 1990 and 2010, as compared with a 25 percent 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 percent through 2030 ((California Department of Finance 2012). Table 4.1-50 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 percent of the population of the Delta counties, and Contra Costa County contributed 27.8 percent. Yolo County had the smallest population (200,849 or 5.3 percent) of all the Delta counties.

Table 4.1-50. 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 4.1-51 presents more detailed information on populations of individual communities in the Delta. Growth rates from 2000 to 2010 were generally higher in the smaller communities than in larger cities such as Antioch and Sacramento. This is likely a result of these communities having lower property and housing prices, and their growth being less constrained by geography and adjacent communities.

Table 4.1-51. 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 habitat may result from urbanization-induced point and non-point source chemical contaminant discharges. 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 will result in increased recreational activities in the region.

4.1.7.1.5 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.* (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 U.S. Environmental Protection Agency (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 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 percent, 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)." It has been suggested, based on consideration of ammonium loading into Suisun Bay, that with reduced discharge of ammonium as a result of the upgrades to the SRWTP, the food web could respond positively (Dugdale *et al.* 2013), which could provide a benefit to Delta Smelt.

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.

4.1.7.1.6 Other Activities

Other future actions within the project area that are likely to occur and may adversely affect Delta Smelt and their habitat include: the dumping of domestic and industrial garbage that decreases water quality; oil and gas development and production that may affect aquatic habitat and may introduce pollutants into the water; federal, state, or local levee maintenance, and maintenance of shipping channels with dredging that may also destroy or adversely affect habitat and interfere with natural, long-term habitat-maintaining processes. The Contra Costa Power Plant, which was owned and operated by NRG Delta, LLC, was retired in 2013 and replaced with the new natural gas power plant, Marsh Landing Generating Station. The Pittsburg Generating Station (PGS) remains in operation and consisted of seven once-through cooling systems, four of which have been retired, one of which is in the process of being retired, and two of which remain in operation. The once-through cooling system intake process can cause the impingement and entrainment of marine animals, kill organisms from all levels of the food chain, and disrupt the normal processes of the ecosystem. Additionally, the plant can discharge heated water that can reach temperatures as high as 100°F into the project area. This sudden influx of hot water can adversely affect the ecosystem and the animals living in it (San Francisco Baykeeper 2010).

On May 4, 2010, the SWRCB adopted a Statewide Policy on the Use of Coastal and Estuarine Water for Power Plant Cooling under Resolution No. 2010–0020 which required existing cooling water intake structures to reflect the best technology available for minimizing adverse environmental impacts (State Water Resources Control Board State Water Resources Control Board 2010). The PGS was required to submit an implementation plan to comply with this policy by December 31, 2017. The PGS chose to comply by retrofitting two of the existing units and retiring one unit. The retrofit and retirement of these units is underway.

4.1.7.1.7 Climate Change

Climate change and associated sea level rise have considerable potential to negatively affect Delta Smelt. These drivers may affect water temperature, and also the location and extent of the low salinity zone, which constitutes much of the rearing habitat for juvenile Delta Smelt. Effects on water temperature are relatively independent of water operations, and are mainly driven by climate (see discussion in Section 4.1.3.5.2 *Water Temperature*). Location of the low salinity zone, however, is also dependent on water operations (e.g., see discussion in Section 4.1.3.5.1 *Abiotic Habitat*).

The most recent analysis of plausible temperature change scenarios by Brown et al. (2016) found that over the time scale of the PP starting operations (i.e., following completion of construction in 2029; see Appendix 3.D *Assumed Construction Schedule for the Proposed Project*), there would be some changes in temperature-related habitat availability during time periods of importance for Delta Smelt, with the extent of these changes varying depending on the climate change scenario analyzed. Brown et al.'s (2016) analysis included a number of locations, the results for which are summarized in their Tables S1, S2, S3, S4, S5, and S6 of the supplemental material to their study. They reported the decadal (2010-2019, 2020-2029, 2030-2039, etc) annual median, minimum, and maximum values for a number of important variables, including the number of days per year when mean daily water temperature is ≥ 27°C, the chronic lethal temperature for juveniles; the number of days per year when mean daily water temperature is ≥ 24°C, the temperature for onset of physiological thermal stress for juveniles; the duration (days per year) of the spawning window (15-20°C); the Julian date of the beginning of the spawning window (15-20°C); the Julian date of the beginning of the maturation window (last day of 24°C to beginning of spawning window); and the duration of the maturation window (number of days from last day of 24°C to beginning of spawning window). Given the timeline for construction and initial operations of the PP, of most relevance to consideration of the cumulative effects are the first three decades of the analysis by Brown et al. (2016), i.e., 2010-2019, 2020-2029, and 2030-2039.

Based on the existing distribution of Delta Smelt, perhaps the most representative locations for consideration from the analysis of Brown et al. (2016) are in the lower San Joaquin River (Prisoners Point, Jersey Point, and Antioch), the Sacramento River (Hood, Rio Vista, and Decker Island), the north Delta (upper Cache Slough, Miner Slough, Liberty Island, and the Sacramento Deep Water Ship Channel), the Sacramento-San Joaquin River confluence (Mallard Island), and Suisun Bay (Martinez), as shown in Tables 4.1-50 to 4.1-55 (see also Figure 1 of Brown et al. [2016]). The main trends in these projections are as follows, based on a comparison of the current decade (2010-2019) to the decade including initial operations of the PP (2030-2039):

- Number of days per years with chronic lethal maximum temperature (≥ 27°C) for juveniles (June-December) (Table 4.1-50)
  - There is generally little difference to no difference between 2010-2019 and 2030-2039, except at Prisoners Point, Jersey Point, and Liberty Island, where maxima increase under both scenarios
  - Maxima also increase at Hood, Rio Vista, and Decker Island in the most warming scenario (by around 5 days)
- Number of days per year with onset of physiological thermal stress (≥ 24°C) for juveniles (June-December) (Table 4.1-51)
  - There is generally greater frequency in 2030-2039 than in 2010-2019, throughout much of the range
  - However, this is not the case for the confluence and Suisun Bay in the least warming scenario (no difference), but is true for the confluence in the most warming scenario
  - For the most warming scenario, the median number of stressful days increases considerably in important existing portions of the species' range, e.g., from around 40 days to 60 days at Rio Vista/Decker Island and from 18 days to 30 days at Mallard Island
- Number of days per year within the spawning window (15-20°C) for adults (Table 4.1-52)
  - For the least warming scenario, the variability generally increases from 2010-2019 to 2030-2039 (minimum number of days decreases, maximum number of days increases), with the median number of days generally decreasing, except at the confluence and Suisun Bay, where the median number of days increases
  - For the most warming scenario, the minimum number of days decreases at all locations, as does the maximum number of days (except at the confluence and Suisun Bay, which increase); however, the median number of days decreases at all locations

- Julian date of the beginning of the spawning window for adults (Table 4.1-53)
  - There is generally little difference between 2010-2019 and 2030-2039 (e.g., 0-5 days earlier in 2030-2039, for the median Julian date)
- Julian date of the beginning of the maturation window (last day of 24°C to beginning of spawning window) for adults (Table 4.1-54)
  - This generally occurs later in the year (often by 10 or more days for median date)
- Duration of the maturation window (number of days from last day of 24°C to beginning of spawning window) for adults (Table 4.1-55)
  - This generally decreases from 2010-2019 to 2030-2039
  - For the least warming scenario, the decreases in medians range from around 2 days at the confluence and Hood to over 30 days in Suisun Bay (with the latter representing a 13 percent shorter maturation window)
  - For the most warming scenario, there are increases in median maturation window duration in the San Joaquin River (around 5-10 days); however, with the exception of the confluence, other locations generally have decreases, ranging from 2-3 days at Decker Island, Upper Cache Slough, and Liberty Island, to around 10 days in Suisun Bay

Overall, the results from Brown et al. (2016) suggest that the main thermal effects of climate change at the onset of PP operations will be an increase in the number of days of physiological thermal stress for juveniles and a decrease in the maturation window for adults. This could negatively affect the Delta Smelt population through habitat compression for juveniles, as juveniles move away from stressful conditions; and reduced fecundity for adults, as fecundity is positively related to fish length, which may be lessened by the shorter maturation period (i.e., less time for growth).

With respect to changes in abiotic habitat availability as a result of sea level rise and changes in precipitation, two studies have suggested a general decline in abiotic habitat extent could occur for Delta Smelt during the important fall juvenile rearing period as the 21st century progresses (Feyrer et al. 2011; Brown et al. 2013). Although both the PP and the NAA include operations that meet the existing flow-based regulations that are intended to protect abiotic habitat for Delta Smelt and other species—chief among which are the fall X2 action from the U.S. Fish and Wildlife Service (2008) SWP/CVP BiOp's RPA and SWRCB Bay-Delta Water Quality Control Plan habitat protection outflows from February to June—declines in abiotic habitat nevertheless could occur while still meeting these standards. However, operations modeling of the PP and NAA suggested that there would be very small differences in X2 between the climate change scenario assumed for the CWF modeling (i.e., the central climate change scenario, Q5, at 2025; see the BA's Appendix 5A, *CalSim II Modeling and Results*, Attachment 1, *Climate Change and Sea Level Rise Scenarios Selection*) and the same scenarios run with existing climate, as shown in Figure 5.A.A.3-17 in the BA's Appendix 5A, Attachment 3, *Operations Sensitivity to Climate Change Projections* (ICF International 2016). As discussed in Section 4.1.7.1.1, *Specific*

Projects and Programs, the SWRCB Bay-Delta Water Quality Control Plan's Delta outflow and other flow-related Delta standards will be updated by spring 2018; this could alter the potential effects on abiotic habitat from climate change (e.g., by requiring greater flows than current standards).

Table 4.1-52. Median, minimum, and maximum values for the number of days each year when mean daily water temperature is ≥ 27°C (chronic lethal maximum temperature), during each decade from 2010-2039, for the juvenile life stage of Delta Smelt (June-December) for the least-warming (PCM-B1) and most-warming (GFDL-A2) climate change scenarios examined by Brown et al. (2016)

Area		2010-2019			2020-2029			2030-2039		
	Location	Median	Minimum	Maximum	Median	Minimum	Maximum	Median	Minimum	Maximum
Scenario PCM-B1 (Least Warming)										
San Joaquin River	Prisoners Point	0	0	8	0	0	0	0	0	11
	Jersey Point	0	0	0	0	0	3	0	0	12
	Antioch	0	0	16	0	0	6	0	0	17
Sacramento River	Hood	0	0	0	0	0	0	0	0	0
	Rio Vista	0	0	5	0	0	0	0	0	5
	Decker Island	0	0	0	0	0	0	0	0	0
North Delta	Upper Cache Slough	0	0	0	0	0	0	0	0	0
	Miner Slough	0	0	0	0	0	0	0	0	0
	Liberty Island	0	0	0	0	0	5	0	0	15
	Deepwater Ship Channel	0	0	0	0	0	0	0	0	0
Confluence	Mallard Island	0	0	0	0	0	0	0	0	0
Suisun Bay	Martinez	0	0	0	0	0	0	0	0	0
Scenario GFDL-A2 (Most Warming)										
San Joaquin River	Prisoners Point	0	0	7	0	0	7	4.5	0	12
	Jersey Point	0	0	5	0	0	16	0	0	12
	Antioch	0	0	11	0	0	21	7.5	0	14
Sacramento River	Hood	0	0	0	0	0	0	0	0	5
	Rio Vista	0	0	3	0	0	3	0	0	7
	Decker Island	0	0	0	0	0	0	0	0	5
North Delta	Upper Cache Slough	0	0	0	0	0	0	0	0	0
	Miner Slough	0	0	0	0	0	0	0	0	0
	Liberty Island	0.5	0	10	0	0	12	5	0	15
	Deepwater Ship Channel	0	0	3	0	0	2	0	0	5
Confluence	Mallard Island	0	0	0	0	0	0	0	0	1
Suisun Bay	Martinez	0	0	0	0	0	0	0	0	0

Table 4.1-53. Median, minimum, and maximum values for the number of days each year when mean daily water temperature is ≥ 24°C (onset of physiological thermal stress), during each decade from 2010-2039, for the juvenile life stage of Delta Smelt (June-December) for the least-warming (PCM-B1) and most-warming (GFDL-A2) climate change scenarios examined by Brown et al. (2016)

Area	Location	2010-2019			2020-2029			2030-2039		
		Median	Minimum	Maximum	Median	Minimum	Maximum	Median	Minimum	Maximum
Scenario PCM-B1 (Least Warming)										
San Joaquin River	Prisoners Point	36.5	8	69	44.5	20	69	51	34	86
	Jersey Point	61.5	13	79	56.5	36	83	69	54	91
	Antioch	29.5	0	65	37.5	7	57	35.5	13	69
Sacramento River	Hood	7.5	0	55	10	0	41	6.5	0	43
	Rio Vista	14	0	58	22.5	1	47	18.5	0	50
	Decker Island	29	0	63	42	6	63	41.5	23	71
North Delta	Upper Cache Slough	0	0	13	0	0	29	0	0	37
	Miner Slough	2.5	0	24	4	0	37	2.5	0	39
	Liberty Island	28	0	46	37	8	56	37.5	13	68
	Deepwater Ship Channel	11.5	0	32	17	0	44	14.5	0	46
Confluence	Mallard Island	0	0	36	0	0	29	0	0	34
Suisun Bay	Martinez	0	0	9	0	0	0	0	0	7
Scenario GFDL-A2 (Most Warming)										
San Joaquin River	Prisoners Point	66.5	35	98	68	63	104	82.5	57	93
	Jersey Point	69.5	23	104	70.5	57	113	79.5	60	98
	Antioch	57	21	93	63.5	55	100	74.5	49	88
Sacramento River	Hood	26.5	2	56	43	18	86	45.5	27	76
	Rio Vista	40.5	18	62	48.5	33	90	55.5	38	82
	Decker Island	42	5	67	46.5	18	94	64	39	83
North Delta	Upper Cache Slough	9	0	22	8.5	0	62	17.5	0	43
	Miner Slough	13.5	0	28	17	0	66	24	3	57
	Liberty Island	36	8	61	42.5	25	88	54	37	78
	Deepwater Ship Channel	18.5	0	50	27	4	76	33	19	70
Confluence	Mallard Island	17.5	0	48	35	9	82	29.5	16	71
Suisun Bay	Martinez	0	0	13	0	0	40	10	0	23

Table 4.1-54. Median, minimum, and maximum values for the duration (number of days each year) of the spawning window (15-20°C), during each decade from 2010-2039, for the adult life stage of Delta Smelt for the least-warming (PCM-B1) and most-warming (GFDL-A2) climate change scenarios examined by Brown et al. (2016)

Area	Location	2010-2019			2020-2029			2030-2039		
		Median	Minimum	Maximum	Median	Minimum	Maximum	Median	Minimum	Maximum
Scenario PCM-B1 (Least Warming)										
San Joaquin River	Prisoners Point	53.5	41	74	51.0	43	68	38.0	32	64
	Jersey Point	56.5	36	65	52.0	36	70	50.5	30	88
	Antioch	57.5	42	72	55.5	42	70	44.5	31	65
Sacramento River	Hood	57.0	21	64	47.0	35	70	50.5	25	87
	Rio Vista	57.0	21	64	47.0	35	70	52.0	29	87
	Decker Island	57.5	25	66	51.5	36	72	63.0	31	88
North Delta	Upper Cache Slough	55.0	26	64	58.5	33	73	48.0	32	68
	Miner Slough	57.0	34	65	53.5	34	72	51.0	30	68
	Liberty Island	57.5	27	65	53.5	34	72	48.5	29	67
	Deepwater Ship Channel	57.0	40	65	57.0	38	71	46.0	31	65
Confluence	Mallard Island	58.5	40	66	58.5	36	74	63.0	31	89
Suisun Bay	Martinez	59.5	26	72	60.5	38	79	72.0	34	90
Scenario GFDL-A2 (Most Warming)										
San Joaquin River	Prisoners Point	54.0	33	79	52.5	19	82	50.0	25	58
	Jersey Point	47.5	28	72	46.0	23	66	46.5	15	58
	Antioch	53.5	29	80	54.0	22	87	50.0	21	58
Sacramento River	Hood	42.0	28	68	44.5	23	67	39.5	20	59
	Rio Vista	42.5	28	70	45.0	22	66	39.5	20	58
	Decker Island	48.0	33	70	51.5	22	71	41.0	20	80
North Delta	Upper Cache Slough	50.0	27	72	45.5	22	72	42.0	17	58
	Miner Slough	42.5	28	71	47.5	22	69	45.0	18	58
	Liberty Island	43.0	27	71	46.5	23	67	44.0	11	65
	Deepwater Ship Channel	52.0	27	82	46.5	16	66	44.0	18	58
Confluence	Mallard Island	51.5	32	73	54.0	23	71	46.5	21	83
Suisun Bay	Martinez	59.0	38	90	63.0	24	80	51.5	22	94

Table 4.1-55. Median, minimum, and maximum values for the julian date of the beginning of the spawning window (15-20°C) each year, during each decade from 2010-2039, for the adult life stage of Delta Smelt for the least-warming (PCM-B1) and most-warming (GFDL-A2) climate change scenarios examined by Brown et al. (2016)

Area	Location	2010-2019			2020-2029			2030-2039		
		Median	Minimum	Maximum	Median	Minimum	Maximum	Median	Minimum	Maximum
Scenario PCM-B1 (Least Warming)										
San Joaquin River	Prisoners Point	86.0	82	97	90.0	81	111	89.0	69	94
	Jersey Point	100.0	86	109	98.0	92	116	97.0	80	108
	Antioch	93.0	83	104	93.5	84	113	94.5	69	106
Sacramento River	Hood	101.5	88	126	100.5	93	118	101.0	82	111
	Rio Vista	101.5	88	126	1005	93	117	100.5	82	109
	Decker Island	102.5	89	127	105.0	93	119	101.5	82	112
North Delta	Upper Cache Slough	100.5	83	117	96.0	84	118	94.0	68	103
	Miner Slough	100.5	84	110	97.5	91	117	95.0	80	108
	Liberty Island	101.0	85	117	100.0	92	118	97.5	81	109
	Deepwater Ship Channel	97.0	83	106	95.5	84	113	94.0	68	102
Confluence	Mallard Island	101.0	86	110	100.0	92	117	97.5	81	109
Suisun Bay	Martinez	101.5	88	127	100.5	93	119	101.0	81	111
Scenario GFDL-A2 (Most Warming)										
San Joaquin River	Prisoners Point	82.5	75	99	84.5	70	105	86.5	81	96
	Jersey Point	93.0	79	112	96.5	78	109	98.5	85	119
	Antioch	89.5	77	105	86.0	72	108	91.0	82	103
Sacramento River	Hood	98.0	82	113	101.0	92	110	103.0	88	120
	Rio Vista	97.0	81	113	100.5	92	110	103.0	88	120
	Decker Island	99.0	82	114	101.5	92	111	104.5	89	124
North Delta	Upper Cache Slough	94.5	76	112	96.5	67	109	95.0	84	119
	Miner Slough	95.5	78	112	98.0	70	109	95.0	85	119
	Liberty Island	96.5	79	113	100.5	78	109	99.0	86	120
	Deepwater Ship Channel	90.5	76	112	95.5	67	108	92.5	84	119
Confluence	Mallard Island	95.5	79	113	98.5	78	110	99.5	86	120
Suisun Bay	Martinez	97.0	80	113	101.0	79	110	103.5	88	124

Table 4.1-56. Median, minimum, and maximum values for the julian date of the beginning of the maturation window (last day of 24°C to beginning of spawning window), during each decade from 2010-2039, for the adult life stage of Delta Smelt for the least-warming (PCM-B1) and most-warming (GFDL-A2) climate change scenarios examined by Brown et al. (2016)

Area	Location	2010-2019			2020-2029			2030-2039		
		Median	Minimum	Maximum	Median	Minimum	Maximum	Median	Minimum	Maximum
Scenario PCM-B1 (Least Warming)										
San Joaquin River	Prisoners Point	247.5	205	269	251.0	227	274	253.5	237	270
	Jersey Point	255.0	204	275	259	236	277	259.5	252	292
	Antioch	246.0	200	269	251.5	227	275	256.0	236	291
Sacramento River	Hood	223.0	210	235	223.0	212	249	230.0	216	267
	Rio Vista	233.5	196	250	248.5	225	273	246.0	223	269
	Decker Island	236.0	217	252	247.5	222	273	250.0	224	277
North Delta	Upper Cache Slough	206.0	205	227	214.5	200	233	227.0	202	264
	Miner Slough	218.0	197	230	212.5	198	236	212.0	198	250
	Liberty Island	235.0	213	256	246.5	224	274	250.0	226	291
	Deepwater Ship Channel	221.5	199	234	219.0	211	237	222.0	204	265
Confluence	Mallard Island	220.5	199	234	220.0	210	237	219.0	199	266
Suisun Bay	Martinez	205.0	199	211	228.5	226	231	224.0	224	224
Scenario GFDL-A2 (Most Warming)										
San Joaquin River	Prisoners Point	260.5	224	280	256.5	236	278	251.5	234	265
	Jersey Point	264.0	217	278	264.0	251	285	260.5	240	279
	Antioch	261.0	217	282	257.0	236	279	251.5	234	277
Sacramento River	Hood	232.5	207	262	249.5	216	276	236.0	216	251
	Rio Vista	252.5	215	280	251.0	226	277	248.0	231	263
	Decker Island	246.5	215	270	253.0	235	281	251.5	235	265
North Delta	Upper Cache Slough	215.0	207	260	222.5	207	276	227.0	198	248
	Miner Slough	216.0	210	260	222.0	214	259	227.0	199	249
	Liberty Island	252.5	208	273	253.0	217	281	249.5	228	264
	Deepwater Ship Channel	221.0	212	261	241.0	215	276	230.5	214	250
Confluence	Mallard Island	226.0	216	262	235.5	215	276	229.0	213	251
Suisun Bay	Martinez	211.5	198	236	210.5	187	258	224.0	197	227

Table 4.1-57. Median, minimum, and maximum values for the duration of the maturation window (number of days from last day of 24°C to beginning of spawning window), during each decade from 2010-2039, for the adult life stage of Delta Smelt for the least-warming (PCM-B1) and most-warming (GFDL-A2) climate change scenarios examined by Brown et al. (2016)

Area	Location	2010-2019			2020-2029			2030-2039		
		Median	Minimum	Maximum	Median	Minimum	Maximum	Median	Minimum	Maximum
Scenario PCM-B1 (Least Warming)										
San Joaquin River	Prisoners Point	202.0	185	243	208.5	188	243	194.0	173	213
	Jersey Point	211.0	178	262	206.5	182	226	192.5	165	218
	Antioch	203.0	188	255	212.0	194	245	188.0	168	228
Sacramento River	Hood	245.0	231	268	241.0	211	258	243.5	189	258
	Rio Vista	234.0	202	267	225.5	206	255	207.0	187	248
	Decker Island	235.5	218	243	233.5	203	261	214.5	179	246
North Delta	Upper Cache Slough	264.0	236	276	243.0	226	264	230.5	189	265
	Miner Slough	249.0	230	276	249.5	226	272	244.5	208	265
	Liberty Island	223.5	218	268	219.5	190	255	215.5	154	233
	Deepwater Ship Channel	235.0	228	264	239.0	222	264	226.0	188	262
Confluence	Mallard Island	249.0	234	262	244.0	222	268	247.0	193	266
Suisun Bay	Martinez	255.0	255	255	238.0	229	247	221.0	221	221
Scenario GFDL-A2 (Most Warming)										
San Joaquin River	Prisoners Point	188.0	174	223	185.5	166	208	198.5	192	220
	Jersey Point	193.0	176	259	195.5	180	207	198.5	174	220
	Antioch	194.0	173	232	189.0	168	209	203.5	175	221
Sacramento River	Hood	237.0	198	260	222.0	192	250	229.5	210	256
	Rio Vista	225.0	185	237	209.0	188	237	219.0	205	232
	Decker Island	216.0	187	263	209.5	185	229	213.5	201	239
North Delta	Upper Cache Slough	239.0	201	269	227.5	194	253	236.0	210	260
	Miner Slough	240.0	202	266	230.0	195	256	232.0	210	253
	Liberty Island	215.0	178	263	213.5	189	233	212.5	201	233
	Deepwater Ship Channel	225.5	200	264	218.5	193	231	221.0	205	249
Confluence	Mallard Island	231.5	195	261	221.5	191	252	231.5	210	255
Suisun Bay	Martinez	257.0	223	267	253.0	200	281	246.5	233	271

4.1.7.1.8 Conclusion for Cumulative Effects

With the important exception of climate change, a number of factors discussed for cumulative effects will have neutral or potentially positive effects on Delta Smelt. Specific projects and actions such as EcoRestore and the update to the Bay Delta Water Quality Control Plan will have positive effects on Delta Smelt. Water diversions within the Delta will not increase above existing levels, given little change since the 1930s (see discussion by Nobriga and Herbold 2009); indeed, there may be some decreases in diversions as some lands are restored to tidal habitat, for example. In addition, more diversions may be screened as part of existing efforts (e.g., Anadromous Fish Screen Program) and, as discussed in Section 4.1.7.1.2 *Water Diversions*, there is little evidence to suggest that such diversions have appreciable effects on Delta Smelt (Nobriga et al. 2004; Nobriga and Herbold 2009). Agricultural practices are increasingly regulated (e.g., Irrigated Lands Regulatory Program; Central Valley Regional Water Quality Control Board 2016) and, as discussed for water diversions, will not increase in extent within the Delta and adjacent areas of importance to Delta Smelt; there may be some decreases in the extent of agriculture within the Delta as tidal habitats are restored. Increased urbanization as the result of the addition of a projected 650,000 residents between 2010 and 2025 in Delta counties (Table 4.1-50) has the potential to result in additional negative effects to Delta waterways that Delta Smelt inhabit, as discussed in Section 4.1.7.1.4 *Increased Urbanization*. However, the Delta Protection Commission's (2010) Land Use and Resource Management Plan for the Primary Zone of the Delta provides a number of policies intended to limit the potential effects of urbanization, and the Delta Stewardship Council's Delta Plan (2013) includes policies such as locating new urban development wisely (e.g., within areas designated for residential, commercial, or industrial development in city or county general plans)[33]. Such policies are intended to limit the potential for development to affect the Delta, which may also limit potential urbanization effects on Delta Smelt habitat. With the updates to the SRWTP and the possibility of increased phytoplankton abundance and therefore zooplankton, there is potential for improvements in the prey base for Delta Smelt. As described in Section 4.1.7.1.7, *Climate Change*, the effects of greater water temperature have the potential to negatively affect the Delta Smelt population through habitat compression for juveniles and reduced fecundity caused by a shorter maturation period; such changes could occur by the time the NDD are completed and the PP's dual conveyance operations begin. In addition, there could also be negative effects from climate change and sea level rise reducing abiotic habitat extent, although modeling for the PP and NAA suggest that such effects would be limited at the onset of PP operations.

The proposed project's adverse effects on Delta Smelt will be similar or reduced, compared to the NAA. The take minimization and mitigation measures will ensure that loss of habitat will be fully mitigated and that take will be minimized.

4.1.7.2 Potential to Jeopardize Continued Existence of the Species

The issuance of the ITP will not jeopardize the continued existence of Delta Smelt for the following reasons.

[33] On June 23, 2016 the Sacramento Superior Court ruled to set aside the Delta Plan until specified revisions are completed.

Level of Take – The overall potential for take is high, prior to consideration of the effects of implementing TMMs. Covered activities have a high likelihood of resulting in mortality of individuals. The covered activities will result in permanent impacts on 93.4 acres of aquatic habitat: 5.6 acres for the NDD (shallow water habitat), 245 acres near and upstream of the NDD (shallow water habitat, including 36 acres of spawning beach habitat), 2.9 acres at the HOR gate (tidal perennial habitat), and 22.4 acres at barge landings (tidal perennial habitat). These habitat losses are small relative to the overall area of habitat available to Delta Smelt, and therefore will not have a population-level effect. Entrainment losses at the south Delta export facilities (i.e., the main source of entrainment) will be similar or lower to the entrainment under the NAA; as described in Section 4.1.6.3.2, *South Delta Exports*, this could amount to around 1.3 percent of the adult Delta Smelt population being lost to entrainment under the PP, for example. The PP includes OMR criteria that are the same or more restrictive than those from the U.S. Fish and Wildlife Service (2008) BiOp, which were implemented to avoid jeopardy to the species from entrainment. Entrainment of Delta Smelt of larval/young juvenile Delta Smelt at the NDD could occur but which, as noted in Section 4.1.6.3.1, *North Delta Exports*, may be limited to less than 0.1 percent of the population of fish too small to be screened. Although not quantifiable, losses from entrainment at other facilities (NBA Barker Slough Pumping Plant, RRDS, MIDS, and CCC Rock Slough intake) would be maintained at the apparently low levels currently occurring at these facilities. Inclusion of the fall X2 requirements from the U.S. Fish and Wildlife Service (2008) BiOp in the PP also ensures that take from effects on abiotic habitat is limited to a level that does not create potential for jeopardy of the species. Indirect take from effects to habitat has the potential to affect a large proportion of the Delta Smelt population, principally from sediment removal by the NDD (potentially leading to greater water clarity) and effects from *Microcystis* caused by longer water residence time in the south Delta. However, as described in the next section, take minimization measures will limit these potential mechanisms.

Take Minimization Measures – The proposed AMMs described in Section 5.4.1 *Delta Smelt*, greatly reduce the potential for mortality of individuals, which makes it unlikely that activities will affect reproductive rates of the population or survivorship of individuals. Operational criteria also will minimize the potential for take of Delta Smelt (see Section 3.3.2, *Operation Criteria*): for entrainment, this includes having NDD fish screens meeting agency requirements (1.75-mm opening, 0.2-ft/s approach velocity) and having OMR criteria for south Delta exports that are the same or more restrictive than those from the U.S. Fish and Wildlife Service (2008) BiOp; for abiotic habitat, this consists of inclusion of the fall X2 requirements from the U.S. Fish and Wildlife Service (2008) BiOp. Proposed spring outflow criteria for Longfin Smelt (see Section 4.2.7.2.2 *Effect of Take Minimization Measures* for that species and Section 5.3.2 *Longfin Smelt* in Chapter 5 *Take Minimization and Mitigation Measures*) may also potentially benefit Delta Smelt, relative to not having these spring outflow criteria in place, although the effect of spring outflow on Delta Smelt is uncertain. Such benefits could occur for example by reducing south Delta exports (to increase outflow) and therefore reducing south Delta entrainment directly, or by reducing north or south Delta exports with the result that Delta Smelt larvae may be distributed farther downstream (as reflected in lower X2, shown to be an important driver of entrainment in the percentage entrainment loss regression; see Tables 4.D-5 and 4.D-6 in Appendix 4.D *Comparison of Key Hydrological Variables for Proposed Project with Longfin Smelt Spring Outflow Criteria to No Action Alternative and Proposed Project Scenarios*). However, as previously noted, the risk for entrainment would in any case be carefully managed in real time that will occur under both the NAA and PP. Entrainment, as well as other potential management actions for Delta Smelt relative to spring outflow will be a subject of the Adaptive Management Program, which will implement research to reduce uncertainties and incorporate new information into management actions.

Related to other take minimization measures, as described in Section 3.2.10.6 *Dispose Spoils*, 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 will mitigate the effects of sediment removal by the NDD. Preferential south Delta export pumping in the summer will minimize the potential for take caused by longer residence times which could affect *Microcystis* toxicity to Delta Smelt prey.

Mitigation – Mitigation will fully mitigate habitat loss and any loss of individuals associated with habitat loss. High-quality, larger-scale, intact habitat will be acquired, enhanced, and managed in perpetuity, at ratios ranging from 1:1 for potential reduced access to the shallow water habitat near and upstream of the NDD (with the exception of a 3:1 ratio for the sandy beach spawning habitat), to 5:1[34] for the shallow water habitat at the NDD. In total, 347.7 acres will be provided as mitigation (273 acres of shallow-water habitat, of which 108 acres will be sandy spawning beach habitat, for NDD mitigation; 74.7 acres of tidal perennial habitat for HOR gate and barge landings mitigation).

While the Bay-Delta Delta Smelt population appears to be in decline (IEP MAST Team 2015), the project's activities will not exacerbate this decline. The applicant's take minimization measures will ensure impacts on habitat and individuals are minimized, and the mitigation will ensure an appropriate extent of habitat is restored.

For Delta Smelt, environmental drivers and habitat attributes that IEP MAST Team (2015) described as of importance to the population include water temperature, salinity and the size and location of the low salinity zone (i.e., what has been discussed principally as abiotic habitat in Section 4.1.3.5.1 *Abiotic Habitat*), turbidity, entrainment and transport, predation risk, contaminants, food and feeding, and harmful algal blooms (e.g., *Microcystis*). The potential effects of the Proposed Project on these drivers and attributes, as relevant, have been described generally in the analyses presented in Section 4.1.1 *Construction Effects*, Section 4.1.2 *Maintenance Effects*, and Section 4.1.3 *Operations Effects*. The Proposed Project will not threaten the survival of Delta Smelt because, by inclusion of appropriate minimization and mitigation measures, the covered activities will not result in significant losses of individuals of the species or habitat. The covered activities also will not substantially contribute to the fragmentation of remaining habitat because the potential for creation of barriers to movement (principally at the NDD, for upstream migrants) will be mitigated as necessary.

Considering the level of take described previously, the take minimization measures in Section 5.3.1 *Delta Smelt*, and that the loss of habitat will be fully mitigated, the Proposed Project will

[34] The 5:1 mitigation ratio assumes in-water work in June; should work not occur in June, the ratio would be 3:1. This may vary by intake.

not adversely affect the reproduction and survival of Delta Smelt, and the issuance of the ITP will not jeopardize the continued existence of the species.

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