Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

APPENDIX 5.C
FLOW, PASSAGE, SALINITY, AND TURBIDITY

ADMINISTRATIVE DRAFT
BAY DELTA CONSERVATION PLAN

Admin Draft

April 2012

ICF INTERNATIONAL

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

Admin Draft

ICF International. 2012. *Appendix 5.C: Flow, Passage, Salinity, and Turbidity. Administrative Draft. Bay Delta Conservation Plan*. April. (ICF 00282.11). Sacramento, CA. Prepared for the California Department of Water Resources, Sacramento, CA.

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

Appendix C

Flow, Passage, Salinity, and Turbidity

C.0 Executive Summary

Flows originating upstream and flowing through the Sacramento and San Joaquin River systems and into the Sacramento–San Joaquin River Delta (Delta) play a significant role in creating the habitat conditions that fish experience throughout their life cycles. Flow velocity, depth, duration, timing, and quality can affect abiotic factors such as salinity, turbidity, dissolved oxygen (DO) concentration, and temperature, as well as influence the total area and characteristics of wetted habitat accessible to fish. Flows and these related parameters also can influence fish migration patterns through and upstream of the Delta.

Comparison of the Bay Delta Conservation Plan (BDCP) preliminary proposal (PP)[1] with existing biological conditions[2] shows that, on average, the total volume of flow in the upstream and Delta areas is generally the same, but some daily, monthly, or water year–type patterns may shift under the preliminary proposal. Overall, there are minimal upstream changes, but some substantial shifts in how water moves through the Delta under the preliminary proposal. This appendix evaluates the effects on fish that result from changes in flows and flow-related parameters by comparing the preliminary proposal to the existing biological conditions. The BDCP could affect flows and related conditions in four primary ways:

- Conservation Measure (CM) 1 includes the new north Delta intakes, operations of which could affect Sacramento River inflow to the Delta, Delta hydrodynamics, and outflow to the Bay.
- CM2 includes Yolo Bypass fisheries enhancements that would improve passage in the Yolo Bypass for salmon, steelhead, and sturgeon while somewhat reducing Sacramento River flows between the Fremont Weir and the confluence of the Sacramento River and Yolo Bypass flows.
- CM4 includes restoration of 65,000 acres of tidal marsh that could result in changes in turbidity and tidal excursion in specific Delta locations and subregions.
- Operations of upstream reservoirs to meet downstream and Delta flow requirements could result in changes in temperatures in key spawning and egg incubation areas, changes in wetted areas that could result in redd dewatering, and changes in accessible rearing habitat.

This appendix has the following components:

- A description of the potential mechanisms for changes in flow and the related parameters of temperature, salinity, turbidity, and DO.
- An overview of the historical operations and management of flows in the State Water Project (SWP)/Central Valley Project (CVP) systems.
- A description of species exposure to potential changes in flows.

[1] See Table C.0-1 for a description of the preliminary proposal.

[2] Existing biological conditions: this condition is the state of the environment at the time of the analysis and assumes current operations.

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

- A description of the methods used to predict the potential effect of changes in flows under the BDCP.
- Results of the application of these methods.
- Based on these results, a comprehensive description of the expected flow-related effect on each life stage of each covered fish species. (Population-level effects on each species are presented in Chapter 5.)

The methods used to assess flows and the various flow-related parameters are based on CALSIM and DSM2 outputs, upstream temperature models, particle tracking modeling (PTM), multiple biological models, assumed and measured locations of fish, previous studies in the Delta, Delta Regional Ecosystem Restoration Implementation Plan (DRERIP) analyses, and/or professional judgment. The methods used reflect the best available tools and data regarding fish abundance, movement, and behavior. These methods were applied to a comparison of the PP with two baseline conditions (EBC1 and EBC2) at two time periods in the permit term, which include climate change assumptions (early long-term [ELT] and late long-term [LLT]). Appendix 2.C, *Climate Change*, includes more detailed information about climate changes assumptions, results, and analyses. Table C.0-1 provides a description of each of these conditions. For some methods, five water-year types (40-30-30 Sacramento River Index) were identified in CALSIM to determine the variation in flow-related effects under different flow conditions.

Table C.0-1. Definition of Analytical Conditions

Condition	Description
Existing Biological Condition 1 (EBC1)	This condition assumes current operations based on the 2008 USFWS and 2009 NMFS BiOps, excluding the Fall X2 actions. Ultimately, this would be similar to how the CVP/SWP has been operated since 2009.
Existing Biological Condition 2 (EBC2)	This condition assumes current operations based on the 2008 USFWS and 2009 NMFS BiOps, including the Fall X2 actions called for in the USFWS BiOp.
EBC2_ELT	This condition assumes that EBC2 continues into the future and includes conditions expected in Year 15 of the PP (2025).
EBC2_LLT	This condition assumes that EBC2 continues into the future and includes conditions expected in Year 50 of the PP (2060).
PP_ELT	This condition reflects the preliminary proposal in Year 15 (with the new intake facility but prior to full implementation of the restoration activities).
PP_LLT	This condition assumes full implementation of the BDCP preliminary proposal, and reflects Year 50.
USFWS = U.S. Fish and Wildlife Service. NMFS = National Marine Fisheries Service. BiOp = biological opinion. CVP/SWP = Central Valley Project/State Water Project.	

The following methods are used to evaluate flow-related effects.

- **CALSIM**: Simulate flows and storage in the SWP/CVP distribution system based on priority weighted objective functions and user-defined constraints under various flow conditions and water project operations.
- **DSM2-HYDRO:** Uses CALSIM output to predict depth and velocity of flow in Delta channels.

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

- **DSM2-QUAL:** Uses DSM2-HYDRO output to predict water temperature, DO, and salinity in the Delta and Suisun Marsh.
- **DSM2-Fingerprinting:** Uses DSM2-HYDRO output to show sources of flow in Delta channels.
- **DSM2-PTM**: Uses DSM2-HYDRO and both hypothetical release sites and data from trawls to estimate the movement of larval delta smelt that are assumed to be influenced primarily by flows.
- **MIKE 21**: Modeling software used to develop a two-dimensional hydrodynamic model that predicts water surface elevation, flow, and average velocity at each computational grid cell in the Yolo Bypass.
- **Reclamation Temperature Model:** Uses CALSIM flow and climatic model output to predict temperature in the Trinity, Feather, American, and Stanislaus River basins and upstream reservoirs.
- **Sacramento River Water Quality Model (SRWQM):** Simulates mean daily (using 6-hour meteorology) reservoir and river temperatures at key locations on the Sacramento River based on CALSIM output.
- **Reclamation Egg Mortality Model:** Uses results of water temperature modeling Reclamation Temperature Model and SRWQM) to estimate Chinook salmon egg mortality below each major SWP and CVP reservoir.
- **SALMOD:** Estimates juvenile Chinook salmon production in the upper Sacramento River, as a result of effects of flow and temperature on juvenile rearing habitat.
- **Sacramento Ecological Flows Tool:** Links flow management actions to changes in the physical habitats for salmonids using daily flow; data from submodels of temperature, substrate, and meander, including the SRWQM; and studies of habitat suitability, stranding, and dewatering.
- **Delta Passage Model (DPM):** Uses coded wire tag (CWT) and acoustic tag data to estimate the proportion of Chinook salmon runs that would occur in various Delta channels and their survival during downstream migration.
- **Assessment of Effectiveness of Nonphysical Barriers:** Uses results of recent studies at Georgiana Slough and Old River to estimate potential effectiveness of barriers in other Delta locations that would aid in successful migration.
- **DRERIP:** Uses results of scientific studies to establish conceptual models of the stressors and mechanisms that are thought to affect the population dynamics of various resident and migratory fish species, as well as habitat functions.
- **Winter–Spring X2-Abundance Regression:** Used to estimate relative abundance of longfin smelt in the fall based on winter–spring X2 (as an indication of outflow).
- **Delta smelt abiotic habitat index:** Used to calculate delta smelt abiotic habitat.
- **Yolo Bypass Fry Growth Model:** Used to estimate the differences in growth of Chinook salmon fry in the Yolo Bypass compared to the mainstem lower Sacramento River.

No single one of these methods could be used for all life stages of all species. As a result, it was necessary to employ these methods in combination to complete the assessment of flow-related effects. For example, the SRWQM could not be applied to San Joaquin River effects, and the DPM can be applied only to Chinook salmon passage through Delta channels.

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

These methods were applied to each species and life stage as appropriate, and the results of the assessment are presented in Section C.5. The conclusions presented in Section C.6 report multiple results because multiple methods were applied to some species and life stages, but attempt to provide a determination of the effect of each topic on each life stage. The conclusions therefore provide a determination of the flow-related effects on each species and life stage. Chapter 5 considers the importance of these changes on each species and the total effect on the population as a result of the preliminary proposal.

C.0.1 Summary of Conclusions

Table C.0-3 and Table C.0-4 summarize the main conclusions of the effects of BDCP on flow and flow-related parameters independent of climate change. In general, there are very few upstream effects, some adverse effects in the north Delta as a result of decreased flows, improvements in the south Delta as result of increased flows, and mixed results for passage and movement, although adaptive management and monitoring are expected to help improve actual outcomes.

Table C.0-2 summarizes the results of the numerous analyses of the effects of the BDCP on flow and flow-related parameters in the Plan Area by species and life stage. Effects of the SWP/CVP are separated by each of five water-year types when possible (wet [W], above-normal [AN], below-normal [BN], dry [D], and critical [C]). For analyses based on limited water years (e.g., analyses using DSM2 modeled flows), summaries were calculated only for all water years. The tables are based on consideration of the percentage change between baseline (EBC1, EBC2, EBC2_ELT, and EBC2_LLT) and the PP (PP_ELT and PP_LLT) for each method applied. *As such, effects shown in each cell reflect multiple independent results for each life stage, and therefore may include multiple colors, and do not indicate the relative importance of the change to the species. The importance of these changes is considered and described as part of the rollup in Chapter 5.*

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

Table C.0-2. Summary of Conclusions for Flow and Flow-Related Parameters

Upstream Habitat Effects
1. Except for Sacramento River spring-run Chinook salmon and Feather River green sturgeon egg incubation, the preliminary proposal would not result in adverse effects on upstream spawning. 2. The preliminary proposal would have no effects on spring- or winter-run Chinook salmon adult holding flows. 3. Upstream rearing habitat for covered species would not change substantially. Some benefits and adverse effects to winter-run rearing habitat are expected. However, some adverse effects on rearing habitat are expected for Feather River green sturgeon and Pacific and river lamprey.
Passage, Movement, and Migration Effects
4. Overall, flows in upstream areas during migration and transport periods for anadromous fish are not substantially changed under the preliminary proposal, with some exceptions. 5. Attraction flows and olfactory cues in the west Delta for upstream anadromous migrating fish will be altered because of shifts in exports from the south Delta to the north Delta under the preliminary proposal. 6. The preliminary proposal improvements in fish passage facilities at the Fremont Weir and within the Yolo Bypass (CM2) will reduce delay and stranding of upstream migrating adult anadromous covered fish species from the Sacramento River basin. 7. Chinook salmon smolt survival during outmigration through the Delta includes tradeoffs between positive and negative flow changes in the Yolo Bypass and Sacramento River, with uncertainty to be informed by monitoring and adaptive management. 8. Increase in Stockton Deep Water Ship Channel dissolved oxygen levels (CM14) will improve upstream migration conditions for fall-run Chinook salmon, steelhead, and other species in the San Joaquin River basin. 9. Modification of the Suisun Marsh Salinity Control Gate operation will improve or maintain passage for adult anadromous fish. 10. Nonphysical fish barriers (CM16) have the potential to inhibit juvenile fish from entering the interior Delta, but further research is necessary to evaluate effectiveness; unintended passage impedance for adults also requires research. 11. Reduced Sacramento River flows may reduce longfin smelt and delta smelt larval transport, with the potential to reduce survival for longfin smelt. 12. Changes in Sacramento River flow may result in an overall decrease in channel margin bench habitat, but restoration will offset this effect.
Delta Habitat Effects
13. The reduction in OMR reverse flows and the corresponding increase in net positive downstream flows through the south Delta channels are expected to improve migration cues, improve migration rates and pathways, and contribute to improved larval and juvenile survival and reduced adult straying; reverse OMR flows will be greater in certain water-year types. 14. Increased Yolo Bypass inundation will create substantial biological benefits to Sacramento splittail spawning and rearing, with other species likely to benefit; stranding risk is generally low. 15. The delta smelt fall abiotic habitat index is estimated to be similar between the preliminary proposal and existing biological conditions in the drier 40–50% of years and will be lower under the preliminary proposal in the wetter 50–60% of years, with the magnitude of difference depending on existing biological conditions; if occupied by delta smelt, restored habitat may decrease the magnitude of difference in wetter years and result in a greater habitat index in drier years.
DO = dissolved oxygen. OMR = Old and Middle River.

Draft

Table C.0-3. Summary of Flow-Related Biological Effects of BDCP in the Upstream Area Compared to EBC2_ELT and EBC2_LLT[3]

Species	Life Stage	Metric	All	Wet	Above Normal	Below Normal	Dry	Critical	All	Wet	Above Normal	Below Normal	Dry	Critical	All	Wet	Above Normal	Below Normal	Dry	Critical
A. Sacramento River			**Sacramento River (River Mile 194 to Keswick)**						**Sacramento River (River Mile 143 to 194)**						**Sacramento River (North Delta to River Mile 143)**					
Steelhead	Egg/Embryo	Spawning habitat[1]		Analysis by water year type not conducted.					No analysis conducted in this reach.						No spawning habitat present.					
		Water temperature[3,6]																		
		Redd dewatering[1]																		
	Fry/Juvenile	Rearing habitat[1]													Not a significant rearing reach.					
		Water temperature[3]																		
		Stranding[1]																		
	Adult	Water temperature[3]													No analysis conducted in this reach.					
Winter-run Chinook salmon	Egg/Embryo	Spawning habitat[2]							No spawning or rearing below Red Bluff Diversion Dam.						No spawning or rearing below Red Bluff Diversion Dam.					
		Redd dewatering[1]		Analysis by water year type not conducted.																
	Fry	Habitat[4]																		
		Stranding[1]																		
	Adult	Water temperature[3]																		
Spring-run Chinook salmon	Egg/Embryo	Spawning habitat[2]							No analysis conducted in this reach.						No analysis conducted in this reach.					
		Redd dewatering[1]		Analysis by water year type not conducted.																
	Fry	Habitat[1]																		
		Stranding[1]																		
	Adult	Water temperature[3]																		
Fall-run Chinook salmon	Egg/Embryo	Spawning habitat[2]							No analysis conducted in this reach.						No analysis conducted in this reach.					
		Redd dewatering[1]		Analysis by water year type not conducted.																
	Fry	Habitat[1,5]																		
		Stranding[1]		Analysis by water year type not conducted.																
	Adult	Water temperature[3]																		
Late fall-run Chinook salmon	Egg/Embryo	Spawning habitat[2]							Not a significant spawning or rearing reach.						No spawning habitat present, not a significant rearing reach.					
		Redd scour[1]		Analysis by water year type not conducted.																
		Water temperature[7]																		
		Redd dewatering[1]																		
	Fry/Juvenile	Rearing habitat[1,5]																		
		Water temperature[3]		Analysis by water year type not conducted.																
		Stranding[1]																		
	Adult	Water temperature[3]							No analysis conducted in this reach.						No analysis conducted in this reach.					
Sacramento splittail	All Life Stages	Water temperature[8]							No analysis conducted in this reach.						No analysis conducted in this reach.					
		Seasonal flows[5]	No analysis conducted in this reach.																	

[3] EBC2_ELT and EBC2_LLT are model scenarios that include the Fall X2 RPA.

Percent change in metric evaluated for each life stage in each subregion (by water year type as applicable). Changes considered to be beneficial are indicated as positive and changes considered to be adverse are indicated as negative regardless of direction of change in metric.

	>75% decrease		25–50% decrease		5–25% increase		50–75% increase		Little change (± ≤5%)
	50–75% decrease		5–25% decrease		25–50% increase		>75% increase		Division by zero, cannot compute

These results reflect physical changes that have a biological basis, depending on the specific metric used for evaluation. The left half of the cell represents ELT results. The right half of the cell represents LLT results. When the left and right portions of the cell are the same color, ELT and LLT results were the same. For cells that are split into more than one row (a top half and bottom half, or in some cases up to six rows in one cell), each row represents a different location or a different modeling method.

Admin Draft

Species	Life Stage	Metric	All	Wet	Above Normal	Below Normal	Dry	Critical	All	Wet	Above Normal	Below Normal	Dry	Critical	All	Wet	Above Normal	Below Normal	Dry	Critical
White sturgeon	Egg/Embryo	Water temperature[8]							No analysis conducted in this reach.						No analysis conducted in this reach.					
		Seasonal flows[9]	No analysis conducted in this reach.																	
	Larvae	Water temperature[8]													No analysis conducted in this reach.					
	Juvenile	Water temperature[8]																		
	Adult	Water temperature[8]																		
		Seasonal flows[9]	No analysis conducted in this reach.																	
Green sturgeon	Egg/Embryo	Water temperature[8]		Analysis by water year type not conducted.					No analysis conducted in this reach.						No analysis conducted in this reach.					
		Seasonal flows[9]																		
	Larvae	Water temperature[8]							No analysis conducted in this reach.						No analysis conducted in this reach.					
	Juvenile	Water temperature[8]																		
	Adult	Water temperature[8]																		
Pacific lamprey	Egg/Embryo	Water temperature[10]		Analysis by water year type not conducted.					No analysis conducted in this reach.						No analysis conducted in this reach.					
		Redd dewatering[11]																		
	Ammocete	Water temperature[10]																		
		Stranding[11]																		
River lamprey	Egg/Embryo	Water temperature[10]		Analysis by water year type not conducted.					No analysis conducted in this reach.						No analysis conducted in this reach.					
		Redd dewatering[11]																		
	Ammocete	Water temperature[10]																		
		Stranding[11]																		

Percent change in metric evaluated for each life stage in each subregion (by water year type as applicable). Changes considered to be beneficial are indicated as positive and changes considered to be adverse are indicated as negative regardless of direction of change in metric.

	>75% decrease		25–50% decrease		5–25% increase		50–75% increase		Little change (± ≤5%)
	50–75% decrease		5–25% decrease		25–50% increase		>75% increase		Division by zero, cannot compute

These results reflect physical changes that have a biological basis, depending on the specific metric used for evaluation. The left half of the cell represents ELT results. The right half of the cell represents LLT results. When the left and right portions of the cell are the same color, ELT and LLT results were the same. For cells that are split into more than one row (a top half and bottom half, or in some cases up to six rows in one cell), each row represents a different location or a different modeling method.

Admin Draft

1

Species	Life Stage	Metric	All	Wet	Above Normal	Below Normal	Dry	Critical	All	Wet	Above Normal	Below Normal	Dry	Critical	All	Wet	Above Normal	Below Normal	Dry	Critical
B. Clear Creek, Trinity River, and Feather River			**Clear Creek**						**Trinity River**						**Feather River**					
Steelhead	Egg/Embryo	Spawning habitat[5]																		
		Water temperature[12]														Analysis by water year type not conducted.				
		Redd dewatering[9]																		
	Fry/Juvenile (rearing)	Rearing habitat[5]		Analysis by water year type not conducted.																
		Water temperature[13]								Analysis by water year type not conducted.						Analysis by water year type not conducted.				
	Adult	Water temperature[13]																		
Spring-run Chinook salmon	Egg/Embryo	Water temperature[14]														Analysis by water year type not conducted.				
		Redd dewatering[15]																		
	Fry	Water temperature[13]	No analysis conducted.													Analysis by water year type not conducted.				
		Rearing habitat[5]																		
	Adult	Water temperature[13]														Analysis by water year type not conducted.				
Fall-run Chinook salmon	Egg/Embryo	Water temperature[16]																		
		Redd dewatering[9]							No analysis conducted.											
	Fry	Rearing habitat[5]														Analysis by water year type not conducted.				
	Adult	Water temperature[17]														Analysis by water year type not conducted.				
Sacramento splittail	All Life Stages	Water temperature[8]	Not found in Clear Creek.						Not found in Trinity River.											
		Seasonal flows[5]																		
White sturgeon	Egg/Embryo	Water temperature[8]	Not found in Clear Creek.						Not found in Trinity River.											
		Seasonal flows[5]																		
	Larvae	Water temperature[8]																		
	Juvenile	Water temperature[8]																		
	Adult	Water temperature[8]													No analysis conducted.					

Administrative Draft

Percent change in metric evaluated for each life stage in each subregion (by water year type as applicable). Changes considered to be beneficial are indicated as positive and changes considered to be adverse are indicated as negative regardless of direction of change in metric.

	>75% decrease		25–50% decrease		5–25% increase		50–75% increase		Little change (± ≤5%)
	50–75% decrease		5–25% decrease		25–50% increase		>75% increase		Division by zero, cannot compute

These results reflect physical changes that have a biological basis, depending on the specific metric used for evaluation. The left half of the cell represents ELT results. The right half of the cell represents LLT results. When the left and right portions of the cell are the same color, ELT and LLT results were the same. For cells that are split into more than one row (a top half and bottom half, or in some cases up to six rows in one cell), each row represents a different location or a different modeling method.

Species	Life Stage	Metric	All	Wet	Above Normal	Below Normal	Dry	Critical	All	Wet	Above Normal	Below Normal	Dry	Critical	All	Wet	Above Normal	Below Normal	Dry	Critical
Green sturgeon	Egg/Embryo	Water temperature[8]	Not found in Clear Creek.						Not found in Trinity River.											
		Seasonal flows[5]																		
	Larvae	Water temperature[18]																		
	Juvenile	Water temperature[8]																		
	Adult	Water temperature[18]																		
Pacific lamprey	Egg/Embryo	Water temperature[10]	Not found in Clear Creek.							Analysis by water year type not conducted.						Analysis by water year type not conducted.				
		Redd dewatering[11]																		
	Ammocete	Water temperature[10]																		
		Stranding[11]																		
River lamprey	Egg/Embryo	Water temperature[10]	Not found in Clear Creek.							Analysis by water year type not conducted.						Analysis by water year type not conducted.				
		Redd dewatering[11]																		
	Ammocete	Water temperature[10]																		
		Stranding[11]																		

Percent change in metric evaluated for each life stage in each subregion (by water year type as applicable). Changes considered to be beneficial are indicated as positive and changes considered to be adverse are indicated as negative regardless of direction of change in metric.								
	>75% decrease		25–50% decrease		5–25% increase		50–75% increase		Little change (± ≤5%)
	50–75% decrease		5–25% decrease		25–50% increase		>75% increase		Division by zero, cannot compute
These results reflect physical changes that have a biological basis, depending on the specific metric used for evaluation. The left half of the cell represents ELT results. The right half of the cell represents LLT results. When the left and right portions of the cell are the same color, ELT and LLT results were the same. For cells that are split into more than one row (a top half and bottom half, or in some cases up to six rows in one cell), each row represents a different location or a different modeling method.								

Admin Draft

Species	Life Stage	Metric	All	Wet	Above Normal	Below Normal	Dry	Critical	All	Wet	Above Normal	Below Normal	Dry	Critical	All	Wet	Above Normal	Below Normal	Dry	Critical
C. American, Stanislaus, and San Joaquin Rivers			**American River**						**Stanislaus River**						**San Joaquin River**					
Steelhead	Egg/Embryo	Spawning habitat[5]													No spawning habitat present; not a significant rearing reach.					
		Water temperature[19]		Analysis by water year type not conducted.						Analysis by water year type not conducted.										
		Redd dewatering[9]																		
	Fry/Juvenile (rearing)	Rearing habitat[5]								Analysis by water year type not conducted.										
		Water temperature[3]		Analysis by water year type not conducted.																
	Adult	Water temperature[20]														Analysis by water year type not conducted.				
Spring-run Chinook salmon	Egg/Embryo	Upstream habitat	Not found in American River.						Not found in Stanislaus River.						No locations analyzed upstream of Vernalis in San Joaquin River.					
	Fry	Upstream habitat																		
	Juvenile	Migration habitat[5]																		
	Adult	Water temperature[9]																		
Fall-run Chinook salmon	Egg/Embryo	Instream flows[5]																		
		Water temperature[21]																		
		Redd dewatering[9]																		
	Fry	Rearing habitat[5]													No analysis conducted.					
	Adult	Water temperature[20]		Analysis by water year type not conducted.						Analysis by water year type not conducted.					No locations analyzed upstream of Vernalis in San Joaquin River.					
Sacramento splittail	All Life Stages	Water temperature[8]							Not found in Stanislaus River.											
		Seasonal flows[5]																		
White sturgeon	Egg/Embryo	Seasonal flows	Not found in the American River.						No analysis conducted.						No locations analyzed upstream of Vernalis in San Joaquin River.					
	Larvae	Water temperature[8]																		
		Seasonal flows							No analysis conducted.											
	Juvenile	Water temperature[8]																		
	Adult	Water temperature							No analysis conducted.											
Pacific lamprey	Egg/Embryo	Water temperature[10]		Analysis by water year type not conducted.						Analysis by water year type not conducted.					No locations analyzed upstream of Vernalis in San Joaquin River.					
		Redd dewatering[11]																		
	Ammocete	Water temperature[10]																		
		Stranding[11]																		
River lamprey	Egg/Embryo	Water temperature[10]		Analysis by water year type not conducted.						Analysis by water year type not conducted.					No locations analyzed upstream of Vernalis in San Joaquin River.					
		Redd dewatering[11]																		
	Ammocete	Water temperature[10]																		
		Stranding[11]	Results too complex to summarize																	

1

Percent change in metric evaluated for each life stage in each subregion (by water year type as applicable). Changes considered to be beneficial are indicated as positive and changes considered to be adverse are indicated as negative regardless of direction of change in metric.								
	>75% decrease		25–50% decrease		5–25% increase		50–75% increase		Little change (± ≤5%)
	50–75% decrease		5–25% decrease		25–50% increase		>75% increase		Division by zero, cannot compute
These results reflect physical changes that have a biological basis, depending on the specific metric used for evaluation. The left half of the cell represents ELT results. The right half of the cell represents LLT results. When the left and right portions of the cell are the same color, ELT and LLT results were the same. For cells that are split into more than one row (a top half and bottom half, or in some cases up to six rows in one cell), each row represents a different location or a different modeling method.								

Administrative Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

Notes:

The effects shown in each cell reflect independent results for each life stage and do not indicate the relative importance of the change to the species. The importance of these changes will be considered and described as part of the net effects in Chapter 5.

[1] Based on SacEFT results.

[2] Based on SacEFT (all years) and egg mortality model results (by water year type).

[3] Based on water temperature exceedance tables.

[4] Based on SacEFT and SALMOD results.

[5] Based on percent difference in CALSIM flow; assumes that habitat availability is proportional to flow.

[6] Based on CALSIM reservoir cold water pool.

[7] Based on egg mortality model and temperature exceedance analysis.

[8] Based on percent change of percent days or months temperature threshold exceeded (if difference in percent days (months) <1%, effect classified as ≤5%, otherwise, based on computed percent change.

[9] Based on CALSIM outputs.

[10] Based on percent change of number cohorts exposed to > threshold temperature.

[11] Based on predicted redd cohorts exposed to >50% flow reduction in consecutive months.

[12] Clear Creek based on CALSIM outputs; Trinity results too complex to summarize quantitatively, so summary based on conclusions in Appendix C text; Feather River based on water temperature exceedance tables.

[13] Clear Creek based on CALSIM outputs; Trinity based on predicted frequencies of temperature threshold exceedance; Feather based on water temperature exceedance tables.

[14] Clear Creek based on CALSIM outputs; Trinity based on CALSIM reservoir cold water pool; Feather based on water temperature exceedance tables.

[15] Clear Creek and Feather based on CALSIM outputs; Trinity based on expected project operations.

[16] Clear Creek based on CALSIM outputs; Trinity and Feather based on Reclamation egg mortality model and Feather also based on water temperature exceedance tables.

[17] Clear Creek based on CALSIM outputs; Trinity and Feather based on predicted frequencies of temperature threshold exceedance.

[18] Based on water temperature exceedance tables for Honcut Creek, only.

[19] Based on water temperature exceedance tables and CALSIM reservoir cold water pool.

[20] American based on water temperature exceedance tables, Stanislaus based on predicted frequencies of temperature threshold exceedance; San Joaquin based on CALSIM outputs.

[21] Based on Reclamation egg mortality model.

Admin Draft

Percent change in metric evaluated for each life stage in each subregion (by water year type as applicable). Changes considered to be beneficial are indicated as positive and changes considered to be adverse are indicated as negative regardless of direction of change in metric.

	>75% decrease		25–50% decrease		5–25% increase		50–75% increase		Little change (± ≤5%)
	50–75% decrease		5–25% decrease		25–50% increase		>75% increase		Division by zero, cannot compute

These results reflect physical changes that have a biological basis, depending on the specific metric used for evaluation. The left half of the cell represents ELT results. The right half of the cell represents LLT results. When the left and right portions of the cell are the same color, ELT and LLT results were the same. For cells that are split into more than one row (a top half and bottom half, or in some cases up to six rows in one cell), each row represents a different location or a different modeling method.

Table C.0-4. Summary of Flow-Related Biological Effects of BDCP on Fish Movement, Fish Passage, and Delta Habitat Compared to EBC2_ELT and EBC2_LLT[4]

Species	Life Stage	Metric	All	Wet	Above Normal	Below Normal	Dry	Critical	All	Wet	Above Normal	Below Normal	Dry	Critical
A. Sacramento River			**Sacramento River (River Mile 194 to Keswick)**						**Sacramento River (North Delta to River Mile 143)**					
Steelhead	Egg/Embryo, Fry		Non-migratory life stages.											
	Juvenile	Migration flows[1]							No analysis conducted.					
	Adult	Attraction and migration flows[1]												
		Kelt migration flows[1]												
Winter-run Chinook salmon	Egg/Embryo, Fry		Non-migratory life stages.											
	Juvenile	Migration flows[1]							No analysis conducted.					
	Adult	Attraction and migration flows[1]	No analysis conducted.											
Spring-run Chinook salmon	Egg/Embryo, Fry		Non-migratory life stages.											
	Juvenile	Migration flows[1]							No analysis conducted.					
	Adult	Attraction and migration flows[1]												
Fall-run Chinook salmon	Egg/Embryo, Fry		Non-migratory life stages.											
	Juvenile	Migration flows[1]							No analysis conducted.					
	Adult	Attraction and migration flows[1]												
Late fall–run Chinook salmon	Egg/Embryo, Fry		Non-migratory life stages.											
	Juvenile	Migration flows[1]							No analysis conducted.					
	Adult	Attraction and migration flows[1]												
White sturgeon	Egg/Embryo	N/A	Non-migratory life stage.											
	Larvae	Transport flows[2]	These life stages do not occur above RM 194.											
	Juvenile	Migration flows[1]												
	Adult	Attraction and migration flows[3]												
Green sturgeon	Egg/Embryo		Non-migratory life stage.											
	Larvae	Transport flows[1]												
	Juvenile	Migration flows[1]	No analysis conducted.											
	Adult	Attraction and migration flows[1]												
Pacific lamprey	Egg/Embryo, Ammocoete		Non-migratory life stages.											
	Macropthalmia	Migration flows[1]		Analysis by water year type not conducted.					Analysis not conducted.					
	Adult	Attraction and migration flows[1]												
River lamprey	Egg/Embryo, Ammocoete		Non-migratory life stages.											
	Macropthalmia	Migration flows[1]		Analysis by water year type not conducted.					Analysis not conducted.					
	Adult	Attraction and migration flows[1]												

[4] EBC2_ELT and EBC2_LLT are model scenarios that include the Fall X2 RPA.

Percent change in metric evaluated for each life stage in each subregion (by water year type as applicable). Changes considered to be beneficial are indicated as positive and changes considered to be adverse are indicated as negative regardless of direction of change in metric.

	>75% decrease		25–50% decrease		5–25% increase		50–75% increase		Little change (± ≤5%)
	50–75% decrease		5–25% decrease		25–50% increase		>75% increase		Division by zero, cannot compute

These results reflect physical changes that have a biological basis, depending on the specific metric used for evaluation. The left half of the cell represents ELT results. The right half of the cell represents LLT results. When the left and right portions of the cell are the same color, ELT and LLT results were the same. For cells that are split into more than one row (a top half and bottom half, or in some cases up to six rows in one cell), each row represents a different location or a different modeling method.

1

Species	Life Stage	Metric	All	Wet	Above Normal	Below Normal	Dry	Critical	All	Wet	Above Normal	Below Normal	Dry	Critical	All	Wet	Above Normal	Below Normal	Dry	Critical
B. Clear Creek, Trinity River, and Feather River			**Clear Creek**						**Trinity River**						**Feather River**					
Steelhead	Egg/Embryo, Fry		Non-migratory life stages.																	
	Juvenile	Migration flows[1]																		
	Adult	Attraction and migration flows[1]																		
		Kelt migration flows[1]																		
Spring-run Chinook salmon	Egg/Embryo, Fry		Non-migratory life stages.																	
	Juvenile	Migration flows[1]																		
	Adult	Attraction and migration flows[1]																		
Fall-run Chinook salmon	Egg/Embryo, Fry		Non-migratory life stages.																	
	Juvenile	Migration flows[1]																		
	Adult	Attraction and migration flows[1]																		
Green sturgeon	Egg/Embryo	N/A	Not found in Clear Creek.						Not found in Trinity River.						Non-migratory life stages.					
	Larvae																			
	Juvenile														No analysis conducted.					
	Adult	Attraction and migration flows[1]																		
Pacific lamprey	Egg/Embryo, Ammocoete		Not found in Clear Creek.						Non-migratory life stages.						Non-migratory life stages.					
	Macropthalmia	Migration flows[1]							Analysis not conducted.							Analysis by water year not conducted.				
	Adult	Attraction and migration flows[1]																		
River lamprey	Egg/Embryo, Ammocoete		Not found in Clear Creek.						Non-migratory life stages.						Non-migratory life stages.					
	Macropthalmia	Migration flows[1]							Analysis not conducted.							Analysis by water year not conducted.				
	Adult	Attraction and migration flows[1]																		

2

Percent change in metric evaluated for each life stage in each subregion (by water year type as applicable). Changes considered to be beneficial are indicated as positive and changes considered to be adverse are indicated as negative regardless of direction of change in metric.								
	>75% decrease		25–50% decrease		5–25% increase		50–75% increase		Little change (± ≤5%)
	50–75% decrease		5–25% decrease		25–50% increase		>75% increase		Division by zero, cannot compute
These results reflect physical changes that have a biological basis, depending on the specific metric used for evaluation. The left half of the cell represents ELT results. The right half of the cell represents LLT results. When the left and right portions of the cell are the same color, ELT and LLT results were the same. For cells that are split into more than one row (a top half and bottom half, or in some cases up to six rows in one cell), each row represents a different location or a different modeling method.								

Administrative Draft

Species	Life Stage	Metric	All	Wet	Above Normal	Below Normal	Dry	Critical	All	Wet	Above Normal	Below Normal	Dry	Critical	All	Wet	Above Normal	Below Normal	Dry	Critical
C. American, Stanislaus, and San Joaquin Rivers			**American River**						**Stanislaus River**						**San Joaquin River (Vernalis)**					
Steelhead	Egg/Embryo, Fry		Non-migratory life stages.																	
	Juvenile	Migration flows[1]																		
	Adult	Attraction and migration flows[1]																		
		Kelt migration flows[1]																		
Spring-run Chinook salmon	Egg/Embryo, Fry		Non-migratory life stages.																	
	Juvenile migrants	Migration flows[1]	Not found in America River.						Not found in Stanislaus River.											
	Adult																			
Fall-run Chinook salmon	Egg/Embryo, Fry		Non-migratory life stages.																	
	Juvenile	Migration flows[1]																		
	Adult	Attraction and migration flows[1]																		
White sturgeon	All life stages		Not found in the American River.						No analysis conducted.						No analysis conducted.					
Pacific lamprey	Egg/Embryo, Ammocoete		Non-migratory life stages.																	
	Macropthalmia	Migration flows[1]		No analysis by water year type.						No analysis by water year type.						No analysis by water year type.				
	Adult	Attraction and migration flows[1]														No analysis by water year type.				
River lamprey	Egg/Embryo, Ammocoete		Non-migratory life stages.																	
	Macropthalmia	Migration flows[1]		No analysis by water year type.						No analysis by water year type.						No analysis by water year type.				
	Adult	Attraction and migration flows[1]																		

1

Percent change in metric evaluated for each life stage in each subregion (by water year type as applicable). Changes considered to be beneficial are indicated as positive and changes considered to be adverse are indicated as negative regardless of direction of change in metric.							
	>75% decrease		25–50% decrease		5–25% increase		50–75% increase		Little change (± ≤5%)
	50–75% decrease		5–25% decrease		25–50% increase		>75% increase		Division by zero, cannot compute
These results reflect physical changes that have a biological basis, depending on the specific metric used for evaluation. The left half of the cell represents ELT results. The right half of the cell represents LLT results. When the left and right portions of the cell are the same color, ELT and LLT results were the same. For cells that are split into more than one row (a top half and bottom half, or in some cases up to six rows in one cell), each row represents a different location or a different modeling method.							

Administrative Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

Species	Life Stage	Metric	All	Wet	Above Normal	Below Normal	Dry	Critical
D. Delta Area								
Steelhead	Egg/Embryo, Fry		These life stages not present in Delta area or not analyzed.					
	Juvenile		No analysis conducted.					
	Adult	Fremont Weir passage[4]		No analysis by water year type.				
		Attraction flows (Sacramento basin populations)[5]						
		Attraction flows (San Joaquin basin population)[7,8]		Analysis by water year type not conducted.				
Winter-run Chinook salmon	Egg/Embryo, Fry		These life stages not present in Delta area or not analyzed.					
	Juvenile	Smolt through-Delta survival[6]		No analysis by water year type.				
	Adult	Fremont Weir passage[4]						
		Attraction flows[5]						
Spring-run Chinook salmon	Egg/Embryo, Fry		These life stages not present in Delta area or not analyzed.					
	Juvenile	Smolt through-Delta survival[6]		No analysis by water year type.				
	Adult	Fremont Weir passage[4]						
		Attraction flows (Sacramento basin populations)[5]						
		Attraction flows (San Joaquin basin population)[7,8]		Analysis by water year type not conducted.				
Fall-run Chinook salmon	Egg/Embryo, Fry		These life stages not present in Delta area or not analyzed.					
	Juvenile	Smolt through-Delta survival (Sacramento basin populations)[6]		No analysis by water year type.				
		Smolt through-Delta survival (San Joaquin basin populations)[6]						
		Smolt through-Delta survival (Mokelumne basin populations)[6]						
	Adult	Fremont Weir passage[4]						
		Attraction flows (Sacramento basin populations)[5]						
		Attraction flows (San Joaquin basin population)[7,8]		Analysis by water year type not conducted.				
Late fall–run Chinook salmon	Egg/Embryo, Fry		These life stages not present in Delta area or not analyzed.					
	Juvenile		No analysis conducted.					
	Adult	Attraction flows (Sacramento basin populations)[5]						
Delta smelt	Eggs		Non-migratory life stage.					
	Larvae	Transport flows[9]		Analysis by water year type not conducted.				
	Juvenile, Adults	Fall abiotic habitat[11/12]						
Longfin smelt	Eggs		Non-migratory life stage.					
	Larvae	Transport flows[10]						
	Juveniles, Adults		No analysis conducted.					
Sacramento splittail	All life stages		No analysis conducted.					

Percent change in metric evaluated for each life stage in each subregion (by water year type as applicable). Changes considered to be beneficial are indicated as positive and changes considered to be adverse are indicated as negative regardless of direction of change in metric.

	>75% decrease		25–50% decrease		5–25% increase		50–75% increase		Little change (± ≤5%)
	50–75% decrease		5–25% decrease		25–50% increase		>75% increase		Division by zero, cannot compute

These results reflect physical changes that have a biological basis, depending on the specific metric used for evaluation. The left half of the cell represents ELT results. The right half of the cell represents LLT results. When the left and right portions of the cell are the same color, ELT and LLT results were the same. For cells that are split into more than one row (a top half and bottom half, or in some cases up to six rows in one cell), each row represents a different location or a different modeling method.

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

Species	Life Stage	Metric	All	Wet	Above Normal	Below Normal	Dry	Critical
D. Delta Area								
White sturgeon	Egg/Embryo		This life stage is not present in the Delta area.					
	Larvae, Juveniles		No analysis conducted.					
	Adult	Fremont Weir passage[4]		Analysis by water year type not conducted.				
Green sturgeon	Egg/Embryo		This life stage is not present in the Delta area.					
	Larvae, Juveniles		No analysis conducted.					
	Adult	Fremont Weir passage[4]		Analysis by water year type not conducted.				
Pacific lamprey	Egg/Embryo		This life stage is not present in the Delta area.					
	Ammocoete, Macropthalmia		No analysis conducted.					
	Adult	Attraction flows (Sacramento basin populations)[7]		No analysis by water year type.				
		Attraction flows (San Joaquin basin population)[7,8]						
River lamprey	Egg/Embryo		This life stage is not present in the Delta area.					
	Ammocoete, Macropthalmia		No analysis conducted.					
	Adult	Attraction flows (Sacramento basin populations)[7]		Analysis by water year type not conducted.				
		Attraction flows (San Joaquin basin population)[7,8]						
All species	Results are the same for all regions of Delta	Water temperature		No analysis by water year type.				
		Dissolved oxygen						
		Channel margin habitat benches	Results too complex to summarize					

Species	Life Stage	Metric	All	Wet	Above Normal	Below Normal	Dry	Critical
E. Yolo Bypass								
Steelhead	Egg/Embryo, Fry		These life stages are not present in the Yolo Bypass.					
	Juvenile	Stranding[14]		No analysis by water year type.				
	Adult	Passage[14]						
Winter-run Chinook salmon	Egg/Embryo		This life stage not present in the Yolo Bypass.					
	Fry		No analysis conducted.					
	Juvenile	Stranding[14]		No analysis by water year type.				
	Adult	Passage[14]						
Spring-run Chinook salmon	Egg/Embryo		This life stage not present in the Yolo Bypass.					
	Fry		No analysis conducted.					
	Juvenile	Stranding[14]		No analysis by water year type.				
	Adult	Passage[14]						

Percent change in metric evaluated for each life stage in each subregion (by water year type as applicable). Changes considered to be beneficial are indicated as positive and changes considered to be adverse are indicated as negative regardless of direction of change in metric.								
	>75% decrease		25–50% decrease		5–25% increase		50–75% increase		Little change (± ≤5%)
	50–75% decrease		5–25% decrease		25–50% increase		>75% increase		Division by zero, cannot compute
These results reflect physical changes that have a biological basis, depending on the specific metric used for evaluation. The left half of the cell represents ELT results. The right half of the cell represents LLT results. When the left and right portions of the cell are the same color, ELT and LLT results were the same. For cells that are split into more than one row (a top half and bottom half, or in some cases up to six rows in one cell), each row represents a different location or a different modeling method.								

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

Species	Life Stage	Metric	All	Wet	Above Normal	Below Normal	Dry	Critical
E. Yolo Bypass								
Fall-run Chinook salmon	Egg/Embryo		This life stage not present in the Yolo Bypass.					
	Fry		No analysis conducted.					
	Juvenile	Stranding[14]		No analysis by water year type.				
	Adult	Passage[14]						
Late fall–run Chinook salmon	Egg/Embryo, Fry		These life stages are not present in the Yolo Bypass.					
	Juvenile	Stranding[14]		No analysis by water year type.				
	Adult	Passage[14]						
Sacramento splittail	Egg/Embryo, Larvae, Early Juveniles	Yolo Bypass Habitat Area[13]						
	Juvenile	Yolo Bypass Habitat Area[13]						
		Stranding[14]		No analysis by water year type.				
	Adult	Yolo Bypass Habitat Area[13]						
		Stranding[14]		No analysis by water year type.				
White sturgeon	Egg/Embryo, Larvae		These life stages are not present in the Yolo Bypass.					
	Juvenile	Stranding[14]		No analysis by water year type.				
	Adult	Passage[14]						
Green sturgeon	Egg/Embryo, Larvae		These life stages are not present in the Yolo Bypass.					
	Juveniles	Stranding[14]		No analysis by water year type.				
	Adult	Passage[14]						
Pacific lamprey	Egg/Embryo		These life stages are not present in the Yolo Bypass.					
	Ammocoete							
	Adult	Passage	No analysis conducted.					
River lamprey	Egg/Embryo		These life stages are not present in the Yolo Bypass.					
	Ammocoete							
	Adult	Passage	No analysis conducted.					

1

Percent change in metric evaluated for each life stage in each subregion (by water year type as applicable). Changes considered to be beneficial are indicated as positive and changes considered to be adverse are indicated as negative regardless of direction of change in metric.								
	>75% decrease		25–50% decrease		5–25% increase		50–75% increase		Little change (± ≤5%)
	50–75% decrease		5–25% decrease		25–50% increase		>75% increase		Division by zero, cannot compute
These results reflect physical changes that have a biological basis, depending on the specific metric used for evaluation. The left half of the cell represents ELT results. The right half of the cell represents LLT results. When the left and right portions of the cell are the same color, ELT and LLT results were the same. For cells that are split into more than one row (a top half and bottom half, or in some cases up to six rows in one cell), each row represents a different location or a different modeling method.								

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

Notes:
The effects shown in each cell reflect independent results for each life stage and do not indicate the relative importance of the change to the species. The importance of these changes will be considered and described as part of the net effects in Chapter 5.
[1] Based on CALSIM.
[2] Differences between EBC and PP scenarios for average number of months per year exceeding 17,700 cfs at Wilkins Slough and 31,000 cfs at Verona (February–May, based on CALSIM).
[3] Differences between EBC and PP scenarios for average number of months per year exceeding 5,300 cfs at Wilkins Slough (November–-May, based on CALSIM) and CALSIM flow estimates at Wilkins Slough and Verona.
[4] Based on 2009 DRERIP analysis of the Yolo Bypass Conservation Measure (Qualitative score only—DRERIP Magnitude 1 = 5-–5%, Magnitude 2 = 25–50%, etc).
[5] Based on DSM2-QUAL Fingerprinting outputs and CALSIM at Rio Vista outputs.
[6] Based on Delta Passage Model.
[7] Based on DSM2-QUAL Fingerprinting outputs.
[8] San Joaquin flow percentage very low under all scenarios.
[9] Based on DSM2 Particle Tracking Model outputs (Matinez).
[10] Based on Kimmerer et al. (2009) X2-abundance regressions, averaged over survey types, and DSM2 Particle Tracking Model outputs for all-year summary.
[11] Based on fall abiotic habitat (see Feyrer et al. 2011) calculated without restoration.
[12] Based on fall abiotic habitat (see Feyrer et al. 2011) calculated with restoration and 50% use, for LLT scenarios only.
[13] Based on CALSIM flows and MIKE-21 analysis.
[14] Based on 2009 DRERIP analysis of the Yolo Bypass Conservation Measure.

Admin Draft

Percent change in metric evaluated for each life stage in each subregion (by water year type as applicable). Changes considered to be beneficial are indicated as positive and changes considered to be adverse are indicated as negative regardless of direction of change in metric.								
	>75% decrease		25–50% decrease		5–25% increase		50–75% increase		Little change (± ≤5%)
	50–75% decrease		5–25% decrease		25–50% increase		>75% increase		Division by zero, cannot compute
These results reflect physical changes that have a biological basis, depending on the specific metric used for evaluation. The left half of the cell represents ELT results. The right half of the cell represents LLT results. When the left and right portions of the cell are the same color, ELT and LLT results were the same. For cells that are split into more than one row (a top half and bottom half, or in some cases up to six rows in one cell), each row represents a different location or a different modeling method.								

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

Appendix 5.C

Flow, Passage, Salinity, and Turbidity

Contents

Page

Appendix C Flow, Passage, Salinity, and Turbidity C.0-1
C.0 Executive Summary C.0-1
C.0.1 Summary of Conclusions C.0-4
C.1 Overview of Flow in the Sacramento River, San Joaquin River, and Delta Systems C.1-1
C.1.1 Flow and Flow-Related Parameters C.1-1
C.1.1.1 Dissolved Oxygen C.1-3
C.1.1.2 Salinity C.1-3
C.1.1.3 Temperature C.1-3
C.1.1.4 Turbidity C.1-3
C.1.1.5 Passage C.1-4
C.2 System Hydrology and Operations C.2-1
C.2.1 Historical Operations C.2-1
C.2.2 Preliminary Proposal Modeling C.2-2
C.2.2.1 Baseline Operations C.2-2
C.2.2.2 Proposed Operations C.2-3
C.3 Species Exposure to Flow and Flow-Related Parameters C.3-1
C.4 Methods Used C.4-1
C.4.1 CALSIM II and DSM2 Models C.4-7
C.4.1.1 CALSIM II Inflows C.4-7
C.4.1.2 CALSIM Reservoir Operations C.4-8
C.4.1.3 CALSIM Delta Operations C.4-8
C.4.1.4 CALSIM Outflow-Salinity Relationships C.4-9
C.4.1.5 CALSIM Artificial Neural Network C.4-9
C.4.1.6 DSM2 ..... C.4-10
C.4.2 Upstream Habitat Methods C.4-12
C.4.2.1 Salmonids C.4-12
C.4.2.2 Sturgeon C.4-20
C.4.2.3 Lamprey C.4-24
C.4.3 Passage, Movement, and Migration Methods C.4-27
C.4.3.1 Migration of Adult Anadromous Covered Fish Species C.4-27
C.4.3.2 Downstream Migration of Juvenile Anadromous Covered Fish Species C.4-30
C.4.3.3 Transport Flows for Larval Smelts C.4-52
C.4.4 Delta Habitat (Plan Area) Methods C.4-54
C.4.4.1 General Flow Changes in the Plan Area C.4-54
C.4.4.2 Yolo Bypass Floodplain Habitat (Conservation Measure 2 Yolo Bypass Fisheries Enhancement) C.4-54
C.4.4.3 Wetland and Riparian Bench Inundation (Juvenile Salmonids) C.4-62

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

C.4.4.4 Water Temperature C.4-65
C.4.4.5 Dissolved Oxygen C.4-66
C.4.4.6 Turbidity (Water Clarity) C.4-67
C.4.4.7 Delta Smelt Fall Abiotic Habitat Index C.4-67
C.5 Results C.5-1
C.5.1 CALSIM and DSM2 Results C.5-1
C.5.2 Upstream Habitat Results C.5-1
C.5.3 Passage, Movement, and Migration Results C.5-1
C.5.4 Delta Habitat (Plan Area) Results C.5-1
C.6 Conclusions C.6-1
C.6.1 Summary of Changes in Flow C.6-1
C.6.1.1 Upstream Flows C.6-1
C.6.1.2 Delta Flows C.6-2
C.6.1.3 Salinity C.6-6
C.6.1.4 Turbidity C.6-8
C.6.1.5 Temperature and Dissolved Oxygen C.6-9
C.6.2 Flow-Related Biological Effects C.6-9
C.6.2.1 Upstream Spawning and Egg Incubation C.6-9
C.6.2.2 Holding Flows C.6-11
C.6.2.3 Upstream Rearing Habitat C.6-12
C.6.2.4 Passage, Migration, and Movement C.6-13
C.6.2.5 Delta Area Effects C.6-18
C.7 References C.7-1
C.7.1 Personal Communications C.7-15

Attachment C.A CALSIM and DSM2 Results for the Preliminary Proposal Modeling Scenarios

Attachment C.B Sacramento River Ecological Flows Tool (SacEFT): Design & Guidelines (v.2.00)—ESSA Technologies Ltd., June 2010

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

List of Tables

Page

Table C.0-1. Definition of Analytical Conditions C.0-2
Table C.0-2. Summary of Conclusions for Flow and Flow-Related Parameters C.0-5
Table C.0-3. Summary of Flow-Related Biological Effects of BDCP in the Upstream Area Compared to EBC2_ELT and EBC2_LLT C.0-6
Table C.0-4. Summary of Flow-Related Biological Effects of BDCP on Fish Movement, Fish Passage, and Delta Habitat Compared to EBC2_ELT and EBC2_LLT C.0-12
Table C.1-1. Potential Species Presence and Exposure by Life Stage in the Subregions of the Upstream and Delta Areas, and Potential to Be Affected by Changes in Flows C.1-2
Table C.2-1. Allowable North Delta Diversions (cfs) in Different Months for a Range of Sacramento River Flows at Freeport (cfs) C.2-6
Table C.4-1. Summary of Methods Used for Each Region and Species Life Stage C.4-2
Table C.4-2. Description of Methods Used and the Benefits and Limitations of Each Method C.4-4
Table C.4-3. CALSIM Locations Used to Assess Changes in Flows during Downstream Migration of Juvenile Anadromous Covered Fish Species C.4-32
Table C.4-4. Description of Modeled Reaches and Junctions in the Delta Passage Model C.4-37
Table C.4-5. Delta Passage Model Reaches and Associated Nodes from DSM2-HYDRO and CALSIM II Models C.4-38
Table C.4-6. Sampling Gear Used to Create Juvenile Delta Entry Timing Distributions for Each Central Valley Run of Chinook Salmon C.4-40
Table C.4-7. Reach-specific migration speed and sample size of acoustically-tagged smolts released during December and January for three consecutive winters (2006/2007, 2007/2008, and 2008/2009) C.4-41
Table C.4-8. Sample Size and Slope (β_0) and Intercept (β_1) Parameter Estimates with Associated Standard Error (in Parenthesis) for the Relationship between Migration Speed and Flow for Reaches Sac1, Sac2, and Geo/DCC C.4-42
Table C.4-9. Reach-Specific Survival and Parameters Defining Functional Relationships or Probability Distributions for Each Chinook Salmon Run C.4-45
Table C.4-10. Individual Release-Group Survival Estimates, Release Dates, Data Sources, and Associated Calculations Used to Inform Reach-Specific Mean Survivals and Standard Deviations Used in the Delta Passage Model for Reaches Where Survival Is Uninfluenced by Delta Conditions C.4-45
Table C.4-11. Mean and standard errors of coefficient values for the Intercept-only models and flow models for predicting survival for the reaches Interior Delta via San Joaquin River and Interior Delta via Old River C.4-48
Table C.4-12. Run-Specific Metrics and Associated Data Sources Used to Calculate Run-Specific Estimates of Smolt Production to Inform Calculations of Mortality at the Delta Intake Facilities C.4-52
Table C.4-13. Relationships between X2 and Longfin Smelt Abundance Indices (Log-Transformed) from Fall Midwater Trawls, Bay Midwater Trawl, and Bay Otter Trawl That Were Used to Estimate Preliminary Proposal Effects C.4-54
Table C.4-14. Description of Model Runs using MIKE 21 Yolo Bypass Model C.4-55
Table C.4-15. DSM2-QUAL Stations Used to Analyze Temperature Effects in the Plan Area C.4-65

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

Table C.4-16. Temperature Thresholds or Ranges Examined for Differences between Preliminary Proposal and Existing Biological Conditions Scenarios C.4-66
Table C.4-17. Fitted Values for Delta Smelt Abiotic Habitat Index, without and with Preliminary Proposal Late Long-Term Restoration Extent Included C.4-72
Table C.6-1. Average Annual and Monthly Mean Outflows for Each of the Six CALSIM Scenarios C.6-6
Table C.6-2. Summary of the Location (Kilometers from the Golden Gate Bridge) of X2 under Each CALSIM Scenario C.6-7

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

List of Figures

Page

Figure C.4-1. Percent of Winter-Run Chinook Redds Dewatered as a Function of the Difference between Spawning Flow and Incubation Flow C.4-16
Figure C.4-2. Map of the Sacramento–San Joaquin River Delta Showing the Modeled Reaches and Junctions of the Delta Applied in the Delta Passage Model C.4-36
Figure C.4-3. Conceptual Diagram Depicting the "Migration" of a Single Daily Cohort of Smolts Entering from the Sacramento River and Migrating through the Delta Passage Model C.4-39
Figure C.4-4. Delta Entry Distributions for Chinook Salmon Smolts Applied in the Delta Passage Model for Sacramento River Winter-Run, Sacramento River Spring-Run, Sacramento River Fall-Run, Sacramento River Late Fall-Run, San Joaquin River Fall-Run, and Mokelumne River Fall-Run Chinook Salmon C.4-40
Figure C.4-5. Reach-Specific Migration Speed (km/day) as a Function of Flow (m^3/sec) Applied in Reaches Sac1, Sac2, and Geo/DCC C.4-42
Figure C.4-6. Figure from Perry (2010) Depicting the Mean Entrainment Probability (Proportion of Fish Being Diverted into Reach Geo/DCC) as a Function of Fraction of Discharge (Proportion of Flow Entering Reach Geo/DCC) C.4-44
Figure C.4-7. Reach-Specific Survival as a Function of Flow Applied in Reaches Sac1, Sac2, Sac3, Sac4, SS, and Interior Delta via the San Joaquin River C.4-47
Figure C.4-8. Interior Delta Survival as a Function of Delta Exports (Newman and Brandes 2010) as Applied for Sacramento Races of Chinook Salmon Smolts Migrating through the Interior Delta via Reach Geo/DCC C.4-49
Figure C.4-9. Percent of Smolts Consumed as a Function of the Number of Predators Present at the North Delta Intake Diversion Facilities (PP_ELT Scenario) C.4-50
Figure C.4-10. Percent of Smolts Consumed as a Function of the Number of Predators Present at the North Delta Intake Diversion Facilities (PP_LLT Scenario) C.4-50
Figure C.4-11. Weekly Average Size of Fall-Run Chinook Salmon Captured by Rotary Screw Trap at Knights Landing in 1996–1999 and 2002 ..... C.4-59
Figure C.4-12. Travel time (average number of days since release) of tagged hatchery fall-run Chinook salmon juveniles released in the Sacramento River upstream of the Fremont Weir and recaptured at Chipps Island between 1980 and 2001 ..... C.4-60
Figure C.4-13. Survival Indices for Tagged Hatchery Fall-Run Chinook Salmon Juveniles Released in the Sacramento River Upstream of the Fremont Weir and Recaptured at Chipps Island between 1980 and 2001 ..... C.4-61
Figure C.4-14. Estimated Ocean Recovery Rates for Tagged Hatchery Fall-Run Chinook Salmon Juveniles Released in the Estuary between 1993 and 2006 ..... C.4-62
Figure C.4-15. Bench Habitat Analysis Sites C.4-64
Figure C.4-16. Abiotic Habitat Index of Delta Smelt in Relation to X2 ..... C.4-70

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

Acronyms and Abbreviations

ACID	Anderson-Cottonwood Irrigation District
AFRP	Anadromous Fish Restoration Program
ANN	Artificial Neural Network
BDCP	Bay Delta Conservation Plan
BiOp	biological opinion
BOD	biochemical oxygen demand
CCWD	Contra Costa Water District
CDOM	colored dissolved organic material
CEQA	California Environmental Quality Act
cfs	cubic feet per second
CM	Conservation Measure
cm	centimeter
CVP	Central Valley Project
CVPIA	Central Valley Project Improvement Act
CWT	coded wire tag
DCC	Delta Cross Channel
DSM2	Delta Simulation Model II
DO	dissolved oxygen
DOSS	NMFS Delta Operations for Salmonids and Sturgeon
DPM	Delta Passage Model
DRERIP	Delta Regional Ecosystem Restoration Implementation Plan
DWR	California Department of Water Resources
E/I	export/inflow
EBC	existing biological conditions
EC	electrical conductivity
ELT	early long-term
ESA	Endangered Species Act
ESU	evolutionarily significant unit
FL	fork length
FMWT	fall midwater trawl
FRWA	Freeport Regional Water Authority
ft/s	feet per second
GAM	generalized additive modeling
GCID	Glenn-Colusa Irrigation District
HSI	Habitat Suitability Index
IFIM	Instream Flow Incremental Methodology
km	kilometers
LLT	late long-term
LOWESS	locally weighted regression-scatterplot smoothing

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

LSZ	low salinity zone
m/s	meters per second
m^3/s	cubic meters per second
mg/L	milligrams per liter
mm	millimeter
μscm^{-1}	microSiemens per centimeter
NDD	north Delta diversions
NMFS	National Marine Fisheries Service
OMR	Old and Middle River
PP	preliminary proposal
ppt	parts per thousand
PTM	particle tracking modeling
RBDD	Red Bluff Diversion Dam
Reclamation	U.S. Department of the Interior, Bureau of Reclamation
RM	river mile
ROA	restoration opportunity areas
RPA	Reasonable and Prudent Alternative
SacEFT	Sacramento River Ecological Flows Tool
SAV	submerged aquatic vegetation
SMSCG	Suisun Marsh Salinity Control Gates
SRWQM	Sacramento River Water Quality Model
SS	suspended sediment
SSC	suspended sediment concentration
STN	summer townet
SWAN	Simulation Waves Nearshore
SWP	State Water Project
State Water Board	State Water Resources Control Board
TAF	thousand acre-feet
TSS	total suspended solids
USACE	U.S. Army Corps of Engineers
USFWS	U.S. Fish and Wildlife Service
VAMP	Vernalis Adaptive Management Plan
WOMT	water operations management team
WQCP	Bay-Delta Water Quality Control Plan
WUA	weighted usable area
WY	water year
YBFR	Yolo Bypass Fry Rearing
YCI	year class strength indices
YOY	young-of-the-year

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

Appendix 5.C

Flow, Passage, Salinity, and Turbidity

C.1 Overview of Flow in the Sacramento River, San Joaquin River, and Delta Systems

Fish that inhabit the Sacramento–San Joaquin River Delta (Delta) system are directly and/or indirectly affected by the flows in the Sacramento and San Joaquin Rivers and their tributaries, as well as the San Francisco Bay/Sacramento–San Joaquin River Delta (Bay-Delta) area, during all or some of their life stages (See Appendix 2.A, *Species Accounts*, for a detailed description of potential exposure of each life stage to various flow-related stressors). Currently, besides natural variation in hydrology, the primary drivers for flows in the system are reservoir operations for flood control, fish habitat needs, and water supply and upstream and in-Delta diversions. The State Water Project (SWP) and Central Valley Project (CVP) are only two of many projects that appropriate water within the Bay-Delta estuary. Each upstream reservoir (SWP or CVP) is operated with these three basic monthly operating constraints: (1) requirement for some empty storage space in the months with high potential rainfall (flood control), (2) minimum monthly reservoir releases for downstream fish habitat and water temperature conditions, and (3) downstream delivery or diversion targets for the monthly release of storage for beneficial uses by the water contractors (water supply). Habitat suitability and availability can vary based on how these flows are managed and ultimately can determine survivability of aquatic species.

The preliminary proposal is expected to result in changes in flows primarily as a result of the change in export location (new north Delta intake) and its associated specified changes in monthly Delta operational objectives (required salinity objectives, outflow objectives, export/inflow [E/I] objectives, Old and Middle River [OMR] flow objectives, maximum exports); and habitat restoration that may modify hydrodynamics in the Delta. These hydrodynamic changes in turn can change salinities, concentrations of dissolved oxygen (DO), turbidity, and flows. Flow change in the Delta as a result of the preliminary proposal, particularly in the Yolo Bypass and lower Sacramento River can affect the migration success of fish. No substantial changes in reservoir operations are expected as a result of the preliminary proposal.

C.1.1 Flow and Flow-Related Parameters

The flow-related parameters assessed in this appendix include those physical and chemical constituents that are affected by flow, which in turn can have biological effects on fish. These factors can have enormous impact on species survivability. Each of the following parameters has been identified as key for determining suitable habitat for aquatic species that reside in or migrate through the Delta. The operations and management of the flood control and water supply facilities that affect the Delta can be adjusted to influence each parameter. More detail regarding the potential effects and exposure of each species life stage to these parameters is provided in Table C.1-1 and in Appendix 2.A, *Species Accounts*.

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

Table C.1-1. Potential Species Presence and Exposure by Life Stage in the Subregions of the Upstream and Delta Areas, and Potential to Be Affected by Changes in Flows

		Upstream Area						Passage and Movement			Delta Area						
Species	Life Stage	Stanislaus/ Mainstem San Joaquin[1] Rivers	Mainstem Sacramento River	Feather River	American River	Trinity River	Clear Creek	Yolo Bypass	Stockton Deepwater Ship Channel	Delta and Suisun Marsh Channels	North Delta	South Delta	East Delta	West Delta	Suisun Marsh	Cache Slough	Yolo Bypass
Steelhead	Egg/Embryo	■	■	■	■	■	■										
	Fry	■	■	■	■	■	■										
	Juvenile	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	Adult	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Winter-run Chinook salmon	Egg/Embryo		■														
	Fry		■					■	■	■	■	■		■	■	■	■
	Juvenile		■					■	■	■	■	■		■	■	■	■
	Adult		■					■	■	■	■			■	■	■	■
Spring-run Chinook salmon	Egg/Embryo	■	■	■		■	■										
	Fry	■	■	■		■	■	■	■	■	■	■		■	■	■	■
	Juvenile		■	■		■	■	■	■	■	■	■		■	■	■	■
	Adult	■	■	■		■	■	■	■	■	■			■	■	■	■
Fall-/late fall–run Chinook salmon	Egg/Embryo	■	■	■	■	■	■										
	Fry	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	Juvenile		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	Adult	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Delta smelt	Eggs									■	■				■	■	
	Larva								■	■	■	■	■	■	■	■	
	Juvenile									■	■	■	■	■	■	■	
	Adult								■	■	■	■	■	■	■	■	
Longfin smelt	Eggs										■					■	
	Larva								■	■	■	■	■	■	■	■	
	Juvenile									■		■		■	■		
	Adult								■	■	■	■	■	■	■	■	
Sacramento splittail	Egg/Embryo	■	■	■	■			■		■	■	■	■	■	■	■	■
	Larvae	■	■	■	■			■		■	■	■	■	■	■	■	■
	Juvenile	■	■	■	■			■	■	■	■	■	■	■	■	■	■
	Adult	■	■	■	■			■	■	■	■	■	■	■	■	■	■
White sturgeon	Egg/Embryo	■	■	■													
	Larva	■	■	■													
	Juvenile	■	■	■				■	■	■	■	■	■	■	■	■	■
	Adult	■	■	■	■			■	■	■	■	■	■	■	■	■	■
Green sturgeon	Egg/Embryo		■	■		■											
	Larva		■	■		■											
	Juvenile		■	■		■		■		■	■	■	■	■	■	■	■
	Adult		■	■		■		■		■	■	■	■	■	■	■	■
Pacific lamprey	Egg/Embryo	■	■	■	■	■	■										
	Ammocoete	■	■	■	■	■	■	■			■	■	■	■		■	■
	Adult	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
River lamprey	Egg/Embryo	■	■	■	■	■											
	Ammocoete	■	■	■	■	■		■			■	■	■	■		■	■
	Adult	■	■	■	■	■		■	■	■	■	■	■	■	■	■	■

= Life stage not present or likely to be exposed
■ = Life stage present or has potential to be exposed

[1] Analyses in mainstem San Joaquin River were limited to Vernalis only.

Administrative Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

C.1.1.1 Dissolved Oxygen

DO is a measure of how much oxygen is available in the water column for support of aquatic species that rely on oxygen for survival. Different species have varying tolerances of DO levels, but in general many of the fish species in the Delta require high DO levels (5–7 milligrams per liter [mg/L]). When DO levels fall, species become stressed and move toward areas of higher DO if pathways exist. Low DO levels can create passage barriers and increase species mortality.

C.1.1.2 Salinity

The concentration of the dissolved salt in a body of water is salinity. Usually measured in parts per thousand (ppt), the salinity gradient transitioning from the ocean to a freshwater stream can vary between 0.5 ppt (fresh water) to ~32–37 ppt (sea water). Historically in the Delta, the point in the salinity gradient that has been tracked and managed is 2 ppt bottom salinity and is referred to as X2. Salinity also can affect the allowable concentration of DO. Within the Plan Area, fresh water can support DO concentrations as high as 9 mg/L, and salt water can accommodate only up to 8 mg/L. Many fish species have a preferred range of salinity and a range of physiological tolerance to salinity, both of which can influence their distribution.

C.1.1.3 Temperature

Water temperature is critical in the control of chemical reactions and biological processes that can alter water chemistry and the water column's carrying capacity for DO. Warmer water has less available DO carrying capacity. Warmer water also has increased potential for greater biological processes, including algae production, which in turn also can alter DO on a diurnal cycle that fluctuates with exposure to sunlight. Temperature is also a key factor in the mortality of aquatic species during all life stages, with egg survival and juvenile rearing being two of the phases most sensitive to temperature.

C.1.1.4 Turbidity

Turbidity is a measure of the amount of suspended solids at any point in the Delta. Suspended solids may be sediment, algae, or other solids. In general, as water moves downstream and flow velocity decreases, heavier particles settle out, falling toward the river bottom, and turbidity is reduced. As flow velocities increase during periods of high flow, or ebb and flow of tidal cycles, sediment can re-suspend as it is agitated, and turbidity will increase. Algal bloom also can alter turbidity during periods of high biological production. A correlation between turbidity and total suspended solids (TSS) is somewhat unique for each location or situation. Turbidity also can be measured using a Secchi disk. This black and white disk is lowered into the water until it can no longer be seen; the depth (Secchi depth) then is recorded as a measure of the transparency of the water that is inversely related to turbidity. The Delta flow regimes are in a constant state of flux; as velocities and depths vary with floodflows, deliveries, and tides, sediment and biological matter are regularly circulated and suspended, creating a highly turbid environment. Turbidity and its composition varies widely depending on season and location. In the winter, turbidity is high and is mostly due to suspended sediment associated with increased runoff from storms. This sediment settles out as water moves downstream. Turbidity during spring and summer tends to increase as a result of increased algal productivity. There has been a general trend towards decreased turbidity in the Delta over the past four decades (B.J. Miller pers. comm.). Turbidity may be biologically important to delta smelt

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

because it can provide cover from predators and provide a better contrast (background) to catch their prey. Turbidity may provide cover from predators for multiple other covered species. To the extent that turbidity is an index of food supply, it also correlates with basic food availability.

C.1.1.5 Passage

For the purposes of this appendix, passage refers to the ability of aquatic species to migrate beyond a potential barrier. In the Delta and the tributaries, migrating adult fish species, outmigrating juveniles, and resident or rearing fishes may find barriers to free movement through Delta waterways—not all waterways are connected at all flow levels and there can be nonphysical barriers such as water quality constraints (zones of low DO). Passage constraints can delay or prohibit successful spawning or the ocean growth stage. Passage will be described in the context of a physical facility, or alteration of flow that has the potential to change corridors or the potential for fish to move through a region over the annual flow cycle.

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

C.2 System Hydrology and Operations

This section includes a description of historical SWP/CVP operations in the Delta (i.e., operations under State Water Resources Control Board [State Water Board] water right Decision 1485 [D-1485] and Decision 1641 [D-1641]) and revised operations as a result of the 2008 U.S. Fish and Wildlife Service (USFWS) and 2009 National Marine Fisheries Service (NMFS) Biological Opinions [BiOps]). A general description of each modeling scenario evaluated in this appendix also is given.

C.2.1 Historical Operations

Water quality and flow objectives for the Delta were established in the State Water Board's 1978 Bay-Delta Water Quality Control Plan (WQCP) and were implemented in D-1485 in 1978. In general, D-1485 mandated that SWP and CVP manage water operations to maintain minimum Delta outflow and also maintain salinity at concentrations similar to what would have been without the projects. The D-1485 objectives for minimum Delta outflows and maximum salinity (EC) varied with water-year type (i.e., runoff). These outflow and water quality objectives were the primary regulatory requirements for operations of the SWP/CVP Delta exports until 1995. Fish protection at the SWP/CVP facilities was provided by the fish collection facilities (fish salvage) and upstream habitat mitigation was supported by the Four-Pumps Agreement in 1986, which mandated compensation for fish entrainment of some fish species (i.e., striped bass, Chinook salmon, and steelhead) based on the number of fish salvaged each year.

The 1995 WQCP introduced several changes in the D-1485 objectives. These new Delta objectives included the location of the average 2 ppt salinity (abbreviated as X2) for February through June, which was variable (adaptive) depending on runoff conditions in the previous month. The 1995 WQCP also introduced the E/I ratio, which limited total SWP/CVP exports to a specified fraction of the combined Delta inflow. The 1995 WQCP objectives were implemented as amendments to D-1485 and in the 1999 D-1641. The Vernalis Adaptive Management Plan (VAMP) was authorized as the implementation of the San Joaquin River minimum flow objectives during the February through June period. The D-1641 objectives for minimum outflow, maximum E/I, maximum EC at several stations in the Delta, and X2 in the months of February through June must be satisfied by the SWP and CVP Delta operations. Reservoir releases and Delta exports are the two basic methods for satisfying these Delta objectives.

The Central Valley Project Improvement Act (CVPIA) imposed additional restrictions on CVP pumping and upstream reservoir release flows for anadromous fish protection. Further regulations have been imposed under the federal Endangered Species Act (ESA) by NMFS and USFWS to reduce the effects of the SWP and CVP operations on listed species take. The Reasonable and Prudent Alternative (RPA) actions included in the recent BiOps issued by NMFS (2009) and USFWS (2008) augment the fish protection provided by the D-1641 objectives and generally impose greater pumping restrictions (through limitations on the reverse OMR flow). As a result of these ESA restrictions, SWP and CVP water deliveries for a given runoff hydrology have been reduced relative to Delta operations under D-1641 or under D-1485.

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

C.2.2 Preliminary Proposal Modeling

C.2.2.1 Baseline Operations

For the preliminary proposal effects analysis, the existing condition to which the preliminary proposal (PP) was compared was consistent with the BiOp RPAs (EBC1). However, because Component 3, Action 4 of the USFWS RPA (hereafter, Fall X2 action), which requires that X2 position be maintained by increasing Delta outflow during wet and above-normal water-year types, has never been triggered because of recent dry hydrologic conditions, a second existing condition (EBC2) was evaluated that included all RPA actions except for the Fall X2 action. This was done to be consistent with recent case law that defined the California Environmental Quality Act (CEQA) baseline as the physical conditions actually existing at the time of the analysis.

Four baseline model scenarios (EBC1, EBC2, EBC2_ELT, and EBC2_LLT) differing in operational assumptions and climate change conditions were evaluated for this analysis. Table C.0-1 provides a description of each as well as a description of the three model scenarios related to the preliminary proposal. Two additional EBC2 model scenarios were used in the analysis that differed from EBC2 in climate change assumptions. The EBC2_ELT scenario incorporated early long-term (ELT) (2025) climate assumptions that included 15 centimeters (cm) of sea level rise, more variable precipitation, and warmer temperatures. The EBC2_LLT scenario incorporated late long-term (LLT) (2060) climate assumptions that included 45 cm of sea level rise, more variable precipitation than in the ELT, and warmer temperatures than in the ELT. This allows comparison of conditions without the preliminary proposal in the future with climate change to conditions with the preliminary proposal with climate change, which can show those changes attributable to climate change versus those attributable to the preliminary proposal. The EBC2 case included several other changes in the current CVP water demands in the Sacramento River basin (upstream demands). The CALSIM results from the four available baseline condition scenarios provide comparisons of reservoir operations (storage), release flows, Delta inflows, channel flows, exports (south Delta and north Delta), and Delta outflow, which have direct and indirect effects on the covered fish species.

The baseline operations simulated with the monthly CALSIM model include many of the USFWS/NMFS BiOps RPA actions at upstream reservoirs and in the Delta. However, because many of these actions include adaptive management in response to changing environmental conditions (e.g., flow, temperature, turbidity, fish sampling), the CALSIM model implementation required several approximations. In the end, the baseline modeling provides a reasonable representation of the likely operations of the SWP and CVP reservoirs and Delta pumping, and provides a basis of comparison for various model scenarios. A technical committee, formed to determine the best methods for including the BiOp actions in the CALSIM model, concluded that:

> The RPAs in the Service's BO are based on physical and biological phenomena that do not lend themselves to simulations using a monthly time step. Much scientific and modeling judgment has been employed to represent the implementation of the RPAs. The group believes the logic put into CALSIM II represents the RPAs as best as possible at this time, given the scientific understanding of environmental factors enumerated in the BO and the limited historical data for some of these factors. The simulated Old and Middle River (OMR) flow conditions and CVP and SWP Delta export operations, resulting from these assumptions, are believed to be a reasonable representation of conditions expected to prevail under the RPAs over large spans of years (refer to CALSIM II modeling results for more details on simulated operations). Actual OMR flow conditions and Delta export operations will differ from simulated operations for numerous reasons, including having near real-time knowledge and/or estimates of turbidity, temperature, and fish spatial distribution that are

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

> unavailable for use in CALSIM II over a long period of record. Because these factors and others are believed to be critical for smelt entrainment risk management, the Service adopted an adaptive process in defining the RPAs. Given the relatively generalized representation of the RPAs, assumed for CALSIM II modeling, much caution is required when interpreting outputs from the model. (from the February 10, 2010 technical memorandum on representation of USFWS BiOp actions in CALSIM.

The CALSIM results shown in Attachment A provide the appropriate basis for comparison and evaluation of the likely flow effects from the PP, even without inclusion of the magnitude of the outflow requirements and OMR flow restrictions that might be identified each year in the various adaptive management committees (e.g., USFWS smelt committee, NMFS Delta Operations for Salmonids and Sturgeon [DOSS]) and review processes (e.g., water operations management team [WOMT]).

C.2.2.2 Proposed Operations

Two preliminary proposal model scenarios were analyzed that differed in climate change assumptions. Both model scenarios assumed that new intake facilities in the north Delta were constructed and operational. The PP_ELT model scenario incorporated ELT climate and restoration assumptions, and the PP_LLT scenario incorporated LLT climate and restoration assumptions. The PP would include modified operations of the existing SWP and CVP Delta facilities and proposed operations for the new conveyance facilities. These PP operations are briefly described below.

The PP would make some modifications to the existing SWP and CVP Delta operations to further protect fish populations and to accommodate new Delta facilities and proposed habitat restoration. For example, the proposed gate on the Fremont Weir will allow about 3,000–5,000 cubic feet per second (cfs) into the Yolo Bypass at a lower Sacramento River flow than under existing conditions. This will reduce the Sacramento River flow at Freeport when the Fremont Weir gate is opened. This change is expected to provide considerable benefits for migrating Chinook salmon and other fish that rear in the Yolo Bypass floodplain.

The existing SWP and CVP Delta operations are summarized here so that the PP modifications to these existing operations can be identified and described. Delta operations can be simplified into two sets of rules; (1) rules controlling the maximum allowable exports and (2) rules controlling the minimum required Delta outflow. Several different objectives are used to control the allowable exports, and several more objectives are used to control the minimum required Delta outflow. The proposed BDCP north Delta intakes will require a third category of Delta rules: (3) rules governing maximum allowable north Delta diversions. The new rules governing the north Delta diversions may increase the allowable PP exports because some of the rules governing south Delta exports (e.g., E/I ratio) would not apply to the PP north Delta intakes.

C.2.2.2.1 Maximum Allowable Export Rules

Several D-1641 rules govern the maximum SWP and CVP pumping capacities. The PP assumes the CVP pumping capacity is 4,600 cfs, which requires use of the new Delta-Mendota Canal/California Aqueduct Intertie (DMC–CA Intertie) facility in the winter months. The PP assumes the existing south Delta SWP maximum diversion to the Clifton Court Forebay (CCF) of 6,680 cfs with additional diversions of 1/3 of the San Joaquin River flow at Vernalis (to a maximum monthly pumping of 8,500 cfs) between December 15 and March 15. SWP pumping to the maximum SWP Harvey O. Banks Pumping Plant (SWP Banks) physical capacity of 10,300 cfs was assumed for the PP using the north Delta intakes.

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

The E/I ratio was introduced in the 1995 WQCP and limits the SWP and CVP combined pumping to 65% of the Delta inflow from July to January, and to 35% of the Delta inflow from February to June. The rule is applied with a 7-day moving average of inflow and a 3-day average of export pumping. The 35% is increased to 45% in February if the January runoff was low (D-1641). This E/I ratio was assumed to apply only to south Delta exports; the PP north Delta intake diversions were assumed to be exempt from this E/I rule. The south Delta pumping was limited by the E/I calculated with the inflow minus the north Delta diversions.

An additional limit on exports was imposed by the 2009 NMFS BiOp with an export/San Joaquin River inflow ratio that applies in April and May. This ratio effectively limits the combined export to 1,500 cfs for San Joaquin River inflows of less than 6,000 cfs. This limit was assumed for the EBC cases, but was not included in the PP operations.

The USFWS and NMFS BiOps introduced new limits on the reverse (negative) OMR flow in the months of December–June of many years (adaptively managed based on turbidity and fish monitoring). For example, a minimum OMR limit of -2,000 cfs would restrict exports to about 2,000 cfs plus the Old River flow diverted from the San Joaquin River near Mossdale. The PP north Delta intakes would allow these OMR limits to be satisfied while pumping additional water from the Sacramento River. The OMR limits will vary each year with fish and turbidity conditions; however, the CALSIM modeling assumed a monthly OMR limit that varies with the water-year type.

The final constraints on Delta exports are related to the seasonal (monthly) water supply deliveries that are assumed for south of Delta SWP and CVP contractors. The San Luis Reservoir provides about 2 million acre-feet of seasonal storage for meeting the peak summer water demands. The San Luis Reservoir storage allows relatively high exports to continue through the fall and winter period. SWP exports include Article 21 deliveries to contractors with local storage capacity (e.g., surface reservoirs or groundwater storage) once San Luis Reservoir is filled. Because the PP would allow higher exports and fill San Luis Reservoir earlier each year, the PP will include higher SWP Article 21 "bonus" deliveries.

C.2.2.2.2 Minimum Required Delta Outflow Rules

Several D-1641 objectives currently control Delta outflow. Minimum monthly outflows are specified in D-1641 for each month, which often depend on the water-year type (i.e., runoff conditions). For example, a minimum monthly outflow of 3,000 cfs is specified in September of all years. A minimum monthly outflow of 8,000 cfs is specified in July of wet and above normal water-year types (about half of the years). The PP operations include these D-1641 monthly outflow rules.

The second set of D-1641 objectives that control Delta outflow are the maximum salinity objectives specified for each month or period. For example, salinity (EC) objectives are specified at Emmaton and Jersey Point to protect agricultural diversions, and salinity (chloride) objectives are specified at the Contra Costa Water District (CCWD) Rock Slough intake (PP#1) to protect drinking water supplies. Because Delta outflow is the major factor determining salinity in the Delta channels, these salinity objectives are satisfied by increasing Delta outflow (normally by reducing exports). The D-1641 salinity objectives are assumed to apply to the EBC and the PP cases (ELT and the LLT).

The third set of rules that control Delta outflow is the spring X2 objectives introduced in the 1995 WQCP. The location (kilometers [km] upstream of the Golden Gate Bridge) of the 2 ppt salinity (i.e., upstream edge of estuarine salinity gradient) is specified, based on the month and the (unimpaired) runoff in the previous month. This was formulated as an adaptive objective; the required outflow

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

increased with higher runoff conditions. D-1641 provides equivalent Delta outflows for the X2 objectives; X2 at Collinsville (81 km) can be satisfied with an outflow of 7,100 cfs and X2 at Chipps Island (75 km) can be satisfied with an outflow of 11,400 cfs. The CALSIM model includes changes in the outflow needed to satisfy the salinity objectives or the X2 objectives for the ELT and LLT cases. San Francisco Bay tidal salinity modeling (i.e., 3-D UnTRIM model) results were used to estimate the effects of assumed sea level rise on the salinity gradient for the ELT and LLT. The increased salinity effects were translated into higher CALSIM required outflows needed to satisfy the EC and X2 objectives.

The 2008 USFWS BiOp included an additional outflow requirement for September and October of wet and above normal water-year types (about half the years). The Fall X2 rule requires X2 to be downstream of Collinsville (7,100 cfs outflow) in above normal years and downstream of Chipps Island (11,400 cfs outflow) in wet years. The Fall X2 rule was included in the EBC2, EBC2_ELT, and EBC2_LLT cases, but not the EBC1 or PP cases.

C.2.2.2.3 Rules for North Delta Intake Diversions

The proposed north Delta intakes would operate under several parameters related to fish screen approach velocity and sweeping velocity. Some of these operational parameters could limit operations within the tidal cycle. However, only the maximum allowable north Delta diversions, using daily or monthly flows, could be incorporated into the CALSIM modeling of the PP scenarios (ELT and LLT). These new operational rules may vary between months and are referred to as *bypass flow rules* for the north Delta intakes. For example, the basic bypass flow rule for the months of July–September was assumed to be 5,000 cfs in all years. All Sacramento River flow above 5,000 cfs could be diverted at the north Delta intakes, subject to the other Delta rules for minimum required Delta outflow. The minimum bypass flow in October and November was assumed to be 7,000 cfs in all years.

The PP north Delta intake diversion rules in December–June were assumed to be more complicated, with bypass flows increasing with the inflow. Some low-level pumping of about 5% of the river flow was allowed most of the time, but major diversions could not begin until the Sacramento River flow was greater than a threshold (of about 10,000 cfs to 15,000 cfs). The total diversions were limited to remain less than 50% of the Sacramento River flow. These bypass flow rules have an effect similar to the E/I ratio—generally limiting the north Delta diversion to a moderate fraction of Sacramento River inflow. These monthly bypass flow rules control how much of the Delta exports are diverted from the north Delta intakes.

The fairly complex bypass flow criteria can be summarized by determining the allowable north Delta diversions for a range of Sacramento River at Freeport flows. Table C.2-1 shows the allowable north Delta diversions in each month for a range of Sacramento River at Freeport flows. The first two columns show the allowable diversions in the months of July–September and in the months of October–November. The bypass flow criteria are constant values of 5,000 cfs in July–September and 7,000 cfs in October and November. The allowable diversions are easily calculated and increase directly with Sacramento River flows above the bypass criteria. For example, with a Sacramento River flow of 10,000 cfs, the allowable north Delta diversion would be 5,000 cfs in July–September and 3,000 cfs in October and November. At a Sacramento River flow of 15,000 cfs, the allowable diversion would be 10,000 cfs in July–September and 8,000 cfs in October and November.

In the months of December through June, the bypass flow criteria are more complex and depend on the Sacramento River storm flow sequence and magnitude. Table C.2-1 shows the allowable

Administrative Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

diversions for the three levels of bypass flow criteria that are applied during the months of December–April. Until after the first major storm flow occurs (defined as flows of greater than 20,000 cfs at Wilkins Slough for 10 days) only low-level pumping of about 6% of the Sacramento River flow at Freeport greater than 5,000 cfs is allowed. This low level of north Delta diversion flow will provide maximum protection for juvenile fish migration (e.g., winter-run Chinook salmon) that may occur during the first major storm event each year.

After the first major storm event, the allowable north Delta diversions increase according to three bypass flow criteria levels; level I applies for the first 15 days of Freeport flows greater than about 25,000 cfs, level II applies for the next 15 days of Freeport flows greater than 25,000 cfs, and level III applies for the remainder of the period through June. It is likely that the level I and level II criteria would apply to the first month with substantial runoff each year; most of the north Delta diversions will be governed by the level III bypass criteria for the December–June fish protection period.

The level III diversions in December–April would be 500 cfs for a Freeport flow of 10,000 cfs, 3,000 cfs for a Freeport flow of 15,000 cfs, 7,000 cfs for a Freeport flow of 20,000 cfs, and 12,000 cfs for a Freeport flow of 25,000 cfs. The diversion rules with three criteria levels are specified separately for May and June. The level III diversions are slightly higher in May and June. The allowable north Delta diversions with a Freeport flow of 15,000 cfs would be 3,600 cfs in May and 4,200 cfs in June. The allowable north Delta diversions with a Freeport flow of 20,000 cfs would be 7,600 cfs in May and 8,200 cfs in June. The allowable north Delta diversions with a Freeport flow of 25,000 cfs would be 12,600 cfs in May and 13,200 cfs in June.

Full diversions of 15,000 cfs would be allowed in July–September with a Freeport flow of 20,000 cfs, would be allowed in October and November with a Freeport flow of 22,000 cfs, would be allowed in December–April for level III diversions with a Freeport flow of about 40,000 cfs, and would be allowed in May and June with a Freeport flow of about 27,500 cfs. These assumed bypass flow criteria are very limiting in the months of December–June for Sacramento River at Freeport flow of less than 15,000 cfs (which is common in dry and critical years).

Table C.2-1. Allowable North Delta Diversions (cfs) in Different Months for a Range of Sacramento River Flows at Freeport (cfs)

Months	Jul–Sep	Oct–Nov	Dec–Apr			May	May	May	Jun	Jun	Jun
Level			I	II	III	I	II	III	I	II	III
Sacramento River at Freeport Flow (cfs)			first 15 days of 2nd storm	second 15 days of 2nd storm	after 30 days of high flows	first 15 days of 2nd storm	second 15 days of 2nd storm	after 30 days of high flows	first 15 days of 2nd storm	second 15 days of 2nd storm	after 30 days of high flows
5,000	–	–	–	–	–	–	–	–	–	–	–
10,000	5,000	3,000	300	300	500	300	300	600	300	300	700
15,000	10,000	8,000	600	1,600	3,000	600	2,000	3,600	600	2,400	4,200
20,000	15,000	13,000	1,600	4,100	7,000	2,100	5,250	7,600	2,600	6,400	8,200
25,000	15,000	15,000	4,100	8,100	12,000	6,100	9,250	12,600	6,600	10,400	13,200
30,000	15,000	15,000	7,600	12,100	15,000	10,100	13,250	15,000	10,600	14,400	15,000
35,000	15,000	15,000	12,100	15,000	15,000	14,100	15,000	15,000	14,600	15,000	15,000
40,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000

Adraft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

C.3 Species Exposure to Flow and Flow-Related Parameters

All of the covered fish species would be exposed to preliminary proposal–related changes in flows in the Sacramento River system, the San Joaquin River system, the Delta, or a combination of these areas. Table C.1-1 indicates which life stages for each species would be exposed to various areas in the Study Area, which provides the basis for why certain methods and analyses are applicable to the various life stages of each species. Additional detail about the life histories and a conceptual model for each species are provided in Appendix 2.A, *Species Accounts*.

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

C.4 Methods Used

Several methods were used to assess the potential effects on fish related to changes in flows from the preliminary proposal. Table C.4-1 indicates which methods were applied for each area of interest (upstream habitat, Delta habitat, and passage/movement) and to each life stage of each species. Table C.4-2 provides a description of each method used and its benefits and limitations.

Admin Draft

1 **Table C.4-1. Summary of Methods Used for Each Region and Species Life Stage**

Flow Parameter Change or Species Affected	Geographic Region or Life Stage	CALSIM	DSM2-PTM	DSM2-HYDRO	DSM2-QUAL	DSM2-Fingerprinting	MIKE21	Reclamation Temperature Model	Sacramento River Water Quality Model	Delta Passage Model	DRERIP	Sacramento Ecological Flows Tool	Reclamation Egg Mortality Model	SALMOD	Winter/Spring X2–Abundance Regression	Delta Smelt Abiotic Habitat Index	Yolo Bypass Fry Growth Model
Upstream Abiotic Habitat	Sacramento River and San Joaquin River	X						X	X			X	X	X			
Fish Movement (Migration, Transport, and Passage)	Yolo Bypass, Lower Sacramento River, Lower San Joaquin River	X	X	X		X				X	X						
Plan Area (Delta) Habitat	North Delta, South Delta, Central Delta	X	X	X	X		X				X				X	X	X
Steelhead	Eggs/Embryo	X						X	X			X					
	Fry and Rearing Juveniles	X		X				X	X			X					
	Juvenile Migrants	X		X	X			X	X								
	Adults	X			X	X		X	X		X						
Winter-Run Chinook Salmon	Eggs/Embryo	X						X	X			X	X	X			
	Fry	X						X	X			X		X			
	Juvenile Migrants	X		X	X					X	X						
	Adults	X			X	X		X	X		X						
Spring-Run Chinook Salmon	Eggs/Embryo	X						X	X			X	X	X			
	Fry	X						X	X			X		X			
	Juvenile Migrants	X		X	X					X	X						
	Adults	X			X	X		X	X		X						
Fall-/Late Fall–Run Chinook Salmon	Eggs/Embryo	X						X	X			X	X	X			
	Fry	X						X	X			X		X			X
	Juvenile Migrants	X		X	X					X	X						
	Adults	X			X	X		X	X		X						

Admin Draft

Flow Parameter Change or Species Affected	Geographic Region or Life Stage	CALSIM	DSM2-PTM	DSM2-HYDRO	DSM2-QUAL	DSM2-Fingerprinting	MIKE21	Reclamation Temperature Model	Sacramento River Water Quality Model	Delta Passage Model	DRERIP	Sacramento Ecological Flows Tool	Reclamation Egg Mortality Model	SALMOD	Winter/Spring X2–Abundance Regression	Delta Smelt Abiotic Habitat Index	Yolo Bypass Fry Growth Model
Delta Smelt	Eggs				X												
	Larva	X	X	X	X												
	Juvenile	X			X											X	
	Adult				X												
Longfin Smelt	Eggs				X												
	Larva	X	X	X	X												
	Juvenile	X			X										X		
	Adult				X												
Sacramento Splittail	Eggs/Embryo	X					X										
	Fry	X					X										
	Juveniles	X					X				X						
	Adults	X					X				X						
White Sturgeon	Egg/embryo	X						X	X		X						
	Larva	X						X	X		X						
	Juvenile	X			X			X	X		X						
	Adult	X			X			X	X		X						
Green Sturgeon	Egg/embryo	X						X	X			X					
	Larva	X						X	X								
	Juvenile	X			X			X	X		X						
	Adult	X			X			X	X		X						
Pacific Lamprey	Eggs	X						X	X								
	Ammocoetes	X						X	X								
	Macropthalmia	X			X												
	Adult	X			X	X											
River Lamprey	Eggs	X						X	X								
	Ammocoetes	X						X	X								
	Macropthalmia	X			X												
	Adult	X			X	X											

Admin Draft

Table C.4-2. Description of Methods Used and the Benefits and Limitations of Each Method

	Description of Method	Benefits of Method	Limitations of Method
CALSIM	Provides monthly average flows for entire SWP/CVP system based on 82-year record.	Based on historical record and system-wide. Allows comparisons of changes in flows under a range of alternative operations. Used extensively to determine change in water operations and flows.	Monthly time step limits use for daily or instantaneous effects analysis; does not accurately simulate real-time operational strategies to meet temperature objectives.
DSM2-HYDRO	One-dimensional hydraulic model used to predict flow rate, stage, and water velocity in the Delta and Suisun Marsh.	Numerous output nodes throughout the Plan Area. Provides information in short time steps that can be used to assess tidal hydrodynamics. Used extensively to determine change in water operations and flows.	One-dimensional model; very data intensive; runs for limited period (only 16 years).
DSM2-PTM	Simulates fate and transport of neutrally buoyant particles through space and time in the Delta and Suisun Marsh.	Allows assessment of particle fate, transport, and movement rate from numerous starting points to numerous end points. Provides information on movement of planktonic larval fish such as delta and longfin smelt in a tidal environment. Used extensively in Central Valley fishery assessments.	One-dimensional model; no "behavior" can be given to particles; very data-intensive and generally allows tracking for only up to 180 days.
DSM2-QUAL	Used to predict water temperature, dissolved oxygen, and salinity in the Delta and Suisun Marsh.	Numerous output nodes throughout the Plan Area. Used extensively in Central Valley fishery assessments.	One-dimensional model; very data-intensive; runs for limited period (only 16 years).
DSM2-Fingerprinting	Calculates the proportion of water from different sources at specific locations in the Delta.	Allows assessment of water composition at numerous locations throughout the Plan Area. Useful for assessing changes in potential olfactory cues and attraction flows as well as water movement through the Delta.	One-dimensional model; very data-intensive; runs for limited period (only 16 years).
MIKE21	Modeling software used to develop a two-dimensional hydrodynamic model that predicts water surface elevation, flow, and average velocity in the Yolo Bypass.	Two-dimensional model provides improved definition over one-dimensional models. Can be used to assess changes in physical habitat conditions for fish within the inundated floodplain as a function of specific flows.	The model is static such that changes in flows are not modeled dynamically.
Reclamation Temperature Model	Uses CALSIM flow and climatic model output to predict monthly water temperature on the Trinity, Feather, American, and Stanislaus River basins and upstream reservoirs.	Large geographic extent makes model widely applicable to the preliminary proposal effects analysis. Used extensively in Central Valley fishery assessments.	Monthly time step limits use for daily or instantaneous effects analysis; does not accurately simulate real-time reservoir operational strategies to meet temperature objectives.

Admin Draft

	Description of Method	Benefits of Method	Limitations of Method
Sacramento River Water Quality Model	Simulates mean daily reservoir and river temperatures at key locations on the Sacramento River based on CALSIM output.	Daily time step allows more accurate simulation of real-time operation strategies and can be used to assess temperature effects at a more biologically meaningful time step. Provides input to the Reclamation egg mortality and SALMOD models. Used extensively in Central Valley fishery assessments.	Temporal downscaling routines have limited precision and are not always accurate. Cannot reflect real-time management decisions for coldwater pool and temperature management.
Delta Passage Model	Simulates migration and mortality of Chinook salmon smolts entering the Delta from the Sacramento, Mokelumne, and San Joaquin Rivers through a simplified Delta channel network, and provides quantitative estimates of relative Chinook salmon smolt survival through the Delta to Chipps Island.	Accounts for movement of migrating juvenile Chinook salmon runs down different Delta channels; based on a growing number of field studies of juvenile salmon migration.	Many of the model assumptions are based on results from large, hatchery-reared late fall–run and fall-run Chinook salmon that may not be representative of smaller, wild-origin fish. Model is applicable only to fish migrating and not to those rearing in the Delta.
Sacramento Ecological Flows Tool	Links flow management actions to changes in the physical habitats and predicts effects of habitat changes to several fish species.	Incorporates flow and water temperature inputs with multiple model concepts and field and laboratory studies to predict effects on multiple performance measures for fish species; peer-reviewed model.	Limited to upper Sacramento River; limited set of focal species (steelhead, Chinook salmon, and green sturgeon); third in a sequence of models (CALSIM and SRWQM), so limitations of previous models are compounded.
SALMOD	Predicts effects of flows on habitat quality and quantity for all races of Chinook salmon in the Sacramento River.	Measures effects of flows on spawning, egg incubation, and juvenile growth in terms of smolt production. Used extensively in Central Valley fishery assessments.	Only assesses effects of flow and water temperature; not reasonably accurate for small spawner numbers (<500 fish).
Reclamation Egg Mortality Model	Predicts temperature-related proportional losses of Chinook salmon eggs due to operational changes.	Assesses effects at multiple locations within multiple rivers. Used extensively in Central Valley fishery assessments.	Limited to effects on eggs only; monthly time step limits use for daily or instantaneous effects analysis; third in a sequence of models (CALSIM and Reclamation Water Temperature Model), so limitations of previous models are compounded.
DRERIP	Used to assess importance of stressors, develop methods, and aid in qualitative assessments of preliminary proposal actions in the Plan Area.	Conceptual models have been peer-reviewed and include individual fish species and habitat functions. Provides information on potential stressors and mechanisms for effects analysis.	Outputs are limited to qualitative assessments based on best professional judgment of topical experts.

Admin Draft

	Description of Method	Benefits of Method	Limitations of Method
Longfin Smelt Winter-Spring X2–Abundance Regression	Used to estimate relative abundance of longfin smelt in the fall based on winter-spring X2 (as an indication of outflow)	Method has been peer-reviewed and includes regressions based on observed data.	Changes in the nature of the relationship in recent years appear to have occurred as a result of factors other than outflow
Delta Smelt Abiotic Habitat Index	Used to calculate area of delta smelt abiotic habitat.	Method has been peer-reviewed and includes regressions based on observed data.	Was developed based on a portion of delta smelt fall habitat (Suisun Bay, Suisun Marsh, and West Delta subregions) that does not incorporate other areas where recent occurrence has been appreciable; based on two abiotic factors; based on linked statistical models without accounting for uncertainty in each model.
Yolo Bypass Fry Growth Model	Used to estimate the differences in growth of Chinook salmon fry in the Yolo Bypass compared to the mainstem lower Sacramento River.	Provides comparison of alternate migratory routes for fry in terms of growth and size-related survival.	Currently limited to fall-run Chinook salmon. Enhanced growth rate on Yolo Bypass floodplain is modeled as a function of duration of flooding and does not include potential benefits of productivity related to flooded area.

CVP = Central Valley Project.
DRERIP = Delta Regional Ecosystem Restoration Implementation Plan.
PTM = particle tracking model.
Reclamation = U.S. Department of the Interior, Bureau of Reclamation.
SRWQM = Sacramento River Water Quality Model.
SWP = State Water Project.

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

C.4.1 CALSIM II and DSM2 Models

The CALSIM II model was used to evaluate the performance of the SWP and CVP systems for existing or future levels of water supply development, potential future facilities, and current or alternative operational requirements. Key model output includes reservoir storage levels, river flows, water diversions, Delta exports, water deliveries, and Delta outflow. The CALSIM model was used to simulate the monthly reservoir storage and flows for the Water Year (WY) 1922–2003 period (82 years) for each EBC and PP scenario.

CALSIM II simulates SWP and CVP operations assuming a repeat of the historical (measured) monthly runoff for the Central Valley region for WY 1922–2003. Existing upstream reservoir operations (above the SWP and CVP reservoirs) and diversions for irrigation (by nonproject water users) are calculated for the adjusted hydrology inputs for the CALSIM model. These calculated hydrology inputs correspond to a specified "level of development" (e.g., 2005, or 2010, or 2025 [ELT], or 2060 [LLT]). The model uses an optimization algorithm to calculate SWP and CVP reservoir and Delta operations to meet assumed water demands on a monthly time step. Reservoir storage, releases, and Delta conditions are controlled by many different objectives. The model results are governed by specified "weights" for meeting (satisfying) the various regulatory and operational priorities. The Delta outflow–salinity response is approximated with Artificial Neural Network (ANN) "internal equations." Delta exports and outflow, along with X2 position and electrical conductivity (EC) at a few key regulatory locations, are the major model outputs. The CALSIM II model originally was described by Draper and coauthors (2004) and documentation provided by California Department of Water Resources (DWR) (2002); CALSIM has been subjected to two peer reviews in the past 8 years (Close et al. 2003; Lund et al. 2006). Much more information on the CALSIM II model can be found at <www.modeling.water.ca.gov>.

DSM2 is a one-dimensional (with branched-channels) tidal hydrodynamic model used to simulate tidal elevations and tidal flows (velocities), water quality, and particle tracking in the Delta (Anderson and Mierzwa 2002). DSM2 was used to describe the existing conditions in the Delta and for simulations of the changes from the baseline for the preliminary proposal (tidal restoration) and with climate change (sea level rise). The DSM2 model has three separate components: HYDRO, QUAL, and particle tracking (PTM). HYDRO simulates tidal flows, tidal velocities, and tidal elevations for the specified Delta channel geometry and tidal boundary elevations at Martinez. QUAL simulates the concentrations of conservative (i.e., no decay or growth) variables such as salinity and non-conservative (decay or growth) variables such as temperature and turbidity given the inflows and tidal flows in the Delta channels simulated by HYDRO. PTM simulates mixing and transport of neutrally buoyant (suspended) particles based on the channel geometry and tidal flows simulated by HYDRO.

C.4.1.1 CALSIM II Inflows

Reservoir inflows and other watershed runoff are calculated from the historical measurements of river flows during 1922–2003 and assumed upstream nonproject reservoir operations and water diversions. Most of the SWP and CVP reservoirs have upstream storage projects that regulate the natural unimpaired inflows. These regulated inflows are generally determined with separate upstream watershed and reservoir simulation models. The 82-year sequences of inflow were adjusted slightly for the assumed ELT and LLT scenarios to accommodate assumed changes due to climate change. The changes in the CALSIM inflows for the ELT and LLT scenarios are described in

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

the climate change appendix (Appendix 2.C); inflow was shifted from the April–June period into the January–March period, and total runoff was slightly higher (5%).

C.4.1.2 CALSIM Reservoir Operations

Reservoir inflow generally is stored, unless the end-of-month storage would exceed the monthly specified maximum storage level (volume) for flood control. The monthly minimum reservoir releases are specified and must be satisfied, and there may be downstream water supply demands for diversion along the river or in the Delta for export pumping or for required Delta outflow.

Although minimum reservoir storage volumes can be specified, the CALSIM model of the SWP and CVP operations does not use minimum storage levels to govern (limit) reservoir drawdown and carryover storage at the end of September. The water supply deliveries are adjusted according to the runoff and storage levels, and the water supply deficits (specified for dry years) are used indirectly to limit reservoir drawdown.

Upstream CVP reservoirs generally are linked to each other through balancing rules and are somewhat linked to the Delta operations. However, in many months each reservoir operates independently to fill during the winter and spring and release water for the local water supply diversions and minimum specified river flows.

The CALSIM model was used to determine what the monthly storage and flows from each upstream reservoir would be under the various modeling scenarios. These monthly storage levels (elevations) and monthly flows were used to directly assess changes in aquatic habitat or indirectly as inputs to other biological models.

C.4.1.3 CALSIM Delta Operations

The CALSIM model simulates Delta operations by comparing the Delta inflows with the Delta flow and salinity (EC) objectives to determine the required Delta outflow and the allowable Delta exports. CALSIM first meets south-of-Delta monthly demands, determines whether additional exports can be accommodated by additional upstream reservoir releases, then estimates the outflow required to satisfy the most stringent of the salinity or X2 objectives and adjusts the exports (or upstream releases) to fully satisfy the D-1641 objectives and the USFWS/NMFS BiOp actions (described in Section C.2.2).

The CALSIM II model uses a monthly time step to calculate reservoir storage and river flows. While monthly time steps are reasonable for long-term planning analyses of water operations, two major components of the preliminary proposal include operations that depend on flow variability at scales less than monthly: the operation of the modified Fremont Weir and the diversion/bypass flow rules associated with the proposed north Delta intakes. In an effort to better represent the sub-monthly flow variability, particularly in early winter, a monthly to daily flow disaggregation technique was included in the CALSIM II model for the flows at the Fremont Weir (Sacramento River at Verona) and the north Delta intakes (Sacramento River at Freeport). The technique applies historical daily patterns to transform the monthly flows into daily flows. The historical daily flow was adjusted (using a ratio) to match the CALSIM monthly average flow; some smoothing was needed between months.

The preliminary proposal north Delta intakes would be operated with bypass flow rules that govern the fraction of Sacramento River flow that can be diverted during a month (described in

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

Section C.2.2 above). Bypass rules are designed to avoid increased upstream tidal transport from downstream channels, to protect the fish migrating past the intake facilities, and to preserve the natural hydrograph. The north Delta intakes and the associated bypass flow rules are the major changes in Delta operations that would result from the preliminary proposal.

The CALSIM inflows, north Delta intake diversions, required Delta outflow, south Delta exports, and specified Delta agricultural diversions were used to calculate Delta channel flows at several locations (based on the DSM2 simulated flow splits). CALSIM monthly flows were calculated for the Sacramento River at Rio Vista, Threemile Slough, Georgiana Slough, Sutter Slough, Steamboat Slough, OMR at Bacon Island , and San Joaquin River at Stockton and at Antioch. These channel flows were used to assess changes in habitat directly or indirectly as inputs to other biological models.

C.4.1.4 CALSIM Outflow-Salinity Relationships

There are two methods for estimating the outflow-salinity response in CALSIM. One method was introduced by CCWD in 1993 and is based on historical outflow and salinity (EC) data from several west Delta locations. The other is a generalized multiple regression method (artificial neural network [ANN]) based on the DSM2 simulations of the Delta outflow–salinity relationships at several regulatory compliance locations (Emmaton, Jersey Point, Rock Slough).

The outflow–salinity curves illustrate the basic relationships between Delta outflow and salinity distribution in the estuary upstream of Martinez (Contra Cost Water District 2010). These outflow–salinity relationships were introduced by CCWD staff (Denton 1993) using the concept of effective Delta outflow and negative exponential salinity–outflow curves (known as the *G-model* formulation). The effective Delta outflow is estimated from the daily historical outflow (DAYFLOW data file). The effective Delta outflow is similar to a moving average, with a period of about 3 months. Salinity (measured as EC) at Suisun Bay and Delta locations can be well-represented with negative exponential EC–outflow curves. These EC–outflow relationships were estimated using historical monthly average outflow and EC values during WY 1976–1991. This 16-year period often is used for Delta salinity modeling with DSM2 because it includes both dry-year and wet-year sequences.

C.4.1.5 CALSIM Artificial Neural Network

The other method used in CALSIM to estimate the outflow required to satisfy X2 or salinity objectives is an ANN. Operation of the SWP/CVP facilities and management of Delta flows are often dependent on Delta outflow needed for compliance with D-1641 salinity objectives. An ANN statistical estimation method was developed by DWR (Sandhu et al. 1999) that attempts to mimic the flow–salinity relationships simulated with DSM2 but provides an internal calculation that can be used in the monthly CALSIM model calculations. The ANN is used to match the simulated Delta inflow and exports with the outflow needed to satisfy the monthly salinity objectives. A more detailed description of the use of ANNs in the CALSIM model is provided in Wilbur and Munévar (2001).

The ANN developed by DWR (Seneviratne and Wu 2007) statistically correlates the salinity results from a DSM2 model run to the Delta inflows, Delta exports, Delta Cross Channel (DCC) gate operations and an indicator of tidal energy. The ANN was calibrated with the DSM2 results that may represent historical or future conditions using a full circle (iterative) analysis (Seneviratne and Wu 2007). Separate ANN calibrations were used for the existing conditions and the ELT and LLT conditions (with sea level rise and tidal restoration).

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

The preliminary proposal (ELT and LLT) used the ANN method for estimating Delta outflow requirements. The ANN method requires calibration whenever the outflow–salinity relationship in the Delta changes. The preliminary proposal assumed different tidal restoration acres for the ELT and LLT timeframes. In addition, the DSM2 modeling included 15 cm of sea level rise at ELT and 45 cm of sea level rise at LLT. Each combination of restoration and sea level condition may result in different outflow–salinity relationships and therefore require a different ANN calibration (coefficients). Attachment A describes the increased Delta outflow requirements that were simulated with the ANN for the ELT and LLT timeframes.

C.4.1.6 DSM2

HYDRO was used to determine the change in flows at various locations in the Delta. The QUAL module was used to simulate source water "fingerprinting," which calculates the fraction of the water or salinity contributed from each water source (Delta inflows) based on HYDRO outputs. The fractions of water and salt normally are tracked from the Sacramento River, San Joaquin River, Martinez boundary, eastside streams (Mokelumne and Cosumnes Rivers combined), agricultural drains (all combined), and the Yolo Bypass. For source-water fingerprinting, a tracer with constant concentration is assumed for each source tracked, while keeping the concentrations at other inflows as zero. For constituent (e.g., EC) fingerprinting analysis, the concentrations of the desired constituent are specified at each tracked source, while keeping the concentrations at other inflows as zero (Anderson 2003). Particle tracking modeling (PTM) was used in the analysis of transport flows of delta smelt and as a proxy for tracking transport of DO. At a junction the path of a particle is determined randomly based on the proportion of flow. The proportion of flow determines the probability of movement into each reach. A random number based on this determined probability then determines where the particle will go. A particle that moves into an open water area, such as a reservoir, no longer retains its position information. A DSM2 open water area is considered a fully mixed reactor. The probability of a particle leaving the open water area is calculated from the fraction of the volume leaving the open water area. Particles entering exports or agricultural diversions are removed and recorded. Once particles pass the Martinez boundary, they are removed and recorded.

The general documentation and description of the DSM2 model, along with calibration results, are available at the DWR website:

<http://baydeltaoffice.water.ca.gov/modeling/deltamodeling/models/dsm2/dsm2.cfm>.

This page includes an online introduction to the many aspects of the DSM2 modeling system, with particular attention to the necessary inputs and data files (most of these do not change between cases). A draft tutorial document was written by DWR in 2002, which provides good background on the general methods and data requirements for modeling of the Delta and Suisun Marsh, upstream of Martinez. Most of the geometry files and boundary files (tidal elevations at Martinez, river inflows and exports, agricultural diversions, and drainage) are provided with the modeling package. The only changes between most DSM2 cases are the daily or monthly inflows and exports. However, for the ELT and LLT cases, the tidal boundary conditions and boundary EC values at Martinez were adjusted, based on 3-D modeling performed with the UnTRIM modeling (MacWilliams and Gross 2010). Increased salt exchange coefficients were assumed for the ELT and LLT cases to match the 3D results for the 15 cm (0.5 foot) and 45 cm (1.5 feet) sea level rise conditions.

The DSM2 model was recalibrated to better match recent tidal flow and EC data and to include the Liberty Island (south end of Yolo Bypass) inundation, which occurred in 1998. This report

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

(CH2MHill 2009) was prepared to support the BDCP Delta tidal restoration evaluations and provides a very thorough review of the accuracy of modeled tidal elevations, tidal flows, and EC patterns throughout the Delta, in comparison to the very extensive measurements by the U.S. Geological Survey and DWR. This report is available at the DWR website:

<ftp://ftp.modeling.water.ca.gov/pub/delta/DSM2_Users_Group/BDCP/DSM2_Recalibration_102709_doc.pdf>.

DSM2 modeling was used to determine the changes in Delta tidal hydrodynamics and salinity caused by the tidal restoration (RMA 2010) and operational changes for the preliminary proposal. Six DSM2 simulations for 1976–1991 (16-year period) were conducted also to evaluate the likely (combined) effects of future sea level rise on Delta tidal flows and salinity. The EBC2_ELT baseline and PP_ELT cases assumed 6 inches of sea level rise, and the EBC2_LLT baseline and PP_LLT cases assumed 18 inches of sea level rise. The PP was simulated only for the ELT and LLT periods. Two existing baselines were simulated with (EBC2) and without (EBC1) the Fall X2 requirements of the 2009 USFWS BiOp.

The DSM2 model inputs and geometry files were adjusted for each of these six cases. The new intakes were added to the Sacramento River upstream of Sutter Slough; the additional areas of tidal habitat were added to appropriate locations for the PP_ELT (25,000 acres) and the PP_LLT (65,000 acres) cases. Some of the existing gates and barriers were modified for the PP cases. The PP simulations assumed that the Suisun Marsh salinity control radial gates on Montezuma Slough would remain open all year long to allow full connection with tidal restoration areas in Suisun Marsh (this had a salinity effect in the fall months of some years when the gates were operated in the baseline cases). The south Delta agricultural barriers (water level control weirs) were not installed for the PP cases to enhance tidal flows in the proposed south Delta restoration areas.

Many of the DSM2 results for the six BDCP cases are summarized and described in Attachment C.A. Section C.A.5 describes the simulated changes in tidal flows caused by the combination of tidal restoration and sea level rise for the ELT (6 inches) and LLT (18 inches) timeframes. Some shifts in the channel flow diversions (e.g., Sutter, Steamboat, Georgiana, and Threemile Sloughs; DCC) were simulated for the combination of sea level rise and tidal restoration. These shifts in the tidal patterns were greatest for the LLT timeframe with 65,000 acres of tidal restoration and 18 inches of sea level rise.

Section C.A.6 describes the changes in the simulated salinity (EC) patterns within the Delta. Delta outflow is the major control on salinity (EC); because Delta outflow was slightly different for each of the DSM2 cases, the salinity (EC) was also slightly different. The analysis of the salinity patterns focused on the shifts in the relationships between the effective Delta outflow and the salinity at selected Delta locations (i.e., EC monitoring stations). Because the CALSIM model estimates the relationship between Delta outflow and EC (using ANN) in order to calculate the required Delta outflow to satisfy the monthly X2 and EC objectives, the comparison of the CALSIM EC and the DSM2 EC values at these Delta locations is also important.

Section C.A.7 describes the DSM2 "source tracking," which refers to the fraction of water at a Delta location that originated from each Delta inflow (e.g., San Joaquin River, eastside streams, Yolo Bypass, Sacramento, and Martinez). This tracking of inflows and the tidal movement and mixing within the Delta channels provides the logical basis for describing water quality patterns (e.g., seawater intrusion) and also for understanding the movement of water and small drifting organisms (e.g., plankton, larvae) and the Delta channel pathways for migrating fish.

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

Section C.A.8 describes the DSM2 particle tracking results. Because the PTM methods (when and where to inject tracking particles, where and for how long to track the movement and fate of tracking particles) are determined by the model user, the methods used for the BDCP evaluations are described in this section. The PTM results have been found to depend on the general flow patterns. Kimmerer and Nobriga (2008) found that the percentage of tracking particles entrained at the SWP and CVP south Delta pumping plants could be described with "logistical" (S-shape curve) relationships with the overall Delta E/I ratio and the independent variable.

The PTM results were used in the evaluation of estuarine fish movement and survival (See Appendix 5.B, *Entrainment*).

C.4.2 Upstream Habitat Methods

C.4.2.1 Salmonids

The geographic distribution and seasonal timing of spawning, rearing, and emigration vary among Central Valley steelhead and winter, spring, fall, and late-fall runs of Chinook salmon (See Appendix 2.A, *Species Accounts*). These differences determined the river and stream reaches and months for which habitat conditions were analyzed for each salmonid species and race and their life stages. Habitat conditions were analyzed only for streams that potentially will be affected by preliminary proposal conservations actions.

For Central Valley steelhead, the upstream habitat effects analysis for the Sacramento River system focused on habitat conditions in the mainstem Sacramento River, Feather River, American River, and Clear Creek. The effects analysis for the San Joaquin River system focused on conditions in the Stanislaus River and the mainstem San Joaquin River downstream of the Stanislaus River confluence. The effects analysis also analyzed potential effects on Klamath Mountain Province steelhead habitat in the Trinity River.

For Sacramento River winter-run Chinook salmon, the upstream habitat effects analysis considered only habitat conditions in the mainstem Sacramento River because the upper Sacramento River is the only known spawning location for Sacramento River winter-run salmon.

For Central Valley spring-run Chinook salmon, the upstream habitat effects analysis for the Sacramento River system addressed habitat conditions in the mainstem Sacramento River, Feather River, and Clear Creek only. Although spring-run Chinook salmon are known to spawn in several other tributaries to the upper Sacramento River, including Butte, Deer, and Mill Creeks, preliminary proposal operations would not affect instream flows or other habitat conditions in these tributaries. In recent years, an effort has begun to reestablish a naturally reproducing, self-sustaining population of spring-run Chinook salmon on the San Joaquin River. Operations under the preliminary proposal are not expected to affect Millerton Reservoir or releases from Friant Dam to the lower San Joaquin River. Therefore, no changes in habitat conditions are expected in the upper reaches of the river, where adult holding and spawning and juvenile rearing would occur. As a result, only habitat conditions in the mainstem river downstream of the confluence with the Stanislaus River, where downstream migration of juveniles and upstream migration of adults would take place, were analyzed. The effects analysis also evaluated habitat conditions for the Upper Klamath and Trinity Rivers Chinook salmon evolutionarily significant unit (ESU) in the Trinity River.

For Central Valley fall-run/late fall–run Chinook salmon, the upstream habitat effects analysis for the Sacramento River system focused on habitat conditions in the mainstem Sacramento River,

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

Feather River, American River, and Clear Creek, although the analysis for the late fall–run considered only habitat in the mainstem Sacramento River. The effects analysis for the San Joaquin River system considered only conditions in the Stanislaus River and the mainstem San Joaquin River downstream of the Stanislaus River confluence. Preliminary proposal operations are not expected to affect habitat conditions in the Tuolumne, Merced, Mokelumne, or Cosumnes River, and therefore they were not analyzed. The effects analysis also evaluated habitat conditions in the Trinity River for the Upper Klamath and Trinity Rivers Chinook salmon ESU.

C.4.2.1.1 Egg/Alevin

Survival of eggs and alevins (salmonid embryos that still have a yolk sac and remain in the spawning gravel after hatching and before emergence) are affected by water temperatures and flow changes that result in redd dewatering. Changes in instream flows and water temperature during spawning and egg incubation and fluctuations in instream flows that result in redd dewatering are the primary impact mechanisms included in the effects assessment as described below.

Active spawning and egg incubation were assumed to occur for each species or race as follows:

- Steelhead: January through April
- Winter-run Chinook salmon: July through October
- Spring-run Chinook salmon: October through January
- Fall-run Chinook salmon: October through January
- Late fall–run Chinook salmon: February through May

Water Temperature

Water temperature in the upstream spawning and egg incubation habitats for steelhead and salmon is influenced by a number of factors. The primary factors are reservoir storage and coldwater pool within the reservoir, instream flow releases to the river, and seasonal atmospheric conditions. The level of water storage in a reservoir has a strong effect on the volume of cold water (coldwater pool) in the reservoir and, therefore, the temperature of water released during the summer and early fall. The summer and early fall are the times of year when river temperatures are most likely to rise above tolerance thresholds for steelhead and salmon. The effects analysis includes a summary of the May and September storage in each major upstream reservoir in combination with a frequency of exceedance analysis for May and September storage. Instream flows were characterized based on results of CALSIM II hydrologic modeling and presented as both instream flows by month and water year and monthly frequency of exceedance plots to allow examination of the entire range of simulation results for each of the effects analysis conditions examined.

Water temperatures in stream reaches used by steelhead and salmon for spawning were simulated using two separate temperature models. Daily average temperatures in the mainstem Sacramento River in the reach downstream of Keswick Dam were estimated using the Sacramento River Water Quality Model (SRWQM) with post-processed CALSIM II flow data. The SRWQM is used in the effects analysis to predict the effects of reservoir operations on water temperatures in the Sacramento River and Shasta and Keswick Reservoirs. Water temperatures in the Trinity, Feather, American, and Stanislaus Rivers were estimated using the U.S. Department of the Interior, Bureau of Reclamation (Reclamation) Temperature Model. Description of both models, as well as the post-processing procedures used to estimate daily flows from the CALSIM II model output for SRWQM input, is

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

provided below. Note that changes in reservoir storage and instream flows also were used in the upstream effects analysis for approximate estimates of potential changes in water temperature conditions where temperature data were not available (e.g., Clear Creek).

The SRWQM was developed using the HEC-5Q model to simulate mean daily (using 6-hour meteorology) reservoir and river temperatures at key locations on the Sacramento River. The time step of the model is daily, and it provides water temperature each day for the 82-year hydrologic period (WY 1922–2003) used in CALSIM II. The model has been used in the previous SWP and CVP system operational performance evaluation (U.S. Bureau of Reclamation 2008). Monthly flows from CALSIM II are used as input into the SRWQM after being temporally downsized to convert them to daily average flows for HEC5Q input. The conversions are based on the 1921 through 1994 daily historical record for the following aggregated inflows:

- Trinity River above Lewiston.
- Sacramento River above Keswick.
- Incremental inflow between Keswick and Bend Bridge (7-day trailing average for inflows below Butte City).

Each of the total monthly inflows specified by CALSIM II is scaled proportionally to one of these three historical records. Reservoir inflows are proportioned as defined above. Outflows and diversions are smoothed for a better transition at the end of the month without regard for reservoir volume constraints or downstream minimum flows. As flows are redistributed within the month, the minimum flow constraint at Keswick, Red Bluff, and Knights Landing may be violated. In such cases, operation modifications are required for daily flow simulation to satisfy minimum flow requirements. A utility program is included in SRWQM to convert the monthly CALSIM II flows and releases into daily operations. A more detailed description of SRWQM and the temporal downscaling process is included in an RMA calibration report (RMA 2003).

For more information on the SRWQM, see Appendix H of Reclamation's 2008 Biological Assessment: <www.usbr.gov/mp/cvo/OCAP/sep08_docs/Appendix_H.pdf>.

The Reclamation Temperature Model is used in the effects analysis to predict the effects of reservoir operations on water temperatures in the Trinity, Feather, American, and Stanislaus River basins and upstream reservoirs. The model is a reservoir and stream temperature model that simulates monthly reservoir and stream temperatures used for evaluating the effects of SWP/CVP project operations on mean monthly water temperatures in the basin based on hydrologic and climatic input data. It has been applied to past SWP and CVP system operational performance evaluations (U.S. Bureau of Reclamation 1994, 2004, 2008).

The model uses CALSIM II output to simulate mean monthly vertical temperature profiles and release temperatures for seven major reservoirs (Trinity, Whiskeytown, Shasta, Oroville, Folsom, New Melones, and Tulloch); four downstream regulating reservoirs (Lewiston, Keswick, Goodwin and Natoma); and five main river systems (Sacramento, Trinity, Feather, American, and Stanislaus), although the model was not applied to the Sacramento River in the effects analysis because the SRWQM was deemed superior because of its daily time step.

For more information on the Reclamation Temperature Model, see Appendix H of Reclamation's 2008 Biological Assessment at:

<www.usbr.gov/mp/cvo/OCAP/sep08_docs/Appendix_H.pdf>.

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

The temperature data simulated using the SRWQM and Reclamation Temperature Model were used to evaluate effects of potential exposure to seasonally elevated water temperatures on steelhead and salmon egg incubation and hatching success. Several different procedures were used for these evaluations.

- Water temperature exceedance charts were compared and frequency of exceedances were calculated over the simulation period for the different preliminary proposal model scenarios at 56 degrees Fahrenheit (°F) (water temperature thresholds used in the assessment are derived from a synthesis of information from field and laboratory studies such as McCullough 1999).
- Egg mortality in the mainstem Sacramento River for each race of Chinook salmon was estimated for the different model scenarios using the Reclamation Egg Mortality Model. This model estimates proportional salmon mortality for prespawned eggs, fertilized eggs, and preemergent fry of all Chinook salmon races in the Trinity, Sacramento, Feather, American, and Stanislaus rivers based on water temperature output from the SRWQM for the Sacramento River and the Reclamation Temperature Model for other rivers. The daily time step from the SRWQM may underestimate mortality in the Sacramento River (Hannon pers. comm.). The model provides output on an annual time step. The model uses temperature exposure mortality criteria for the three life stages, spawning distribution data, and output from the river temperature models to estimate percentages of egg and fry losses of a given brood of eggs for each run of Chinook salmon. For more information on the Reclamation Salmon Mortality Model, see Appendix L of Reclamation's 2008 Biological Assessment at:

  <www.usbr.gov/mp/cvo/OCAP/sep08_docs/Appendix_L.pdf>.

- Indices of spawning and egg incubation habitat suitability relying on water temperature and flow estimates were computed for steelhead and winter-run and spring-run salmon using the Sacramento River Ecological Flows Tool (SacEFT). The SacEFT system is a database-centered software system for linking flow management actions to changes in the physical habitats for the species of interest. The model uses daily temperature and flow outputs from the SRWQM. SacEFT employs a set of functional relationships to generate habitat-centered performance measures for the species of interest that change in response to flow-management scenarios. SacEFT operates on a daily time step. For more information on SacEFT, see Attachment C.B and the CALFED Bay-Delta Program (CALFED) Ecosystem Restoration Program (ERP) web page:

  <www.dfg.ca.gov/ERP/signature_sacriverecoflows.asp>.

- SALMOD was used to compare egg mortality for each race of salmon due to water temperature and flows on the mainstem Sacramento River from Keswick to Red Bluff Diversion Dam (RBDD) in the reach where spawning and egg incubation occur, for the different preliminary proposal model scenarios. An index of egg mortality was calculated for each year in the Chinook salmon spawning area. SALMOD uses the Instream Flow Incremental Methodology (IFIM), which is a decision-making process with five components: hydrology, geomorphology, biology, water quality (including temperature), and connectivity; and it estimates juvenile salmonid production in fresh water as a function of habitat availability. The primary assumption of the model is that egg and fish mortality is directly proportional to spatially and temporally variable habitat limitations, such as water temperature limits, which themselves are functions of the timing and quantity of flow and meteorological variables, such as air temperature. SALMOD is a spatially explicit model that characterizes habitat quality and carrying capacity using the hydraulic and thermal properties of individual habitat units. Inputs to SALMOD include CALSIM flows, water temperature from SRWQM, spawning distribution based on aerial surveys, spawning timing

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

depending on salmon race, and the number of spawners provided by the user (e.g., recent average escapement). The primary output is juvenile salmon production for each race of salmon in the Sacramento River. For more information on SALMOD, see Appendix P of Reclamation's 2008 Biological Assessment at:

<www.usbr.gov/mp/cvo/OCAP/sep08_docs/Appendix_P.pdf>.

Instream Flows and Redd Dewatering

To assess the effects of instream flows on spawning habitat conditions, information was compiled from CALSIM modeling on instream flows under each model scenario during the spawning and egg incubation periods used in the assessments for steelhead and the four races of Chinook salmon. The instream flows were compared among scenarios based on monthly flows by water year as well as based on frequency of exceedance analyses. The analysis also examined variation in instream flows each month over the entire 82-year simulation to assess differences among months and years.

Redd dewatering occurs when streamflows decrease after fish have spawned. The greater the change in flow after spawning, the greater the proportion of redds that are dewatered (U.S. Fish and Wildlife Service 2006). The proportion of Chinook salmon eggs dewatered on the Sacramento River following a flow decrease is provided by USFWS (2006), which used a two-dimensional hydraulic and habitat model (RIVER2D) to simulate the percentage of redds dewatered across eight Chinook spawning areas from Keswick Dam to Battle Creek (Figure C.4-1).

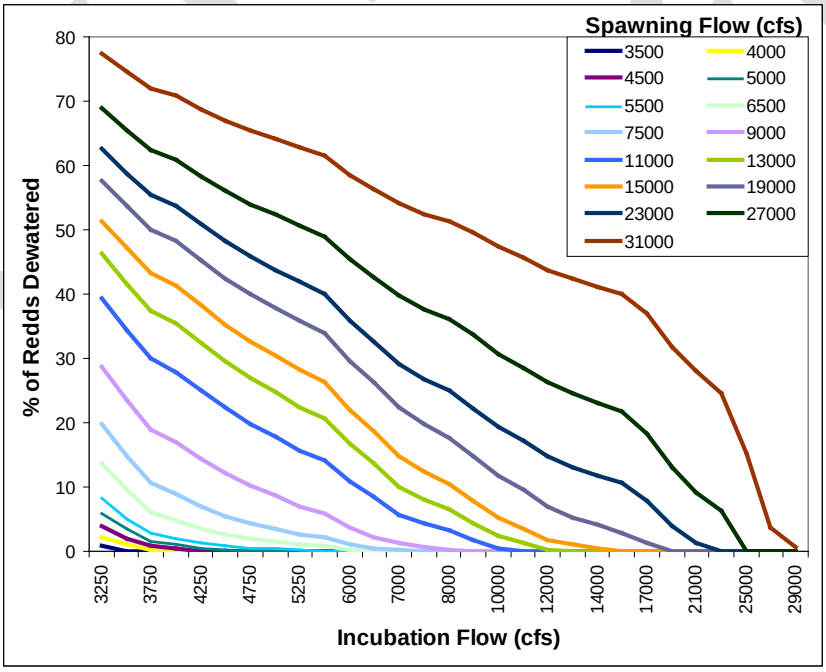


Figure C.4-1. Percent of Winter-Run Chinook Redds Dewatered as a Function of the Difference between Spawning Flow and Incubation Flow

SacEFT and SALMOD also were used to analyze flow effects, including redd dewatering. Daily average flows post-processed from CALSIM II were input into SacEFT and SALMOD to evaluate egg mortality resulting from redd dewatering. SacEFT assesses effects of flows on redd dewatering for

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

steelhead and all races of Chinook salmon in the Sacramento River only. SALMOD assesses effects of flows on redd dewatering for all races of Chinook salmon in the Sacramento River only.

There is currently no model like SacEFT or SALMOD that can incorporate flows to determine the risk of redd dewatering for other Central Valley rivers. Instead, the frequency and magnitude of flow reductions that potentially would result in redd dewatering were estimated using CALSIM flow outputs in these rivers. This estimation of redd dewatering risk was based on a compilation and review of comparative instream flows during the egg incubation period. Spawning flows were defined as the approximate flow on each day of egg deposition. The incubation flow is the lowest flow during the incubation period (after which alevins emerge from the substrate).

C.4.2.1.2 Fry and Upstream Juveniles

Fry and rearing juveniles were assumed to be present upstream for each species or race as follows.

- Steelhead: Year-round
- Winter-run Chinook salmon: August through December
- Spring-run Chinook salmon: Year-round
- Fall-run Chinook salmon: January through May
- Late fall–run Chinook salmon: Year-round

Fry and Juvenile Upstream Rearing Habitat

After emergence, Chinook fry seek nearshore habitats with cover (cobble, woody debris, riparian vegetation) and food sources, including aquatic and terrestrial invertebrates (National Marine Fisheries Service 2009). Cover functions as a refuge from both high-flow velocities and predators (National Marine Fisheries Service 2009). Shallow water rearing habitats are likely more productive than the main river channels, supporting higher growth rates, partially because of higher prey consumption rates, and favorable environmental temperatures. This has been observed previously in shallow inundated floodplains (Sommer et al. 2001).

The effects of preliminary proposal water operations on upstream rearing habitat were analyzed by assessing flow-related habitat suitability indices developed through the IFIM (Mark Gard unpublished data) using both SALMOD and SacEFT modeling. Changes to the extent of suitable rearing habitat were quantified using results of CALSIM II hydrologic modeling (e.g., monthly summary of instream flows over 82 years of hydrologic record, monthly frequency of exceedance analyses by water-year type). Results of simulation modeling of instream flows were compiled each month over the 82-year period of hydrologic simulation, as well as frequency of exceedance analyses monthly by water-year type, to examine potential changes in habitat conditions for rearing habitat.

Indices of weighted usable area (the product of the physical habitat area based on instream flows and the weighting factor for habitat suitability for juvenile salmon or steelhead rearing) were used as a basis for assessing the quantity and quality of habitat changes in upstream rearing areas as a function of flow that would be expected to occur under each model scenario. For fry, results of instream flow studies conducted on both the upper reaches of the Sacramento River (Keswick Dam to RBDD) and Feather River are available to assess the relationship between instream flow and fry rearing habitat (expressed as weighted usable area). These relationships were used in combination

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

with results of daily estimates of instream flows during the fry rearing stage to assess changes in habitat under each model scenario.

Based on SALMOD and SacEFT modeling results and weighted usable area estimates of rearing habitat for each model scenario, comparative indices of predicted changes in rearing habitat quality and availability were developed. Specifically, these included the following:

- Using SALMOD to compare fry and juvenile mortality of all races of Chinook salmon due to habitat limitation on the mainstem Sacramento River from Keswick to RBDD.
- Using results of the SacEFT model to assess changes in fry and juvenile rearing habitat for all races of Chinook salmon and steelhead in the upper Sacramento River under different model scenarios. The relative contribution of habitat-related mortality and habitat conditions to Chinook fry and juveniles was assessed based on a comparison of results among model scenarios.

Depending on the presence of steelhead and spring-run and fall-/late fall–run fry, results of information on instream flows in the Feather River, American River, Trinity River, Stanislaus River, and Clear Creek were used to assess potential differences in juvenile rearing habitat.

Water Temperature

Many of the water temperature analyses used for evaluating effects of the preliminary proposal model scenarios on steelhead and salmon fry are similar to those previously described for the egg/alevin stage.

The SRWQM was used to estimate daily water temperatures in the upper Sacramento River, and the Reclamation Temperature Model was used to estimate monthly temperatures in reaches of the Feather, American, Trinity, and Stanislaus Rivers where fry rearing occurs. Reservoir storage (May and September) and instream flow data also were used to assess fry rearing conditions on the Feather and American Rivers and Clear Creek.

Average daily water temperatures in excess of 65°F are thought to reduce habitat quality for fry rearing and increase fry metabolic rates, and temperatures above 68°F cause significant stress and mortality (water temperature thresholds used in the assessment are derived from a synthesis of information from field and laboratory studies such as McCullough 1999). Short-duration exposure (minutes to hours) to water temperatures greater than 72°F results in severe stress, loss of equilibrium, and lethal conditions. Using modeled flow and temperature data, three different methods to evaluate temperature effects on Chinook fry were applied.

1. Examined monthly water temperature exceedance charts, and frequency of exceedances were calculated over the simulation period for average temperatures above 65°F during the rearing period of each species and race in the Sacramento, American, Trinity, Feather, and Stanislaus Rivers and Clear Creek.
2. Used SALMOD to compare Chinook salmon fry production on the mainstem Sacramento River from Keswick to RBDD, and assess relative contribution of temperature-related stress and mortality relative to and in combination with other sources of fry mortality for each model scenario.
3. Used SacEFT to assess changes in steelhead and Chinook salmon rearing habitat conditions based on water temperature and flows.

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

Stranding

Chinook fry typically select low-velocity shallow channel margin habitat areas for rearing and hence are vulnerable to stranding when flows and water surface recede quickly and trap the fry in isolated channels and pools located along channel margins and in seasonally inundated floodplain habitat. Steelhead and spring-run Chinook salmon juveniles are relatively strong swimmers, but stranding mortality on inundated river channel margins and floodplains is still a concern.

Estimated levels of stranding of salmon and steelhead were estimated using monthly CALSIM II estimates of river flows in each river. Best professional judgment was used to assess the magnitude of effect on each species or run.

C.4.2.1.3 Adult

This section briefly describes the methods used to assess effects on adults that are immigrating, spawning, and emigrating (steelhead kelts).

Immigration, spawning, and emigration were assumed to occur for each species or race as follows.

- Steelhead: September through March (adult upstream migration); January through April (kelt migration)
- Winter-run Chinook salmon: December through July
- Spring-run Chinook salmon: April through August
- Fall-run Chinook salmon: September and October
- Late fall–run Chinook salmon: December through February

Water Temperature

Using flow and temperature data simulated from CALSIM II, SRWQM, and the Reclamation Temperature Model, water temperature exceedance curves were compared and water temperature exceedance frequencies were calculated over the simulation period (65°F water temperature thresholds used in the assessment are derived from a synthesis of information from field and laboratory studies such as McCullough 1999) at various locations where adult migration (and kelt migration for steelhead) occurs in the Sacramento, Feather, American, Stanislaus, and Trinity Rivers and Clear Creek.

Results of September reservoir storage, including frequency of exceedance analyses by month and water-year type over the 82-year period of hydrologic analysis, in combination with information on instream flows, were used to assess potential differences in water temperature conditions between model scenarios. It was assumed for purposes of this analysis that, if there were no changes in instream flows or reservoir storage during the period, adult steelhead or salmon potentially would be occupying a specific reach of the river system, and there would be no effect on adult habitat conditions. Based on results of the water temperature analysis of the modeled exposure and information available from the literature regarding the effects of adult steelhead and salmon exposure to elevated water temperatures prior to spawning, best professional judgment was used to assess potential effects of preliminary proposal operations on adults in the upper Sacramento, Feather, American, Trinity, and Stanislaus Rivers and Clear Creek.

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

C.4.2.2 Sturgeon

C.4.2.2.1 Egg/Embryo

Water Temperature

To determine how the preliminary proposal may affect eggs and embryos of white and green sturgeon, a literature review was completed to identify where and when these life stages would occur in the Bay-Delta system, and the temperatures that would be optimal for their survival. White sturgeon year class strength indices (YCI) indicate greater success of a year class under high spring Delta flows (Fish 2010); therefore, results were disaggregated by water-year type. An analysis, including literature review, in Israel and coauthors (2009) indicated that suitable temperature ranges for white and green sturgeon were 52°F–72°F (11 degrees Celsius [°C]–22°C) and 52°F–73°F (11°C–23°C), respectively, with 57°F–61°F (14°C–16°C) considered the optimal range for white sturgeon and temperatures below 63°F (17°C) considered optimal for green sturgeon. Further literature review indicated that for white sturgeon, embryonic abnormalities and mortality occurred at temperatures of 68°F (20°C) or greater (Wang et al. 1987), and temperatures greater than 17°C–18°C can be lethal to green sturgeon embryos (Van Eenennaam et al. 2005).

Israel and coauthors (2009) indicates that the key period for white sturgeon eggs/embryos is April through May, although February and March were included in the analysis to account for potential earlier spawning by adults; the key period for green sturgeon egg/embryos is April through July.

Literature reviews indicated that the middle portions of the Sacramento River were the primary spawning locations for white sturgeon (Israel and coauthors 2009). Based on California Department of Fish and Game (DFG) 2007–2009 recreational fishery tag data, additional white sturgeon spawning appears to occur in the San Joaquin drainage. Although it does not appear the Feather River system is heavily used by white sturgeon as spawning habitat, this region also was analyzed to determine whether the preliminary proposal may result in altering potentially limiting habitat conditions, thereby improving spawning conditions relative to existing conditions.

Egg incubation requires fast-moving, turbulent waters in river reaches characterized by steep discontinuities in the channel slope and coarse cobble (Moyle 2002). These habitats are available between Battle Creek and RBDD, specifically China Rapids and Iron Canyon (Israel and Klimley 2008). There is also potential for green sturgeon spawning to occur in the Feather River.

The SRWQM was used as the tool to investigate potential preliminary proposal– and climate-related temperature effects on sturgeon egg/embryo habitats in the Sacramento River. This model is described above in the *Egg/Alevin* section under *Salmonids*. The Reclamation Temperature Model, also described above, was used to investigate preliminary proposal– and climate-related effects on temperatures in the Feather River. Although neither of these models estimates San Joaquin River temperatures, mean daily temperatures were reviewed at representative locations to determine existing exceedance frequencies for instream temperatures.

The SacEFT model, described in the *Egg/Alevin* section under *Salmonids*, was used to investigate Sacramento River temperature exceedances for temperature tolerances of green sturgeon eggs under the different preliminary proposal scenarios. For green sturgeon, the model was applied to Sacramento River reaches downstream of Red Bluff during spawning periods and used 63°F (17°C) for a preferred upper temperature threshold and 68°F (20°C) as a maximum threshold. Cech and

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

coauthors (2000) reported that temperatures above 68°F are lethal to embryos. Temperatures exceeding 68°F in the model scenarios were considered lethal to green sturgeon eggs.

C.4.2.2.2 Larvae

Water Temperature

A literature review of larval temperature requirements/thresholds indicates that they are the same as those described previously for eggs/embryos (Israel et al. 2009). Therefore, the analysis for white sturgeon larvae was conducted in the same manner as that described for eggs and embryos in upriver habitats.

Green sturgeon larvae can tolerate water temperatures ranging from 52°F–73°F (11°C–23°C) (Israel et al. 2009). However, Van Eenennaam et al. (2005) concluded that temperatures above 68°F (20°C) are probably detrimental to green sturgeon reproduction. While green sturgeon may survive incubation at the limits of their temperature optimum, reproductive success and young-of-year recruitment are presumably negatively impacted when larvae are exposed to temperatures of 66°F (19°C) or above (Van Eenennaam et al. 2005). Therefore, to remain conservative, the upper thresholds for larval survival by water-year type were analyzed using the SRWQM at 66°F, 68°F, and 73°F. Water temperatures in the Feather River at Honcut Creek and the confluence with the Sacramento River using Reclamation Temperature Model outputs were also evaluated by water year for exceeding the 66°F, 68°F, and 73°F. The period of larval occurrence evaluated for green sturgeon is modified from Israel and Klimley 2008 based on a shortened larval life stage, such that the larval stage is present from April through October.

Although most white sturgeon spawning occurs in the Sacramento River (Kohlhorst et al. 1991), a literature review determined that additional spawning habitat suitability and, therefore, larval rearing locations occur in the Feather and San Joaquin Rivers (e.g., Stevens and Miller 1970; Miller 1972; Kohlhorst 1976; Kohlhorst et al. 1991). Larval rearing habitats for green sturgeon occur downstream of the China Rapids and Iron Canyon spawning habitats (Israel and Klimley 2008). For upper Sacramento River spawning of both sturgeon species, water temperatures were analyzed at RBDD and Hamilton City using the SRWQM. For white sturgeon spawning in the Sacramento River at the confluence with the Feather River, in the Feather River at Honcut Creek, and at the San Joaquin River confluence with the Stanislaus River, water temperatures were investigated using the Reclamation Temperature Model. Temperature exceedance plots and tables were used to evaluate seasonal water temperature distributions by water-year type at all the spawning analysis locations.

C.4.2.2.3 Juvenile

Because juvenile sturgeon are classified in this analysis as those migrating downstream, the flow analysis for juveniles is described in Section C.5.3.

Water Temperature

Effects on juvenile white sturgeon that rear in the lower rivers were evaluated similarly to those on larvae in the late spring in the Sacramento, Feather, and San Joaquin basins. However, because juvenile white sturgeon are observed year-round in the more downstream habitats, year-round exceedance plots for the Feather–Sacramento River confluence and the confluence of the Stanislaus River and San Joaquin River were analyzed. Young-of-the-year (YOY) juvenile green sturgeon occur in the middle to lower Sacramento River from August to March (Israel and Klimley 2008). Therefore,

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

for green sturgeon, water temperatures were analyzed at the Hamilton City and Wilkins Slough locations using the SRWQM and at the Feather River confluence with the Sacramento River using the Reclamation Temperature Model.

Although juvenile white sturgeon are tolerant of warm water temperatures, Cech and coauthors (1984) and Geist and coauthors (2005) found that juvenile white sturgeon begin showing signs of stress when water temperatures reach 20°C (68°F), and Israel and coauthors (2009) suggested that 25°C (77°F) is considered the upper tolerance level. However, some decrease in habitat suitability was assumed to occur between 20°C and 25°C. Optimal juvenile green sturgeon temperatures range from 59°F to 66°F (15°C–19°C), and 81°F (<27°C) is considered lethal (Israel and Klimley 2008). NMFS (74 Federal Register [FR] 52300) indicated an upper temperature threshold of 75°F (24°C). While green sturgeon juveniles may survive for short periods at the limits of their maximum temperature thresholds, optimal rearing temperatures would maximize survival. Therefore, upper temperature threshold values for juvenile survival and optimal rearing were analyzed using the SRWQM at 66°F, 75°F, and 81°F.

C.4.2.2.4 Adult

Water Temperature

White sturgeon spawning occurs during February through May (Kohlhorst 1976); however, prespawn and postspawn adults occur near spawning areas from winter through late spring, so exceedance plots for January through May by water-year type also were investigated. Green sturgeon spawning occurs during March through July (Adams et al. 2007; Mora et al. 2009). Although adult white sturgeon begin to show signs of stress at temperatures above 68°F (20°C) (Cech et al. 1984; Geist et al. 2005), Israel and coauthors (2009) considered temperatures above 77°F (25°C) an upper threshold for prespawn, spawning, and postspawn adults. For green sturgeon, in the absence of adult temperature threshold criteria identified in Israel and Klimley (2008) and based on studies of temperature effects on oxygen uptake and lethal temperature limits (Kaufman et al. 2006; Erickson et al. 2002; Heublein et al. 2009), 52°F was used as the lower threshold, and 75°F and 81°F were used as upper thresholds for adult survival.

The SRWQM was used to investigate the frequency of exceedance of temperature thresholds for adult sturgeon in the Sacramento River spawning reaches. In addition, temperatures were investigated in the Feather River just below Thermalito Afterbay, at Gridley and Honcut Creek.

Spawning Habitat

Gard (1996) developed a suitability index for Sacramento white sturgeon spawning habitat that indicated that white sturgeon are limited to spawning in deep, fast areas with large substrates. This index identified waters with velocities of 3.9–19.95 feet per second (ft/s) as suitable, with velocities of 5–12.5 ft/s as ideal. Further, water depths greater than 6 feet were suitable, while those greater than 10 feet were ideal; habitats with snags and gravel were considered suitable, while those that included cobble, boulder, and bedrock were ideal. The effects analysis did not develop a habitat suitability index (HSI) for white sturgeon spawning habitat specifically but reviewed the habitat factors independently to determine whether and how they would be altered by preliminary proposal operations.

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

There are no weighted usable area curves available for green sturgeon spawning habitat, and because of differences in spawning habitat preferences, white sturgeon cannot be used as a suitability index surrogate.

Seasonal Flows

White sturgeon studies abroad have indicated that only 1–3% of fingerlings released from captive rearing survived to adulthood (Marti 1979, as cited in Moberg and Doroshov 1992). Although to a local population one adult fish has greater reproductive value than one embryo, habitat-scale effects would not affect a single individual alone, but have the potential to affect multiple individuals within and between year classes and age classes. As a result, the potential effects of future changes in flow were also analyzed for each sturgeon life stage. This approach allows the analysis to determine which, if any, age classes potentially would be affected by possible preliminary proposal–related changes to a given habitat parameter, such as flow.

April and May are indentified by Israel and coauthors (2009) as peak periods for white sturgeon eggs and embryos in Bay-Delta rivers. However, as prespawn adults occur throughout the winter and there may be some potential early spawning, the analytical period was expanded to include February and March. As a result, CALSIM was used to investigate potential changes in flows from February to May in suitable white sturgeon spawning reaches. In the Sacramento River these locations included Verona and Wilkins Slough (surrogate for Grimes); for the Feather River the confluence with the Sacramento River and at Thermalito were investigated; for the San Joaquin River the flows at Vernalis were investigated.

As sturgeon recruitment is correlated to flow (Kohlhorst et al. 1991; Beamesderfer and Farr 1997; Fish 2010), the most successful spawning generally occurs in wet and above-normal water years (Israel et al. 2009). As a result, the analysis of the potential flow changes from the preliminary proposal on white sturgeon eggs and embryos is weighted toward these wet and above-normal years in habitats believed to be used by these life stages (although high spring flow conditions commonly occurred in drier year types prior to the construction and operation of major Central Valley dams). However, reviews of CALSIM exceedance plots and average monthly flows for all water-year types were included in this investigation to determine whether there were anticipated changes related to the preliminary proposal or climate change under suboptimal water years. White sturgeon spawning is much more common in the Sacramento River system, although the San Joaquin River appears to support white sturgeon reproduction and, therefore, is included in this analysis. Therefore, exceedance plots were used as a tool to investigate at these locations at what probabilities differentiation between modeled scenarios occurs.

Gard (1996) developed a suitability index for Sacramento River white sturgeon spawning habitat. Velocity was one of the parameters of this index, and velocities of 3.9–19.95 ft/s were identified as suitable, and velocities of 5–12.5 ft/s as ideal. Parsley et al. (1993) found that white sturgeon spawning and egg incubation in the Columbia River occurred in the swiftest available waters (mean water column velocity 0.8–2.8 meters per second (m/s) [2.6–9.2 ft/s]). However, in order to convert the flow data from CALSIM to velocity, channel contour descriptions for each appropriate CALSIM node, including depth and width for each flow level, were required. These parameters were not available to convert modeled flow results to velocity. Therefore, CALSIM flow outputs, rather than velocity, were investigated to determine preliminary proposal–related flow effects on habitats used by sturgeon. Although regionally comprehensive, the CALSIM model does not include nodes at every location throughout the Bay-Delta. As a result, where literature may indicate suitable habitat

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

conditions at a specific location, a surrogate location was needed to relate this to available nodes modeled in CALSIM.

C.4.2.3 Lamprey

For the purposes of this effects analysis, the following assumptions were made based on existing literature and communication with experts regarding the spatial and temporal patterns of the life stages of Pacific and river lamprey.

- Adults spawn in the upper Sacramento, Trinity, Feather, American, and Stanislaus Rivers during the months of January through August (Pacific lamprey) or February through June (river lamprey), although there is temporal variation among locations (Beamish 1980; Moyle 2002; Hannon and Deason 2007; Streif 2007; Luzier et al. 2009).
- Eggs for both species incubate for 18–49 days, depending on water temperature (Brumo 2006) during roughly the same period and in the same locations as the adults spawn.
- Ammocoetes rear in approximately the same locations for 5–7 years (Pacific lamprey) or 3–5 years (river lamprey), although in more silty backwaters than redd locations (Moyle 2002).
- After 5–7 years (Pacific lamprey) or 3–5 years (river lamprey), ammocoetes migrate downstream but do not yet feed parasitically. Migration generally is associated with large flow pulses in winter months (December through March) (U.S. Fish and Wildlife Service unpublished data).
- Both species become macropthalmia once they reach the Delta, where they may reside for a very short period. Macropthalmia do not feed parasitically in the Delta but, once the esophagus is fully formed, will move into the ocean to feed. The marine phase for Pacific lamprey lasts up to 3–4 years, while that for river lamprey lasts only 3–4 months (Moyle 2002).
- Adults migrate upstream to spawn between January and June (Pacific lamprey) or between October and November (river lamprey) and usually die shortly afterward (Moyle 2002).

C.4.2.3.1 Egg/Embryo

Water Temperature

Water temperature results from the SRWQM and the Reclamation Temperature Model were used to assess the exceedances of water temperatures under all model scenarios in the upper Sacramento, Trinity, Feather, American, and Stanislaus Rivers. These temperature models are described above in the *Egg/Alevin* section under *Salmonids*. Pacific lamprey were observed to spawn in the American River between January and May with a peak in April (Hannon and Deason 2007). Streif (2007) and Luzier and coauthors (2009) indicate that spawning occurs during March through July, but this is likely for more northern populations of Pacific lamprey. To be inclusive, the analysis examined the period of January through August. Because Pacific lamprey eggs hatch in 18–49 days, depending on water temperature (Brumo 2006), eggs are assumed to be present during roughly the same period. River lamprey generally spawn between February and June (Beamish 1980; Moyle 2002), and the range for egg incubation period is assumed to be the same as that for Pacific lamprey (18–49 days).

Significant reduction in survival of eggs and embryos of Pacific lamprey has been observed at 22°C (71.6°F) (Meeuwig et al. 2005). For river lamprey, Moyle and coauthors (1995) indicate that "adults need… temperatures [that] do not exceed 25°C," although there is no mention of thermal

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

requirements for eggs in this or any existing literature. Therefore, both 22°C (71.6°F) and 25°C (77°F) were used in the analysis as upper thresholds of river lamprey eggs.

For Pacific lamprey, the effects analysis for the Sacramento River calculated the number of consecutive 49-day periods (the maximum estimate for length of incubation) for the entire 82-year CALSIM period during which at least one day exceeds 22°C (71.6°F), which was predicted using daily data from SRWQM. For other rivers, the number of consecutive 2-month periods during which at least one month exceeds 22°C (71.6°F) was predicted using monthly averaged data from the Reclamation Temperature Model. For river lamprey, both 22°C (71.6°F) and 25°C (77°F) temperature criteria were used. Each individual day or month starts a new "egg cohort," such that, for Pacific lamprey, there are 19,928 to 19,929 cohorts for the Sacramento River, corresponding to 82 years of eggs being laid every day each year from January 1 through August 31, and 643 to 648 cohorts for the other rivers using monthly data over the same period. For river lamprey, which spawn from February 1 through June 30, there are 12,320 egg cohorts for the Sacramento River and 403 to 405 cohorts for the other rivers. As noted above, the incubation periods used in this analysis represent the extreme long end of the egg incubation period and are therefore conservative (Brumo 2006). Also, the utility of the monthly average time step is limited because the extreme temperatures are masked; however, no better analytical tools are currently available for this analysis.

Exact spawning locations of both lamprey species are not well defined. Therefore the analysis is shaped in the following ways:

- For the Sacramento River, this analysis included the farthest upstream (Sacramento River below Keswick) and farthest downstream (Sacramento River at Hamilton City) in the SRWQM output to provide the widest range of temperature conditions for lamprey eggs and embryos.
- For the Feather River, this analysis included the farthest upstream (Fish Barrier Dam) and downstream (below Thermalito Afterbay) locations in which lamprey are thought to spawn (Kurth pers. comm.).
- For the American River, this analysis included the farthest upstream (Nimbus Dam) and downstream (confluence with the Sacramento River) locations in which lamprey are thought to spawn (Hannon pers. comm.).
- For the Stanislaus River, this analysis includes farthest upstream (Knights Ferry) and downstream (Riverbank) locations in which lamprey are thought to spawn (Hannon pers. comm.).
- For the Trinity River, this analysis includes upstream (Lewiston) and downstream (North Fork) locations that encompass the spatial range of the Reclamation Temperature Model in the Trinity River.

Redd Dewatering

Because of limited information on spawning locations and timing in the rivers in the Sacramento and San Joaquin watersheds, it was assumed that a month-over-month reduction in flow rate using CALSIM II output of >50% during the period of redd preference would constitute an adverse effect that would mimic dewatering of lamprey redds. Although there is no information available to determine whether this value is suitable, it was applied to all model scenarios equally as a surrogate for flow reductions in the rivers. As such, there is high uncertainty that these values represent actual redd dewatering events, and results should be treated as rough estimates of flow fluctuations under

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

each model scenario. The analysis was conducted assuming a presence of Pacific lamprey redds during January through August and river lamprey redds from February through June.

Locations for each river used in this analysis were based on available literature, personal conversations with agency experts, and spatial limitations of the CALSIM II model as follows.

- Sacramento River: Keswick and Red Bluff
- Feather River: Thermalito
- American River: Nimbus and at the confluence with the Sacramento River
- Stanislaus River: at the confluence with San Joaquin River
- Trinity River: downstream of Lewiston

For this analysis, the number of months in which flows decreased by at least 50% from the previous month was calculated for each model scenario in all rivers and locations where lamprey are thought to spawn. Small-scale spawning location suitability characteristics (e.g., depth, velocity, substrate) of Pacific or river lamprey are not adequately described to employ a more formal analysis such as a weighted usable area analysis. Therefore, the change in month-over-month flows is used as a surrogate for a more formal analysis, and a month-over-month flow reduction of 50% was chosen as a best professional estimate of flow conditions in which redd dewatering is expected to occur, but does not estimate empirically derived redd dewatering events.

C.4.2.3.2 Ammocoete

Water Temperature

Water temperatures above 22°C (71.6°F) may cause significant levels of death (~50%) or deformation of Pacific lamprey eggs and ammocoetes (Meeuwig et al. 2005). Therefore, the predicted number of Pacific lamprey ammocoete cohorts were examined that experience water temperatures greater than 71.6°F for at least 1 day in the Sacramento River (because daily water temperature data are available) or for at least 1 month in the Feather, American, Stanislaus, and Trinity Rivers over a 7-year period, the maximum likely duration of the ammocoete life stage (Moyle 2002). Each individual day or month starts a new cohort such that there are 18,244 cohorts for the Sacramento River, corresponding to 82 years of ammocoetes being "born" every day each year from January 1 through August 31, and 593 cohorts for the other rivers using monthly data over the same period.

Because the thermal tolerance of river lamprey ammocoetes is unknown, the thermal tolerance of Pacific lamprey ammocoetes of 22°C (71.6°F) and of river lamprey adults of 25°C (77°F) (Moyle et al. 1995) was used. In addition, unlike Pacific lamprey ammocoetes that rear upstream for 5–7 years, river lamprey ammocoetes rear upstream for 3–5 years (Moyle 2002). To be conservative, this analysis assumes a maximum ammocoete duration of 5 years.

The same locations in these rivers as described for redds were used for this analysis because ammocoetes are generally close to redd locations, although in more silty backwaters. The utility of the monthly average time step is limited because the extreme temperatures are masked; however, no better analytical tools are currently available for this analysis.

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

Stranding

Because ammocoetes are relatively immobile in the sediments for 5–7 years (Pacific lamprey) or 3–5 years (river lamprey), there is the potential for stranding events to occur as a result of rapid fluctuations in flows. The analysis of ammocoete stranding was conducted by analyzing a range of month-over-month flow reductions in the Sacramento, Trinity, Feather, American, and Stanislaus Rivers. Predicted flows from CALSIM II were used as inputs for the analysis. The range of flow reductions was 50–90% (in 5% increments) and included the range in which model scenarios were distinguishable and indistinguishable from one another. A cohort of ammocoetes was assumed to be born every month during their spawning period (January through August for Pacific lamprey, February through June for river lamprey) and spend 7 years (Pacific lamprey) or 5 years (river lamprey) rearing upstream. Therefore, a cohort was considered stranded if at least one month-over-month flow reduction was greater than the flow reduction at any time during the period.

There is no information available to determine whether this range is suitable as a surrogate of stranding and, therefore, there is high uncertainty regarding whether it includes the range of a sizable stranding event. Results should be treated as rough estimates of flow fluctuations under each model scenario that lead to dewatering of previously wetted areas, resulting in stranding of Pacific lamprey ammocoetes.

CALSIM II nodes used in the analysis as approximate ammocoete locations were the same as those identified in Section C.5.2.3.1, *Redd Dewatering*.

C.4.3 Passage, Movement, and Migration Methods

C.4.3.1 Migration of Adult Anadromous Covered Fish Species

C.4.3.1.1 Attraction and Upstream Migration Flows

The preliminary proposal may change flow magnitude in various tributaries with SWP/CVP reservoirs and the relative proportions of water reaching the Delta that originates from the Sacramento or San Joaquin River watersheds, with the potential effect of reducing attraction of upstream migrating adult anadromous fishes that may be cueing on scent from the natal river and sources along the way (Williams 2006).

Water-Source Fingerprinting (DSM2-QUAL)

Upstream migrating adult salmonids may home to natal spawning grounds based on cues such as odor (Williams 2006). A recent study indicates that Pacific lamprey adults do not exhibit specific homing behavior to exact spawning locations when passing upstream to spawn (Hatch and Whiteaker 2009). However, lamprey still may be attracted to natal spawning grounds through chemical attraction in water originating from rivers in which ammocoetes are present, as has been hypothesized for sea lamprey (Li et al. 1995), although this has not been confirmed *in situ* (Luzier et al. 2009). If true, a major decision that must be made by returning lamprey adults at the confluence of the Sacramento and San Joaquin Rivers is whether to enter the San Joaquin or Sacramento watershed. Water source–fingerprinting output from DSM2-QUAL was used to assess the relative contribution of water from the Sacramento and San Joaquin Rivers near their confluence for each model scenario. This analysis was conducted for adult steelhead, winter-run Chinook salmon, spring-run Chinook salmon, fall-run Chinook salmon, late fall–run Chinook salmon, Pacific lamprey, and river lamprey during assumed upstream spawning migration periods.

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

Flow Assessment (CALSIM)

Potential changes in the magnitude of attraction and upstream migration flows were based on CALSIM results using a frequency of exceedance analysis, by month and water-year type, and a monthly summary by water-year type over the 82-year period of hydrologic simulation. This was conducted for flows on the mainstem Sacramento River, San Joaquin River, and the major tributaries in the study area based on the assumed occurrence of the species (See Appendix 2.A, *Species Accounts*). The potential effect on migrating anadromous adult covered fish species of estimated changes in attraction flows from the study area watersheds was assessed on the basis of the percentage changes in flows.

In addition to fingerprinting analyses described above, effects of the preliminary proposal on adult salmonid immigration was determined by comparing CALSIM monthly flows among model scenarios in the Sacramento River at Rio Vista during the migration period of each race of Chinook salmon and steelhead.

Upstream adult white sturgeon movements to spawn are triggered by photoperiod, increases in river flow, and preferred temperature range (Israel et al. 2009). Kohlhorst et al. (1991) and Schaffter (1997) concluded that elevated flows provide cues stimulating upstream prespawn adult migration. In addition to providing cues, higher flows increase the ability to pass any migrational barriers to spawning habitat. Flows throughout the Bay-Delta region, including the reduction of seasonal peak flows, have been affected by a number of factors, including dams and diversions (Israel et al. 2009). The reduction of both peak and elevated seasonal flows reduces the migrational cues available for prespawn adult sturgeon. Schaffter (1997) identified a potential threshold of 5,300 cfs (150 cubic meters per second [m^3/s]) in the Sacramento River at Colusa (Wilkins Slough used as a surrogate for this analysis) as a potential flow threshold. To investigate the potential flow-related effects of the project on sturgeon, CALSIM flow outputs of seasonal attraction flows were analyzed to detect differences in flow rates during the attraction (November through May) and upstream migration (mid-February and late May) periods in the Sacramento River in and below known spawning grounds (between Knights Landing and several kilometers upstream of Colusa). In addition, the Israel and coauthors (2009) review of late-winter, early-spring flows upstream of Verona indicated that flows that attracted adult sturgeon and resulted in successful spawning events ranged from 6,356 cfs (180 m^3/s) and 12,360 cfs (350 m^3/s). Therefore, a CALSIM review of when these conditions would occur during February through May under the modeled scenarios also was completed. As DFG (2002) creel surveys indicate that white sturgeon may be using portions of the San Joaquin system for spawning, attraction flows also were investigated at Vernalis during this same period.

Israel and Klimley (2008) identified February through July as peak periods of occurrence in the Bay-Delta for green sturgeon prespawn adults. However, as green sturgeon tagging studies indicate that prespawning upstream movement of reproductively mature adults occurs during the winter and spring months (Emmett et al. 1991; Beamesderfer and Webb 2002; Lindley et al. 2008; Heublein et al. 2009), to detect whether there were any changes in flows that may attract these prespawn adults into the estuary, the analysis also investigated flows during November through January. Upstream movements to spawn apparently are triggered by photoperiod, increases in river flow, and preferred temperature range (Israel and Klimley 2008). Higher flows provide the necessary migration cues and increase the ability to pass any impediments to spawning habitat. As a result, the analysis of potential effects on adult green sturgeon attraction flows investigates potential changes in November through July flows for each water-year type in the Sacramento River at Keswick,

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

Verona, and downstream at Rio Vista and in the Feather River at Thermalito and the confluence with the Sacramento River.

In addition to the fingerprinting analysis described above for lampreys, seasonal flows farther upstream in the watersheds were used to evaluate the effects of the preliminary proposal on relative contribution to flows of tributaries upstream of the Delta. No fingerprinting tools are available for this analysis, although an evaluation of flow rates from CALSIM outputs along the likely migration pathways of Pacific lamprey provides estimates of how the preliminary proposal would affect adult attraction flows. Five locations were chosen at which to evaluate flow rates during January through June (Moyle 2002): Sacramento River upstream of Red Bluff, Feather River at the confluence, the American River at the confluence, San Joaquin River at Vernalis, and Stanislaus at the confluence. Higher flows during this period are assumed to provide better attraction flows. The effects of preliminary proposal water operations on attraction flows for river lamprey adults were assessed using the same methods as the analysis of effects on Pacific lamprey, although migration timing differed between species. Although river lamprey adult migration timing in California is unknown, adults migrate upstream in the Columbia River watershed during fall months (Moyle 2002). Therefore, this analysis assumed this migration period of September through November for river lamprey in the Delta.

C.4.3.1.2 Passage Impediments

Fremont Weir Adult Passage (Conservation Measure 2 Yolo Bypass Fisheries Enhancements)

The main passage impediment for adult steelhead and Chinook salmon in the Sacramento River, downstream of the Shasta/Keswick Dam complex, is the Fremont Weir when the Yolo Bypass is flooded but water is no longer spilling over the weir. *CM2 Yolo Bypass Fisheries Enhancements* proposes a notch in the Fremont Weir to allow diversions from the Sacramento River at lower flows (more frequent inundation) and the construction of effective adult ladders or ramps at the Sacramento and Fremont Weirs (improved passage). Upstream adult migrating anadromous fish that may be affected by CM2 include steelhead, Chinook salmon, white and green sturgeon, and Pacific and river lamprey. Relative to existing biological conditions, the main potential effects of CM2 on upstream adult migrating anadromous fish are as follows:

- Improved passage at Fremont Weir through installation of improved fish ladders or ramps at new notch and longer inundation period.
- Increased attraction into the Yolo Bypass as more Sacramento River flow is diverted through the new notch, which can improve survival as long as passage past Fremont Weir is improved.

Records of Fish Rescued at Fremont Weir

Existing records of fish rescued at Fremont Weir were assembled from reports by DFG (undated) and Healey and Vincik (2011) in order to provide context for the number of fish stranded at Fremont Weir under existing biological conditions that may benefit from improved passage.

DRERIP Evaluation of Fremont Weir and Yolo Bypass Inundation

The 2009 Delta Regional Ecosystem Restoration Implementation Plan (DRERIP) evaluation of Fremont Weir and Yolo Bypass inundation (previously referred to as Water Operations Conservation Measure 2) was used to assess the potential positive and negative outcomes from changing fish passage at Fremont Weir. As with all DRERIP evaluations, the outcomes were rated on

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

a scale of 1–4 for magnitude of the effect on the population and certainty of the outcome (4 being the greatest effect on the population or highest certainty).

Low Dissolved Oxygen (Conservation Measure 14 Stockton Deep Water Ship Channel Dissolved Oxygen Levels)

The main passage impediment for adults in the lower San Joaquin River is the result of depressed DO concentrations in the Stockton Deep Water Ship Channel. The preliminary proposal includes a conservation measure (CM14) designed to ensure that sufficient DO concentrations are maintained in the lower San Joaquin River to provide adequate water quality conditions to allow adult anadromous fish the ability to migrate freely through the area to upstream spawning habitat. This is achieved with an oxygen diffuser. Recent results from a DWR oxygen diffuser demonstration project in the Stockton Deep Water Ship Channel were used to assess the effectiveness of the conservation measure (California Department of Water Resources 2010; Herr 2010).

Nonphysical Fish Barriers (Conservation Measure 16)

Nonphysical fish barriers proposed for various locations in the Delta (e.g., head of Old River and Georgiana Slough–Sacramento River divergence) under CM16 to deter juvenile salmonids from entering the interior Delta have the potential to impede passage of adult anadromous fish that are moving upstream through locations. A qualitative analysis of the potential impeding effects of such barriers was conducted that evaluated the relative position of the barriers in relation to species' position in the water column and the hearing ability of the species in relation to the acoustic deterrent provided by the barriers.

Suisun Marsh Salinity Control Structure Modifications

An analysis of modifications to the Suisun Marsh Salinity Control Gates (SMSCG) and their effects on upstream migrating adult anadromous fish was conducted using best professional judgment.

C.4.3.1.3 Downstream Kelt Migration (Steelhead)

In a manner similar to that described above for attraction and upstream migration flows, CALSIM flow outputs were assessed for differences between preliminary proposal and existing biological conditions during the kelt migration period in the various tributaries in which steelhead are known to occur.

C.4.3.2 Downstream Migration of Juvenile Anadromous Covered Fish Species

C.4.3.2.1 Flow Assessment (CALSIM)

To assess flow effects on migration survival for juvenile anadromous fish species, monthly flows by water-year type over the 82-year hydrologic period, based on results of CALSIM II modeling during the downstream migration periods, were compiled and compared between existing biological conditions and preliminary proposal scenarios. Frequency-of-exceedance analyses were used, by month and water-year type, to characterize instream flows during migration for each river system at the CALSIM locations, and months used for the flow summaries are detailed in Table C.4-3. Higher flows generally are assumed to result in increased survival for juvenile anadromous covered fish species. Many studies have found a positive relationship between juvenile Chinook salmon

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

migration rate and flow in the Columbia River Basin (Raymond 1968; Berggren and Filardo 1993; Scheck et al. 1994). As migration speed increases, survival is also thought to increase, due primarily to decreased cumulative predation losses. For example, the findings of Kjelson and Brandes (1989) and Williams and Mathews (1995) both show a logarithmic survival-flow relationship for juvenile Chinook salmon outmigrants. Newman (2003) and Newman and Rice (2002) also used a logarithmic relationship between smolt survival and flow for Chinook salmon smolts migrating through the Delta. Flow-survival relationships are discussed further in the description of the Delta Passage Model (DPM). Seasonal inundation of the Yolo Bypass has the potential to benefit juvenile salmonids by providing an alternative migration route around the Delta while also providing productive rearing habitat. However, flows entering the Yolo Bypass also mean reduced flows through the Sacramento River downstream to the confluence between Cache Slough and the Sacramento River. The effects of these tradeoffs for Chinook salmon smolts were captured using the DPM. For juvenile steelhead, results of CALSIM II modeling to assess daily average flows passing into the Yolo Bypass and corresponding flows in the mainstem Sacramento River at Freeport were assessed and compared under existing biological conditions and the preliminary proposal operations.

Downstream migration of larval white sturgeon is assisted by higher flows, although it is unclear whether elevated flows may increase recruitment to less suitable rearing habitat (Israel et al. 2009). Fish (2010) found that the five highest year class indices for white sturgeon occurred during the five highest spring outflows at Chipps Island. However, the CALSIM model for analyzing preliminary proposal–related effects did not include a CALSIM node at Chipps Island, and although tightly correlated, expressed gaps in the outflow regime that make it difficult to specify necessary spring outflow for white sturgeon recruitment. As a result, this analysis relied on the 1995 USFWS Anadromous Fish Restoration Program (AFRP) Plan, indicating that flows of 31,000 cfs at Verona and 17,700 cfs at Grimes (Wilkins Slough used as surrogate) from February to June are ideal for adult access, spawning habitat conditions, and downstream larval transport during wet and above-normal years, when sturgeon recruitment is greatest. Israel and coauthors (2009) indicated that spring flows are important for downstream migrating larval white sturgeon in the Sacramento River. February to May CALSIM flow outputs were reviewed at Verona and Wilkins Slough for all water-year types. In addition, an analysis was conducted for each model scenario to determine the percentage of months during wet and above-normal water years in which mean monthly Delta outflow exceeds 15,000 cfs, 20,000 cfs, and 25,000 cfs during April and May per AFRP guidance for green and white sturgeon (U.S. Fish and Wildlife Service 1995). The objective for this AFRP guidance was to increase sturgeon production by providing adequate Delta outflow in wet and above normal water years. The analysis also calculated average April–May outflow and analyzed the exceedance above these thresholds for each model scenario.

Potentially, migrating juvenile white sturgeon benefit from increased river flows for downstream migration rates and increased passage around low-flow barriers. Because the investigation of preliminary proposal–related effects on flows with respect to larval occurrence previously reviewed changes to February through May flows (as described above), the investigation of flow effects on juveniles included June through October flows. An investigation of CALSIM flows during these months for each water-year type was completed to estimate what flow changes the juvenile life stage may encounter in the rivers immediately prior to their year-round occurrence in the bays and Delta.

Admin. Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

Table C.4-3. CALSIM Locations Used to Assess Changes in Flows during Downstream Migration of Juvenile Anadromous Covered Fish Species

	Sacramento River (RM 194 to Keswick)		Sacramento River (North Delta to RM 143)			West Delta	North Delta		North Delta	South Delta	South Delta	West Delta	Feather River						South Delta
Species	**Keswick**	**Red Bluff Diversion Dam**	**Wilkins Slough**	**Verona**	**Yolo Bypass**	**Rio Vista**	**Freeport**	**Sutter/Steamboat Sloughs**	**Georgiana Slough/ Delta Cross Channel**	**Old and Middle Rivers**	**SWP/CVP Exports**	**Delta Outflows**	**Feather River at Thermalito**	**Feather River at Sacramento River Confluence**	**American River at Sacramento River Confluence**	**Clear Creek**	**Trinity River**	**Stanislaus River at Confluence**	**San Joaquin River at Vernalis**
Steelhead		Oct–May			Oct–May	Oct–May	Oct–May	Oct–May	Oct–May	Oct–May		Oct–May		Oct–May	Oct–May	Oct–May	Oct–May	Oct–May	Oct–May
Winter-run Chinook salmon		Nov–Apr				Nov–Apr		Nov–Apr	Nov–Apr	Nov–Apr	Nov–Apr	Nov–Apr							
Spring-run Chinook salmon		Dec–May				Dec–May		Nov–Apr	Nov–Apr	Nov–Apr	Nov–Apr	Nov–Apr		Oct–May		Oct–May	Feb–Oct		Dec–May
Fall-/late fall–run Chinook salmon		Nov–Apr				Nov–Apr		Nov–Apr	Nov–Apr	Nov–Apr	Nov–Apr	Nov–Apr		Feb–May	Feb–May	Feb–May	Feb–May	Feb–May	Feb–May
White sturgeon			Feb–May (Larva)	Feb–May (Larva); Jun–Sep (Juvenile)								Feb–May							
Green sturgeon	Apr–Oct (Larva)	Apr–Oct (Larva)	Apr–Oct (Larva); Aug–Jun (Juvenile)	Apr–Oct (Larva); Aug–Jun (Juvenile)									Apr–Oct (Larva)	Apr–Oct (Larva)					
Pacific lamprey		Dec–May		Dec–May										Dec–May	Dec–May			Dec–May	Dec–May
River lamprey		Dec–May		Dec–May										Dec–May	Dec–May			Dec–May	Dec–May

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

Flow relationships have been examined for white sturgeon (Kohlhorst et al. 1991) but not for green sturgeon (Israel and Klimley 2008). Because of different seasonal occurrences of the two species, flow thresholds for white sturgeon would not apply to green sturgeon. Endogenously feeding green sturgeon larvae migrate downstream during April through October in the upper and middle rivers (Israel and Klimley 2008). The flow analysis of preliminary proposal effects on green sturgeon larvae occurring in the upper Sacramento and Feather Rivers during April through July was similar to that provided for eggs and embryos developing in this habitat. As a result, the larval analysis section addresses periods of larval occurrence in those portions of the river (September and October) not addressed previously for egg/embryo life stages (March through August). Further analysis was conducted to investigate the flows in the middle and lower Sacramento River during periods of downstream migrating YOY juvenile green sturgeon. CALSIM locations selected for the analysis of this portion of the Sacramento River included Wilkins Slough and Verona. Israel and Klimley (2008) indicate that the timing of this downstream migration, notably for YOY green sturgeon, is from August through March. As some larger juveniles may occur in this portion of the river in April, May, and June, an additional review was completed of this period. In the absence of flow-threshold criteria during this downstream migration, the analysis focuses on the percent change in flow during this period. Reduced flows during this period may result in biological effects on this life stage, including downstream migration delays. The analysis grouped months with considerable (more than 5%) increases or decreases in flow under the preliminary proposal scenarios compared to existing biological conditions and then investigated whether there were climate-related effects, or trends in water-year type, affecting these differences in flows. A separate review of April through June was conducted to determine potential effects on slightly older juveniles.

The effects of preliminary proposal water operations on seasonal migration flows for Pacific lamprey macropthalmia were assessed using CALSIM II flow output. Specifically, flow rates along the likely migration pathways of Pacific lamprey during the likely migration period (December through May) were examined to predict how the preliminary proposal may affect migration flows for outmigrating macropthalmia. It was assumed for this analysis that river lamprey macropthalmia migrate downstream at approximately the same time as Pacific lamprey macropthalmia.

C.4.3.2.2 Juvenile Chinook Salmon through-Delta Survival (Delta Passage Model)

Introduction

The DPM simulates migration of Chinook salmon smolts entering the Delta from the Sacramento River, Mokelumne River, and San Joaquin River and estimates survival to Chipps Island. The DPM uses available time-series data and values taken from empirical studies or other sources to parameterize model relationships and inform uncertainty, thereby using the greatest amount of data available to dynamically simulate responses of smolt survival to changes in water management. Although the DPM is based primarily on studies of winter-run Chinook salmon smolt surrogates (late fall–run Chinook salmon), it is applied here for winter-run, spring-run, and fall-run Chinook salmon by adjusting emigration timing and assuming that all migrating Chinook salmon smolts will respond similarly to Delta conditions. DPM results presented here should be considered preliminary due to being based on a still-evolving model.

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

Although studies have shown considerable variation in emigrant size, with Central Valley Chinook salmon migrating as fry, parr, or smolts (Brandes and McLain 2001; Williams 2001), the DPM relies predominantly on data from acoustic tagging studies of large (>100 mm) smolts, and therefore should be applied very cautiously to pre-smolt migrants. Salmon juveniles less than 80 mm are more likely to exhibit rearing behavior in the Delta (Moyle 2002) and thus likely will be represented poorly by the DPM. It has been assumed that the downstream emigration of fry, when spawning grounds are well upstream, is probably a dispersal mechanism that helps distribute fry among suitable rearing habitats. However, even when rearing habitat does not appear to be a limiting factor, downstream movement of fry still may be observed, suggesting that fry emigration is a viable alternative life-history strategy (Healy 1980; Healey and Jordan 1982; Miller et al. 2010). Unfortunately, survival data are lacking for small (fry-sized) juvenile emigrants because of the difficulty of tagging such small individuals. Therefore, the DPM should be viewed as a smolt survival model only, with the fate of pre-smolt emigrants not incorporated into model results.

The DPM has undergone substantial revisions based on comments received through the preliminary proposal anadromous team meetings and in particular through feedback received during a workshop held on August 24, 2010, and a 2-day workshop held June 23–24, 2011. The DPM is viewed as a simulation framework that can be changed as more data or new hypotheses regarding smolt migration and survival become available. The results presented in Section C.6 are based on these revisions.

Survival and abundance estimates generated by the DPM are not intended to predict future outcomes. Instead, the DPM provides a simulation tool that can compare the effects of different water management options on smolt migration survival, with accompanying estimates of uncertainty.

C.4.3.2.3 Model Overview

The DPM is based on a detailed accounting of migratory pathways and reach-specific mortality as Chinook salmon smolts travel through a simplified network of reaches and junctions (Figure C.4-2). The biological functionality of the DPM is based on the foundation provided by Perry and coauthors (2010) as well as other acoustic tagging–based studies (San Joaquin River Group Authority 2008, 2010; Holbrook et al. 2009) and coded wire tag (CWT)–based studies (Newman and Brandes 2010; Newman 2008). Uncertainty is explicitly modeled in the DPM by incorporating environmental stochasticity and estimation error whenever available.

The major model functions in the DPM are:

1. Delta Entry Timing, which models the temporal distribution of smolts entering the Delta for each race of Chinook salmon;
2. Fish Behavior at Junctions, which models fish movement as they approach river junctions;
3. Migration Speed, which models reach-specific smolt migration speed and travel time;
4. Reach-Specific Survival, which models reach-specific survival response to non-flow factors;
5. Flow-Dependent Survival, which models reach-specific survival response to flow;
6. Export-Dependent Survival, which models survival response to water export levels in the Interior Delta reach (see Table C.4-4 for reach description); and

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

7. North Delta Intake Predation, which models the mortality associated with predation at the proposed BDCP North Delta Intake water diversion for Sacramento River runs only.

Functional relationships are described in detail in the *Model Functions* section below.

Model Time Step

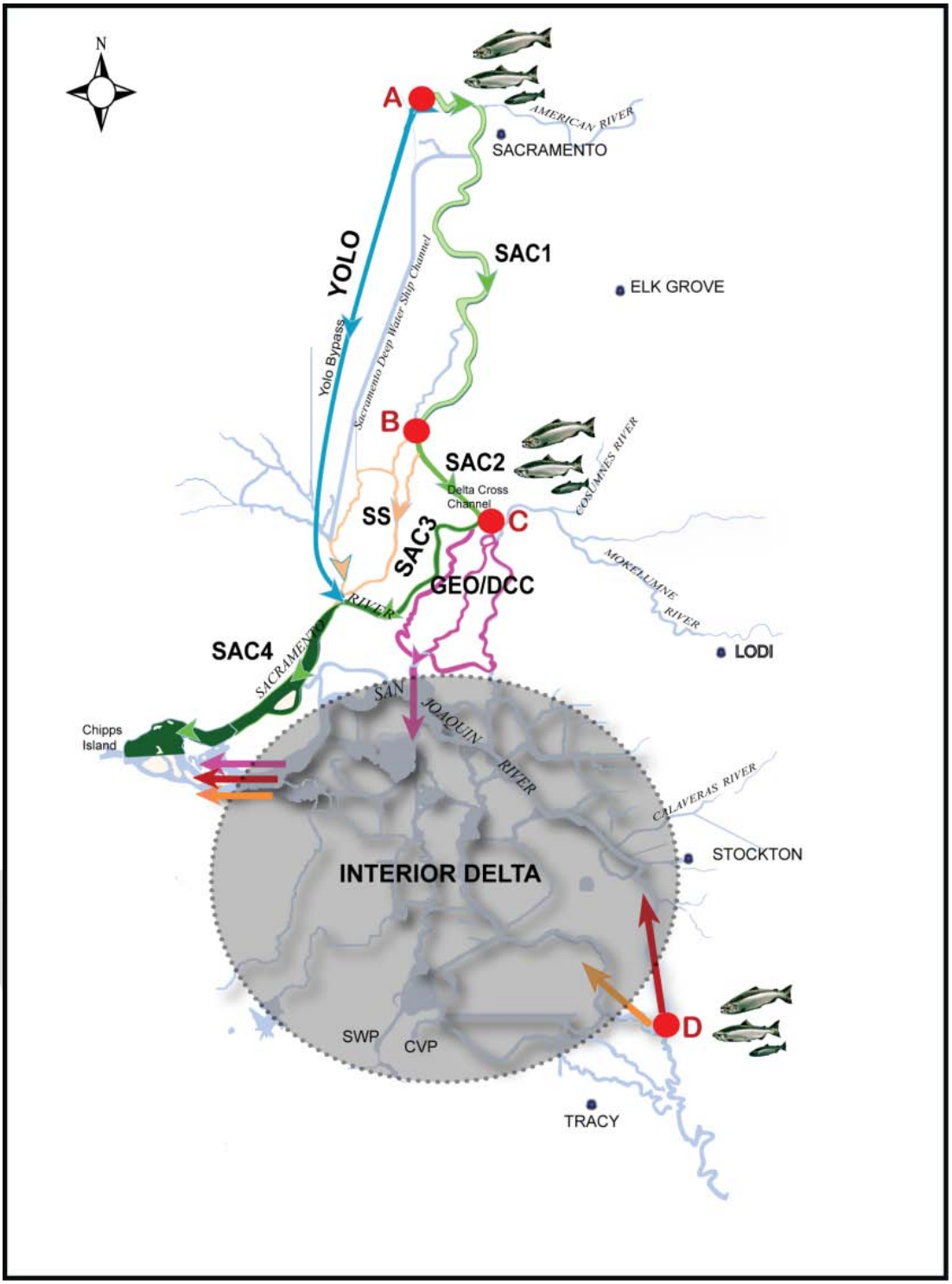
The DPM operates on a daily time step using simulated daily average flows and Delta exports as model inputs. The DPM does not attempt to represent sub-daily flows or diel salmon smolt behavior in response to the interaction of tides, flows, and specific channel features. The DPM is intended to represent the net outcome of migration and mortality occurring over days, not three-dimensional movements occurring over minutes or hours (e.g., Blake and Horn 2003).

Spatial Framework

The DPM is composed of eight reaches and four junctions (Figure C.4-2; Table C.4-4) selected to represent primary salmonid migration corridors where high quality data were available for fish and hydrodynamics. For simplification, Sutter Slough and Steamboat Slough are combined as the reach suspended sediment (SS), and the forks of the Mokelumne River and Georgiana Slough are combined as Geo/DCC. The Geo/DCC reach can be entered by Mokelumne River fall-run Chinook salmon at the head of the South and North Forks of the Mokelumne River or by Sacramento runs through the combined junction of Georgiana Slough and DCC (Junction C). The Interior Delta reach can be entered from three different pathways: Geo/DCC, San Joaquin River via Old River Junction (Junction D), and Old River via Junction D. Because of the lack of data informing specific routes through the Interior Delta, or tributary-specific survival, the entire Interior Delta region is treated as a single model reach. The four distributary junctions (channel splits) depicted in the DPM are Sacramento River at Fremont Weir (head of Yolo Bypass), Sacramento River at head of Sutter and Steamboat Sloughs, Sacramento River at the combined junction with Georgiana Slough and DCC, and San Joaquin River at the head of Old River (Figure C.4-2, Table C.4-4).

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.



Bold headings label modeled reaches, and red circles indicate model junctions. Salmonid icons indicate locations where smolts enter the Delta in the DPM. Smolts enter the Interior Delta from the Geo/DCC reach or from Junction D via Old River or San Joaquin River. Because of the lack of data informing specific routes through the Interior Delta, and tributary-specific survival, the entire Interior Delta region is treated as a single model reach.

Figure C.4-2. Map of the Sacramento–San Joaquin River Delta Showing the Modeled Reaches and Junctions of the Delta Applied in the Delta Passage Model

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

Table C.4-4. Description of Modeled Reaches and Junctions in the Delta Passage Model

Reach/ Junction	Description	Reach Length (km)
Sac1	Sacramento River from Freeport to junction with Sutter Slough	41.04
Sac2	Sacramento River from Sutter Slough junction to junction with Delta Cross Channel	10.78
Sac3	Sacramento River from Delta Cross Channel junction to Rio Vista, California	22.37
Sac4	Sacramento River from Rio Vista, California to Chipps Island	23.98
Yolo	Yolo Bypass from entrance at Fremont Weir to Rio Vista, California	NA[a]
SS	Combined reach of Sutter Slough and Steamboat Slough ending at Rio Vista, California	26.72
Geo/DCC	Combined reach of Georgiana Slough, Delta Cross Channel, and South and North Forks of the Mokelumne River ending at confluence with the San Joaquin River	25.59
Interior Delta	Begins at end of reach Geo/DCC, San Joaquin River via Junction D, or Old River via Junction D, and ends at Chipps Island	NA[b]
A	Junction of the Yolo Bypass and the Sacramento River	NA
B	Combined junction of Sutter Slough and Steamboat Slough with the Sacramento River	NA
C	Combined junction of the Delta Cross Channel and Georgiana Slough with the Sacramento River	NA
D	Junction of the Old River with the San Joaquin River	NA

[a] Reach length for Yolo Bypass is undefined because reach length currently is not used to calculate Yolo Bypass speed and ultimate travel time.
[b] Reach length for the Interior Delta is undefined because salmon can take multiple pathways. Also, timing through the Interior Delta does not affect Delta survival because there are no Delta reaches located downstream of the Interior Delta.

Flow Input Data

With the exception of flow into the SWP and CVP pumping plants, water movement though the Delta is modeled using daily (tidally averaged) flow output from the hydrology module of the Delta Simulation Model II (DSM2-HYDRO; <http://baydeltaoffice.water.ca.gov/modeling/deltamodeling/>). Export flow into the SWP and CVP pumping plants is modeled using monthly flow output from the hydrologic simulation tool CALSIM II (Ferreira 2005) that are "disaggregated" into mean daily flows based on historical patterns. The nodes in the DSM2-HYDRO and CALSIM II models that were used to provide flow for specific reaches in the DPM are shown in Table C.4-5. Technical details for DSM2-HYDRO and CALSIM II models are described elsewhere in this appendix. DSM2 flow data output for each of the six scenarios was used to inform the daily conditions experienced by migrating salmonids in the model.

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

Table C.4-5. Delta Passage Model Reaches and Associated Nodes from DSM2-HYDRO and CALSIM II Models

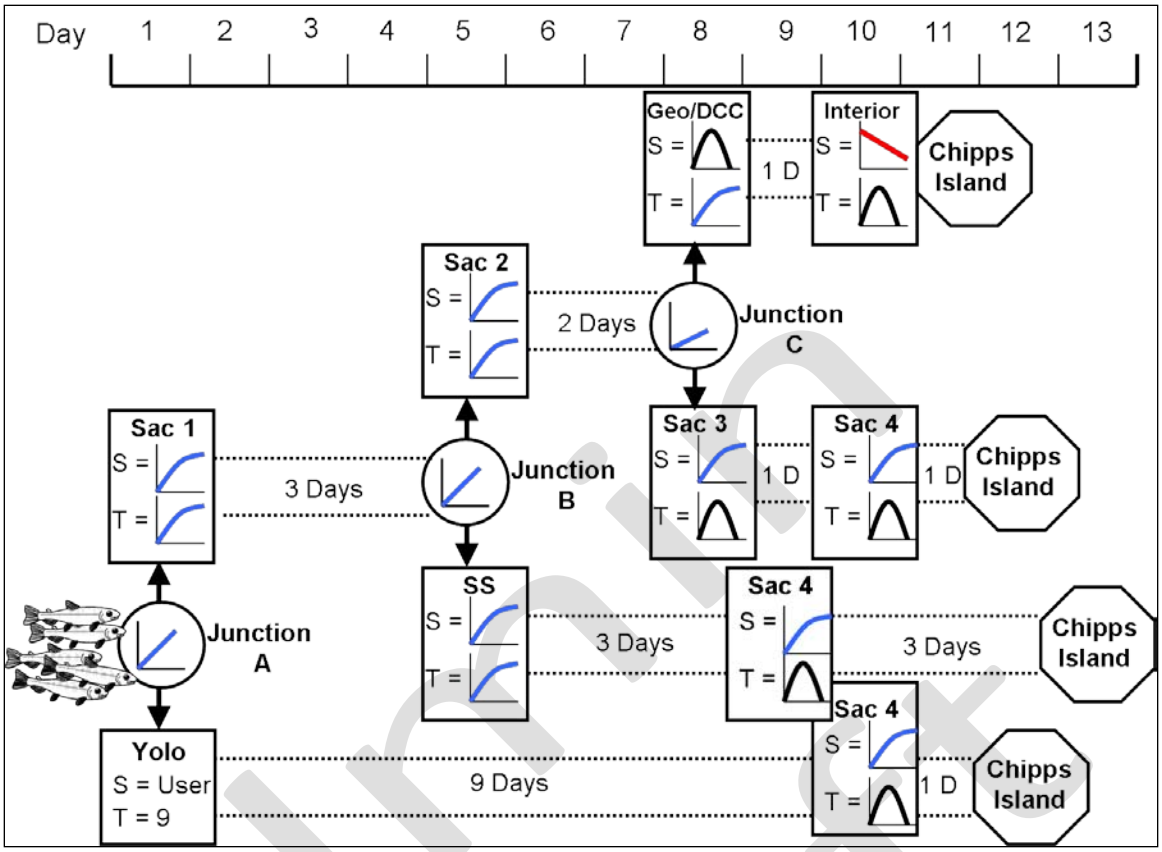
DPM Reach	DSM2 Nodes	CALSIM Node
Sac1	rsac155	
Sac2	rsac128	
Sac3	rsac123	
Sac4	rsac101	
Yolo	d160+d166a	
SS	slsbt011	
Geo/DCC	dcc+georg_sl	
Interior Delta via Geo/DCC		total_exp
Interior Delta via San Joaquin River	rsan058	
Interior Delta via Old River	rold074	

Illustrative Example

To help illustrate the series of operations performed by the DPM, Figure C.4-3 depicts the migration of a single daily cohort of smolts entering from the Sacramento River and migrating through the DPM. It is important to remember that cohorts of differing numbers of smolts are entering the Delta each day during the migration period of each salmon run. As fish encounter junctions in the Delta, they are routed down one of two paths dependent on the proportion of flow entering each downstream reach. In some cases (Junctions A and B) fish movement is directly proportional with flow movement, while at other junctions (Junction C) fish movement, although linear, is not directly proportional with flow movement. As fish enter Delta reaches, their reach survival and migration speed (and therefore migration time) are calculated on the day they enter the reach. All subsequent days that the fish are migrating through a given reach, they are not exposed to mortality, nor is their migration speed adjusted. For reaches where data were available to inform a relationship with flow, reach survival and migration speed are calculated as a function of the flow during the initial day of reach entry. Likewise, where data were available to inform a relationship with Delta exports (Interior Delta), reach survival is calculated as a function of exports as fish enter the reach. Because portions of a single cohort of fish migrate through different routes in the Delta, portions of the cohort will experience differing overall survival rates, differing migration rates, and differing arrival times at Chipps Island. See *Model Functions* section below for detailed descriptions of DPM functional relationships.

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.



Day of the model run is indicated at the top of the diagram. Circles indicate Delta junctions, where the proportion of fish moving to each downstream reach is calculated, and rectangles indicate Delta reaches. The shape of the relationship for each reach-specific survival (S), reach-specific migration speed (T), and proportional fish movement at junctions is depicted. Relationships that are influenced by flow (x variable) are blue, relationships influenced by exports are red, and relationships that are calculated from a probability distribution (and not influenced by flow or exports) are black. Dotted lines indicate migration time through the previous reach, and the Chipps Island icons indicate when fish from each route exited the Delta.

Figure C.4-3. Conceptual Diagram Depicting the "Migration" of a Single Daily Cohort of Smolts Entering from the Sacramento River and Migrating through the Delta Passage Model

Model Functions

Delta Entry Timing

Recent sampling data on Delta entry timing of emigrating juvenile smolts for six Central Valley Chinook salmon runs were used to inform the daily proportion of juveniles entering the Delta for each run (Table C.4-6). Because the DPM models the survival of smolt-sized juvenile salmon, pre-smolts were removed from catch data before creating entry timing distributions. The lower 95th percentile of the range of salmon fork lengths visually identified as smolts by the USFWS in Sacramento trawls was used to determine the lower length cutoff for smolts. A lower fork length cutoff of 70 mm for smolts was applied, and all catch data of fish smaller than 70 mm were eliminated. To isolate wild production, all fish identified as having an adipose-fin clip (hatchery production) were eliminated. Daily catch data for each brood year were divided by total annual catch to determine the daily proportion of smolts entering the Delta for each brood year. Finally, the daily proportions for all brood years were plotted for each race, and a normal distribution was

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

visually approximated to obtain the daily proportion of smolts entering the DPM for each run (Figure C.4-4).

Table C.4-6. Sampling Gear Used to Create Juvenile Delta Entry Timing Distributions for Each Central Valley Run of Chinook Salmon

Chinook Salmon Run	Gear	Agency	Brood Years
Sacramento River Winter Run	Trawls at Sacramento	USFWS	1995–2005
Sacramento River Spring Run	Trawls at Sacramento	USFWS	1995–2005
Sacramento River Fall Run	Trawls at Sacramento	USFWS	1995–2005
Sacramento River Late Fall Run	Trawls at Sacramento	USFWS	1995–2005
Mokelumne River Fall Run	Rotary Screw Trap at Woodbridge	EBMUD	2001–2007
San Joaquin River Fall Run	Kodiak Trawl at Mossdale	DFG	1996–2009
Agencies that conducted sampling are listed: USFWS = U.S. Fish and Wildlife Service, EBMUD = East Bay Municipal District, and DFG = California Department of Fish and Game.			

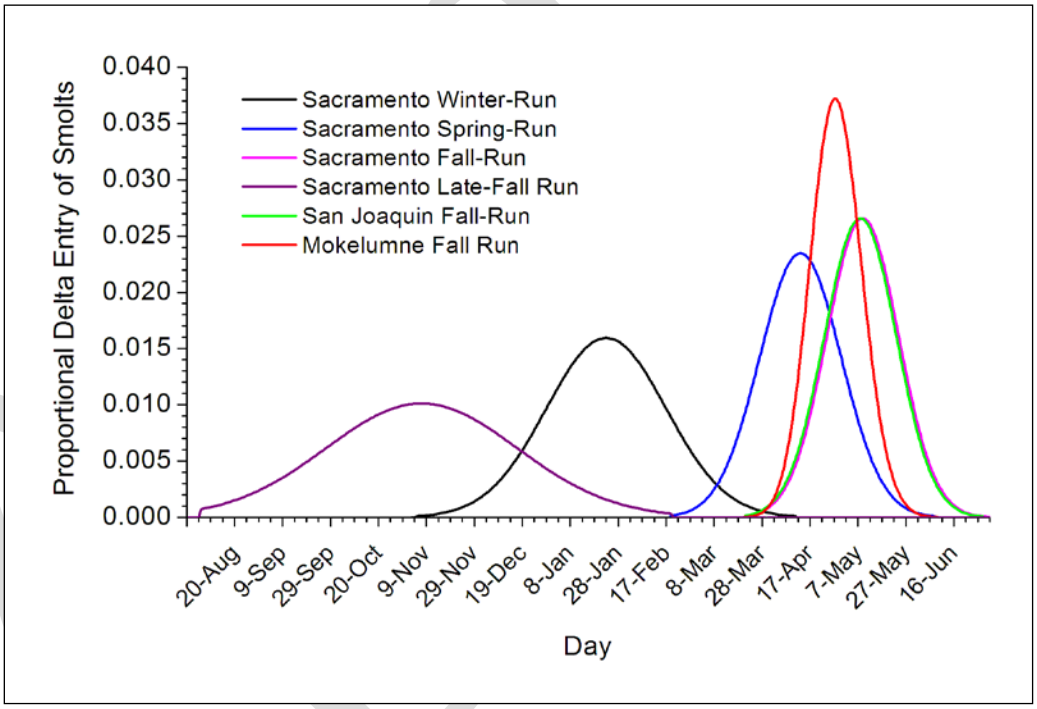


Figure C.4-4. Delta Entry Distributions for Chinook Salmon Smolts Applied in the Delta Passage Model for Sacramento River Winter-Run, Sacramento River Spring-Run, Sacramento River Fall-Run, Sacramento River Late Fall-Run, San Joaquin River Fall-Run, and Mokelumne River Fall-Run Chinook Salmon

Migration Speed

The DPM assumes a net daily movement of smolts in the downstream direction. The rate of smolt movement in the DPM affects the timing of arrival at Delta junctions and reaches, which can affect route selection and survival as flow conditions or water project operations change.

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

Smolt movement in all reaches except Yolo Bypass and the Interior Delta is a function of reach-specific length and migration speed as observed from acoustic tagging results. Reach-specific length (kilometers [km]) (Table C.4-4) is divided by reach migration speed (km/day) the day smolts enter the reach to calculate the number of days smolts will take to travel through the reach.

For north Delta reaches Sac1, Sac2, SS, and Geo/DCC, mean migration speed through the reach is predicted as a function of flow. Many studies have found a positive relationship between juvenile Chinook salmon migration rate and flow in the Columbia River Basin (Raymond 1968; Berggren and Filardo 1993; Schreck et al. 1994), with Berggren and Filardo (1993) finding a logarithmic relationship for Snake River yearling Chinook salmon. Ordinary least squares regression was used to test for a logarithmic relationship between reach-specific migration speed (km/day) and average daily reach-specific flow (cubic meters per second [m^3/sec]) for the first day smolts entered a particular reach for reaches where acoustic tagging data was available (Sac1, Sac2, Sac3, Sac4, Geo/DCC, and SS):

$$Speed = \beta_0 \ln(flow) + \beta_1;$$

Where β_0 is the slope parameter and β_1 is the intercept.

Individual smolt reach-specific travel times were calculated from detection histories of releases of acoustically tagged smolts conducted in December and January for three consecutive winters (2006/2007, 2007/2008, and 2008/2009) (Perry 2010). Reach-specific migration speed (km/day) for each smolt was calculated by dividing reach length by travel days (Table C.4-7). Flow data was queried from the DWR's California Data Exchange website (<http://cdec.water.ca.gov/>).

Table C.4-7. Reach-specific migration speed and sample size of acoustically-tagged smolts released during December and January for three consecutive winters (2006/2007, 2007/2008, and 2008/2009)

Reach	Gauging Station ID	Release Dates	Sample Size	Spped (km/day)			
				Avg	Min	Max	SD
Sac1	FPT	12/05/06–12/06/06, 1/17/07–1/18/07, 12/04/07–12/07/07, 1/15/08–1/18/08, 11/30/08–12/06/08, 1/13/09–1/19/09	452	13.32	0.54	41.04	9.29
Sac2	SDC	1/17/07–1/18/07, 1/15/08–1/18/08, 11/30/08–12/06/08, 1/13/09–1/19/09	294	9.29	0.34	10.78	3.09
Sac3	GES	12/05/06–12/06/06, 1/17/07–1/18/07, 12/04/07–12/07/07, 1/15/08–1/18/08, 11/30/08–12/06/08, 1/13/09–1/19/09	102	9.24	0.37	22.37	7.33
Sac4	GES[a]	12/05/06–12/06/06, 1/17/07–1/18/07, 12/04/07–12/07/07, 1/15/08–1/18/08, 11/30/08–12/06/08, 1/13/09–1/19/09	62	8.60	0.36	23.98	6.79
Geo/DCC	GSS	12/05/06–12/06/06, 1/17/07–1/18/07, 12/04/07–12/07/07, 1/15/08–1/18/08, 11/30/08–12/06/08, 1/13/09–1/19/09	86	14.20	0.34	25.59	8.66
SS	FPT-SDC[b]	12/05/06–12/06/06, 12/04/07–12/07/07, 1/15/08–1/18/08, 11/30/08–12/06/08, 1/13/09–1/19/09	30	9.41	0.56	26.72	7.42

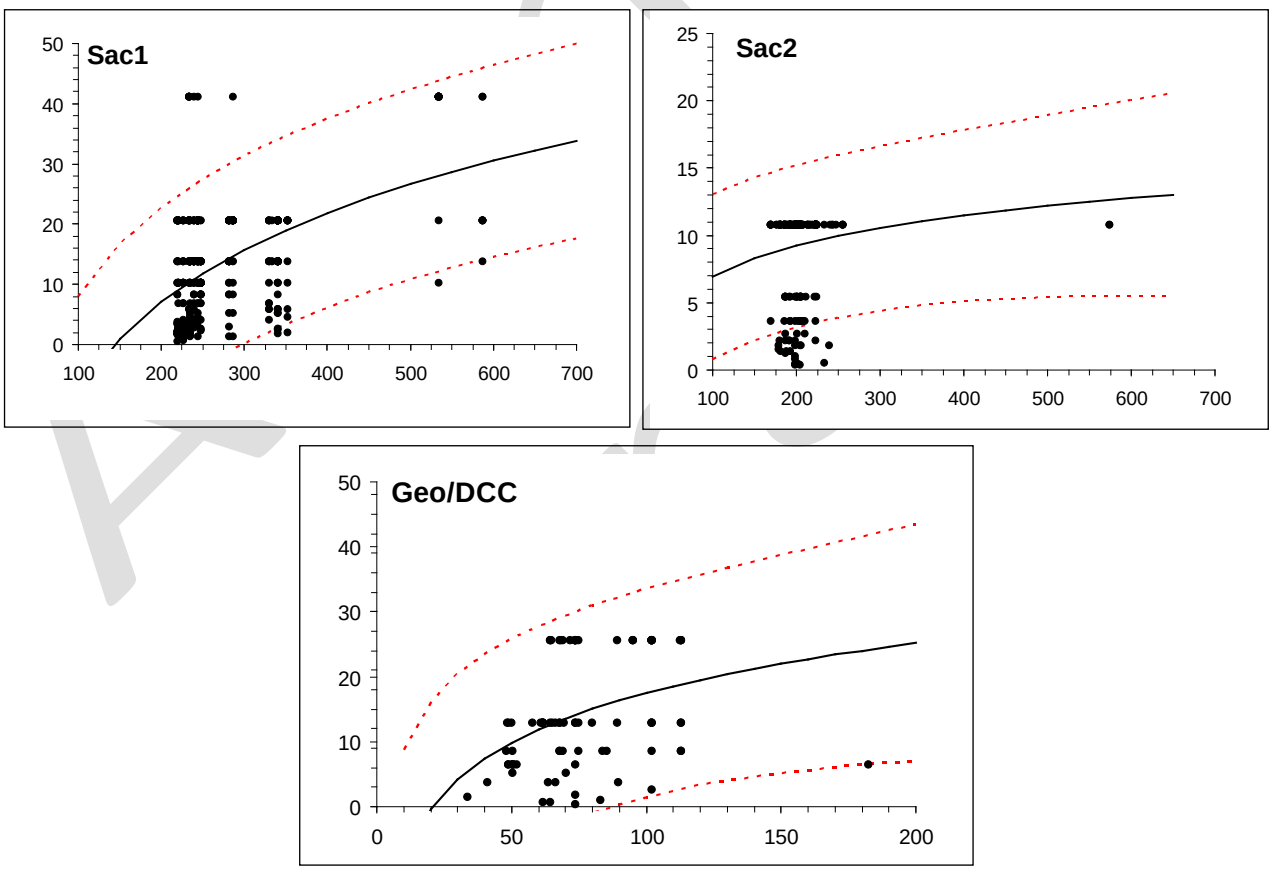
[a] Sac3 flow is used for Sac4 because no flow gauging station is available for Sac4
[b] SS flow is calculated by subtracting Sac2 flow (SDC) from Sac1 flow (FPT).

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

Migration speed was significantly related to flow for reaches Sac1 (df = 450, F = 164.36, P < 0.001), Sac2 (df = 292, F = 4.17, P = 0.042), and Geo/DCC (df = 84, F = 13.74, P <0.001). Migration speed increased as flow increased for all three reaches (Table C.4-8, Figure C.4-5). Therefore, for reaches Sac1, Sac2, and Geo/DCC, mean migration speed and associated standard error of the regression is used to inform a normal probability distribution that is sampled from the day smolts enter the reach to determine their migration speed throughout the reach. The minimum migration speed for each reach is set at the minimum reach-specific migration speed observed from the acoustic tagging data (Table C.4-8).

Table C.4-8. Sample Size and Slope (β_0) and Intercept (β_1) Parameter Estimates with Associated Standard Error (in Parenthesis) for the Relationship between Migration Speed and Flow for Reaches Sac1, Sac2, and Geo/DCC

Reach	N	β_0	β_1
Sac1	452	21.34 (1.66)	-105.98 (9.31)
Sac2	294	3.25 (1.59)	-8.00 (8.46)
Geo/DCC	86	11.08 (2.99)	-33.52 (12.90)



Circles are observed migration speeds of acoustically-tagged smolts from acoustic tagging studies from Perry (2010), solid lines are predicted mean reach survival curves, and dotted lines are 95% prediction intervals used to inform uncertainty.

Figure C.4-5. Reach-Specific Migration Speed (km/day) as a Function of Flow (m^3/sec) Applied in Reaches Sac1, Sac2, and Geo/DCC

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

No significant relationship between migration speed and flow was found for reaches Sac3 (df = 100, F = 1.13, P =0.29), Sac4 (df = 60, F = 0.33, P = 0.57), and SS (df = 28, F = 0.86, P = 0.36). Therefore, for these reaches the observed mean migration speed and associated standard deviation (Table C.4-8) is used to inform a normal probability distribution that is sampled from the day smolts enter the reach to determine their migration speed throughout the reach. As applied for reaches Sac1, Sac2, and Geo/DCC, the minimum migration speed for reaches Sac3, Sac4, and SS is set at the minimum reach-specific migration speed observed from the acoustic tagging data (Table C.4-8).

Yolo Bypass travel time data from Sommer et al. (2005) for acoustic-tagged, fry-sized (mean size = 57 mm fork length [FL]) Chinook salmon were used to inform travel time through the Yolo Bypass in the DPM. Because the DPM models the migration and survival of smolt-sized juveniles, the range of the shortest travel times observed across all three years (1998–2000) by Sommer et al. (2005) was used to inform the bounds of a uniform distribution of travel times (range = 4–28 days), on the assumption that smolts would spend less time rearing, and would travel faster than fry. On the day smolts enter the Yolo Bypass, their travel time through the reach is calculated by sampling from this uniform distribution of travel times.

The travel time of smolts migrating through the Interior Delta in the DPM is informed by observed mean travel time (7.95 days) and associated standard deviation (6.74) from North Delta acoustic tagging studies (Perry 2010). However, the timing of smolt passage through the Interior Delta does not affect Delta survival because there are no Delta reaches located downstream of the Interior Delta.

Fish Behavior at Junctions (Channel Splits)

Perry and coauthors (2010) found that acoustically tagged smolts arriving at Delta junctions exhibited inconsistent movement patterns in relation to the flow being diverted. For Junction B, Perry and coauthors (2010) found that smolts consistently entered downstream reaches in proportion to the flow being diverted. Therefore, smolts arriving at Junction B in the model move proportionally with flow. Similarly, with data lacking to inform the nature of the relationship, a proportional relationship between flow and fish movement for Junction D (San Joaquin River–Old River) also was applied. For Junction A, smolts enter Yolo Bypass in proportion to flow movement once flows entering Yolo Bypass reach 4,000 cfs. This assumption is based on 4,000 cfs of flow being required to initiate floodplain inundation in the Yolo Bypass (i.e., to cause overbank flow from the Tule Canal/Toe Drain); at flows below 4,000 cfs when the floodplain is not inundated, it is assumed that there would be no difference in survival between smolts passing down the Tule Canal/Toe Drain and smolts passing down the Sacramento River (T. Sommer pers. comm.) and therefore the smolts are simply routed down the Sacramento River. The proportion of flow entering the Yolo Bypass is calculated as flow passing over Fremont Weir[5] divided by flow passing over Fremont Weir plus Sacramento River flow at Freeport.[6]

[5] DSM2 does not provide daily simulated flows for Fremont Weir. Daily flows were obtained by disaggregating CALSIM estimates using historic daily patterns of variability.

[6] DSM2 does not provide daily simulated flows for any locations upstream of Freeport. Calculating Yolo Bypass inflow as a function of Freeport flows provides a conservative estimate of the proportion of smolts entering the Yolo Bypass (i.e., it will tend to underestimate the proportion because additional flows from the American River enter the Sacramento River above Freeport).

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

For Junction C (Sacramento River–Georgiana Slough/DCC), Perry (2010) found a linear, nonproportional relationship between flow and fish movement. His relationship for Junction C was applied in the DPM:

$$y = 0.22 + 0.47x;$$

where y is the proportion of fish diverted into Geo/DCC and x is the proportion of flow diverted into Geo/DCC (Figure C.4-6).

In the DPM, this linear function is applied to predict the daily proportion of fish movement into Geo/DCC as a function of the proportion of flow into Geo/DCC.

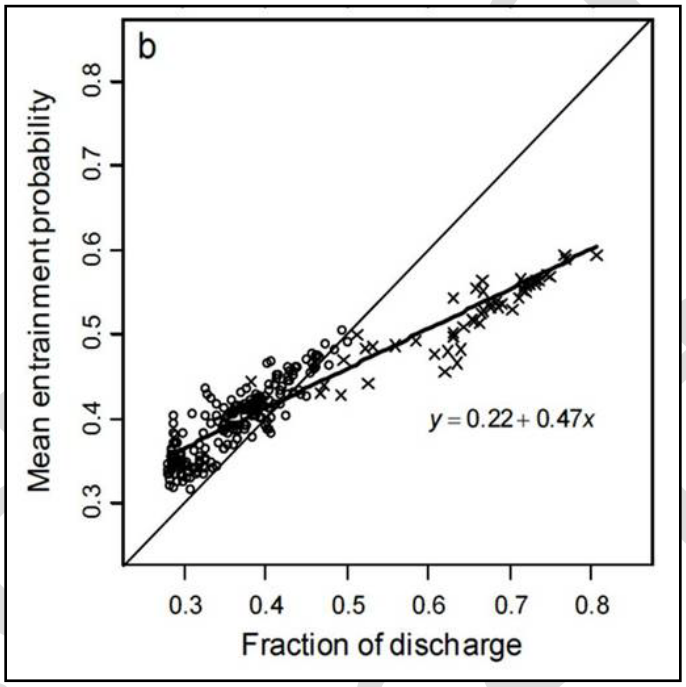


Figure C.4-6. Figure from Perry (2010) Depicting the Mean Entrainment Probability (Proportion of Fish Being Diverted into Reach Geo/DCC) as a Function of Fraction of Discharge (Proportion of Flow Entering Reach Geo/DCC)

Reach-Specific Survival

Reach-specific survival through a given reach is calculated and applied the first day smolts enter the reach. For reaches where literature showed support for reach-level responses to environmental variables, survival is influenced by flow (Sac1, Sac2, Sac3, Sac4, SS, Interior Delta via San Joaquin River, and Interior Delta via Old River) or water exports (Interior Delta via Geo/DCC). For these reaches, daily flow or exports occurring the day of reach entry are used to predict reach survival during the entire migration period through the reach (Table C.4-9). For all other reaches (Geo/DCC and Yolo), reach survival is assumed to be unaffected by Delta conditions and is informed by means and standard deviations of survival from acoustic tagging studies.

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

Table C.4-9. Reach-Specific Survival and Parameters Defining Functional Relationships or Probability Distributions for Each Chinook Salmon Run

Reach	Chinook Salmon Run	Survival
Sac1	All Sacramento runs	Function of flow
Sac2	All Sacramento runs	Function of flow
Sac3	All Sacramento runs	Function of flow
Sac4	All Sacramento runs	Function of flow
Yolo	All Sacramento runs	0.80
SS	All Sacramento runs	Function of flow
Geo/DCC	Mokelumne fall-run	0.407 (0.209)
	All Sacramento runs	0.65 (0.126)
Interior Delta	All Sacramento runs	Function of exports
	San Joaquin fall-run via Old River	Function of flow
	San Joaquin fall-run via San Joaquin River	Function of flow
For reaches where survival is uninfluenced by Delta conditions, mean survival and associated standard deviation (in parenthesis) observed during acoustic tagging studies (Perry 2010) are used to define a normal probability distribution that is sampled from the day smolts enter a reach to calculate reach survival.		

For reaches Geo/DCC and Yolo, no empirical data were available to support a relationship between survival and Delta conditions (flow, exports). Therefore, for these reaches mean reach survival is used along with reach-specific standard deviation to define a normal probability distribution that is sampled from when smolts enter the reach to determine reach survival.

Mean reach survival and associated standard deviation for Geo/DCC are informed by survival data from smolt acoustic-tagging studies from Perry (2010). Separate acoustic-study survival data are applied for smolts migrating through Geo/DCC via the Sacramento River (Sacramento River runs) or Mokelumne River (Mokelumne River fall-run) (Table C.4-10).

Due to lack of available smolt survival data for the Yolo Bypass, and results of coded-wire tagged studies of fry-sized Chinook salmon migrants showing a survival benefit for fry migrating through Yolo Bypass versus mainstem Sacramento River (T. Sommer pers. comm.), Yolo survival is applied as a high constant survival rate of 0.80.

Table C.4-10. Individual Release-Group Survival Estimates, Release Dates, Data Sources, and Associated Calculations Used to Inform Reach-Specific Mean Survivals and Standard Deviations Used in the Delta Passage Model for Reaches Where Survival Is Uninfluenced by Delta Conditions

DPM Reach	Survival	Release Dates	Survival Calculation	Mean	Standard Deviation
Geo/DCC via Mokelumne River	0.648	12/05/06	$S_{C1}*S_{C2}$	0.407	0.209
	0.286	12/04/07–12/06/07	S_{C1}		
	0.286	11/31/08–12/06/08	S_{C1}		
Geo/DCC via Sacramento River	0.648	12/05/06	S_{D1}	0.650	0.126
	0.600	12/04/07–12/06/07	$S_{D1,SAC}*S_{D2}$		
	0.762	1/15/08–1/17/08	$S_{D1,SAC}*S_{D2}$		
	0.774	11/31/08–12/06/08	$S_{D1,SAC}*S_{D2}$		
	0.467	1/13/08–1/19/09	$S_{D1,SAC}*S_{D2}$		
Source: Perry 2010.					

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

Flow-Dependent Survival

For reaches Sac1, Sac2, Sac3, Sac4, SS, Interior Delta via San Joaquin River, and Interior Delta via Old River, flow values on the day of reach entry are used to predict reach survival (Figure C.4-7). Perry (2010) evaluated the relationship between survival among acoustically tagged Sacramento River smolts and Sacramento River flow measured below Georgiana Slough (DPM reach Sac3) and found a significant relationship between survival and flow during the migration period for smolts that migrated through Sutter and Steamboat Sloughs to Chipps Island (Sutter and Steamboat route; SS and Sac4 combined) and smolts that migrated from Georgiana Slough to Chipps Island (Sacramento River route; Sac3 and Sac4 combined). Therefore, for reaches SS, Sac3, and Sac4, the logit survival function from Perry (2010) was used to predict mean reach survival (*S*) from reach flow (*flow*):

$$S = \frac{e^{(\beta_0 + \beta_1 flow)}}{1 + e^{(\beta_0 + \beta_1 flow)}}$$

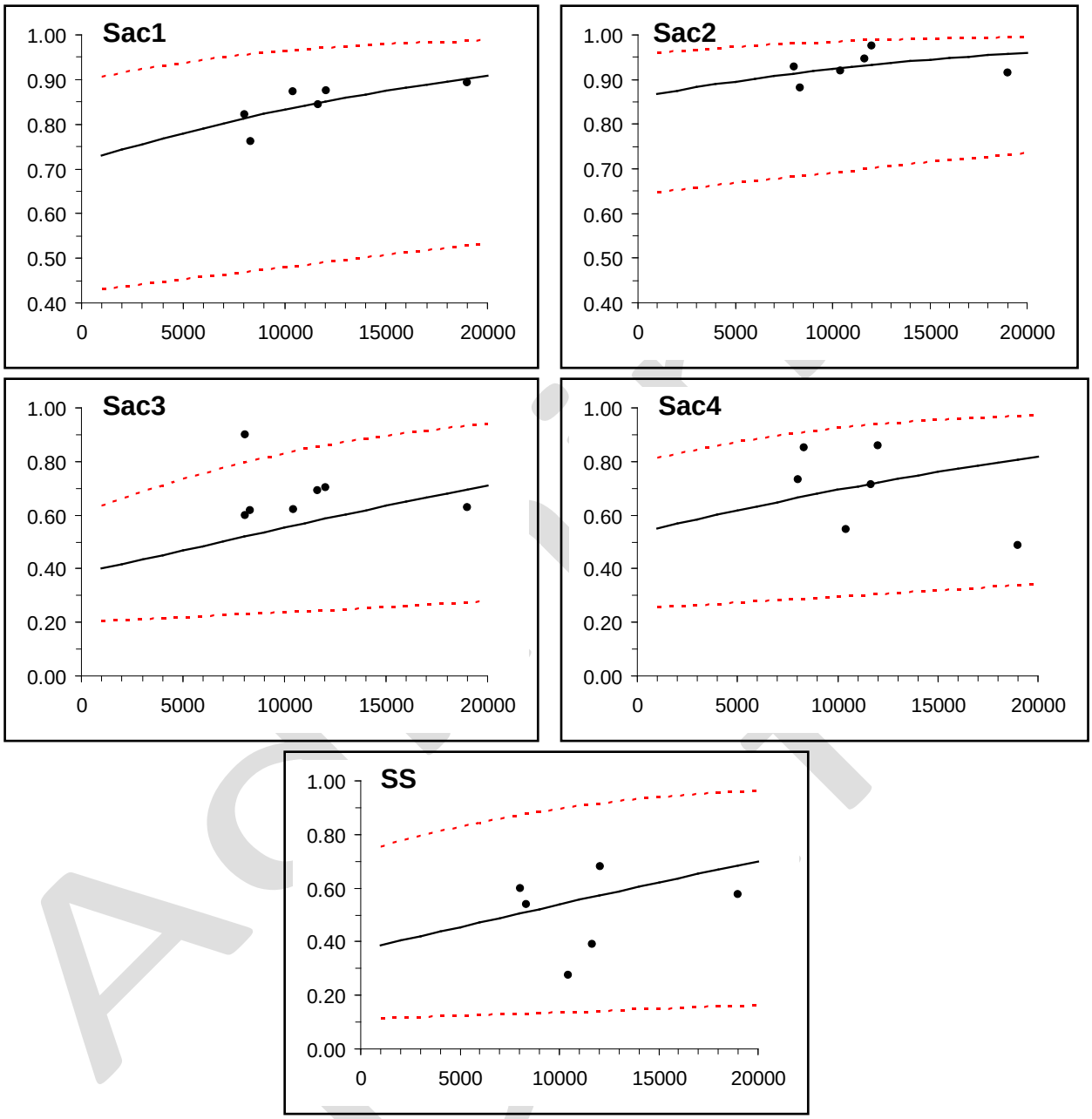
where β_0 (SS = -0.175, Sac3 = -0.121, Sac4 = 0.485) is the reach coefficient and β_1 (0.26) is the flow coefficient, and *flow* is average Sacramento River flow during the experiment standardized to a mean of 0 and standard deviation of 1.

Perry (2010) estimated the global flow coefficient for the Sutter Steamboat route and Sacramento River route as 0.52. Because the Sutter Steamboat route and Sacramento River route from Perry (2010) are each broken into two reaches in the DPM, the flow coefficient was divided in half to partition the flow effect across both reaches. The reach coefficients for SS and Sac3 were calculated as the average intercept value across all release groups for the Sutter Steamboat route and Sacramento River route, respectively. The reach coefficient for Sac4 was estimated by holding the flow coefficient at 0.26 (i.e., half the global flow coefficient of 0.52) and minimizing the residual sum of squares of the logit model about the observed Sac4 group survivals from Perry (2010) while varying the reach coefficient. For reaches Sac3, Sac4, and SS, mean survival and associated standard error predicted from each flow-survival relationship is used to inform a normal probability distribution that is sampled from the day smolts enter the reach to determine their reach survival.

With a flow-survival relationship appearing evident for group survival data of acoustically-tagged smolts in reaches Sac1 and Sac2, Perry's (2010) relationship was applied to Sac1 and Sac2 while adjusting for the mean reach-specific survivals for Sac1 and Sac2 observed during the acoustic tagging studies (Figure C.4-7). Similar to reach Sac4, the flow coefficient was held constant at 0.26 and the residual sum of squares of the logit model was minimized about the observed Sac1 and Sac2 group survivals, respectively, while varying the reach coefficient. The resulting reach coefficients for Sac1 and Sac2 were 1.27 and 2.16, respectively. Similar to reaches Sac3, Sac4, and SS, mean survival and associated standard error predicted from the flow-survival relationship is used to inform a normal probability distribution that is sampled from the day smolts enter the reach to determining Sac1 and Sac2 reach survival.

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.



Circles are observed group survivals from acoustic-tagging studies from Perry (2010), solid lines are predicted mean reach survival curves, and dotted lines are 95% confidence bands used to inform uncertainty. Raw data for Interior Delta reaches from Newman (2010) is not available.

Figure C.4-7. Reach-Specific Survival as a Function of Flow Applied in Reaches Sac1, Sac2, Sac3, Sac4, SS, and Interior Delta via the San Joaquin River

For smolts that migrate through the Interior Delta via San Joaquin River or Old River, survival is modeled either as a function of flow or as an intercept-only model depending on the probability that the flow or intercept-only model was most likely as reported in Newman (2010). Each day, the model that will be used to calculate survival is determined by drawing from a discrete distribution where the probability of the intercept-only model is 0.57 and 0.66, and the probability of the flow model is 0.43 and 0.34 for the San Joaquin and Old River routes, respectively:

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

$$S_{SJ,OR} = \frac{e^{(\beta_0 + \beta_1 flow)}}{1 + e^{(\beta_0 + \beta_1 flow)}}$$, or $S_{SJ,\,OR}$ = Mean +/- (SD)

where $S_{SJ,\,OR}$ is survival through the Interior Delta via the San Joaquin River or Old River, flow is average San Joaquin River flow downstream of the head of Old River or flow in Old River during the coded-wire tagging study standardized to a mean of 0 and standard deviation of 1, β_0 is the intercept, and β_1 is the slope of the respective models (Table C.4-11).

Uncertainty in the flow relationships is represented by using the mean and standard error of the intercept and slope estimates to define normal probability distributions that are re-sampled every day to select new slopes and intercepts for the relationship. Uncertainty in the intercept-only relationships is represented by using the mean and standard error of the intercept to define a normal probability distribution that is sampled from each day.

Table C.4-11. Mean and standard errors of coefficient values for the Intercept-only models and flow models for predicting survival for the reaches Interior Delta via San Joaquin River and Interior Delta via Old River

		Interior Delta via San Joaquin River	Interior Delta via Old River
Intercept-Only Models	mean	0.206	0.090
	SE	0.585	0.629
Flow Models			
Slope	mean	0.578	0.528
	SE	0.576	0.629
Intercept	mean	0.183	0.083
	SE	0.565	0.629

Export-Dependent Survival

As migratory juvenile salmon enter the Interior Delta from Geo/DCC for Sacramento races or Mokelumne River fall-run Chinook salmon, they transition to an area strongly influenced by tides and where exports may influence survival. The export–survival relationship described by Newman and Brandes (2010) was applied as follows:

$$\theta = 0.5948 * e^{(-0.000065 * Total_Exports)};$$

where θ is the ratio of survival between coded wire tagged smolts released into Georgiana Slough and smolts released into the Sacramento River and Total_Exports is the flow of water (cfs) pumped from the Delta from the State and Federal facilities.

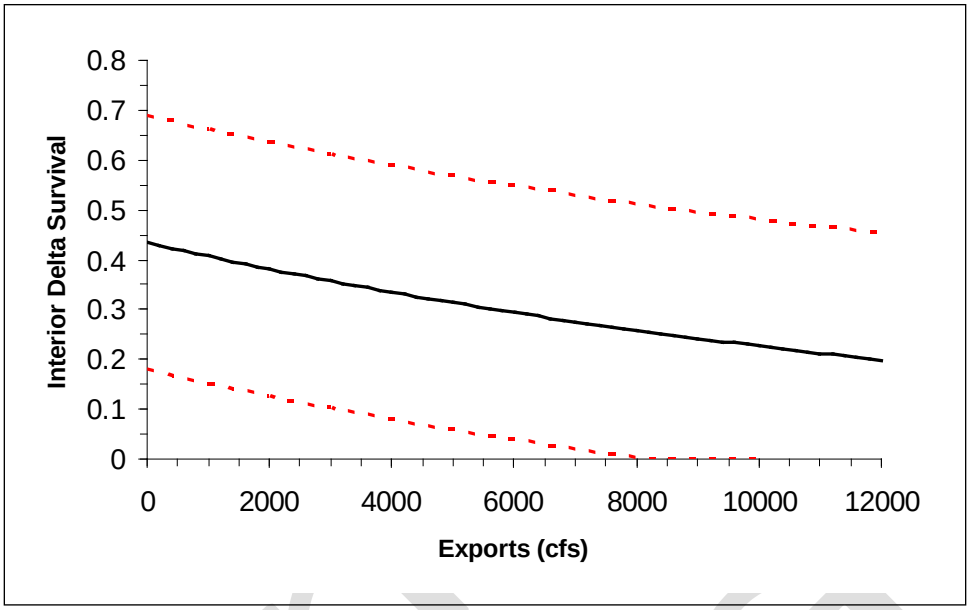
θ was converted from a ratio into a value of survival through the Interior Delta using the equation:

$$S_{ID} = \frac{\theta}{S_{Geo/DCC}} * (S_{Sac3} * S_{Sac4});$$

where S_{ID} is survival through the Interior Delta, θ is the ratio of survival between Georgiana Slough and Sacramento River smolt releases, $S_{Geo/DCC}$ is the survival of smolts in the Georgiana Slough/Delta Cross Channel reach, S_{Sac3} is survival in reach Sac 3 and S_{Sac4} is survival in reach Sac 4 (Figure C.4-8).

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

Uncertainty is represented in this relationship by using the estimated value of θ and the standard error of the equation to define a normal distribution bounded by the 95% prediction interval of the model that is then re-sampled each day to determine the value of θ.



Survival values in reaches Sac3, Sac4, and Geo/DCC were held at mean values observed during acoustic studies (Perry 2010) to depict export effect on Interior Delta survival. Dashed lines are 95% prediction bands used to inform uncertainty in the relationship.

Figure C.4-8. Interior Delta Survival as a Function of Delta Exports (Newman and Brandes 2010) as Applied for Sacramento Races of Chinook Salmon Smolts Migrating through the Interior Delta via Reach Geo/DCC

North Delta Intake Mortality

Sacramento River runs experience predation mortality as a function of the number of predators present at the North Delta intake diversions and the bioenergetic effects of temperature on predation rates. Figure C.4-9 and Figure C.4-10 present the relationships between the proportion of smolts consumed by predators for each Sacramento salmon run for the ELT and LLT BDCP scenarios. The slight differences in slope reflect different water temperatures at the proposed North Delta Intake facilities under these two scenarios.

Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

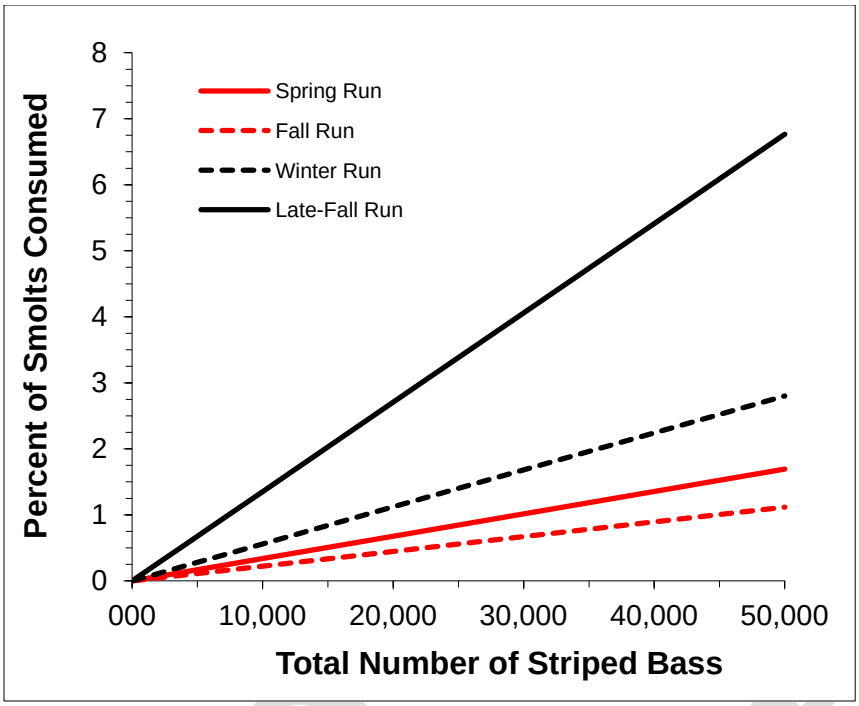


Figure C.4-9. Percent of Smolts Consumed as a Function of the Number of Predators Present at the North Delta Intake Diversion Facilities (PP_ELT Scenario)

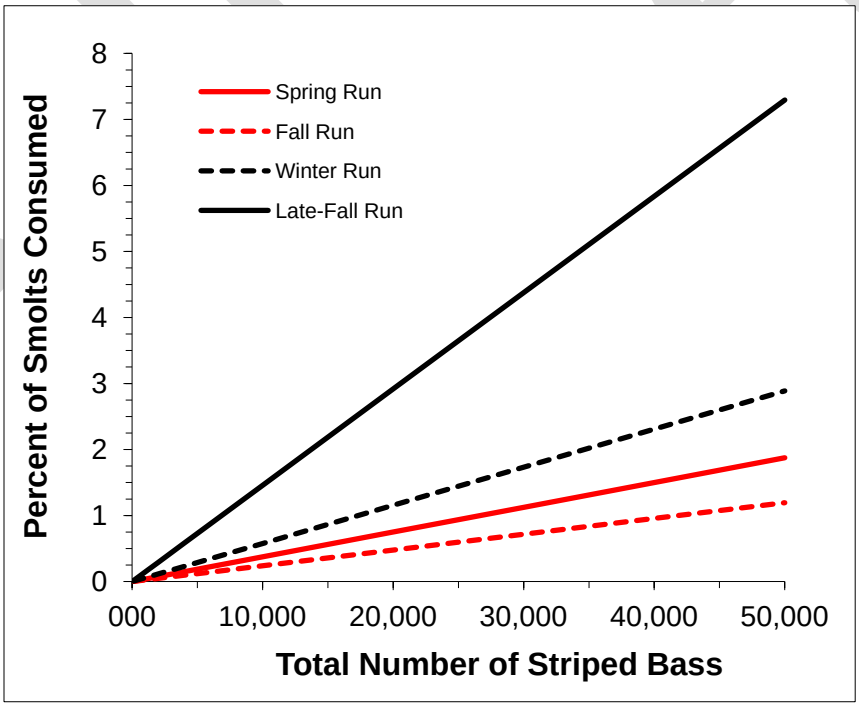


Figure C.4-10. Percent of Smolts Consumed as a Function of the Number of Predators Present at the North Delta Intake Diversion Facilities (PP_LLT Scenario)

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

The proportion of smolts consumed by predators for each Sacramento salmon run (Cr) at the diversion facilities is calculated as follows:

$$C_r = CN_r PN / production_r ;$$

where CN_r is the estimated annual number of smolts consumed by an individual predator for each Sacramento Chinook salmon run, P_N is the number of predators at the diversion facilities (user-defined), and $production_r$ is the estimated annual smolt production for each race.

To simplify the calculations, the DPM does not actually apply predation mortality specifically to the subset of smolts entering reach Sac1, but in fact applies the mortality as a fixed percentage of the overall total number smolts assumed to exist at the start of the model (Table C.4-12). Thus the percentage loss at the North Delta intakes is fixed regardless of the percentage of smolts actually passing down reach Sac1.

The estimated annual number of smolts consumed by an individual predator for each Sacramento Chinook salmon run (CN_r) was calculated using the bioenergetics model provided by Loboschefsky and Nobriga (2010) and described in detail in Appendix 5.F.

Average values of smolt production (production) for each run were estimated using the average annual adult escapement (escapement) for each run for the previous 10 years (2000–2009) provided in USFWS database (<www.fws.gov/Stockton/afrp/documents/GrandTab_020111.pdf>) along with estimates of pre-spawning mortality (prespawn), spawning sex ratio, average fecundity, egg-to-fry survival, and average percent of juveniles entering the Delta as smolts (non-adipose-clipped Chinook salmon >70 mm FL) to calculate the average smolt production for Sacramento River fall-run, spring-run, winter-run, and late fall–run:

$$production = escapement \times (1 - prespawn) \times sex\ ratio \times fecundity \times egg - to - fry \times \%smolt$$

Values for each component of the calculation and data sources are provided in Table C.4-12.

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

Table C.4-12. Run-Specific Metrics and Associated Data Sources Used to Calculate Run-Specific Estimates of Smolt Production to Inform Calculations of Mortality at the Delta Intake Facilities

Data Type	Reference	Data	Reference	Data
	Fall-Run		**Spring-Run**	
Escapement	GrandTab, 10-yr Avg	293,393	GrandTab, 10-yr Avg	8,924
Pre-spawning mortality	Draft Feather River Report 2001	42%	Garman & McReynolds 2005–2008	5.53%
Percent female	Killam 2009	46%	Garman & McReynolds 2005–2008 54.60%	
Fecundity	DFG Annual Reports	4033	DFG Annual Reports	4033
Egg to Fry Survival	Poytress & Carillo 2010	33%	Paytress & Carillo 2010	33%
Fry to Delta Survival	USFWS, unpublished data	53%	USFWS, unpublished data	53%
% smolts entering Delta	USFWS Sacramento Trawls	52%	USFWS Sacramento Trawls	86%
Total Smolts Reaching Delta		**28,700,000**		**2,800,000**
	Winter-Run		**Late Fall–Run**	
Escapement	GrandTab, 10-yr Avg	7,634	GrandTab, 10-yr Avg	16,214
Pre-spawning mortality	Poytress & Carillo 2010	5%	Draft Feather River Report 2001	42%
Percent female	Killam 2009	53.50%	Killam 2009	46%
Fecundity	Poytress & Carillo 2010	3859	DFG Annual Reports	4033
Egg to Fry Survival	Poytress & Carillo 2010	33%	Poytress & Carillo 2010	33%
Fry to Delta Survival	USFWS, unpublished data	53%	USFWS, unpublished data	53%
% smolts entering Delta	USFWS Sacramento Trawls	82%	USFWS Sacramento Trawls	100%
Total Smolts Reaching Delta		**2,100,000**		**3,100,000**

Non-Physical Barrier at Georgiana Slough and Head of Old River

The DPM was used to perform a sensitivity analysis to evaluate the potential effect of a non-physical barrier at Georgiana Slough and the head of Old River on survival of Chinook salmon juveniles based on assumptions of 20%, 50%, and 80% barrier effectiveness (i.e., percentage of fish deterred from entering Georgiana Slough and Old River). The analysis assumed fixed predation mortality based on the presence of 650 striped bass at the north Delta intake facilities. This number was derived from the mean density of striped bass observed at the Glenn-Colusa Irrigation District fish screen in the upper Sacramento River near Hamilton City (i.e., 0.39 predators per linear meter of Glen-Colusa Irrigation District [GCID] intake screen = 130 predators per 1,000-foot-long north Delta diversion screen). The actual number of striped bass found at the proposed north Delta intake might be more or less than this number, or alternatively, the number of predators could be reduced by predator control efforts (see Appendix 5.F).

C.4.3.3 Transport Flows for Larval Smelts

Three approaches were used to predict the effect of the preliminary proposal on transport of larval smelts from spawning locations to downstream rearing habitat: flow assessment, particle-tracking modeling, and X2–abundance regressions.

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

C.4.3.3.1 Flow Assessment (CALSIM)

Average and median monthly Delta, Sacramento, and San Joaquin River outflow and daily maximum outflow late in the migration period for larval delta smelt when water temperatures in the central and south Delta warm (May and June) were evaluated under each model scenario. Flows were assumed to be directly proportional to transport and survival for larval delta smelt.

Similar to flows for delta smelt, flows were assessed during the larval period of longfin smelt. CALSIM II output for December through May X2 position exceedance plots was examined for each model run to determine the frequency of exceedance at or below two compliance points: Roe Island (64 km) and Chipps Island (74 km). Lower X2 (i.e., X2 located farther downstream) was assumed to correspond to higher transport flows. This analysis was refined further by examining CALSIM II output for December through May X2 position for only the 20th–80th percentiles of exceedance plots. X2 position in this middle range had the greatest opportunity to vary among model runs because operational flexibility in the high (upper 20%) and low (lower 20%) ends of the X2 position range was low.

C.4.3.3.2 Particle Tracking Modeling (DSM2-PTM)

For delta smelt, DSM2 particle tracking–model results were used to predict the proportion of particles that would reach the low salinity zone (LSZ), which is approximated as Martinez (downstream limit of the Suisun Bay subregion), after 30 days. The starting distributions and other assumptions for the particle-tracking modeling are described in Appendix 5.B, *Entrainment*. The proportion of particles reaching Martinez was assumed to be directly proportional to transport and survival for larval delta smelt.

The particle-tracking approach for longfin smelt was similar to that described above for delta smelt but instead used the starting distributions described in Appendix 5.B, *Entrainment*, under longfin smelt larval entrainment (i.e., the wetter years and drier years distributions that were previously used by Baxter et al. [2009] in the longfin smelt incidental take permit analysis for the SWP) and evaluated the proportion of particles reaching Martinez for the period February through May.

C.4.3.3.3 X2 Relative-Abundance Regressions (Longfin Smelt)

The abundance of longfin smelt in the Fall Midwater Trawl (FMWT) has been correlated to the location of X2 in the preceding winter and spring months (December through May) (Kimmerer 2002; Kimmerer et al. 2009). While the mechanism behind this relationship is not well understood, one hypothesis is related to the transport of larval longfin smelt out of the Delta to rearing habitats downstream in the Suisun Bay subregion and beyond (Moyle 2002). At the same time, however, while there is a correlation between X2 and longfin smelt abundance, longfin smelt abundance also is significantly correlated with factors such as food abundance (discussed further in Chapter 5). Therefore, there is uncertainty that this evaluation correctly characterizes the mechanism behind the correlation. The X2–longfin smelt abundance relationship was used to evaluate the effects of the preliminary proposal on longfin smelt, under the assumption that lower X2 (farther downstream) would correspond to higher transport flows, which in turn would transport longfin smelt downstream more effectively and contribute to increased survival. Relationships between December and May X2 position and log longfin smelt abundance developed by Kimmerer et al. (2009) were used to determine how the changes in winter-spring X2 position described above might influence longfin smelt abundance the following fall. These relationships were developed using abundance data from the FMWT, Bay Midwater Trawl, and Bay Otter Trawl (Table C.4-13).

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

The log abundance values were interpreted as a relative survival index for each of these relationships, and were reverse log-transformed to determine how the preliminary proposal might influence actual numbers of longfin smelt surviving until the following fall.

Table C.4-13. Relationships between X2 and Longfin Smelt Abundance Indices (Log-Transformed) from Fall Midwater Trawls, Bay Midwater Trawl, and Bay Otter Trawl That Were Used to Estimate Preliminary Proposal Effects

Data Source	Number of Observations (Years)	Statistical Significance (*P* Value)	Intercept	Slope (± 95% Confidence Limits)	1987–1988 Step Change (± 95% Confidence Limits)
Fall Midwater Trawl	38	< 0.0001	7.0	-0.05 ± 0.01	-0.81 ± 0.28
Bay Midwater Trawl	26	0.0001	8.0	-0.06 ± 0.03	-0.75 ± 0.60
Bay Otter Trawl	27	< 0.0001	8.1	-0.06 ± 0.02	-0.46 ± 0.36

Source: Kimmerer et al. 2009.
Note: The 1987–1988 step change is included in order to account for possible reduced zooplankton prey abundance following the invasion of *Corbula amurensis*.

C.4.4 Delta Habitat (Plan Area) Methods

C.4.4.1 General Flow Changes in the Plan Area

Flows in the Plan Area were based on a compilation of information from the hydrologic modeling of changes in seasonal flows in the lower Sacramento River (Rio Vista model node), reverse flows in OMR, and lower Sacramento River stage each month over the 82-year hydrologic period, as well as data summarized by month and water-year type using frequency of exceedance plots. A summary of changes in Delta outflow also was used as an indicator of habitat conditions in the Delta. Comparisons were made using monthly flow estimates for Sutter and Steamboat sloughs as well as Geo/DCC flows. Changes in flows and flow patterns in these areas were used as comparative indices of changes in Delta habitat conditions. Results of frequency of exceedance analyses were used to assess changes in flows over a range of hydrologic conditions.

C.4.4.2 Yolo Bypass Floodplain Habitat (Conservation Measure 2 Yolo Bypass Fisheries Enhancement)

C.4.4.2.1 Sacramento Splittail Habitat Area

Sacramento splittail typically spawn in inundated floodplains and channel margins of the Sacramento, San Joaquin, and Cosumnes Rivers during late winter and spring (Moyle et al. 2004; Feyrer et al. 2005; Sommer et al. 2007). The most important spawning habitat occurs in the inundated floodplains of the Sutter and Yolo Bypasses of the Sacramento River. The preliminary proposal proposes in *CM2 Yolo Bypass Fisheries Enhancements* to increase the frequency and duration of Yolo Bypass inundation by lowering the height of a section of the Fremont Weir and replacing it with an operable gate.

This analysis of floodplain habitat availability addresses habitat availability for all floodplain-dependent life stages because the value of the habitat for the egg/embryo life stage is affected by the behavior (spawning adults) and survival (larvae and juveniles) of the other life stages that use that

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

habitat. Thus, for example, floodplain habitat with suitable conditions for survival of the egg/embryo stage has no habitat value unless it remains inundated long enough for later floodplain-dependent life stages to complete their development.

The hydrologic results of CM2 were assessed using daily CALSIM II output of the Sacramento River spills at the Fremont Weir and concurrent flows for the major west-side bypass tributaries. Predicted spill timing and volume over the weir were used to determine the timing, frequency, and duration of inundation events. The combined volume of flow from Fremont Weir spills and the west-side tributaries was used with MIKE 21 to estimate the areal extent of inundation with depths and water velocities in the bypass. Results of the 2-D modeling were used to estimate habitat availability for splittail with and without implementation of CM2. Inundated floodplain parameters were used to assess benefits to splittail reproduction.

The MIKE 21 flexible mesh model is modeling software used to develop a two-dimensional hydrodynamic model of the Yolo Bypass that predicts water surface elevation, flow, and average velocity at each computational grid cell. The model incorporates existing LiDAR and Toe Drain/Tule Canal bathymetry as well as estimated west-side tributary flows. Outputs of the model were used to predict the potential benefits to species that use the Yolo Bypass as habitat when inundated (e.g., splittail, Chinook salmon, etc.) and to food production.

There were 15 2-D scenarios run with the MIKE 21 model (Table C.4-14).

Table C.4-14. Description of Model Runs using MIKE 21 Yolo Bypass Model

Sacramento River Flow at Verona Sampling Range (cfs)		Restricted Notch Flow (cfs)	Knights Landing Ridge Cut (cfs)	Cache Creek (cfs)	Willow Slough (cfs)	Putah Creek (cfs)	West Side Tributaries Only[1]		West Side Tributaries Plus Notch Flow[2]	
							Run ID	Flow (cfs)	Run ID	Flow (cfs)
23,100	28,600	0	364	473	134	154	10A	1,125	10B	1,125
28,600	32,550	1,000	735	965	179	291	11A	2,170	11B	3,170
32,550	35,300	2,000	971	1,079	213	383	12A	2,647	12B	4,647
35,300	37,500	3,000	1047	1,344	243	439	13A	3,073	13B	6,073
37,500	39,200	4,000	998	1,235	329	415	14A	2,976	14B	6,976
39,200	40,750	5,000	1,359	2,227	353	403	15A	4,343	15B	9,343
40,750	42,150	6,000 (A)	1,654	1,891	218	273	16A	4,037	16B	10,037
54,000	56,000	6,000 (B)	1,911	3,190	428	760	17A	6,289	17B	12,289

[1] Without CM2.
[2] With CM2.

Post-processing analysis of the modeling results included the following assumptions regarding splittail habitat.

- Depth is the most important quantifiable habitat attribute for splittail on the floodplain. Flow velocity is also quantifiable, but model runs indicated that it is consistently low over much of the bypass at all flow rates, which makes it suitable for early stages of splittail.
- Shallow water habitat (less than 2 meters depth) must be inundated continuously for longer than 30 days to provide reproductive benefits for splittail. Thirty days is the estimated minimum time required for development from splittail eggs to emigrating juveniles, based on estimated

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

values reported in the literature (e.g., Feyrer et al. 2004, 2006; Moyle et al. 2004; Sommer et al. 2007). The threshold for depth, 2 m, is based on results from Sommer and coauthors (2004, 2008) and Feyrer and coauthors (2006).

- Only floodplain inundation between February 1 and June 30 benefits splittail. This period was used because year-class abundance of splittail is determined primarily by floodplain spawning and rearing habitat conditions during these months (Sommer pers. comm.).
- HSI values for depth ranges for young splittail were estimated from results in Sommer and coauthors (2008) and discussions with Dr. Sommer as follows: 0 to 1.5 feet = 1.0, deeper than 1.5 to 4.5 feet = 0.5, deeper than 4.5 to 6.5 feet = 0.16, and deeper than 6.5 feet = 0.

An index of Yolo Bypass splittail habitat was computed as the surface area of habitat of the depth ranges listed in the assumptions above weighted by their HSI values and summed over days from February 1 to June 30, but only following 30 days of continuous bypass inundation. It should be noted that MIKE 21 cannot simulate inundated surface areas greater than about 25,000 acres in the bypass because it is designed to model flows only up to those expected in the bypass when the Fremont Weir, with the proposed notch, has just begun to spill. Higher inundated surface areas are expected to be similar among the different scenarios. In addition, surface areas were not estimated for bypass flows (weir plus west-side tributaries) less than 1,185 cfs because this is the lowest flow included in the model simulations.

C.4.4.2.2 Stranding (Steelhead, Chinook Salmon, Sacramento Splittail, White Sturgeon, and Green Sturgeon)

Increased Yolo Bypass floodplain inundation that would occur under the preliminary proposal increases the risk of stranding of covered fish species that may occupy the bypass during their lives, in particular salmonids, Sacramento splittail, and sturgeons. An assessment of this potential negative effect was conducted using best professional judgment and the 2009 DRERIP evaluation of Fremont Weir and Yolo Bypass Inundation (previously referred to as Water Operations Conservation Measure 2), Outcome N3 (Increased stranding of covered species). As with all DRERIP evaluations, the outcomes were rated on a scale of 1–4 for magnitude of the effect on the population and certainty of the outcome (4 being the greatest effect on the population or highest certainty).

C.4.4.2.3 Fall-Run Chinook Salmon Fry Yolo Bypass Growth Analysis

Yolo Bypass Fry Rearing Model Methods

[***Note to Reader:*** *Below ICF presents the results of the first version of the Yolo Bypass Fry Rearing Model. While the model has been developed and revised based on informal review by agency personnel, it is anticipated that further revision will be undertaken in response to formal comments received from this first, documented version of the model and additional meetings with agency personnel. In particular, ICF anticipates conducting analyses for several runs of Chinook salmon fry.*]

To inform the evaluation of CM 2 Yolo Bypass Fisheries Enhancement in relation to potential Chinook salmon growth and survival benefits associated with proposed Fremont Weir modifications and increased floodplain rearing opportunities in the Yolo Bypass, a spreadsheet model, the Yolo Bypass Fry Rearing (YBFR) model, was developed. The YBFR model was designed to evaluate potential benefits by simulating variation in the daily percentages of Chinook salmon fry entering the Yolo Bypass and tracking their relative growth and survival to the estuary and ocean fishery.

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

The following text describes the model development, data sources, functional components, and results of the initial application of the model to the BDCP scenarios and Fremont Weir modifications. The results of the model are provisional as the functional components and assumptions may be revised pending review and completion of other supporting analyses.

Model Development and Overview

The model was formulated as an Excel spreadsheet that can be readily modified to evaluate and compare the effects of alternative hydrologic and Fremont Weir structural and operational conditions. The model currently addresses fall-run Chinook salmon but can be modified to address other runs. Fall-run Chinook salmon were selected because of the relatively large amount of information on the floodplain ecology of fall-run Chinook salmon in the Central Valley.

The YBFR model uses a daily timestep to track the daily percentages and growth of juvenile Chinook salmon that enter the Yolo Bypass or remain in the Sacramento River downstream of the Fremont Weir. The percentages of fish entering the Yolo Bypass are simulated as a function of upstream flows and the frequency and duration of Fremont Weir spills under existing and proposed structural and operational scenarios. Differential growth and survival rates are applied depending on the migration route and availability of floodplain habitat. The size of fish entering the estuary is determined based on travel time, availability of floodplain habitat, and the duration of floodplain inundation. The relative benefits of each of the scenarios are evaluated in terms of the annual percentages of juveniles entering the Yolo Bypass and the relative contributions of these year classes to the ocean fishery. For the purposes of this analysis, fall-run Chinook salmon juveniles that enter the lower Sacramento River (i.e., migrate past the Fremont Weir or enter the Yolo Bypass) at a mean size of 50 mm or less are identified as fry. This distinction is made because juveniles in this size range are the most sensitive to the effects of flow on downstream movements and spills into the Yolo Bypass. In addition, juveniles in this size range are most likely to benefit from floodplain rearing because of their small size and requirement for additional freshwater growth before entering the estuary.

This analysis is based on simulated hydrology (CALSIM results) and synthesized daily flows in the Sacramento River at Wilkins Slough, Sacramento River at Fremont Weir, and daily spills at Fremont Weir for the period 1921–2003 for the baseline (EBC) and preliminary proposal (PP) scenarios. It is emphasized that CALSIM II is a monthly timestep model. All the decisions in the CALSIM II model occur on a monthly timestep. Daily flow patterns used in the YBFR model are provided only to improve the estimates of flows such as the weir spills. CALSIM II does not necessarily comply with regulatory constraints and operational requirements on a daily timestep. This analysis does not imply that all the flow requirements are complied with on a daily timestep, but daily data are used to provide an indication of sub-monthly trends.

Functional Components of Model

Temporal Distribution of Fry at Fremont Weir

Fall-run Chinook salmon fry are tracked as daily cohorts passing Fremont Weir or entering the Yolo Bypass during the primary fall-run emigration period (December 1–June 30). The migration patterns of Chinook salmon fry in the Sacramento River are tied to flow, with peak fry movements generally corresponding to the first major flow peaks during the fry rearing and emigration season. A preliminary analysis of this relationship for winter-run Chinook salmon indicates that the peak fry movements past Knights Landing typically are triggered by flows of 400 m^3/sec (approximately 14,000 ft^3/sec) measured at Wilkins Slough (Redler pers. comm.). This threshold response is also

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

evident for fall-run Chinook salmon juveniles (identified using size-at-date criteria) trapped at Knights Landing in 1996–1999 and 2002 (Snider and Titus 1998, 2000a, 2000b, 2000c).

Based on examination of fall-run migration patterns at Knights Landing (weekly catches standardized by sampling effort), the following assumptions were developed to simulate weekly changes in the relative abundance of fry in the Sacramento River at the Fremont Weir (weekly percentages of fry emigrating past the Fremont Weir):

- Pulses of fry are triggered by weekly average flow ≥14,000 ft^3/sec at Wilkins Slough between January 1 and March 10.
- 30% of fry approach the Fremont Weir in the 2 weeks following the flow trigger.
- Multiple fry pulses can occur if flow drops below and then increases above 14,000 ft^3/sec more than once during the January 1–March 10 window.
- Assumes the following default distribution if flow trigger does not occur:
    - December 10–December 31: 1% per week.
    - January 1–March 10: 5% per week.
    - March 11–June 30: 0–4% per week depending on percentage passing earlier in season.

It should be noted that these rules were based on weekly catch, effort (hours fished), and flow data, and may be modified following completion of an analysis of historical daily catch and flow data being conducted by the California Department of Fish and Game. Currently, the spreadsheet partitions the weekly percentages of fish into equal daily percentages over the 7-day catch week to accommodate a daily timestep.

A multiplier has been built into the spreadsheet to convert daily percentages of fry to numerical abundance. This multiplier is the total number of juveniles (in millions) approaching the Fremont Weir over the entire emigration season, and can be fixed or allowed to vary to reflect annual variation in upstream fry production. The initial model runs have assumed a fixed total of 30 million juveniles approaching Fremont Weir per year.

Percentages of Fry Entering Yolo Bypass

The percentage of fry entering the Yolo Bypass during a given timestep is assumed to be the percentage of the population emigrating past the Fremont Weir multiplied by the percentage of the Sacramento River flow spilling over the Fremont Weir into the Yolo Bypass. This percentage can be adjusted to reflect a higher or lower probability of fry entering the bypass depending on their susceptibility to encountering the weir. For example, somewhat higher percentages of fry may enter the bypass than would be suggested by the percentage of flow alone because of the tendency of fry to occur along the margins of large rivers.

Currently, it is assumed that the Knights Landing catch data provide a reasonable approximation of migration timing and relative abundance of juveniles passing the Fremont Weir. A major limitation of this approach is that it does not account for the contributions of Chinook salmon juveniles from other sources, including the Sutter Bypass, Butte Creek, and Feather River. The temporal distribution and relative contribution of fall-, late fall–, winter- and spring-run Chinook salmon juveniles from these sources would be expected to vary with hydrologic conditions and flow contributions from these sources.

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

Size and Growth of Fry in Sacramento River and Yolo Bypass

The mean size of fish in each daily cohort of fry passing the Fremont Weir was based on the mean size of fall-run Chinook salmon observed in the daily catches at Knights Landing in 1996–1999 and 2002 (Snider and Titus 1998, 2000a, 2000b, 2000c) (Figure C.4-11). Subsequent growth of fish depends on their migration route (Sacramento River or Yolo Bypass), presence of significant floodplain habitat (Yolo Bypass route only), and duration of floodplain inundation.

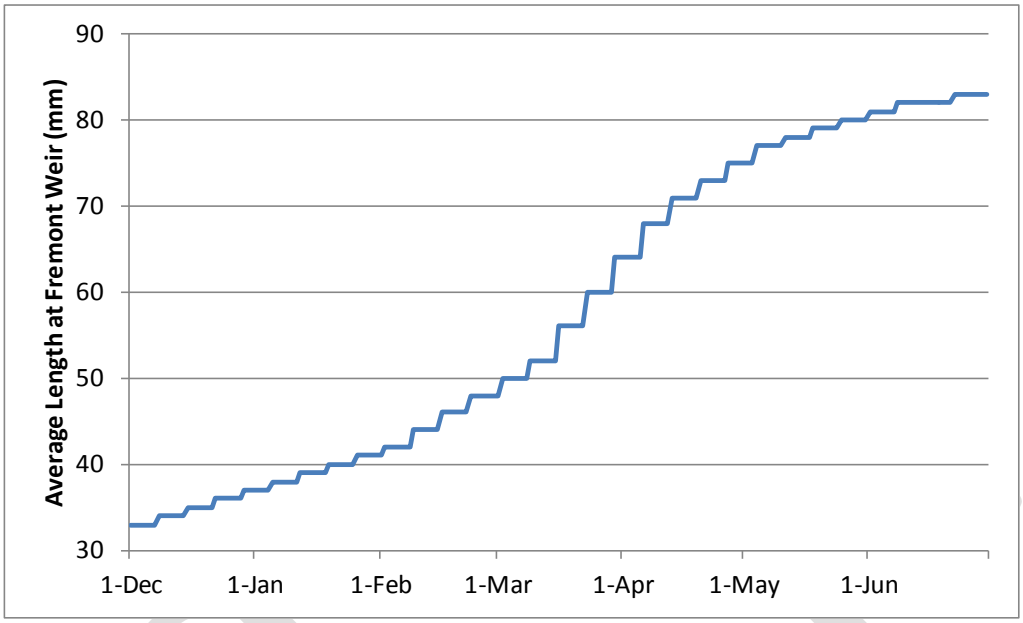


Figure C.4-11. Weekly Average Size of Fall-Run Chinook Salmon Captured by Rotary Screw Trap at Knights Landing in 1996–1999 and 2002

Based on comparative growth studies of Chinook salmon juveniles in Central Valley floodplain (or off-channel) and main channel habitats (Sommer et al. 2001; Jeffres et al. 2008; Limm and Marchetti 2009), the recommended ranges of growth rates for evaluating the potential benefits of floodplain rearing in the Yolo Bypass were 0.52–0.68 mm/d for the Yolo Bypass and 0.24–0.48 mm/d for the Sacramento River. Based on the sizes of fish in these studies, these rates correspond roughly to rates of 0.8–1.0% change in length per day for floodplain-rearing fish and 0.5–0.8% change in length per day for non-floodplain-rearing fish.

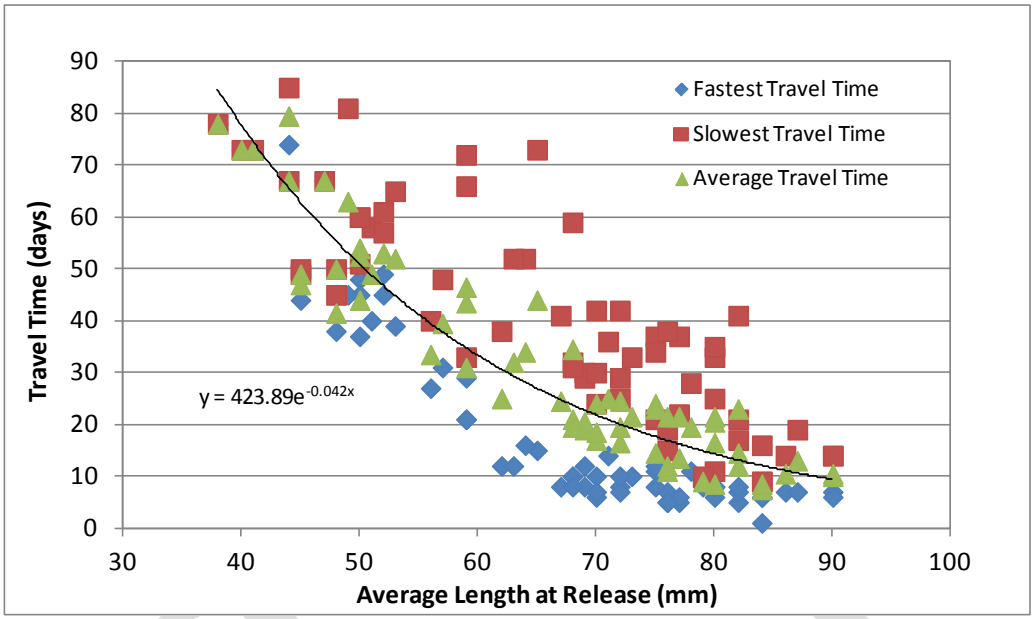
The following assumptions were applied to characterize growth of juveniles in the Yolo Bypass and Sacramento River.

- The growth rate of floodplain- and non-floodplain-rearing juveniles was set at 1.0% and 0.8%, respectively (change in body length per day). This is roughly equivalent to a growth rate of 0.7 mm/d and 0.5 mm/d for a 50-mm fish.
- Floodplain growth benefit occurs only when Fremont Weir spills are ≥3,000 ft^3/sec (corresponds to overbank flows in Toe Drain and initial floodplain inundation of Yolo Bypass).
- Growth rate of fry in the Sacramento River is the same as non-floodplain-rearing fish in the Yolo Bypass (i.e., fish in Yolo Bypass when spills are <3,000 ft^3/sec).
- Growth rate of floodplain-rearing juveniles in the Yolo Bypass shifts to that of non-floodplain-rearing fish when fish leave the Yolo Bypass.

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

Residence Time

The migration rate or residence time of daily cohorts of juveniles migrating down the lower Sacramento River or Yolo Bypass is determined by their mean size upon reaching the Fremont Weir. This relationship is based on average travel time (average number of days since release) of tagged hatchery fall-run juveniles released in the Sacramento River upstream of the Fremont Weir and recaptured at Chipps Island between 1980 and 2001 (Figure C.4-12).



Source: U.S. Fish and Wildlife Service unpublished data.

Figure C.4-12. Travel time (average number of days since release) of tagged hatchery fall-run Chinook salmon juveniles released in the Sacramento River upstream of the Fremont Weir and recaptured at Chipps Island between 1980 and 2001

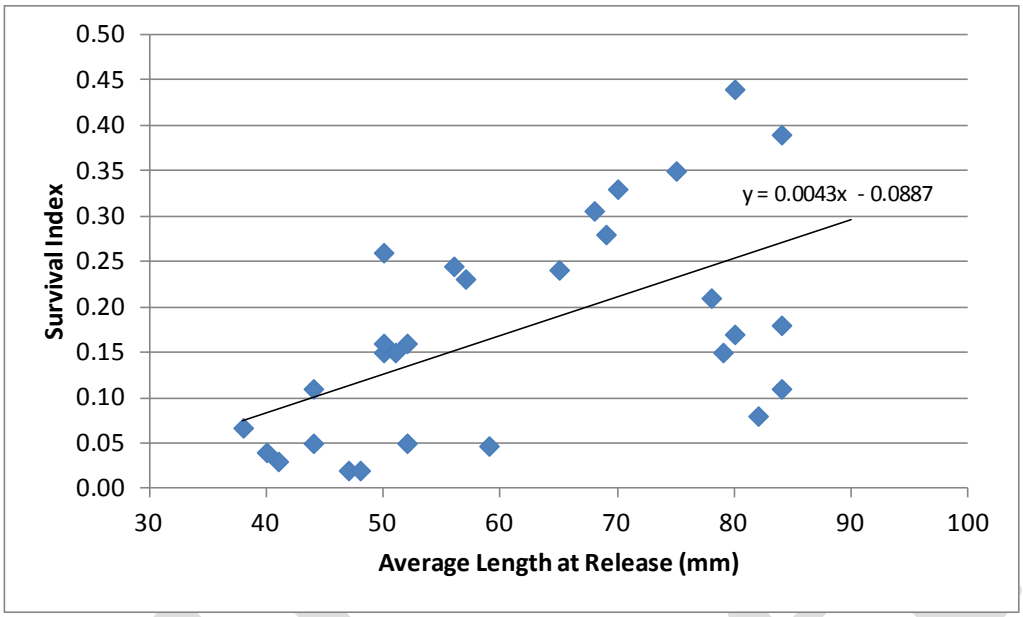
It is assumed that travel time in the lower Sacramento River or Yolo Bypass between the Fremont Weir and Chipps Island varies according to this relationship unless modified by floodplain habitat availability. Specifically, all fish that enter the Yolo Bypass when Fremont Weir spills are ≥3,000 ft^3/sec remain in the Yolo Bypass for the duration of the flood event (exiting the bypass 7 days after spills cease to account for floodplain drainage) regardless of residence time. However, if these drainage events occur before the end of the residence period, the fish are assumed to spend the remainder of this period in the Delta before entering the estuary. This simplification is intended to capture the maximum growth opportunity associated with floodplain rearing. Although residence time of juveniles in the Yolo Bypass is variable, the extended period of floodplain rearing is supported by the relatively slow migration rate, substantial growth, and relatively high concentration of juveniles moving off the floodplain during drainage events (Sommer et al. 2005).

Survival to Estuary

Survival to the estuary (i.e., to Chipps Island) was computed from a regression of survival indices versus size at release of coded-wire-tagged (CWT) hatchery juveniles released in the Sacramento River upstream of the Fremont Weir and recaptured at Chipps Island between 1980 and 2001 (Figure C.4-13). The Chipps Island survival indices are the observed recovery rate (number of fish recovered divided by number released) scaled by a measure of gear efficiency. The data used in the

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

regression were limited to releases of fish classified as fall-run Chinook salmon and released during the primary fall-run Chinook salmon emigration period (January–June). Most of the releases were made in the Sacramento River at Red Bluff Diversion Dam and in Battle Creek at Coleman National Fish Hatchery.



Source: U.S. Fish and Wildlife Service unpublished data.

Figure C.4-13. Survival Indices for Tagged Hatchery Fall-Run Chinook Salmon Juveniles Released in the Sacramento River Upstream of the Fremont Weir and Recaptured at Chipps Island between 1980 and 2001

The survival index–body size relationship was applied to account for the effects of size at migration on survival and does not explicitly account for the effects of flow, migration route, floodplain availability (acre-days), or other environmental variables that may affect overall survival to the estuary. Very few data are available to examine potential differences in survival between juveniles migrating to the estuary via the main channel of the Sacramento River and those migrating to the estuary via the Yolo Bypass. Limited results from experimental releases of tagged fry in the Yolo Bypass and adjacent Sacramento River suggest that survival to the estuary and ocean fishery were at least comparable for these two groups and may in some years be substantially higher for salmon that migrate through the Yolo Bypass (Sommer et al. 2005, 2001). In this analysis, the survival of juveniles to the estuary is assumed to be 20% higher for fish rearing on the Yolo Bypass floodplain relative to fish rearing in the Sacramento River, and it is assumed that further refinement of this assumption will occur following detailed review of the model.

Ocean Survival Index

Ocean recovery rates are the observed recovery rate (number of fish recovered in the ocean commercial and sport fisheries divided by number released) expanded for sampling effort. Recovery rates of hatchery Chinook salmon juveniles released in the estuary and recovered in the ocean fishery were used to develop a general relationship between size of juveniles entering the estuary and relative survival to the ocean fishery. Relative survival to the ocean fishery was computed from a general relationship between ocean recovery rate and mean size at release of CWT hatchery

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

juveniles released in the estuary between 1993 and 2006 (Figure 4). The data examined were limited to releases of juveniles classified as fall-run Chinook salmon and released during the primary smolt migration period (April–June). Most of the releases were made in the Sacramento River at Red Bluff Diversion Dam and in Battle Creek at Coleman National Fish Hatchery.

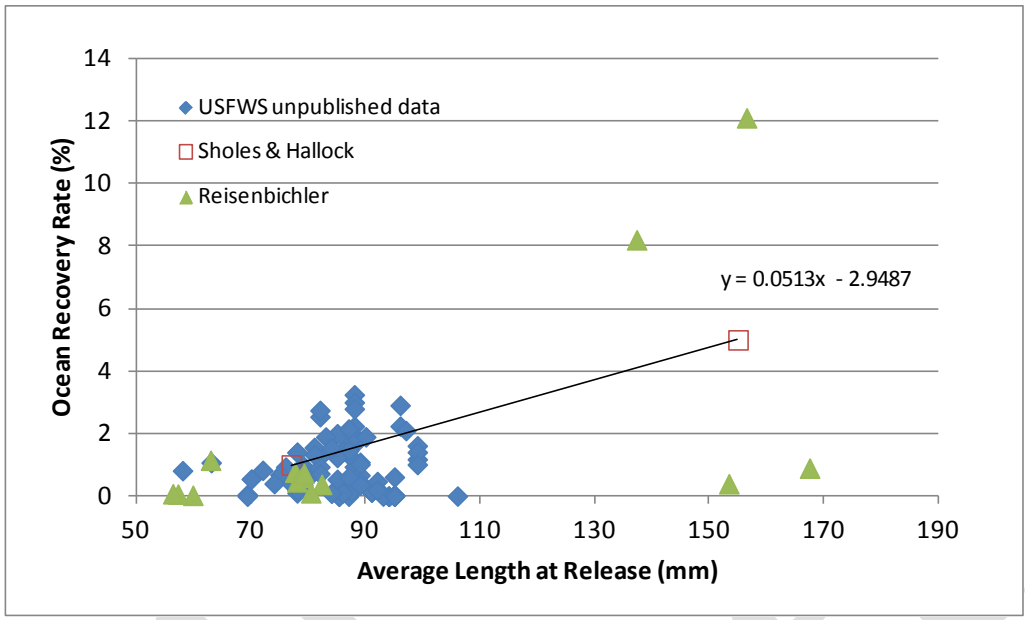


Figure C.4-14. Estimated Ocean Recovery Rates for Tagged Hatchery Fall-Run Chinook Salmon Juveniles Released in the Estuary between 1993 and 2006

Although highly variable (due in part to annual variation in fishing effort), the data indicate a general positive relationship between body size and subsequent fishery returns. This relationship also is supported by the results of two evaluations of the effect of release size and return rates for hatchery fall-run Chinook salmon released from Sacramento River basin hatcheries between 1955 and 1973 (Reisenbichler 1981; Sholes and Hallock 1979). The regression equation used in the model was based on the Sholes and Hallock data, which characterize the general trend in the data.

C.4.4.3 Wetland and Riparian Bench Inundation (Juvenile Salmonids)

A number of Delta levees maintained by USACE and DWR incorporate habitat benches (also referred to as *relic benches*). These are shallow areas along the channel margins that have shallower slopes (e.g., 1:10 instead of the customary 1:3) and are designed to be wetted or flooded during certain parts of the year to provide habitat for covered fish and other species. Generally, there are two types of habitat benches: wetland benches and riparian benches. Wetland benches are at lower elevations where more frequent wetting and inundation may be expected, and riparian benches occupy higher portions of the slope where inundation is restricted to high-flow events. Benches were planted and often secured with riprap or other materials.

Preliminary proposal covered activities that would result in changes in river stage, and inundation frequency and duration of wetland benches, include water operations (reductions in flow below the north Delta diversions; increased flow down the Yolo Bypass into the Cache Slough subregion) and habitat restoration (tidal muting in areas upstream of Restoration Opportunity Areas [ROA]). A

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

comparison of bench elevation data with modeled river stage was conducted at each of 11 wetland benches for which elevation data were available (Figure C.4-15).

Daily river stage outputs from DSM2-HYDRO at the node nearest to each habitat bench were paired with each particular bench. Sites that included several habitat benches with identical elevations close to the same DSM2-HYDRO node were combined for the analysis (i.e., sites 3, 4, and 5; sites 6 and 7) (Figure C.4-15). Because actual elevations of habitat benches varied among sites, inundation frequencies were derived for four different elevations (0, 2, 4, and 6 feet [North American Vertical Datum of 1988 (NAVD 88)]) representing hypothetical bench habitats occurring at these elevations. This facilitated a systematic cross-comparison among sites, without the confounding effect of varying elevations of actual habitat benches. By comparing inundation frequencies across different scenarios and time horizons, we were able to address potential effects of PP on the frequency of bench inundation and hence the functionality of habitat benches under difference scenarios. The lower elevations were assumed to represent the intertidal portion of habitat benches, whereas the higher elevations were assumed to represent the riparian portion of habitat benches.

If the minimum daily stage at the respective site exceeded the elevation of the site, the site was deemed to be completely inundated for a full 24-hour period. The frequency of inundation was calculated as the number of days during which river stage exceeded the minimum elevation of the habitat bench for all model scenarios at each site.

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

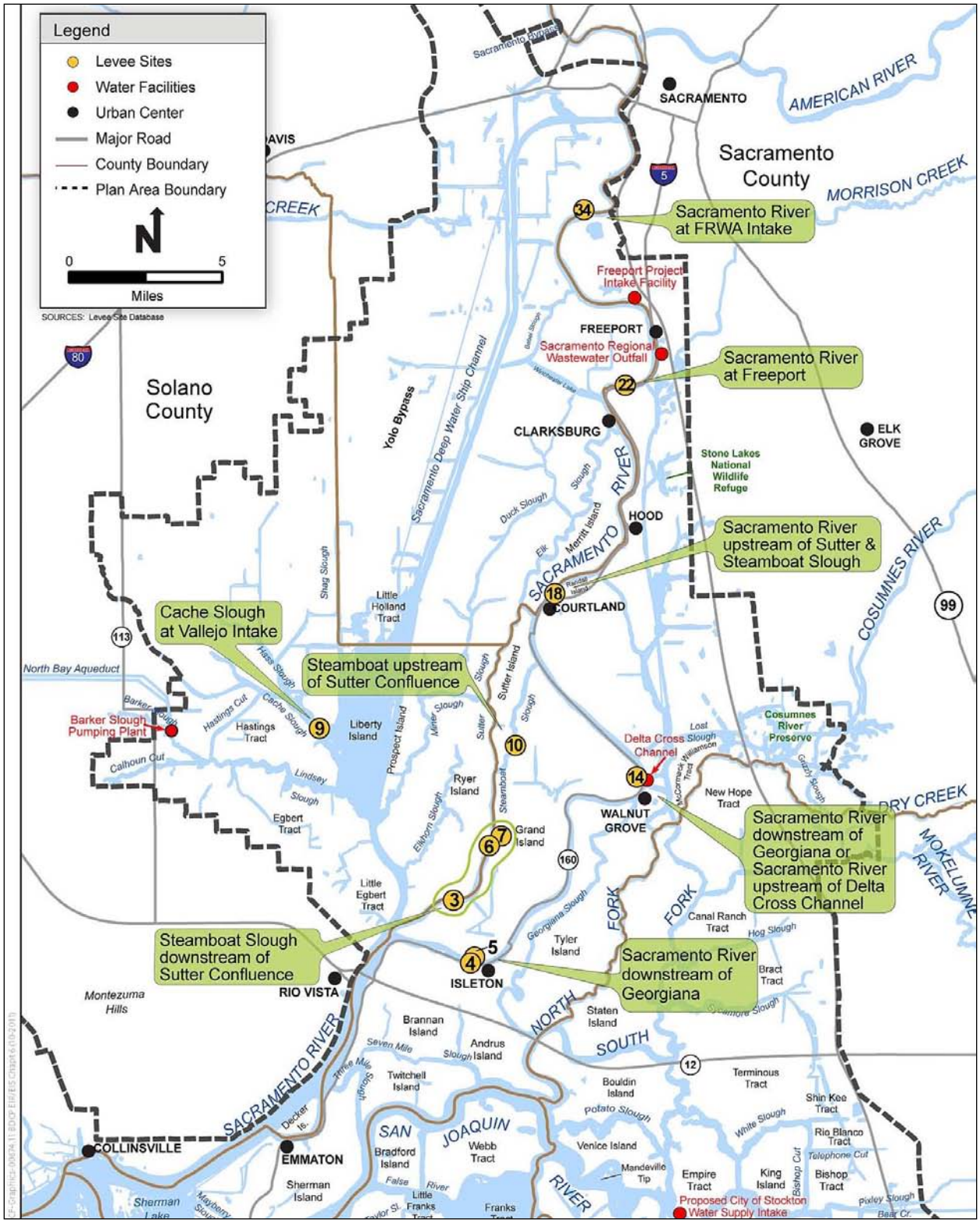


Figure C.4-15. Bench Habitat Analysis Sites

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

C.4.4.4 Water Temperature

Although the primary factor determining water temperatures in the Delta is atmospheric temperature, water temperature could be affected by water operations if residence time, depth, and water velocity change. Daily water temperature was estimated for each model scenario using the DSM2-QUAL nutrient model, which covers water years 1976–1991. Daily data for several stations in each subregion were averaged by subregion (Table C.4-15); in the South Delta subregion, the San Joaquin River stations were kept separate because they had notably higher flows than the remaining stations.

Table C.4-15. DSM2-QUAL Stations Used to Analyze Temperature Effects in the Plan Area

Subregion	Stations
Cache Slough/Sacramento Deepwater Ship Channel	Cache Ryer; ALL_YOLO_OUT; CHAN 405_0; CHAN 409_0; CHAN 402_LENGTH
North Delta	RSAC155; RSAC139; RSAC128; RSAC123; SLSBT011
East Delta	RSMKL024; RSMKL008; RMKL005; RMKL019
South Delta	RMID015; RMID027; CHVCT000; ROLD014; ROLD040; Mildred
San Joaquin	RSAN058; SJR_Brandt_Br; RSAN087
West Delta	RSAC101; RSAC092; PO-649; Franks Tract; RSAN032; Twitchell; RSAC081; RSAC077; Sherman Lake; RSAN007; RSAN018
Suisun Bay	Suisun-Volanti; MontSl_Bend2; SLMZU011; SLGYR003
Suisun Marsh	RSAC054; RSAC064; SLM001 (SLML001); Grizzly; Honker

For each species and life stage, the number of days above certain temperature thresholds or in certain temperature ranges was calculated by year and month to describe differences between existing biological conditions and preliminary proposal scenarios (Table C.4-16). For delta smelt, the median spawning date based on a spawning temperature range of 15°C–20°C in winter-spring also was assessed because temperature changes may shift the spawning period in relation to other potentially important variables such as flow and day length (Wagner et al. 2011). As described in Appendix 2.A, *Species Accounts*, juvenile delta smelt are found in the LSZ and may migrate upstream and downstream in association with it, although other factors contribute to their distribution. There is the potential for delta smelt to move into habitat of a different temperature as salinity (or some other habitat feature associated with salinity) changes location in relation to water operations. In summer, X2 generally moves upstream under the preliminary proposal (see *Results* below), and juvenile delta smelt generally would be expected to move upstream as well. Therefore, a greater proportion of the population would be expected to move into the West Delta subregion from the Suisun Bay subregion. The potential effects of such a movement were examined by comparing the number of stressful (20°C–25°C) and lethal (>25°C) days in the Suisun Bay subregion for the EBC2_ELT and EBC2_LLT scenarios with the number of stressful and lethal days in the PP_ELT and PP_LLT scenarios in the West Delta subregion, for each water year in the 1976–1991 DSM2-QUAL simulation.

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

Table C.4-16. Temperature Thresholds or Ranges Examined for Differences between Preliminary Proposal and Existing Biological Conditions Scenarios

Species	Life Stage (Function)	Threshold or Range	Reference
Steelhead	Juvenile (Rearing)	Suboptimal (<10°C), optimal (10–18°C), supraoptimal (>18°C–26°C), lethal (26°C)	Moyle et al. 2008
	Juvenile (Smoltification)	Suboptimal (<7°C), optimal (7–15°C), supraoptimal (>15°C–24°C), lethal (>24°C)	Moyle et al. 2008
	Adult (Migration)	Suboptimal (<10°C), optimal (10–20°C), supraoptimal (>20°C–23°C), lethal (>23°C)	Moyle et al. 2008
Chinook Salmon	Juvenile (Rearing)	Suboptimal (<13°C), optimal (13–20°C), supraoptimal (>20°C–24°C), lethal (>24°C)	Moyle et al. 2008
	Juvenile (Smoltification)	Suboptimal (<10°C), optimal (10–19°C), supraoptimal (>19°C–24°C), lethal (>24°C)	Moyle et al. 2008
	Adult (Migration)	Suboptimal (<10°C), optimal (10–20°C), supraoptimal (>20°C–21°C), lethal (>21°C)	Moyle et al. 2008
Delta Smelt	Juvenile (Rearing)	Stress (20°C–25°C), lethal (>25°C)	Wagner et al. 2011
	Adult (Spawning)	Median day of the year (15°C–20°C)	Wagner et al. 2011
Longfin Smelt	Juvenile (Rearing) and Adult (Residence)	>20°C	Moyle 2002
White Sturgeon	Juvenile (Rearing), Adult (Migration)	Stress (>20°C), upper limit (>25°C)	Cech et al. 1984; Geist et al. 2005; Israel et al. 2009
Green Sturgeon	Juvenile (Rearing)	>18.9°C (supraoptimal), >24°C (upper limit), >27°C (lethal)	Israel and Klimley 2008;, NMFS (74 FR 52300)
	Adult (Migration)	>24°C (upper limit of oxygen binding), >27°C (lethal)	Erickson et al. 2002; Heublein et al. 2009
Pacific Lamprey and River Lamprey	Macropthalmia and Adult (Migration)	>25°C	Moyle et al. 1995

C.4.4.5 Dissolved Oxygen

Changes to the foodweb as a result of the preliminary proposal may alter the amount of biochemical oxygen demand, which, when combined with changes to residence time and water temperatures as a result of the preliminary proposal, can alter the concentration of DO in Delta channels. Two sets of analyses were conducted to assess potential changes in DO. At the broad scale, spatial and seasonal patterns of DO concentrations in the Delta for the six scenarios were analyzed using DSM2-QUAL estimates for the stations in the subregions shown in Table C.4-16 (*Temperature* subsection above). The DSM2-QUAL nutrient model was used for each model scenario to estimate DO concentrations because of the combined changes in hydrology, phytoplankton production, residence time, and

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

water temperature. The Water Quality Control Plan for the Sacramento River and San Joaquin River Basins (Central Valley Regional Water Quality Control Board 2009) sets DO objectives for the Delta. The objectives are 7.0 mg/L for the Sacramento River (below the I Street Bridge) and all Delta waters west of the Antioch Bridge, 6.0 mg/L for the San Joaquin River (between Turner Cut and Stockton from September 1 through November 30), and 5.0 mg/L for all other Delta waters. Analyses were conducted in relation to these general criteria because few species-specific criteria are given for covered species in the DRERIP conceptual models. An exception is white sturgeon, for which Israel and coauthors (2009) suggested increased levels of stress occur when DO levels are less than 56% of saturation. A rough estimate of the equivalent of 56% saturation in milligrams per liter was obtained through back calculation to predict oxygen solubility in water under a temperature of 68°F (20°C), which equals 4.85 mg/L using a pressure of 720 torr. DO estimates were examined in relation to this criterion for both white and green sturgeon.

At the smaller scale, effects of water operations on the potential for DO were examined using modeled residence times of particles released at Rough and Ready Island as a surrogate for the multiple impaired sloughs in this area (e.g., Pixley Slough, Mosher Slough, Five Mile Slough) (Central Valley Regional Water Quality Control Board 2009). Residence time was estimated by DSM2-PTM up to the time at which 50% of the particles leave the Delta (from exiting the west end at Martinez, SWP/CVP exports, or agricultural diversions). The assumption was that increased residence time would increase the potential for reduced DO levels in these impaired sloughs.

The effects analysis of *CM14 Stockton Deep Water Ship Channel Dissolved Oxygen Levels* on DO is described under *Passage, Movement, and Migration Methods*.

C.4.4.6 Turbidity (Water Clarity)

Water clarity is an important flow-related habitat feature that correlates with the presence of covered species such as delta smelt. No turbidity (water clarity) model exists that is suitable for full integration with other effects analysis tools such as CALSIM. Instead, potential changes in water clarity between the preliminary proposal and existing biological conditions scenarios were assessed for each Plan Area subregion using best professional judgment based on existing published and unpublished literature, particularly the DRERIP conceptual model for sediment (Schoellhamer et al. 2007), and consideration of changes in biological components of turbidity and the likelihood of each subregion becoming erosional/depositional or experiencing changes in wind-driven resuspension of sediment given the anticipated extent of restoration in each ROA.

C.4.4.7 Delta Smelt Fall Abiotic Habitat Index

Potential differences between the preliminary proposal and existing biological conditions in the extent of abiotic habitat for delta smelt in the fall (older juvenile rearing and maturation period) as a function of changes in flows were assessed using a technique based on the method of Feyrer and coauthors (2011). (Appendices 5.G, *Fish Life Cycle Models*, and 5.E, *Habitat Restoration*, include additional analyses of effects on delta smelt related to habitat. The results of this method will be interpreted with consideration of those additional analyses in determining the population-level effect on delta smelt. Chapter 5 considers all of these potential effects on delta smelt to make a final determination on the effects on abundance.) In this section, only the results of the application of the Feyrer and coauthors (2011) method are presented.

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

Feyrer and coauthors (2011) demonstrated that X2 in the fall correlates nonlinearly with an index of delta smelt abiotic habitat in the West Delta, Suisun Bay, and Suisun Marsh subregions. In addition to habitat in these subregions, investigations in recent years have suggested that delta smelt occur year-round in the Cache Slough subregion, including Cache Slough, Liberty Island, and the Sacramento Deep Water Ship Channel (Baxter et al. 2010; Sommer et al. 2011). Whether the same individuals are residing in these areas for their full life cycles or different individuals are moving between upstream and downstream habitats is not known (Sommer et al. 2011). The delta smelt fall abiotic habitat index is the surface area of water in the west Delta, Suisun Bay, and Suisun Marsh weighted by the probability of presence of delta smelt based on water clarity (Secchi depth) and salinity (specific conductance) in the water. Feyrer and coauthors' method found these two variables to be significant predictors of delta smelt presence in the fall and also concluded that water temperature was not a predictor of delta smelt presence in the fall, although it has been shown to be important during summer months (Nobriga et al. 2008).

The extent of the low-salinity zone, which is determined by the location of the X2 isohaline, largely overlaps with the distribution of other essential physical resources and key biotic resources that are necessary to support delta smelt, but is not the only factor that defines the extent of habitat for delta smelt. The delta smelt fall abiotic habitat index developed by Feyrer and coauthors (2011) is based on the probability of presence of delta smelt given certain water clarity and salinity and does not account for other abiotic (e.g., water velocity, depth) and biotic (e.g., food density) factors that may interact with water clarity and salinity to influence the probability of occurrence. The three physical variables (temperature, salinity, and turbidity) combined could explain just a quarter of the variance in patterns of delta smelt presence and absence in the estuary. It is unclear what portion of that fractional explained variance is actually due to turbidity, rather than salinity. (Temperature was not found to be important in the fall.)

The Feyrer 2011 method is based on only 75 of 100 FMWT survey stations in the Delta, which are already disproportionally located in areas that typically experience a circumscribed range of low-salinity conditions. The index reflects the probability of occurrence of delta smelt in the West Delta, Suisun Bay, and Suisun Marsh subregions and does not account for the individuals located in other areas such as the Cache Slough subregion, where a large portion of the total population may exist. Additionally, the overall relationship between X2 and the delta smelt fall abiotic habitat index is the result of two linked statistical analyses, each of which has uncertainty that is compounded when the analyses are combined. The National Research Council (2010) has expressed concern about the effects of compounding uncertainty in linked statistical analyses such as Feyrer and coauthors' (2011) analysis and its implication for quantitative conclusions. Additionally, they noted that the "weak statistical relationship between the location of X2 and the size of smelt populations makes the justification for this action [the prescribed locations for X2 in the Delta in wet and above-normal years] difficult to understand. In addition, although the position of X2 is correlated with the distribution of salinity and turbidity regimes (Feyrer et al. 2007), the relationship of that distribution and smelt abundance indices is unclear" (National Research Council 2010). Nevertheless, this method has been previously applied to analyses for delta smelt habitat and therefore also is included in this effects analysis.

The following sections provide a brief overview of the Feyrer and coauthors (2011) method followed by details on how the method was adapted for use in the effects analysis.

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

C.4.4.7.1 Development of the Original X2–Fall Abiotic Habitat Index

The methods for developing the abiotic habitat index and its relationship to X2 are described in more detail by Feyrer and coauthors (2011). The description below is adapted from their account.

FMWT survey data were used to develop the index. The FMWT samples approximately 100 stations across the estuary each month from September to December (Stevens and Miller 1983). A subset of 73 of the 100 stations was used for analyses to avoid including stations where sampling had not occurred consistently or where delta smelt were rare. Each station was sampled once per month, each of the four months, from 1967 to 2008 with a single 10-minute tow. The only exceptions were that sampling was not conducted in 1974 and 1979, and in 1976 was conducted only in October and November. Measurements of the water quality variables normally are taken coincident with each sample. In total, there were nearly 14,000 individual samples with complete data for analysis spanning 42 years.

Generalized additive modeling (GAM) was used to estimate the probability of occurrence of delta smelt at a trawl station in a given month and year based on water temperature (°C), water clarity (Secchi depth, meters), and salinity (specific conductance, microSiemens per centimeter [µs/cm]). The probability of occurrence (i.e., presence-absence data) was used as the dependent variable rather than a measure of abundance (e.g., catch per trawl) to minimize the possible influence of outliers and bias associated with long-term abundance declines. This approach is supported by recent simulations, based on assumed underlying statistical distributions of fish catch, that suggest habitat curves based on presence-absence are conservative relative to catch per trawl because high frequencies of occurrence could be associated with both high and moderate catch per trawl (Kimmerer et al. 2009).

Model fits were evaluated in terms of the reduction in deviance (a measure of the explanatory power of the model, similar to variance in other modeling techniques such as analysis of variance) attributable to each of the abiotic factors, relative to the null model. The final model included Secchi depth and specific conductance but did not include water temperature, as it did not give an appreciable reduction in deviance. The final model accounted for 26% of the deviance, although it is not possible to determine what proportion of the deviance is independently attributable to Secchi depth and specific conductance when both are combined. (When individually included in the model, Feyrer and coauthors [2011] noted that specific conductance reduced deviance by 18% and Secchi depth reduced specific deviance by 14%.)

The delta smelt fall abiotic habitat index was calculated as follows:

$$H_y = \sum_{S=1}^{73} \left[A_S \frac{1}{4} \sum_{m=Sep}^{Dec} \hat{\pi}_{y,m,s} \right],$$

(Equation 1)

Where H_y is the fall abiotic habitat index, A_s is the surface area of station s and $\hat{\pi}_{y,m,s}$ is the GAM estimate of the probability of occurrence.

Station surface areas of each station were obtained from DFG and originally were reported by Feyrer and coauthors (2007). Surface areas were generated by GIS and ranged from 90 to

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

1,251 hectares for the 73 stations. Summation of the probability of occurrence–weighted surface areas provided an index that accounts for both the quantity and quality (in terms of probability of occurrence) of abiotic habitat for delta smelt.

Locally weighted regression–scatterplot smoothing (LOWESS regression) was used to develop a data-driven relationship between the habitat index and estuarine outflow (expressed as X2). Consistent with the habitat index described above, the average September through December X2 was used. The data were averaged over the 4-month fall period to minimize the influence of sampling error that could occur if the data were summarized over shorter temporal scales. For instance, shorter averaging periods might be less reliable because samples are taken irrespective of tidal conditions across a geographic region with large tidal excursions, and because abundance estimates, and by extension distribution, can be highly variable among months (Newman 2008). The delta smelt fall abiotic habitat index and its relationship to X2 are represented by the blue diamonds in Figure C.4-16, with the LOWESS smoothed fit depicted as the red squares. The LOWESS smoothed fit explained 85% of the variation in the estimates of abiotic habitat (i.e., $r^2 = 0.85$).

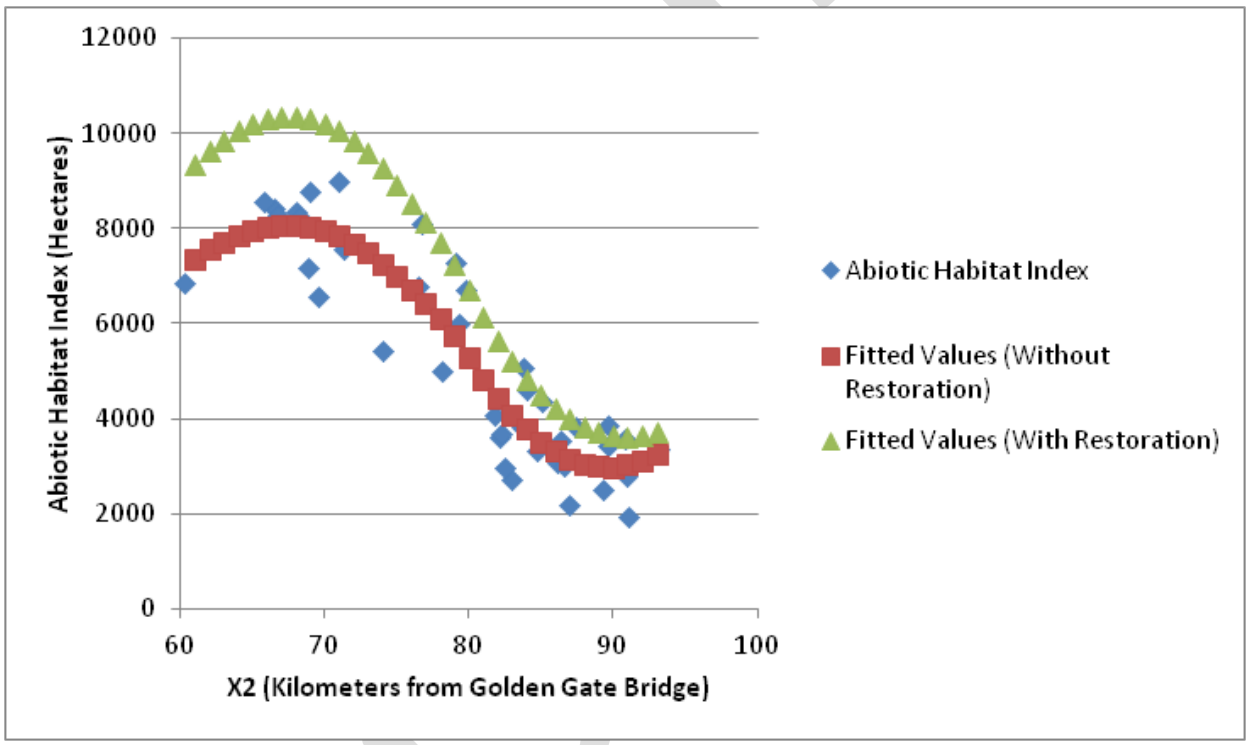


Figure C.4-16. Abiotic Habitat Index of Delta Smelt in Relation to X2

Blue diamonds represent values estimated by Feyrer and coauthors (2011), with red squares indicating the best-fit, locally weighted regression with the estimates (without habitat restoration, i.e., current Delta configuration). Green diamonds represent the fitted values based on the assumption that restored habitat in the Suisun Marsh and West Delta ROAs has a probability of delta smelt presence similar to adjacent areas. This is discussed in the next section.

C.4.4.7.2 Adjustment of the Original Delta Smelt Fall Abiotic Habitat Index to Incorporate Preliminary Proposal Restoration Areas

The original delta smelt fall abiotic habitat index was adjusted to incorporate hypothetical restoration areas in the West Delta and Suisun Marsh ROAs. The subtidal portions of the

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

hypothetical restoration sites were assumed to have the same probability of occurrence of delta smelt as the existing estuary sites (stations) to which they were directly connected. The probability of occurrence was calculated for each station and associated restoration site in each month of the 42-year time series. The probability of occurrence and habitat area augmented by restoration were incorporated into Equation 1 to give an adjusted estimate of the delta smelt fall abiotic habitat index. These estimates were again related to average September through December X2 using a LOWESS regression ($r^2 = 0.87$), as illustrated by the green triangles in Figure C.4-16.

C.4.4.7.3 Use of the Delta Smelt Fall Abiotic Habitat Index in the Effects Analysis

The two equations estimating delta smelt fall abiotic habitat index from X2 were used to generate a lookup table of X2 versus abiotic habitat index (Table C.4-17). The X2-abiotic habitat index equations estimate the habitat index to decrease with X2 downstream of 67 km and to increase with X2 upstream of 90 km (Figure C.4-16). It was assumed that there would be little change in habitat index with X2 position lower than 67 km and greater than 90 km. Therefore, X2 less than 67 km was given an index of 8,069 hectares without restoration and 10,341 hectares with restoration, whereas X2 greater than 90 km was given an index of 2,987 hectares without restoration and 3,642 hectares with restoration. For each year of the CALSIM period (1922–2003), the average X2 was calculated for September through December and the abiotic habitat index for each of the six model scenarios was estimated by linear interpolation of the values shown in Table C.4-17. Two sets of analyses were conducted. The first analysis included all six scenarios and considered only the effects of the preliminary proposal on the existing configuration of the Delta without accounting for habitat restoration. The second analysis examined differences in abiotic habitat index between the preliminary proposal in the late long-term (PP_LLT, assuming full restoration in the Suisun Marsh and West Delta ROAs) and EBC1, EBC2, and EBC2_LLT. In the second set of analyses, the abiotic habitat index was calculated using the assumption that 25%, 50%, 75%, and 100% of the restored habitat would be used by delta smelt. This analysis is limited to tidal restoration in the low salinity zone and doesn't necessarily account for delta smelt use of inshore areas or areas outside the low salinity zone, such as Cache Slough.

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

Table C.4-17. Fitted Values for Delta Smelt Abiotic Habitat Index, without and with Preliminary Proposal Late Long-Term Restoration Extent Included

X2 (kilometers)	Abiotic Habitat Index (Hectares)	
	Without Restoration	With Restoration
67	8,069	10,341
68	8,067	10,344
69	8,027	10,296
70	7,950	10,198
71	7,837	10,053
72	7,685	9,852
73	7,491	9,587
74	7,261	9,270
75	7,000	8,912
76	6,716	8,525
77	6,414	8,121
78	6,099	7,710
79	5,735	7,253
80	5,292	6,712
81	4,835	6,158
82	4,430	5,659
83	4,081	5,225
84	3,777	4,840
85	3,523	4,511
86	3,314	4,231
87	3,160	4,007
88	3,054	3,834
89	2,996	3,712
90	2,987	3,642

C.4.4.7.4 Major Assumptions

Two major assumptions are associated with the use of the delta smelt fall abiotic index for the preliminary proposal effects analysis.

The relationship between X2 and the delta smelt fall abiotic habitat index that was developed under existing conditions remains the same under future configurations of the Plan Area incorporating restoration.

This assumption is unlikely to be valid because implementation of habitat restoration probably will change the relationship between X2 and the delta smelt fall abiotic habitat index because of changes in salinity and water clarity distributions in relation to X2. Changes in other abiotic (e.g., water temperature) and biotic factors (e.g., food density) also may influence the nature of the relationship. CALSIM and DSM2 modeling used for the effects analysis incorporate changes in channel geometry

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

for a hypothetical habitat restoration program but cannot be used to adjust the fundamental X2–abiotic habitat index relationship. It is also unlikely that the actual location and extent of habitat restoration areas will be exactly the same as those used in the hypothetical case, which would affect the flow–X2 relationship, and by extension, the appropriateness of the X2–abiotic habitat relationship.

Subtidal restoration areas have the same probability of occurrence of delta smelt as adjacent open estuary sites.

This assumption may be only partially valid because the subtidal restoration sites may differ from adjacent open estuary sites in terms of important abiotic characteristics (e.g., water depth) that could alter the probability of delta smelt occurrence. However, delta smelt have been found across a wide range of habitats, including open-water areas (e.g., Moyle 2002), as well as small intertidal marsh channels (Gewant and Bollens 2011). It is likely that habitat characteristics within tidal habitat (e.g., tidal excursion, velocity, temperature, turbidity) influence their use by delta smelt and that channel width itself is not a constraint (Sommer and Mejia 2011). The width of levee breaches into the restoration areas also may influence the probability of occurrence of delta smelt.

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

C.5 Results

C.5.1 CALSIM and DSM2 Results

These results are presented in Attachment C.A, *CALSIM and DSM2 Results for the Preliminary Proposal Modeling Scenarios*.

C.5.2 Upstream Habitat Results

[This section is a separate file.]

C.5.3 Passage, Movement, and Migration Results

[This section is a separate file.]

C.5.4 Delta Habitat (Plan Area) Results

[This section is a separate file.]

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

C.6 Conclusions

C.6.1 Summary of Changes in Flow

The preliminary proposal would result in very minimal changes in upstream flows or reservoir operations. As such, there are only a few instances in which changes to the environment and related effects on fish may occur. Flow-related temperature effects on spring-run Chinook salmon and green sturgeon spawning and egg incubation are described in Section C.6.2. In the Delta, flows in and around the San Joaquin River and south Delta would increase, reflecting the reduced use of the south Delta export facilities. However, the flow patterns in the north Delta could be altered by operations of the new north Delta export facilities and the increased inundation of the Yolo Bypass. These operational changes will reduce some Sacramento River flows, resulting in reduced flows in Sutter, Steamboat, and Georgiana Sloughs and the DCC. Similarly, the reduced flows in the Sacramento River would slightly reduce flows in Threemile Slough. These changes in flow patterns in the north Delta can affect the migration and passage of fish through and within the Delta, as described in Section C.6.2. The changes in Delta flows are not expected to result in any substantial changes in turbidity or DO, as described below. However, the changes in Delta operations under the preliminary proposal related primarily to the new north Delta intake could have effects on salinity in some locations, as described below. In most instances, these changes in salinity are compounded by the effects of restoration activities that would occur as part of the preliminary proposal and sea level rise. The following sections provide a discussion of the general trends of changes in flows throughout the Plan Area. More detailed results are provided in Attachment C.A and are the basis for the biological results presented in Section C.6.2.

C.6.1.1 Upstream Flows

The CALSIM results indicate that there would be some change in how reservoirs are operated. The largest changes to reservoir operations result from changes in runoff and inflow caused by climate change unrelated to the preliminary proposal. Carryover storage in all the upstream reservoirs is predicted to be generally higher under PP compared to EBC2 at the same climate and sea level rise conditions. Generally, this increased carryover storage is a result of the following:

- No Fall X2 standard under the PP;
- The ability to pump in the spring months when natural runoff is higher because of the added flexibility of north Delta intakes; and
- Reduced pumping in the summer and fall months, when generally more water needs to be released from the reservoirs to maintain the water quality conditions in the Delta.

The increased Oroville storage is expected to allow for more flexibility to operate for temperature needs under the PP. Coldwater pool management is predicted to be challenging for the CVP facilities in the LLT both with and without the PP due to the changes in inflows and sea level rise associated with temperature rise assumed in the LLT.

In general, the PP would increase carryover storage (end-of-September storage, often the lowest each year) compared to the EBC scenarios. However, SWP/CVP operations are expected to change operations to address the increased outflow needs caused by sea level rise and climate change.

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

These results suggest that the management of storage for the coldwater pool (May storage is an indicator) would be increasingly difficult in the future, despite the fact that the PP would have increased carryover. The frequency of the end-of-September storage falling below 2,000 thousand acre-feet (TAF) would increase by about 10% under both the PP and EBC in the LLT. Considerable adaptation measures would need to be implemented on the upstream operation of the CVP to manage the coldwater pool under the extreme sea level rise and climate change by 2060. Operation of the PP would lessen these challenges, but the effect of climate change and sea level rise would overwhelm these improvements.

These general conclusions are based on the CALSIM data, which are summarized below for each reservoir and river, and the actual operational constraints of the SWP/CVP. Because the CALSIM model uses a monthly time step, it does not necessarily capture the day-to-day operations that would respond to potential adverse effects, such as temperature changes and minimum flow and storage requirements. However, because the preliminary proposal is not expected to require substantial changes in upstream SWP/CVP operations, the CALSIM results indicate considerable monthly changes are not expected to occur in reality. Rather, DWR and U.S. Department of the Interior, Bureau of Reclamation (Reclamation) reservoir operators would continue to operate the reservoirs and associated flows on a daily basis in a manner that meets flow, storage, and temperature requirements.

C.6.1.2 Delta Flows

The primary changes in Delta operations result from the north Delta intakes and the increased flows into the Yolo Bypass at the Fremont Weir. These changes generally divert water from the Sacramento River into either the new intake or the Yolo Bypass, reducing flows in Sutter, Steamboat, Threemile, and Georgiana Sloughs; in the DCC; and at Rio Vista. Reductions in south Delta pumping that are possible with the north Delta intakes increase OMR flows and San Joaquin River flows at Antioch by the amount of the reduced pumping. While climate change may affect flows in the San Joaquin, Mokelumne, and Cosumnes Rivers, no effects of the preliminary proposal are expected in the Delta channels connected to these river inflows. A summary of changes at each Delta location is provided below. However, these changes reflect the general trends and not necessarily the outer bounds of potential changes that could occur across water-year types and months within those water years. The effects analysis used detailed modeling results to determine the biological responses to specific daily, monthly, and water year–type changes. These are reported in the Results section above.

C.6.1.2.1 Sacramento River Flows at Freeport

Other than flows exiting the Yolo Bypass, the Sacramento River flow at Freeport provides the largest Delta inflow and represents the water available for diversion at the proposed north Delta intakes. The average modeled annual inflow at Freeport was reduced by about 650 TAF (up to 4%), primarily as a result of the increased Fremont Weir spills into the Yolo Bypass that would occur under the preliminary proposal. Similarly, PP_ELT and PP_LLT monthly median flows at Freeport were similar to EBC1 but were shifted in some months as a result of the increased spills at the Fremont Weir and other changes in upstream reservoir releases, as discussed above.

The modeled Freeport median flows were similar in October, November, and December for the EBC1 and PP cases. The Freeport median flows in January, February, and March for the PP cases were about 3,000 cfs less than EBC1 flows, reflecting the increased spills at the Fremont Weir into

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

the Yolo Bypass. The April and May median flows at Freeport were similar for the PP cases and EBC1 conditions. The June median flows were increased for the PP cases. The Freeport median flows for the PP cases in July, August, and September were reduced by about 3,000 cfs compared to EBC1 flows because of changes in upstream reservoir releases. The preliminary proposal north Delta intakes allowed higher exports in April, May, and June and subsequently allowed reduced reservoir releases and reduced exports. The PP cases had inflows and exports that were distributed more evenly during the highest agricultural demand period of April through September.

C.6.1.2.2 San Joaquin River Flows at Vernalis

The only changes in the San Joaquin River flows are caused by the assumed climate change effects on reduced San Joaquin River (above Friant Dam) inflows and reduced tributary inflows. No changes from preliminary proposal operations were simulated.

C.6.1.2.3 Yolo Bypass Flows to the Delta

The Yolo Bypass flows are the sum of Fremont Weir spills and Cache Creek and Putah Creek flows. Although the preliminary proposal ELT and LLT cases allow some additional flows into the Yolo Bypass at the Fremont Weir, the monthly sequence of Yolo Bypass flows was very similar. A few more months have flows of 2,000–6,000 cfs (notch capacity), and the high-flow months have slightly more flow (6,000 cfs).

C.6.1.2.4 Mokelumne River and Cosumnes River Flows to the Delta

The monthly inflows from the Mokelumne River near Thornton, just below the Cosumnes River, are very low during the summer months. These predicted flows were nearly identical for all CALSIM cases. Most Cosumnes River runoff enters the Delta, and the Mokelumne River is highly regulated by Pardee and Camanche Reservoirs. The minimum flows below Woodbridge Dam are specified based on runoff, and reservoir spills are rare. There were no effects of the preliminary proposal on these river flows.

C.6.1.2.5 San Joaquin River Diversions to Old River

The preliminary proposal would not result in changes in the San Joaquin River flows at Old River, but some changes are expected as a result of climate change. The median head of predicted Old River flow for December through May was about half of the San Joaquin River flow at Vernalis. The median flows in June through September were about 40% of the San Joaquin River flow at Vernalis because of the effects of the south Delta rock barriers. The annual average head of Old River diversion flow was nearly the same for all six CALSIM cases and was equal to about half of the San Joaquin River flow.

C.6.1.2.6 Old and Middle River Flows

The CALSIM modeling assumed that some OMR reverse flow restrictions would apply for each of the applicable months (December through June). The restrictions were assumed to vary somewhat with runoff conditions. The assumed restrictions were held constant for each of the EBC1 cases, the three EBC2 cases, and the two preliminary proposal cases. Because negative OMR flow is toward the south Delta pumps, the greatest negative values indicate higher pumping. The minimum values indicate the maximum pumping from the central Delta. For example, the October and November minimum flows for EBC1 were -10,000 cfs. The October and November median flows were -8,000 cfs.

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

However, there are no OMR flow restrictions in October and November. The EBC1 December minimum flow was -9,600 cfs, but the median flow was -5,871 cfs (the assumed OMR limit in 30% of the years). This suggests that the OMR limits were reducing the December exports to this level in several of the years. The January through March and June minimum flows were -5,000 cfs because the assumed OMR limits were restricting pumping to this level in many of the years in these months. The minimum flows in April and May were higher than the limit of -5,000 cfs because the NMFS exports/San Joaquin River ratio that applies in April and May was reducing the exports more than the OMR limits. EBC1 flows in July through September were -11,000 to -10,000 cfs, and median flows were -10,000 to -9,000 cfs.

The preliminary proposal ELT and LLT cases shifted pumping from the south Delta to the north Delta intakes and thereby increased the OMR flows (reduced negative OMR flows). The median predicted OMR flows for the preliminary proposal ELT and LLT cases were about 2,000 cfs higher in October and November; about the same in December; 2,000 cfs higher in January; 5,000 cfs higher in February; 3,500 cfs higher in March; 1,500 cfs higher in June; 6,000 cfs higher in July; 6,500 cfs in August; and 4,500 cfs higher in September.

C.6.1.2.7 Sutter Slough and Steamboat Slough Flows

Sutter and Steamboat Sloughs divert about 40% of the Sacramento River flow. The monthly median predicted diversion flows into Sutter and Steamboat Sloughs were similar for the EBC1 case and the three EBC2 cases because the Sacramento River flows were similar. The median diversions into Sutter and Steamboat Sloughs were lower for the PP_ELT and PP_LLT cases because the north Delta intakes reduce the Sacramento River flow at Sutter and Steamboat Sloughs. The median diversions in October, April, May, and June were about the same for the EBC and the preliminary proposal scenarios. The median diversions were reduced by 1,000 cfs in November, July, and September; 2,000 cfs in January and August; and 4,000 cfs in February and March. The reductions in the Sutter and Steamboat Slough diversions were about 40% of the simulated north Delta intake diversions. The annual average diversions into Sutter and Steamboat Sloughs were about 6,500 TAF (42% of the Sacramento River flow at Freeport) for the EBC1 case and three EBC2 cases, and were reduced to about 5,500 TAF (36% of the Sacramento River flow at Freeport) for the two preliminary proposal scenarios.

C.6.1.2.8 Delta Cross Channel and Georgiana Slough Flows

Similar to Steamboat and Sutter Sloughs, CALSIM predicted reduced monthly median diversion flows in the PP_ELT and PP_LLT cases for DCC and Georgiana Slough because the north Delta intakes reduced the Sacramento River flow. The annual average diversions into the DCC and Georgiana Slough were about 3,750 TAF (24% of the Sacramento River flow at Freeport) for the EBC1 case and three EBC2 cases, and were reduced to about 3,150 TAF (21% of the Sacramento River flow at Freeport) for the two preliminary proposal cases.

C.6.1.2.9 Sacramento River Flows at Rio Vista

The modeled minimum flows in September through December for Rio Vista (3,000–4,500 cfs, depending on water-year type) were generally satisfied. The EBC1 monthly median flows were about 5,500 cfs in October; 7,500 cfs in November; 12,500 cfs in December; 22,000 cfs in January; 29,000 cfs in February; 23,000 cfs in March; 13,000 cfs in April; 10,000 cfs in May; 6,500 cfs in June; 10,500 cfs in July; 8,500 cfs in August; and 6,500 cfs in September. The median flows at Rio Vista for

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

the three EBC2 cases were similar because the Yolo Bypass and Sacramento River inflows were generally the same. The median monthly Rio Vista flows were reduced in the months when the north Delta intake diversions were simulated for the PP_ELT and PP_LLT cases. The reduced Rio Vista flows were generally about the same as the north Delta intake diversions. The annual average Sacramento River flows at Rio Vista were about 14,000 TAF for the EBC1 case and three EBC2 cases, and were reduced to about 12,000 TAF for the PP_ELT and PP_LLT cases.

C.6.1.2.10 Threemile Slough Flows

The Threemile Slough flows are about 3% of the Rio Vista flows and were reduced slightly for the preliminary proposal cases because the Rio Vista flows were reduced by the north Delta intake diversions. The predicted annual average Threemile Slough flows were about 1,000 TAF for the EBC1 case and the three EBC2 cases, and were reduced to about 750 TAF for the two preliminary proposal cases.

C.6.1.2.11 San Joaquin River Flows at Antioch

San Joaquin River flows at Antioch were increased in the PP_ELT and PP_LLT cases because the reduction in south Delta exports will increase OMR and San Joaquin River flows by the same amount. For the preliminary proposal cases, predicted monthly median flows were about 0 cfs in October and November, and were reversed to -2,000 cfs only in December. The San Joaquin River flows were about 1,500 cfs in January; 8,500 cfs in February; 6,500 cfs in March; 3,000 cfs in April; 2,500 cfs in May and June; 1,000 cfs in July; 500 cfs in August; and 150 cfs in September. The summer periods of reverse San Joaquin River flow were generally eliminated by the preliminary proposal north Delta intake diversions.

C.6.1.2.12 Delta Outflow

The CALSIM-simulated Delta outflow is the sum of all the upstream and Delta operations, and it is the major link with salinity in the Delta and with the X2 position. Delta outflow requirements often limit the Delta exports, so the simulated Delta outflow for many months is equal to the minimum Delta outflow requirement for each month. The EBC1 case did not include the BiOp Fall X2 requirements, so the required Delta outflow was controlled by the D-1641 objectives. The annual average outflow required for EBC1 (D-1641) was 4,250 TAF. The three EBC2 cases included the BiOp Fall X2 requirements, and the predicted average annual required outflow was about 5,000 TAF for EBC2, about 5,250 TAF for EBC2_ELT, and about 5,750 TAF for EBC2_LLT. The BiOp Fall X2 requirements (intended for wet and above-normal years) raised the annual average required outflow for EBC1 by about 750 TAF. The EBC2_ELT and EBC2_LLT cases had even higher required outflows caused by changes in the outflow required to meet X2 because of sea level rise and habitat restoration effects on salinity intrusion.

The monthly median outflows simulated by CALSIM for each modeling scenario are shown in Table C.6-1. About half of the months had excess Delta outflow compared to the outflow requirements, but the outflow in most of these months likely was controlled by the maximum allowed export/inflow (E/I) ratio.

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

Table C.6-1. Average Annual and Monthly Mean Outflows for Each of the Six CALSIM Scenarios

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Average Annual Outflow (TAF)	15,533	15,743	16,157	16,282	14,875	15,210
Monthly Median Outflow (cfs)						
January	22,361	21,730	21,342	21,903	21,277	22,074
February	36,554	35,578	35,846	37,339	36,181	35,855
March	26,890	26,801	25,701	25,784	24,828	24,486
April	18,921	18,804	18,708	18,283	12,470	13,037
May	15,899	15,655	13,911	12,806	11,352	11,400
June	7,243	7,249	7,243	8,336	8,086	9,290
July	8,000	8,000	8,000	8,520	8,000	8,000
August	4,000	4,000	4,000	4,112	4,000	4,000
September	3,610	3,621	3,659	3,430	3,000	3,000
October	4,000	4,403	5,425	7,813	4,000	9,234
November	5,088	10,313	9,844	10,415	4,500	4,500
December	8,086	7,696	8,666	9,156	8,867	9,219

TAF = thousand acre-feet.
cfs = cubic feet per second.

The predicted monthly median outflows for the PP_ELT and PP_LLT cases were similar (within 1,000 cfs) to the EBC1 median outflows in October through February; 2,000 cfs less in March; 6,000 cfs less in April; 4,000 cfs less in May; and similar in June through September. The annual average Delta outflow for the EBC1 case was 15,500 TAF. The annual average outflows were 14,875 TAF for the PP_ELT case and 15,200 TAF for the PP_LLT case.

C.6.1.2.13 Effects of Habitat Restoration on Delta Flows and Tidal Hydrodynamics

Tidal habitat restoration under the preliminary proposal would affect flows and tidal hydrodynamics in channels throughout the Delta. This topic is covered in detail in Appendix 5.E, *Habitat Restoration*.

C.6.1.3 Salinity

Salinity is included in this appendix to assess the potential for changes to habitat as a result of changes in flows that may cause changes in salinity. (Salinity as a drinking water quality parameter is addressed in the BDCP EIR/EIS.) The preliminary proposal allows more salt into the western Delta because of increased tidal mixing associated with the addition of tidal marsh areas and reduced Delta outflow. Substantial increases in salinity at Emmaton and moderate increases at Jersey Point and Rock Slough caused by the preliminary proposal are generally attributable to the reduction in Sacramento River flows in these areas. However, slight reductions in average annual salinity at Threemile Slough are expected as a result of major salinity decreases in July and August caused by higher outflows. As the preliminary proposal is implemented and more tidal marsh is restored, salinity effects at these locations intensify. At Emmaton under PP_LLT, the largest increases in salinity occur from May to September, while there are minimal changes in salinity from

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

October through April. Jersey Point and Rock Slough are also expected to have additional increases in salinity in the LLT as a result of restoration activities. The annual average salinity at Threemile Slough is further reduced in the LLT because of substantial salinity reductions in October and November resulting from higher Sacramento River flow.

Salinity can be controlled somewhat by Delta outflow. Higher Delta outflow moves the salinity gradient west and lowers the X2 (decreases the distance from the Golden Gate Bridge). Under the PP scenarios, X2 moves upstream (lower outflow) in some months, with the reduced inflows or higher exports that are allowed with the north Delta intake. However, the PP scenarios will meet the required D-1641 X2 locations from February through June and the minimum Delta outflows, as described above and shown in Table C.6-2.

Table C.6-2. Summary of the Location (Kilometers from the Golden Gate Bridge) of X2 under Each CALSIM Scenario

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
A. EBC1												
Min	67.1	51.7	47.3	47.2	47.2	47.2	47.3	48.5	49.1	56.2	66.0	63.5
Max	94.7	93.9	92.2	89.7	86.9	83.3	83.2	87.4	90.5	91.2	91.5	92.6
Avg	88.5	86.3	77.9	67.6	60.7	60.7	63.4	67.5	74.6	80.4	85.2	86.4
B. PP_ELT												
Min	72.8	52.2	47.7	47.6	47.6	47.7	47.7	49.3	51.0	62.3	74.7	71.4
Max	93.1	92.6	92.4	90.1	86.8	82.3	83.2	87.1	90.2	90.5	92.1	93.5
Avg	89.0	86.8	78.3	68.3	62.1	62.4	66.7	71.8	77.0	81.6	86.5	88.5
C. PP_LLT												
Min	73.8	54.6	48.8	48.7	48.7	48.7	49.0	51.6	54.8	69.9	83.4	79.3
Max	92.4	94.3	91.6	90.1	85.7	83.5	84.5	89.1	92.1	91.6	91.9	92.7
Avg	85.7	85.1	79.7	68.9	63.2	63.8	68.0	73.7	78.9	83.2	87.5	89.2
D. EBC2												
Min	67.3	51.7	47.3	47.2	47.2	47.2	47.3	48.5	49.3	57.1	67.3	65.8
Max	94.6	93.4	92.2	87.2	83.2	82.3	82.5	87.2	90.2	90.9	90.8	92.4
Avg	84.1	82.3	76.3	67.4	60.8	61.0	63.6	67.8	74.7	80.4	85.2	82.5
E. EBC2_ELT												
Min	69.5	52.4	47.8	47.6	47.6	47.7	47.9	49.8	51.5	62.1	73.6	70.9
Max	93.9	94.4	93.6	90.4	87.0	82.7	83.1	87.6	90.2	90.8	90.9	92.6
Avg	84.1	82.3	76.6	67.9	61.7	61.9	64.6	68.9	75.9	80.3	85.1	82.7
F. EBC2_LLT												
Min	72.2	55.4	50.0	49.6	49.6	49.5	50.0	53.1	55.7	71.4	81.2	73.9
Max	94.6	94.7	94.0	90.4	87.3	83.8	84.6	88.7	90.9	90.9	92.1	94.3
Avg	83.7	82.7	78.2	69.4	63.5	63.7	66.5	71.4	77.6	80.8	85.8	83.4

The three EBC2 cases, which included BiOp Fall X2 requirements in September through November of about half of the years (wet and above-normal), had corresponding reduced X2 values in the 50–90% cumulative values. The changes in the monthly X2 ranges or in the monthly median values were relatively small because the monthly range in outflows remained similar for each of the EBC1 and EBC2 baseline cases. The preliminary proposal cases allowed some of the X2 positions to move

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

upstream (lower outflow), with the higher exports that were allowed in some months with the north Delta intake. The required D-1641 X2 locations from February through June and the minimum Delta outflows were satisfied by the preliminary proposal cases, although CALSIM results reported above may be based on relaxations of the requirements in certain months.

C.6.1.4 Turbidity

Firm conclusions regarding changes in turbidity in the Plan Area are difficult to make. Uncertainty in sediment supply in the future is high because of factors such as the maturation schedule of habitat restoration within ROAs. In addition, the potential use of fill-in materials or wind breaks in the ROAs to reduce wind-driven sediment resuspension also could greatly affect turbidity. These and other factors limit the feasible scope of the analysis.

The analysis focused on whether the different subregions would become erosional, which would increase turbidity, or depositional, which would decrease turbidity. The analysis also evaluated whether seasonal wind resuspension within ROAs is likely to be greater with the preliminary proposal, thereby increasing turbidity. Factors such as submerged aquatic vegetation (SAV), benthic filter feeders, organic materials, and the potential substantial effects on the critical shear stress of erosion from changes in benthic algae and macrofauna have not been considered in the present analysis of turbidity because of a lack of data, a lack of modeling tools, or both.

The Delta will remain regionally depositional in the LLT timeframe, in both EBC and PP scenarios, although the location of the depositional regions will differ. The effects of sea level rise will depend on the balance between sediment supply from the watersheds and the rate of sea level rise, so it is unclear whether sediment supply will be sufficient to maintain the current extent of tidal marsh. The initial effect of the ROAs in the PP is to decrease sediment supply downstream, but the longer-term effects are uncertain as the ROAs reach a dynamic equilibrium.

Under the PP, the North Delta subregion will receive less sediment because of increased flows through the Yolo Bypass, but this may not be a large enough factor to differentiate these effects from the overall effects due to sea level rise and climate change alone in the LLT under existing conditions. The Cache/Yolo Bypass–region ROAs will become depositional with sediment that otherwise would be carried down the Sacramento River. While the ROAs have the potential to increase water clarity in existing open water areas such as Liberty Island at least initially, wind resuspension of unconsolidated sediment during the summer is likely to decrease water clarity in the region seasonally. The West Delta ROA will accrete sediment, resulting in a local increase in water clarity in combination with decreased supply due to sediment deposition in the Cache/Yolo region during winter-spring high-flow conditions. However, decreased sediment supply could result in erosion and a decrease in water clarity, leaving a mixed outcome for this region. The East Delta subregion is likely to experience increased water clarity due to the ROAs, both because of decreased flow through Georgiana Slough and because of deposition in the East Delta ROAs of the small amount of sediment originating from the Mokelumne and Cosumnes Rivers. The effect of seasonal winds will be minor because the ROAs are not large in the East Delta. The South Delta ROA consists of large open water areas that (barring establishment of SAV such as *Egeria densa*) likely will experience decreased water clarity due to wind resuspension in the summer. However, deposition in the ROAs also could increase water clarity, resulting in an overall mixed outcome.

The effect of the Suisun Bay subregion ROAs, both locally and due to effects from upstream ROAs, is complicated. Suisun Bay is currently erosional and the opening of ROAs upstream is likely to

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

increase this erosion. If Suisun Bay continues to deepen and intertidal regions are lost, wind waves will become less effective at suspending sediment, so erosion rates may slow even in the presence of reduced sediment supply. The new ROAs may exert a local decrease in water clarity from seasonal resuspension due to wind. However, predicting the overall result for water clarity is uncertain due to the depositional environment in the ROAs and increased regional erosion. The ROAs in Suisun Marsh likely will be depositional because of local sediment supply, resulting in local increases in water clarity. The effects of wind resuspension in decreasing water clarity likely will be limited to the larger ROAs in this region, depending on wind direction.

Turbidity is only one component of habitat that may be required for the success of some fish species. As such, similar to the salinity changes described above, the effects of turbidity on fish and fish habitat will be explored further in Appendices 5.G, *Fish Life Cycle Models*, and 5.E, *Habitat Restoration*, to better integrate the multiple factors composing fish habitat and the potential effects of the preliminary proposal.

C.6.1.5 Temperature and Dissolved Oxygen

Temperature changes are expected to vary according to year and location but these changes rarely translate to adverse effects on species, as described below. In-Delta water temperature and DO concentrations are not expected to change in response to the preliminary proposal. Water temperatures and DO in the Delta are affected primarily by atmospheric conditions (air temperature, winds, solar radiation, and climate change). Water temperatures are typically in thermal equilibrium with the atmospheric conditions and therefore are not influenced strongly by changes in river flows affected by proposed project operations. Similarly, with the exception of known low DO channels in the south Delta, DO concentrations in the river channels and bays are typically in equilibrium with atmospheric conditions, and proposed project operations are not anticipated to result in biologically significant changes within the Delta. As a result of these factors, it was concluded that proposed project operations would not result in adverse changes in either water temperatures or DO concentrations n the Delta that would affect the target species. Changes in long-term seasonal water temperatures are anticipated to occur within the Delta, however, in response to future climate changes that are independent of proposed project operations, but that also are expected to result in changes in habitat conditions that could potentially adversely affect the population dynamics of the covered species in the future (LLT climate changes).

C.6.2 Flow-Related Biological Effects

The following information is summarized in Table C.0-3 and Table C.0-4, above, and describes in detail the conclusions for each species for flow-related parameters in upstream and Delta areas, and for passage, migration, and movement.

C.6.2.1 Upstream Spawning and Egg Incubation

Conclusion 1. Except for Sacramento River spring-run Chinook salmon and Feather River green sturgeon egg incubation, the preliminary proposal would not result in adverse effects on upstream spawning.

Overall, there would be minimal changes to upstream flows and as such, very few effects on spawning and egg incubation. Most of the differences and associated effects on spawning and egg incubation habitat observed among the modeled scenarios were attributable to near-term and long-

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

term climate change effects. In many instances, increased steelhead, winter-run, Pacific lamprey, and river lamprey egg mortality under future conditions is primarily a result of natural seasonal and interannual variation in river flows, coldwater storage, and temperature effects on incubating eggs that were largely independent of preliminary proposal operations. Increased temperatures during egg incubation periods for spring-run Chinook salmon on the Sacramento River and green sturgeon, Pacific lamprey, and river lamprey on the Feather River would result in adverse effects on these species.

Steelhead. No adverse effects were detected on steelhead spawning and egg incubation habitat conditions based on CALSIM, SacEFT, and water temperature modeling results. The predicted magnitude and frequency of instream flows, reservoir storage, and water temperatures potentially affecting the quantity and quality of spawning and incubation habitat under proposed project and future baseline conditions were comparable. Based on the results, preliminary proposal operations likely would have small annual effects on flows and water temperatures during the steelhead spawning and incubation period, but would not affect long-term habitat conditions relative to future baseline conditions.

Winter-run Chinook salmon. No major or consistent adverse effects were detected on upstream spawning and egg incubation habitat conditions (e.g., reservoir storage, instream flows, water temperatures during egg incubation) for Sacramento River winter-run Chinook salmon based on results from the Reclamation egg mortality model, SacEFT, SALMOD, and other tools. Positive and negative changes in instream flows that affect habitat quality and quantity, such as reduced summer and fall flows relative to existing conditions, were detected in the Sacramento River. Differences in flow in the Sacramento River in September of wetter years between existing and preliminary proposal operations reflect, in large part, differences in fall operations for downstream low-salinity habitat that was included as an operating criterion under the EBC2 conditions but was not included in preliminary proposal operations.

Spring-run Chinook salmon. No major or consistent adverse effects were detected on upstream spawning and egg incubation habitat conditions (e.g., reservoir storage, instream flows, water temperatures during egg incubation) in the Feather River, Trinity River, San Joaquin River, or Clear Creek for spring-run Chinook salmon based on results from the Reclamation egg mortality model, SALMOD, CALSIM outputs, and other tools. Most spring-run Chinook salmon spawn in tributaries such as the Feather River and Mill, Deer, Butte, and Clear Creeks, in which spring-run egg mortality would not be affected by preliminary proposal operations.

In the Sacramento River, model results were mixed. The egg mortality model indicated that there is a 5–10% increase in egg mortality of spring-run Chinook salmon under preliminary proposal operations relative to existing biological conditions in wet, above-normal, and below-normal water years. This increase was a result of increased water temperatures during fall months, particularly September. Refinements in reservoir operations and coldwater pool management, including real-time management, which CALSIM cannot model, may reduce this effect, but this has not been evaluated using the hydrologic and water temperature simulation models. However, results of the SacEFT and SALMOD models, which account for flow, temperature, and other variables in the upper Sacramento River, predict that spawning habitat conditions will not be different (SALMOD) or will be improved (SacEFT) under the proposed project compared to existing biological conditions, which is in contrast to the egg mortality model results described above.

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

Fall-run Chinook salmon. No major adverse effects were detected on upstream spawning or egg incubation habitat conditions (e.g., reservoir storage, instream flows, water temperatures during egg incubation) for fall-run Chinook salmon in the Sacramento River based on results of model analyses using the Reclamation egg mortality model, SacEFT, SALMOD, and other tools. Small positive and negative changes were detected in the Sacramento River, such as reduced summer and fall flows relative to existing conditions. No substantive changes in reservoir storage or river flows affecting fall-run Chinook salmon habitat conditions were detected in the Feather, American, San Joaquin, Stanislaus, or Trinity Rivers or Clear Creek. Preliminary proposal operations have no effect on flows or water temperatures in other tributaries, including the Mokelumne, Cosumnes, Merced, and Tuolumne Rivers, or habitats in areas such as Mill, Deer, Butte, and Battle Creeks.

Late fall–run Chinook salmon. No major adverse effects were detected on late fall–run Chinook spawning and egg incubation habitat conditions in the Sacramento River based on CALSIM, SacEFT, SALMOD, and other modeling tools. Although most changes in spawning habitat were attributable to climate change, the SacEFT model indicated that preliminary proposal operations would result in a small incremental reduction (5%) in the number of years with "good" spawning habitat conditions for late fall–run Chinook salmon.

White and green sturgeon. Spawning white sturgeon and their eggs would experience similar flow and water temperature conditions under preliminary proposal operations relative to existing biological conditions. There are small beneficial and adverse effects on spawning and egg incubation habitat conditions, but no major or consistent adverse effects were detected in the Sacramento, Feather, or Stanislaus Rivers. The greatest changes in upstream habitat conditions resulted from natural variation in interannual hydrology (e.g., between wet and dry years) and future climate change. These major habitat effects were largely independent of differences between existing conditions and preliminary proposal operations. Likewise, no major or consistent adverse effects were detected on upstream spawning and egg incubation habitat conditions (e.g., instream flows and water temperatures during egg incubation) in the Sacramento River for green sturgeon based on results from the Reclamation egg mortality model, SacEFT, CALSIM outputs, and other tools. In the Feather River. However, there is a reduction in flows during July and August of 29% on average, but this effect does not translate into a consistent adverse effect on green sturgeon based on water temperature exposure. There were no meaningful differences between existing biological conditions and preliminary proposal operations in exceedance of water temperature tolerances of 63°F and 68°F. The only effect is an increase of exposure to the upper threshold of green sturgeon tolerance of 73°F in up to 8% more months under preliminary proposal operations compared to existing biological conditions.

Pacific and river lamprey. No major or consistent adverse effects in the Sacramento, Trinity, American, and Stanislaus Rivers are predicted on upstream spawning and egg incubation habitat conditions (e.g., reservoir storage, instream flows, water temperatures during egg incubation) for Pacific lamprey and river lamprey based on results from the Reclamation temperature model, CALSIM, and other tools. There are small to moderate adverse effects on Pacific and river lamprey predicted in the Feather River.

C.6.2.2 Holding Flows

Holding flows were evaluated for spring- and winter-run Chinook salmon adults. As described below, no adverse effects of the preliminary proposal are expected.

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

Conclusion 2. The preliminary proposal would have no effects on spring- or winter-run Chinook salmon adult holding flows.

No major or consistent adverse effects were detected on upstream adult holding habitat conditions (e.g., instream flows) in the Sacramento River for spring- and winter-run Chinook salmon or in the Feather and Trinity Rivers or Clear Creek for spring-run Chinook salmon based on results from CALSIM. The greatest changes in upstream habitat conditions resulted from natural variation in interannual hydrology (e.g., between wet and dry years) and future climate change. Increased adverse conditions reflect natural seasonal and interannual variation in river flows, coldwater storage, and temperature effects on holding adults that were largely independent of preliminary proposal operations.

C.6.2.3 Upstream Rearing Habitat

Upstream rearing habitat for covered species would not change substantially, although some increase in Feather River temperature may adversely affect green sturgeon and river lamprey, and a decrease in late fall–run Chinook salmon rearing habitat also may occur. For spring-run Chinook salmon, fall-run Chinook, green sturgeon, white sturgeon, Pacific lamprey, and river lamprey, the greatest changes in upstream habitat conditions resulted from natural variation in interannual hydrology (e.g., between wet and dry years) and future climate change. Increased adverse conditions reflects natural seasonal and interannual variation in river flows, coldwater storage, and temperature effects on rearing habitat that were largely independent of preliminary proposal operations.

Conclusion 3. Upstream rearing habitat for covered species would not change substantially. Some benefits and adverse effects to winter-run rearing habitat are expected. However, some adverse effects on rearing habitat are expected for Feather River green sturgeon and Pacific and river lamprey.

Steelhead. No major adverse effects were detected on steelhead fry/juvenile rearing habitat conditions based on CALSIM, SacEFT, and water temperature modeling results. The predicted magnitude and frequency of instream flows, reservoir storage, and water temperatures potentially affecting the quantity and quality of rearing habitat under proposed project and future baseline conditions were comparable. Most of the differences and associated effects on steelhead rearing habitat observed among the modeled scenarios were attributable to near- and long-term climate change effects. Based on the results, preliminary proposal operations likely would have small annual effects on flows and water temperatures affecting steelhead rearing habitat, but would not affect long-term habitat conditions relative to future baseline conditions. In the Sacramento River between the RBDD and Keswick, the SacEFT model indicated that preliminary proposal operations would result in a small incremental increase (5%) in the number of years with “good” rearing habitat conditions for steelhead.

Winter-run Chinook salmon. The SacEFT model predicted that winter-run Chinook salmon fry/juvenile rearing habitat in the Sacramento River would be classified as *good* in 17–20% more years under preliminary proposal operations relative to existing conditions. Juvenile stranding risk was classified as *good* in 20–26% fewer years under preliminary proposal operations relative to existing conditions,

Spring-run Chinook salmon. No major or consistent adverse effects were detected on upstream fry/juvenile rearing habitat conditions (e.g., instream flows, water temperature, stranding) in the

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

Feather River, Trinity River, San Joaquin River, or Clear Creek for spring-run Chinook salmon based on results from CALSIM and the Reclamation water temperature model.

Fall-run Chinook salmon. No major or consistent adverse effects were detected on upstream fry/juvenile rearing habitat conditions (e.g., instream flows, water temperature, stranding) in upstream waterways for fall-run Chinook salmon based on results from CALSIM and the Reclamation water temperature model.

Late fall–run Chinook salmon. No adverse effects were detected on late fall–run Chinook fry/juvenile rearing habitat conditions in the Sacramento River based on CALSIM, SALMOD, and water temperature modeling. The predicted magnitude and frequency of instream flows, reservoir storage, and water temperatures potentially affecting the quantity and quality of rearing habitat in the Sacramento River under proposed project and future baseline conditions were comparable. Most of the differences and associated effects on late fall–run Chinook salmon rearing habitat observed among the modeled scenarios were attributable to near- and long-term climate change effects. Despite these results, the SacEFT model indicated that preliminary proposal operations would result in an incremental reduction of 14–28% in the number of years with "good" rearing habitat conditions for late fall–run Chinook salmon. However, based on the weight of evidence (SALMOD results, flow, and temperature exceedance analyses), there should be no detectable change in rearing habitat conditions for late fall–run Chinook salmon in the upper Sacramento River.

Green and white sturgeon. No major or consistent adverse effects were detected on upstream larvae/juvenile rearing habitat conditions (e.g., instream flows, water temperature, and stranding) in the Sacramento River or upstream waterways for green or white sturgeon based on results from CALSIM and the Reclamation water temperature model. Additionally, larval and juvenile white sturgeon would experience similar or slightly improved flow and water temperature conditions. Green sturgeon larvae will experience reduced flows in the Feather River from July through September, when flows are reduced by 42% on average in wet, above-normal, below-normal, and dry water years. However, reduced flows are not expected to translate into water temperature effects in a major or consistent way, except during the LLT implementation period, during which exposure to the upper 73°F water temperature threshold will occur 5–14% more often under preliminary proposal operations than under existing biological conditions independent of climate change.

Pacific and river lamprey. No major or consistent adverse effects were detected on upstream ammocoete rearing habitat conditions (e.g., instream flows, water temperature, stranding) in upstream waterways for Pacific lamprey or in the Sacramento, Trinity, American, and Stanislaus Rivers for river lamprey based on results from CALSIM and the Reclamation water temperature model. In the Feather River, there is a small to moderate increase in exposure to elevated water temperatures and increased ammocoete stranding risk. This increase in exposure to elevated water temperatures is expected to result in a small to moderate increase in mortality of ammocoetes in the region below the Thermalito Afterbay.

C.6.2.4 Passage, Migration, and Movement

Passage, migration, and movement were evaluated for upstream and Delta areas for all species. Overall, the results indicate that there will be some improved and some reduced passage as a result of the preliminary proposal.

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

Conclusion 4. Overall, flows in upstream areas during migration and transport periods for anadromous fish are not substantially changed under the preliminary proposal, with some exceptions.

The great majority of modeled river flow estimates upstream of the Plan Area suggested that, once effects associated with climate change were factored out, average differences in flow between PP and EBC during covered fish species migration and transport periods would be minor (Table C.0-3). The general pattern was for little change, with minor increases or decreases depending on water-year type. There were essentially no changes in migration flows in Clear Creek, the Stanislaus River, and the San Joaquin River at Vernalis. Analyses were based on the assumption that migration and transport are enhanced with increased flows, although there were few specific thresholds or ranges that could be applied. Summaries of the main patterns are provided below.

Steelhead. The Feather River was the only location where migration flows during periods of steelhead occurrence exhibited a number of differences between preliminary proposal and existing conditions: migration flows for juveniles and kelts were somewhat (generally 10% or more) greater under the preliminary proposal in most water-year types, but for adults, preliminary proposal flows were greater (10–20% more) only in dry and critical years.

Winter-run Chinook salmon. The analysis suggested little difference between existing conditions and preliminary proposal average flows during the juvenile downstream migration period in the upper Sacramento River (River Mile [RM] 194 to Keswick).

Spring-run Chinook salmon. As with steelhead, the Feather River was the only location with appreciable differences in migration flows between preliminary proposal and existing conditions, with the former averaging 5–30% greater than the latter in most water-year types.

Fall-run/late fall–run Chinook salmon. Migration flows for fall-run Chinook salmon were generally little different between preliminary proposal and existing conditions at most locations, except the Sacramento River (RM 194 to Keswick), American River, and Feather River. In the upper Sacramento River, adult migration flows were around 10–20% less under the preliminary proposal in wet and above-normal water years, and either similar or up to 20% greater under the preliminary proposal in the remaining water-year types. In the American River, appreciably less average adult migration flow (7–26%) occurred under preliminary proposal conditions than under existing conditions in wet and above-normal years, whereas in critical years preliminary proposal flows were 13–39% greater. Juvenile migration flows in the Feather River averaged around 10–20% greater than existing biological conditions for above-normal, below-normal, and dry years and were similar in other years. Adult migration flows were 12–32% less on average under the preliminary proposal in wet, above-normal, and below-normal years, in contrast to a similar percentage greater under the preliminary proposal in critical years. For late fall–run Chinook salmon adults, there was little difference in migration flows between the preliminary proposal and existing conditions in the Sacramento River (RM 194 to Keswick).

White sturgeon. Analyses for white sturgeon focused on the Sacramento River (North Delta to RM 143 subregion—i.e., Wilkins Slough and Verona CALSIM nodes). For juveniles, average migration flows at Verona were more than 5% lower under the preliminary proposal scenarios in all water-year types, ranging from around 6–11% in critical years to 20% in wet years. Larval transport flows were represented by the average number of months per year that exceeded thresholds of 17,700 cfs (Wilkins Slough) and 31,000 cfs (Verona) and were variable in terms of estimated effects. The results ranged from little change or somewhat more frequent exceedances of flow thresholds (16%

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

greater in above-normal years) under the preliminary proposal relative to existing conditions at Wilkins Slough, to reduced flow threshold exceedances at Verona of 9–50%. (The latter value occurred in dry years, when the average number of months exceeding the threshold was low regardless of scenario.)

Green sturgeon. Flows for green sturgeon migration were analyzed in the upper Sacramento River and Feather River and demonstrated contrasting changes for different life stages. Preliminary proposal flows that were lower than flows under the existing conditions were evident for larvae and juveniles in both systems and occurred primarily in wet, above-normal, and below-normal years, with the preliminary proposal flows in the Feather River falling in the 25–50% reduction category on average and those in the Sacramento River falling in the 5–25% reduction category. In contrast, adult migration flows were either similar or, in the case of the Feather River, somewhat increased in above-normal, below-normal, and dry water years.

Pacific lamprey. Average flows during Pacific lamprey migration periods were similar under the preliminary proposal and existing conditions (or slightly greater, up to 10%, under the preliminary proposal) on the Sacramento River (RM 194 to Keswick), Feather River, American River, Stanislaus River, and San Joaquin River at Vernalis.

River lamprey. Average flows during river lamprey migration periods generally were similar under the preliminary proposal and existing conditions for macropthalmia, with differences occurring for adults that typically indicated lower flows under the preliminary proposal than existing conditions. For adults, the difference was less than 5% for the Stanislaus River and San Joaquin River at Vernalis, whereas flows were 6–13% lower under the preliminary proposal for the Sacramento River (RM 194 to Keswick), Feather River, and American River.

Conclusion 5. Attraction flows and olfactory cues in the west Delta for upstream anadromous migrating fish will be altered because of shifts in exports from the south Delta to the north Delta under the preliminary proposal.

Sacramento River flows downstream of the north Delta intakes will be reduced under preliminary proposal operations relative to existing conditions, while reduced exports in the south Delta generally will increase the proportion of water in the west Delta originating from the San Joaquin River. The change in olfactory cues (percentage of Sacramento River or San Joaquin River water at Collinsville predicted using DSM2 modeling within the fingerprint analysis) differed by species (Table C.0-3).

Under the preliminary proposal, the average percentage of Sacramento River–origin water was always lower than for the existing conditions, ranging from 2–4% less for steelhead to 8–10% less for fall-run Chinook salmon. Under the preliminary proposal, the percentage of San Joaquin water was generally considerably greater than under existing conditions, at least in relative terms; however, the actual percentages involved were low (single digits) because a very low percentage of San Joaquin River water contributes to the water in the west Delta in any scenario.

Adult attraction/migration flows at Rio Vista under the preliminary proposal were lower than flows under existing conditions for most water-year types. The relative difference between scenarios ranged from 5–9% in all except critical water years (little changed) for winter-run and late fall–run Chinook salmon to more than 20% in some water-year types for steelhead, spring-run Chinook salmon, and fall-run Chinook salmon; the latter species had up to around 50–60% lower average flows under the preliminary proposal in wet and above-normal years. In dry and critical years,

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

differences in migration flows between preliminary proposal and existing conditions were often less than 5%, and in some cases preliminary proposal flows were greater (e.g., fall-run Chinook salmon in the LLT).

Conclusion 6. The preliminary proposal improvements in fish passage facilities at the Fremont Weir and within the Yolo Bypass (CM2) will reduce delay and stranding of upstream migrating adult anadromous covered fish species from the Sacramento River basin.

The suite of actions proposed to improve adult fish passage as part of *CM2 Yolo Bypass Fisheries Enhancements* is expected to benefit Sacramento River basin covered fish species by reducing stranding and delay in the Yolo Bypass. Limited stranding and rescue data indicate that appreciable percentages (10% or more) of the green sturgeon spawning population in particular currently may be negatively affected by the passage impediment caused by the Fremont Weir. The efficacy of the passage improvements at the Fremont Weir and other locations in the Yolo Bypass (e.g., Lisbon Weir) cannot be estimated, but will be monitored, and adjustments will be made through adaptive management. Resulting improvements in migration may vary by year type as a result of differing inundation frequencies and volumes, but overall CM2 is expected to have a major positive effect on upstream migrating anadromous covered fish species, in particular sturgeons and salmonids.

Conclusion 7. Chinook salmon smolt survival during outmigration through the Delta includes tradeoffs between positive and negative flow changes in the Yolo Bypass and Sacramento River, with uncertainty to be informed by monitoring and adaptive management.

The results of the DPM showed that through-Delta survival of Chinook salmon smolts was generally similar or slightly lower under the preliminary proposal than under existing biological conditions. The difference in survival between preliminary proposal scenarios and existing biological conditions in the early and late long-term ranged from averages of considerably less than 1% of the smolts entering the Delta (San Joaquin–origin fall-run Chinook) to 1–2% of smolts for fall-, spring-, and winter-run Chinook from the Sacramento River and fall-run Chinook from the Mokelumne River. It is unknown whether these differences are outside the range of error for the model but, regardless, they are low. The observed patterns represented tradeoffs between positive and negative aspects of the preliminary proposal relative to the existing biological conditions, as assumed in the model. Positive aspects of the preliminary proposal include the increased diversion of fish into the Yolo Bypass for smolts migrating down the Sacramento River that encounter the new notch at the Fremont Weir. The Yolo Bypass migration route is assumed to have survival equal to the maximum survival in the nearby Sacramento River, as well as offering the advantage of avoidance of diversion through Georgiana Slough or the DCC into the low-survival interior Delta. The benefits of increased entry into the Yolo Bypass were greatest for winter-run Chinook, followed by spring-run and finally fall-run, for which there was little benefit because their assumed timing is during a period when Yolo Bypass inundation is generally too low to promote appreciable diversion. The relatively good survival assumed through the Yolo Bypass is based on studies conducted on fish smaller than smolts, and the assumption will require refinement based on monitoring studies of acoustically tagged smolts to be conducted in the future. Reductions in south Delta exports also improve survival of smolts, although as noted in Appendix 5.B, *Entrainment*, there are situations in drier water years where exports from the south Delta are increased because of bypass requirements at the north Delta intakes. Such situations generally arise during the fall-run migration period and explain the lower survival through the interior Delta of this race.

Negative aspects of the preliminary proposal include an assumed increase in predation of Sacramento River–origin smolts in the vicinity of the north Delta intake structures because of

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

predators holding station in the area; the current modeling assumed approximately 1% of each run would be lost (see Section C.5.3.2.3 for details), but this number is uncertain and will be refined through targeted studies as part of the adaptive management program under BDCP. The potential benefits of habitat restoration in the Delta also are not captured by the DPM results, which focus on flow-related survival and migration routes through the Delta. In addition, there is an unquantified trade-off between increased predation in the north Delta at the new diversion facilities and the reduction in predation in CCF from reduced south Delta exports.

Conclusion 8. Increase in Stockton Deep Water Ship Channel dissolved oxygen levels (CM14) will improve upstream migration conditions for fall-run Chinook salmon, steelhead, and other species in the San Joaquin River basin.

Preliminary results from the oxygen diffusion system that forms the basis for CM14 suggest that it can raise DO levels to meet total maximum daily load objectives (at least 6 mg/L of DO from September 1 to November 30, and at least 5 mg/L at all times). The long-term funding for operations and maintenance of this facility, coupled with improvements that would be implemented based on adaptive management and monitoring, will ensure that any passage impediments caused by low DO in this area for upstream migrating adult fall-run Chinook salmon and steelhead in the San Joaquin River basin would be minimized. Improvement of DO in the vicinity of the ship channel also will benefit any other covered fish species using that area of the Delta.

Conclusion 9. Modification of the Suisun Marsh Salinity Control Gate operation will improve or maintain passage for adult anadromous fish.

As operations of the SMSCG become less frequent, upstream passage for adult anadromous fish such as Chinook salmon, steelhead, sturgeons, and lampreys will have less potential for delay and subsequent effects on reproduction in natal tributaries. Passage will be improved or maintained at low levels expected from reduced operations under the preliminary proposal.

Conclusion 10. Nonphysical fish barriers (CM16) have the potential to inhibit juvenile fish from entering the interior Delta, but further research is necessary to evaluate effectiveness; unintended passage impedance for adults also requires research.

Juvenile Chinook salmon and steelhead, and juvenile and adult delta smelt, longfin smelt, and Sacramento splittail are most likely to benefit from nonphysical barriers at important channel divergences such as Sacramento River–Georgiana Slough and San Joaquin River–Old River because these species have hearing abilities that are likely to respond to the main barrier stimulus (i.e., the acoustic signal). As such, these barriers could be an effective tool for precluding these species from entering the interior Delta, where mortality may be higher than in the main channels of the Sacramento and San Joaquin Rivers. There is little potential to inhibit white and green sturgeon or Pacific and river lamprey from entering the interior Delta because these species have little sensitivity to the acoustic deterrence of the nonphysical barriers. The effectiveness of nonphysical barriers will depend on the water velocity characteristics in the vicinity of the barrier and on the extent to which predatory fish congregate along the barrier.

However, nonphysical barriers could be encountered by upstream migrating adult anadromous fishes (e.g., winter- and spring-run Chinook salmon, steelhead, Sacramento splittail, sturgeons, and lampreys). The potential for impedance or delay would be low for fish with poor hearing ability (sturgeons and lampreys), whereas the potential for impedance of the other species would increase as water depth decreases and a greater portion of the water column is occupied by the barrier.

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

Ongoing testing at Georgiana Slough and the head of the Old River will provide more insight into the potential effectiveness of CM16 under various flow and geomorphic conditions, as will monitoring, research, and adaptive management of the conservation measure.

Conclusion 11. Reduced Sacramento River flows may reduce longfin smelt and delta smelt larval transport, with the potential to reduce survival for longfin smelt.

Decreased transport flows in the lower Sacramento River have been identified as one mechanism that could adversely affect the growth and survival of larval delta and longfin smelt. Compared to existing biological conditions, the preliminary proposal reduces Delta outflows during the winter-spring delta smelt and longfin smelt larval period, potentially reducing downstream longfin larval transport and subsequent survival. Projected reductions assume a direct relationship between outflow (expressed as X2) and longfin smelt abundance. However, the correlation is not understood, and it may not reflect larval transport but may instead be reflective of some other relationship. The longfin smelt analysis estimated that once climate change–related flow effects had been factored out, changes in outflow during the larval period have the potential to reduce abundance of older life stages represented in Bay-Delta trawl surveys by 8–24% in the ELT and 1–18% in the LLT on average. Results of particle tracking modeling for longfin smelt estimated that the potential for emigration to the LSZ in Suisun Bay (as represented by the number of particles reaching Martinez) was on average 0–8% lower under the preliminary proposal compared with existing biological conditions when accounting for climate change–related effects.

For delta smelt, larval transport under the preliminary proposal as assessed by particle tracking ranged from little difference from existing conditions up to 20% less, after accounting for flow-related climate change effects. The assumption that delta smelt larval survival is proportional to flow, however, has not been confirmed. In contrast to longfin smelt, relationships estimating subsequent abundance of older life stages from changes in transport flows are not present, so the estimated changes solely reflect changed potential in larval transport.

C.6.2.5 Delta Area Effects

Conclusion 12. Changes in Sacramento River flow may result in an overall decrease in channel margin bench habitat, but restoration will offset this effect.

Results of the analysis of the effects of changes in Sacramento River flow and water surface elevation on channel margin bench habitat showed site-specific differences attributable to site elevation and the interplay of differing flows and other effects such as tidal muting from the preliminary proposal. At the north Delta sites, inundation frequency under the preliminary proposal was on average similar to or lower than under existing conditions, whereas average inundation duration was lower in the early long-term and higher in the late long-term. At the Cache Slough site, considerable increases in inundation frequency and duration under the preliminary proposal may be a result of the site's low elevation combining with tidal dampening because of restoration. Reductions in bench habitat inundation at existing sites may be offset by restoration at other sites within the North Delta and Cache Slough subregions, as described for *CM4 Tidal Habitat Restoration* and analyzed in Appendix 5.E, *Habitat Restoration*.

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

Conclusion 13. The reduction in OMR reverse flows and the corresponding increase in net positive downstream flows through the south Delta channels are expected to improve migration cues, improve migration rates and pathways, and contribute to improved larval and juvenile survival and reduced adult straying; reverse OMR flows will be greater in certain water-year types.

As a result of preliminary proposal operations, the frequency and magnitude of OMR reverse flows are expected to be reduced significantly during the late winter and spring period for wet, above-normal, and critical years, which coincides with the seasonal period of migration of many of the juvenile fish such as Chinook salmon, steelhead, larval and juvenile delta and longfin smelt, and juvenile splittail through the interior Delta channels. The predicted improvements in south Delta flow conditions (significantly reduced OMR reverse flows, improved net positive downstream flows, improved olfactory cues, and attraction flows for the San Joaquin River and its tributaries) are significant benefits of the PP operations on flow conditions affecting habitat, migration, and survival of fish inhabiting the Delta.

Improved hydrologic conditions in the south Delta in response to proposed project operations are expected to contribute to improvement in the flow cues followed by juvenile and adult fish passing upstream and downstream through the Delta and thereby improve migration and survival and reduce straying. Reduction in OMR reverse flows also is expected to reduce the movement of planktonic larval and juvenile fish (e.g., delta and longfin smelt, Chinook salmon) from the Sacramento River through the interior Delta to the south Delta and thereby improve their survival and abundance. However, as noted in Appendix 5.B, *Entrainment*, OMR reverse flows may be increased in the late winter/spring in drier water-year types because of export restrictions at the north Delta intakes, which would negatively affect species present there at the time, such as juvenile spring-run Chinook salmon and larval-juvenile delta smelt.

In dry and below-normal water years, the reverse OMR flows are increased compared to existing biological conditions, which may translate to adverse effects on Chinook salmon and splittail juveniles, and delta smelt and longfin smelt larvae and juveniles. However, the reverse OMR flows under the preliminary proposal for all water years are still within the requirements of the NMFS and USFWS BiOps for SWP and CVP operations, and the biological response of these species to relatively small OMR reverse flow changes may not result in adverse changes in species survival.

Conclusion 14. Increased Yolo Bypass inundation will create substantial biological benefits to Sacramento splittail spawning and rearing, with other species likely to benefit; stranding risk is generally low.

Based on results of hydrologic models, modification to the Fremont Weir to increase inundation of the Yolo Bypass floodplain during the winter and spring months (CM2) would create substantial biological benefits to splittail spawning success and rearing; increased benefits to rearing and migration by other juvenile and adult fish also are expected. The benefits of enhanced growth for Chinook salmon fry on the Yolo Bypass are examined in Appendix 5.F, *Biological Stressors on Covered Fish*. The area of increased inundation was greatest in wet and above normal year types, but the percent increase was greatest in the drier year types, when little or no inundated habitat was found under existing biological conditions. Consequently, the benefits of increased inundation to splittail were found to be greatest in below normal, dry, and critical water years, when seasonal flows in the Sacramento River are lowest and little spawning and rearing habitat is available. In below normal water-year types, habitat area for splittail was on average almost 300% greater under the preliminary proposal scenarios compared to existing biological conditions. In dry and critical year types, no habitat area for splittail was found under existing biological conditions, while small

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

areas (about 100 acres) were found occasionally under the preliminary proposal scenarios. The anticipated benefits would be greatest for those fish that rear in floodplain habitats as juveniles during downstream migration, including juvenile winter- and fall-run Chinook salmon. Other fish such as steelhead, late fall–run Chinook salmon, green and white sturgeon, and Pacific lamprey would be expected to benefit from using the flooded bypass as a migratory corridor, but would not be expected to rear extensively in the flooded area. Splittail, which spawn on seasonally inundated floodplain habitat, would be expected to benefit from access to spawning and juvenile rearing floodplain habitat.

Fish species such as splittail and juvenile Chinook salmon that historically used seasonally inundated floodplain habitat for spawning or juvenile rearing have adapted behavior to respond to flow recessions and draining of floodplain habitat. The DRERIP analysis of stranding suggested low magnitude of negative effect for all species examined other than juvenile steelhead, for which the potential for stranding was assessed to be slightly higher. In general, the risk of stranding juvenile fish in the Yolo Bypass has not been identified as a major potential source of mortality but will be informed by monitoring and adaptive management of improvements to the floodplain.

Conclusion 15. The delta smelt fall abiotic habitat index is estimated to be similar between the preliminary proposal and existing biological conditions in the drier 40–50% of years and will be lower under the preliminary proposal in the wetter 50–60% of years, with the magnitude of difference depending on existing biological conditions; if occupied by delta smelt, restored habitat may decrease the magnitude of difference in wetter years and result in a greater habitat index in drier years.

The delta smelt fall abiotic habitat index was lower under the preliminary proposal, with restoration, relative to existing biological conditions, particularly for years with higher flow (Table C.0-3). The greatest differences were for years with higher flow under the EBC2 scenarios, which incorporated the USFWS (2008) BiOp requirements for Fall X2 in above-normal and wet years. The differences were relatively low between EBC1 and preliminary proposal (including restoration) scenarios because the requirements for Fall X2 were not included under the modeling for EBC1. Under the assumption that restored areas have abiotic characteristics similar to adjacent areas, the magnitude of the reductions under the preliminary proposal may be reduced in wetter years, and there may be a similar or greater habitat index in drier years (Table C.0-3). However, this assumption will depend on the characteristics in the ROAs, a topic explored in more detail in Appendix 5.E, *Habitat Restoration*. The likely change in the X2–abiotic habitat index relationship under future configurations of the Delta and the potential influence of additional factors such as water temperature add uncertainty to potential effects. Monitoring in restored areas will provide information on physicochemical characteristics of the new habitat to inform the nature of changes in the delta smelt fall abiotic habitat index.

Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

C.7 References

Adams, P. B., C. Grimes, J. E. Hightower, S. T. Lindley, M. M. Moser, and M. J. Parsley. 2007. Population Status of North American Green Sturgeon, *Acipenser medirostris*. *Environmental Biology of Fishes* 79:339–356.

Anderson, J. 2003. *Delta Island Consumptive Use (DICU) Values Used for the South Delta Improvements Program (SDIP) Simulations*. July 30. California Department of Water Resources Delta Modeling Section.

Anderson, J. and M. Mierzwa. 2002. Section 6.5, Gates: An Introduction to Modeling Flow Barriers in DSM2. Pages 164–168 in DSM2 tutorial, *An Introduction to the Delta Simulation Model II (DSM2) for Simulation of Hydrodynamics and Water Quality of the Sacramento–San Joaquin Delta*. Draft. February. Sacramento, CA: Delta Modeling Section, Office of State Water Project Planning, California Department of Water Resources.

Baxter, R. D., M. L. Nobriga, S. B. Slater, and R. W. Fujimura. 2009. *Effects analysis – State Water Project Effects on Longfin Smelt.* February. California Department of Fish and Game.

Baxter, R., R. Breuer, L. Brown, L. Conrad, F. Feyrer, S. Fong, K. Gehrts, L. Grimaldo, B. Herbold, P. Hrodey, A. Mueller-Solger, T. Sommer, and K. Souza. 2010. *IEP 2010 Pelagic Organism Decline Workplan and Synthesis of Results*. Interagency Ecological Program Report. Available: <http://www.water.ca.gov/iep/docs/FinalPOD2010Workplan12610.pdf>.

Beamesderfer, R. C. P. and M. A. H. Webb. 2002. Green Sturgeon Status Review Information. Gresham, OR: S. P. Cramer & Associates.

Beamesderfer, R. C. P., and R. A. Farr. 1997. Alternatives for the Protection and Restoration of Sturgeons and their Habitat. *Environmental Biology of Fishes* 48:407–417.

Beamish, R. J. 1980. Adult Biology of the River Lamprey (*Lampetra ayresi*) and the Pacific Lamprey (*Lampetra tridentata*) from the Pacific Coast of Canada. *Canadian Journal of Fish and Aquatic Science* 53:2898–2908.

Bell, M. C. 1986. *Fisheries Handbook of Engineering Requirements and Biological Criteria*. Sacramento, CA: U.S. Army Corps of Engineers, Fish Passage Development and Evaluation Program.

Bennett, W. A. 2005. Critical Assessment of the Delta Smelt Population in the San Francisco Estuary, California. *San Francisco Estuary and Watershed Science* 3(2):article 1. Available: <http://escholarship.org/uc/item/0725n5vk>.

Berggren, T. J., and M. J. Filardo. 1993. An Analysis of Variables Influencing the Migration of Juvenile Salmonids in the Columbia River Basin. *North American Journal of Fisheries Management* 13(1):48–63.

Blake, A. and M. J. Horn. 2003. *Acoustic Tracking of Juvenile Chinook Salmon Movement in the Vicinity of the Delta Cross Channel, Sacramento River, California – 2001 Study Results*. Prepared for U.S. Geological Survey and SRI International.

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

Bovee, K. D. 1978. *Probability-of-Use Criteria for the Family Salmonidae*. Instream Flow Informational Paper 4. (FWS/OBS-78/07.) U.S. Fish and Wildlife Service.

Brandes, P. L., and J. S. McLain. 2001. Juvenile Chinook Salmon Abundance, Distribution, and Survival in the Sacramento-San Joaquin Estuary. Pages 39–95 in Contributions to the Biology of Central Valley Salmonids. *Fish Bulletin* 179:2. Available: <http://escholarship.org/uc/item/6sd4z5b2>.

Bricker, J. D. 2003. *Bed Drag Coefficient Variability under Wind Waves in a Tidal Estuary: Field Measurements and Numerical Modeling*. PhD thesis. Stanford University, Stanford, CA.

Brown, K. 2007. Evidence of Spawning by Green Sturgeon, *Acipenser medirostris*, in the Upper Sacramento River, California. *Environmental Biology of Fishes* 84:245–258.

Brumo, A. F. 2006. *Spawning, Larval Recruitment, and Early Life Survival of Pacific Lampreys in the South Fork Coquille River, Oregon*. Master's thesis. Oregon State University. Corvallis, OR. Available: <http://ir.library.oregonstate.edu/jspui/bitstream/1957/3139/6/Abel%2bBrumo-M.S._THESIS_Fisheries%2bScience-2006-2.pdf>.

California Department of Fish and Game. 2002. California Department of Fish and Game Comments to National Marine Fisheries Service Regarding Green Sturgeon Listing.

California Department of Fish and Game. 2008. GrandTab Salmon Escapement Report. Available: <http://www.calfish.org/tabid/104/Default.aspx>.

California Department of Fish and Game. Undated, 1955-1968. *Records of Ladder Operations, Fish Stranding, and Rescue Efforts at the Fremont Weir*.

California Department of Fish and Game. Unpublished data for Bay-Delta fishery monitoring.

California Department of Water Resources and California Department of Fish and Game. 2005. *Suisun Marsh Salinity Control Gates Salmon Passage Evaluation Report, 2004*. Draft report. May 18.

California Department of Water Resources. 2004. Phase 2 Report, Evaluation of Project Effects on Instream Flows and Fish Habitat. SP-F16. February. Oroville Facilities Relicensing Federal Energy Regulatory Commission Project No. 2100.

California Department of Water Resources. 2010. *Stockton Deep Water Ship Channel Demonstration Dissolved Oxygen Aeration Facility Project*. Final report. December. (ICF 00508.10.) Prepared by ICF International, Sacramento, CA.

California Department of Water Resources. Unpublished data cited in the 2009 Delta Regional Ecosystem Restoration Implementation Plan evaluation of Fremont Weir and Yolo Bypass Inundation.

Cappiella, K., C. Malzone, R. Smith, and B. Jaffe. 1999. *Sedimentation and Bathymetry Changes in Suisun Bay: 1867–1990*. Menlo Park, CA: U. S. Geological Survey.

Cavallo, B., R. Kurth, and J. Kindopp. 2003. *Distribution and Habitat Use of Steelhead and Other Fishes in the Lower Feather River, 1999-2001*. Interim report. (SP-F10, Task 3a.) Sacramento, CA: California Department of Water Resources.

Cech, J. J. Jr., and C. E. Crocker. 2002. Physiology of Sturgeon: Effects of Hypoxia and Hypercapnia. *Journal of Applied Ichthyology* 18:320–324.

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

Cech, J. J. Jr., S. I. Doroshov, G. P. Moberg, B. P. May, R. G. Schaffter, and D. M. Kohlhorst. 2000. *Biological Assessment of Green Sturgeon in the Sacramento-San Joaquin Watershed (Phase 1)*. Final report to the CALFED Bay-Delta Program. (Project 98-C-15, Contract B-81738.) Davis, CA.

Cech, J. J. Jr., S. J. Mitchell, and T. E. Wragg. 1984. Comparative Growth of Juvenile White Sturgeon and Striped Bass: Effects of Temperature and Hypoxia. *Estuaries* 7(1):12–18.

Central Valley Regional Water Quality Control Board. 2005. *Amendments to the Water Quality Control Plan for the Sacramento River and San Joaquin River Basins for the Control Program for Factors Contributing to the Dissolved Oxygen Impairment in the Stockton Deep Water Ship Channel*. Available: <http://www.swrcb.ca.gov/centralvalley/water_issues/tmdl/central_valley_projects/san_joaquin_oxygen/final_staff_report/do_tmdl_final_draft.pdf>.

Central Valley Regional Water Quality Control Board. 2009. *Clean Water Act Section 305(b) and 303(d) Integrated Report for the Central Valley Region*. Final staff report. Rancho Cordova, CA. Available: <http://www.waterboards.ca.gov/centralvalley/water_issues/tmdl/impaired_waters_list/final_2008_303d/r5_2008_ir_final_stfrpt_sept09.pdf>.

Chamberlain, C. D. 2003. Trinity *River Juvenile Fish Stranding Evaluation, May to June 2002*. (AFWO-F-01-03.) U.S. Fish and Wildlife Service, Arcata Fish and Wildlife Office.

Close, A., W. M. Haneman, J. W. Labadie, D. P. Loucks, J. R. Lund, D. C. McKinney, and J. R. Stedinger. 2003. *A Strategic Review of CALSIM II and its Use for Water Planning, Management, and Operations in Central California*. December 4. Oakland, CA: California Bay Delta Authority Science Program, Association of Bay Governments.

Coastal Engineering Research Center. 1984. *Shore Protection Manual*, Vols. 1 and 2. Washington, DC: U.S. Government Printing Office.

Dean, R. G., and R. A. Dalrymple. 2002. *Coastal Processes with Engineering Applications.* New York: Cambridge University Press.

Delta Regional Ecosystem Restoration Implementation Plan (DRERIP). 2009. WOCM 2: Fremont Weir and Yolo Bypass Inundation. May 18, 2009. Available: <http://baydeltaconservationplan.com/BDCPPlanningProcess/BackgroundDocuments/FullDRERIPWorksheets.aspx>.

Deng, X., J. P. Van Eenennaam, and S. I. Doroshov. 2002. Comparison of Early Life Stages and Growth of Green and White Sturgeon. *American Fisheries Society Symposium* 28:237–248.

Denton, D. N. 1986. *Clear Creek Fishery Study*. Red Bluff, CA: California Department of Water Resources.

Denton, R. A. 1993. Accounting for Antecedent Conditions in Seawater Intrusion Modeling–Applications for the San Francisco Bay-Delta. Pages 448–453 in H. W. Shen, S. T. Su, and E. Wen (eds.). *Hydraulic Engineering '93, Proceedings of the 1993 Conference.* American Society of Civil Engineers.

Dobson, A. J. 2002. *An Introduction to Generalized Linear Models*. 2nd ed. Boca Raton, FL: Chapman & Hall/CRC.

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

Draper, A. J., A. Munévar, S. K. Arora, E. Reyes, N. L. Parker, F. I. Chung, and L. E. Peterson. 2004. CalSim: Generalized Model for Reservoir System Analysis. *Journal of Water Resources Planning and Management* 130(6):480–489.

Emmett, R. L., S. L. Stone, S. A. Hinton and M. E. Monaco. 1991. *Distribution and Abundance of Fishes and Invertebrates in West Coast Estuaries, Volume II: Species Life History Summaries.* Estuarine Living Marine Resources Report Number 8. Rockville, MD: National Oceanic and Atmospheric Administration/National Ocean Service Strategic Environmental Assessments Divisions.

Erickson, D. L., J. A. North, J. E. Hightower, J. Weber, and L. Lauck. 2002. Movement and Habitat Use of Green Sturgeon *Acipenser medirostris* in the Rogue River, Oregon, USA. *Journal of Applied Ichthyology* 18:565–569.

Fagherazzi, S., C. Palermo, M. C. Rulli, L. Carniello, and A. Defina. 2007. Wind Waves in Shallow Microtidal Basins and the Dynamic Equilibrium of Tidal Flats. *Journal of Geophysical Research* 112, F02024. doi:10.1029/2006JF000572.

Ferreira, I. C., S. K. Tanaka, S. P. Hollinshead, and J. R. Lund. 2005. Musings on a Model: CalSim II in California's Water Community. *San Francisco Estuary and Watershed Science* 3(1).

Feyrer, F., J. Hobbs and T. Sommer. 2004. Salinity Inhabited by Age-0 Splittail (*Pogonichthys macrolepidotus*) as Determined by Direct Field Observation and Retrospective Analyses with Otolith Chemistry. *San Francisco Estuary and Watershed Science* 8(2).

Feyrer, F., K. Newman, M. Nobriga, and T. Sommer. 2011. Modeling the Effects of Future Outflow on the Abiotic Habitat of an Imperiled Estuarine Fish. *Estuaries and Coasts* 34:120–128.

Feyrer, F., M. L. Nobriga, and T. R. Sommer. 2007. Multidecadal Trends for Three Declining Fish Species: Habitat Patterns and Mechanisms in the San Francisco Estuary, California, USA. *Canadian Journal of Fisheries and Aquatic Sciences* 64:723–734.

Feyrer, F., M. L. Nobriga, T. Sommer, and K. Newman. 2010. Modeling the Effects of Future Freshwater Flow on Abiotic Habitat of an Imperiled Estuarine Fish. *Estuaries and Coasts*. doi:10.1007/s12237-010-9343-9.

Feyrer, F., T. R. Sommer, and R. D. Baxter. 2005. Spatial–Temporal Distribution and Habitat Associations of Age-0 Splittail in the Lower San Francisco Estuary Watershed. *Copeia* 2005:159–168.

Feyrer, F., T. Sommer, and W. Harrell. 2006. Managing Floodplain Inundation for Native Fish: Production Dynamics of Age-0 Splittail (*Pogonichthys macrolepidotus*) in California's Yolo Bypass. *Hydrobiologia* 573:213–226.

Fish, M. 2010. A White Sturgeon Year-Class Index for the San Francisco Estuary and Its Relation to Delta Outflow. *Interagency Ecological Program Newsletter* 23(2):80–84.

Fretwell, M. R. 1989. Homing Behavior of Adult Sockeye Salmon in Response to a Hydroelectric Diversion of Home Streamwaters at Seton Creek. *International Pacific Salmon Fisheries Commission Bulletin* 25.

Ganju, N. K., and D. H. Schoellhamer. 2006. Annual Sediment Flux Estimates in a Tidal Strait Using Surrogate Measurements. *Estuarine, Coastal and Shelf Science* 69:165–178.

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

Ganju, N. K., and D. H. Schoellhamer. 2007. Calibration of an Estuarine Sediment Transport Model to Sediment Fluxes as an Intermediate Step for Simulation of Geomorphic Evolution. *Continental Shelf Research*. doi:10.1016/j.csr.2007.09.005.

Ganju, N. K., and D. H. Schoellhamer. 2010. Decadal-Timescale Estuarine Geomorphic Change under Future Scenarios of Climate and Sediment Supply. *Estuaries and Coasts* 33:15–29.

Ganju, N. K., D. H. Schoellhamer, and B. E. Jaffe. 2009. Hindcasting of Decadal-Timescale Estuarine Bathymetric Change with a Tidal-Timescale Model. *Journal of Geophysical Research-Earth Surface* 114, F04019. doi:10.1029/2008JF001191.

Ganju, N. K., D. H. Schoellhamer, J. C. Warner, M. F. Barad, and S. G. Schladow. 2004. Tidal Oscillation of Sediment between a River and a Bay: A Conceptual Model. *Estuarine, Coastal and Shelf Science* 60(1):81–90.

Ganju, N. K., D. H. Schoellhamer, M. C. Murrell, J. W. Gartner, and S. A. Wright. 2006. Constancy of the Relation between Floc Size and Density in San Francisco Bay. Pages 75–91 in J. P. Maa, L. H. Sanford, and D. H. Schoellhamer, (eds.). *Estuarine and Coastal Fine Sediment Dynamics – INTERCOH 2003*. Amsterdam: Elsevier.

Gard, M. 1996. *Sacramento River White Sturgeon Spawning Criteria*. U.S. Fish and Wildlife Service, Instream Flow Assessments Branch.

Gard, M. 2005. *Upper Sacramento River Instream Flow Incremental Methodology Study Scoping Report*. Sacramento, CA: U.S. Fish and Wildlife Service.

Geist, D. R., R. S. Brown, V. Cullinan, S. R. Brink, K. Lepla, P. Bates, and J. A. Chandler. 2005. Movement, Swimming Speed, and Oxygen Consumption of Juvenile White Sturgeon in Response to Changing Flow, Water Temperature, and Light Level in the Snake River, Idaho. *Transactions of the American Fisheries Society* 134:803–816.

Gibson, R. N. 1992. Tidally-Synchronised Behavior in Marine Fishes. Pages 63–81 in Ali, M. A. (ed.). *Rhythms in Fishes*. New York: Plenum Press.

Hallock, R. J., R. F. Eldwell, and D. H. Fry. 1970. Migrations of adult king salmon *Oncorhynchus tshawytscha* in the San Joaquin Delta, as Demonstrated by the Use of Sonic Tags. *Fish Bulletin* 151. Sacramento, CA: California Department of Fish and Game.

Hannon, J. and B. Deason. 2007. *American River Steelhead (Oncorhynchus mykiss) Spawning 2001–2007*. U.S. Bureau of Reclamation.

Harrell, W. C., and T. R. Sommer. 2003. Patterns of Adult Fish Use on California's Yolo Bypass Floodplain. Pages 88–93 in P. M. Faber (ed.). *California Riparian Systems: Processes and Floodplain Management, Ecology, and Restoration*. 2001 Riparian Habitat and Floodplains Conference Proceedings. Sacramento, CA: Riparian Habitat Joint Venture.

Hatch, D. R., and J. M. Whiteaker. 2009. A Field Study to Investigate Repeat Homing in Pacific Lamprey. Pages 191–202 in L. R. Brown, S. D. Chase, M. G. Mesa, R. J. Beamish, and P. B. Moyle (eds.). *Biology, Management, and Conservation of Lamprey in North America*. Symposium 72. Bethesda, MD: American Fisheries Society.

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

Healey, M. C. 1980. Utilization of the Nanaimo River Estuary by Juvenile Chinook Salmon (*Oncorhynchus tshawytscha*). U.S. National Marine Fisheries Service Fishery Bulletin 77:653–668.

Healey, M. C. and F. P. Jordan. 1982. Observations on Juvenile Chum and Chinook and Spawning Chinook in the Nanaimo River, British Columbia, during 1975-1981. *Canada Manuscript Report of Fisheries and Aquatic Sciences* 1659:4.

Healey, M., and R. Vincik. 2011. Memorandum on Fremont Weir Sturgeon Rescue. Submitted to Joseph R. Johnson of California Department of Fish and Game on May 6, 2011.

Henning, J. A., R. E. Gresswell, and I. A. Fleming. 2006. Juvenile Salmonid Use of Freshwater Emergent Wetlands in the Floodplain and its Implications for Conservation Management. *North American Journal of Fisheries Management* 26:367–376.

Herr, J. 2010. *Modeling, Upstream Loading and D.O. in the DWSC 2008-2009*. Presentation at the San Joaquin River Dissolved Oxygen Total Maximum Daily Load Technical Working Group Meeting, June 24, 2010.

Heublein, J. C., J. T. Kelly, C. E. Crocker, A. P. Klimley, and S. T. Lindley. 2009. Migration of Green Sturgeon, *Acipenser medirostris*, in the Sacramento River. *Environmental Biology of Fishes* 84:245–258.

Holbrook, C. M., R. W. Perry, and N. S. Adams. 2009. *Distribution and Joint Fish-Tag Survival of Juvenile Chinook Salmon Migrating through the Sacramento-San Joaquin River Delta, California, 2008*. Open-file report 2009-120. U.S. Geological Survey.

Israel, J. 2003. *Life History, Ecology, and Status of Klamath River Steelhead*. University of California, Davis.

Israel, J. A., A. M. Drauch, M. Gingras, and M. Donnellan. 2009. Life History Conceptual Model for White Sturgeon (*Acipenser transmontanus*). Final report. California Department of Fish and Game Delta Regional Ecosystem Restoration and Implementation Program.

Israel, J. A., and A. P. Klimley. 2008. Life History Conceptual Model for North American Green Sturgeon (*Acipenser medirostris*). Final report. California Department of Fish and Game Delta Regional Ecosystem Restoration and Implementation Program.

Israel, J. A., and B. May. 2010. Indirect Genetic Estimates of Breeding Population Size in the Polyploidy Green Sturgeon (*Acipenser medirostris*). *Molecular Ecology* 19:1058–1070.

Jeffres, C. A., J. J. Opperman, and P. B. Moyle. 2008. Ephemeral floodplain habitats provide best growth conditions for juvenile Chinook salmon in a California river. *Environmental Biology of Fishes* 83:449–458.

Jones, N. L., and S. G. Monismith. 2008. The Influence of Whitecapping Waves on the Vertical Structure of Turbulence in a Shallow Estuarine Embayment. *Journal of Physical Oceanography* 38(7):1563–1580. doi: 10.1175/2008JPO3766.1.

Kaufman, R. C., A. G. Houck, and J. J. Cech Jr. 2006. Effects of Temperature and Carbon Dioxide on Green Sturgeon Blood–Oxygen Equilibria. *Environmental Biology of Fishes* 76:119–127.

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

Kelly, F., T. Champ, N. McDonnell, M. Kelly-Quinn, S. Harrison, A. Arbuthnott, P. Giller, M. Joy, K. McCarthy, P. Cullen, C. Harrod, P. Jordon, D. Griffiths and R. Rosell. 2007. *Investigation of the Relationship between Fish Stocks, Ecological Quality Ratings (Q-Values), Environmental Factors and Degree of Eutrophication*. U.S. Environmental Protection Agency.

Kennedy, T., and T. Cannon. 2002. Stanislaus River Salmonid Density and Distribution Survey Report (2000–2001). Sacramento, CA: Fishery Foundation of California.

Kimmerer, W. J. 2002. Physical, Biological, and Management Responses to Variable Freshwater Flow into the San Francisco Estuary. *Estuaries* 25:1275–1290.

Kimmerer, W. J. 2004. *Ecosystem-Level Changes following Foodweb Disruption by an Introduced Clam in the San Francisco Estuary*. October. CALFED Science Conference, Sacramento, CA.

Kimmerer, W. J., and M. L. Nobriga. 2008. Investigating Particle Transport and Fate in the Sacramento-San Joaquin Delta using a Particle Tracking Model. *San Francisco Estuary and Watershed Science* 6(1):4.

Kimmerer, W. J., E. S. Gross, and M. L. MacWilliams. 2009. Is the Response of Estuarine Nekton to Freshwater Flow in the San Francisco Estuary Explained by Variation in Habitat Volume? *Estuaries and Coasts* 32:375–389.

Kimmerer, W. J., W. A. Bennett, and J. R. Burau. 2002. Persistence of Tidally-Oriented Vertical Migration by Zooplankton in a Temperate Estuary. *Estuaries* 25(3):359–371.

Kjelson, M. A., and P. L. Brandes. 1989. The Use of Smolt Survival Estimates to Quantify the Effects of Habitat Changes on Salmonid Stocks in the Sacramento-San Joaquin Rivers, California. In C. D. Levings, L. B. Holtby, and M. A. Henderson (eds.). Proceedings of the National Workshop on the Effects of Habitat Alteration on Salmonid Stocks. *Canadian Special Publications in Fisheries and Aquatic Sciences* 105:100–115.

Kohlhorst, D. W. 1976. Sturgeon Spawning in the Sacramento River in 1973, as Determined by Distribution of Larvae. *California Fish and Game* 62(1):32–40.

Kohlhorst, D. W., L. W. Botsford, J. S. Brennan, and G. M. Cailliet. 1991. Aspects of the Structure and Dynamics of an Exploited Central California Population of White Sturgeon (*Acipenser transmontanus*). Pages 277–293 in P. Williot (ed.), *Proceedings of the First International Symposium on the Sturgeon*. CEMAGREF, Bordeaux, France.

Li, W., P. W. Sorensen, and D. D. Gallaher. 1995. The Olfactory System of Migratory Adult Sea Lamprey (*Petromyzon marinus*) is Specifically and Acutely Sensitive to Unique Bile Acids Released by Conspecific Larvae. *Journal of General Physiology* 105:569–587.

Limm, M. P., and M. P. Marchetti. 2009. Juvenile Chinook salmon (Oncorhynchus tshawytscha) growth in off-channel and main-channel habitats on the Sacramento River, CA using otolith increment widths. *Environmental Biology of Fishes* 85:141–151.

Lindley, S. T., M. L. Moser, D. L. Erickson, M. Belchik, D. W. Welch, E. L. Rechisky, J. T. Kelly, J. Heublein, and A. P. Klimley. 2008. Marine Migration of North American Green Sturgeon. *Transactions of the American Fisheries Society* 137:182–194.

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

Loboschefsky, E., and M. Nobriga. 2010. *Proposed Methods for a BDCP Effects Analysis Predation Model. University of California, Davis and U.S. Fish and Wildlife Service, Bay-Delta Fish and Wildlife Office*. Unpublished. June.

Lund, J. R., D. Ford, L. Grober, T. Harmon, and D. McKinney. 2006. *Review Panel Report, San Joaquin River Valley CalSim II Model Review*. January 12. Prepared for the CALFED Science Program – California Water and Environment Modeling Forum.

Luzier, C. W., J. Brostrom, C. Cook-Tabor, D. Goodman, R. D. Nelle, K. G. Ostrand, H. Schaller, and B. Streif. 2009. Proceedings of the Pacific Lamprey Conservation Initiative Work Session – October 28–29, 2008. Portland, OR: U. S. Fish and Wildlife Service, Regional Office. http://www.fws.gov/columbiariver/publications/Lamprey_Conservation_Proceedings_Final_09.pdf.

Marti, Y. Y. 1979. Development of Sturgeon Management in the Southern Seas of the USSR. Pages 73–85 in *Biological resources of inland waters of the USSR*. Moscow: Publishing House Nauka.

McCullough, D. A. 1999. *A Review and Synthesis of Effects of Alteration to the Water Temperature Regime on Freshwater Life Stages of Salmonids, with Special Reference to Chinook Salmon*. Document 910-R-99010. Seattle, WA: U.S. Environmental Protection Agency.

McEwan, D. 2001. Central Valley Steelhead. Pages 1–43 in R. L. Brown (ed.). *Contributions to the Biology of Central Valley Salmonids*. California Department of Fish and Game.

McKee, L. J., N. K. Ganju, and D. H. Schoellhamer. 2006. Estimates of Suspended Sediment Entering San Francisco Bay from the Sacramento and San Joaquin Delta, San Francisco Bay, California. *Journal of Hydrology* 323:335–352.

Meeuwig, M. H., J. M. Bayer, and J. G. Seelye. 2005. Effects of Temperature on Survival and Development of Early Life Stage Pacific and Western Brook Lampreys. *Transactions of the American Fisheries Society* 134:19–27.

Miller, J. A., A. Gray, and J. Merz. 2010. Quantifying the Contribution of Juvenile Migratory Phenotypes in a Population of Chinook Salmon *Oncorhynchus tshawytscha*. *Marine Ecology Progress Series* 408:227–240.

Miller, L. W. 1972. Migrations of sturgeon tagged in the Sacramento-San Joaquin Estuary. *California Fish and Game* 58:102–106.

Moberg, G. P., and S. I. Doroshov. 1992. *Reproduction in Cultured White Sturgeon,* Acipenser transmontanus*.* National Marine Fisheries Service National Oceanic and Atmospheric Administration Technical Report 106:99–104.

Mora, E. A., S. T. Lindley, D. L. Erickson, and A. P. Klimley. 2009. Do Impassable Dams and Flow Regulation Constrain the Distribution of Green Sturgeon in the Sacramento River, California? *Journal of Applied Ichthyology* 25:39–47.

Moyle, P. B. 2002. *Inland Fishes of California*, Revised and Expanded. Berkeley: University of California Press.

Moyle, P. B., J. A. Israel, and S. E. Purdy. 2008. *Salmon, Steelhead, and Trout in California: Status of an Emblematic Fauna*. A report commissioned by California Trout. University of California, Davis Center for Watershed Sciences.

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

Moyle, P. B., R. D. Baxter, T. Sommer, T. C. Foin, and S. A. Matern. 2004. Biology and Population Dynamics of the Sacramento Splittail (*Pogonichthys macrolepidotus*) in the San Francisco Estuary: a review. San Francisco Estuary and Watershed Science 2(2). Available: <http://repositories.cdlib.org/jmie/sfews/vol2/iss2/art3>.

Moyle, P. B., R. M. Yoshiyama, J. E. Williams, and E. D. Wikramanayake. 1995. *Fish Species of Special Concern in California*. 2nd Edition. Prepared for California Department of Fish and Game, Rancho Cordova. Contract No. 2128IF.

Myrick, C. A. 1998. *Temperature, Genetics, and Rational Effects on Juvenile Rainbow Trout (*Oncorhynchus mykiss*) Bioenergetics*. PhD dissertation. University of California, Davis.

Myrick, C. A., and J. J. Cech Jr. 2000. Temperature Influences on California Rainbow Trout Physiological Performance. *Fish Physiology and Biochemistry* 22(3):245–254.

National Marine Fisheries Service. 2005. *Green Sturgeon (*Acipenser medirostris*) Status Review Update*. Santa Cruz, CA: National Marine Fisheries Service Southwest Fisheries Science Center.

National Marine Fisheries Service. 2009. *Biological Opinion and Conference Opinion on the Long-Term Operations of the Central Valley Project and State Water Project*. National Marine Fisheries Service Southwest Region. June 4.

National Research Council. 2010. *A Scientific Assessment of Alternatives for Reducing Water Management Effects on Threatened and Endangered Fishes in California's Bay-Delta*. National Academy of Sciences, National Research Council, Committee on Sustainable Water and Environmental Management in the California Bay-Delta. Washington, DC.

Newman, K. B. 2003. Modelling Paired Release-Recovery Data in the Presence of Survival and Capture Heterogeneity with Application to Marked Juvenile Salmon. *Statistical Modelling* 3:157–177.

Newman, K. B. 2008. An Evaluation of Four Sacramento-San Joaquin River Delta Juvenile Salmon Studies. Prepared for CALFED Science Program. March.

Newman, K. B., and J. Rice. 2002. Modeling the Survival of Chinook Salmon Smolts Out-migrating through the Lower Sacramento River System. *Journal of the American Statistical Association* 97:983–993.

Newman, K. B., and P. L. Brandes. 2010. Hierarchical modeling of juvenile Chinook salmon survival as a function of Sacramento-San Joaquin Delta water exports. *North American Journal of Fisheries Management* 30:157–169.

Nobriga, M. L., M. Zoltan, and Z. P. Hymanson. 2004. Evaluating Entrainment Vulnerability to Agricultural Irrigation Diversions: A Comparison Among Open-Water Fishes. *American Fisheries Society Symposium* 39:270–281.

Nobriga, M. L., T. R. Sommer, F. Feyrer, and K. Fleming. 2008. Long-Term Trends in Summertime Habitat Suitability for Delta Smelt (*Hypomesus transpacificus*). *San Francisco Estuary and Watershed Science* 6(1):article 1.

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

Opperman, J. 2008. *Floodplain Conceptual Model*. Sacramento, CA: Delta Regional Ecosystem Restoration Implementation Plan. Available: <http://www.science.calwater.ca.gov/pdf/drerip/DRERIP%20Floodplain%20Conceptual%20Model_2007%20final%20012208%20(5).pdf>.

Parsley, M. J., L. G. Beckman, and G. McCabe Jr. 1993. White Sturgeon Spawning and Rearing Habitat in the Columbia River Downstream of McNary Dam. *Transactions of the American Fisheries Society* 122:217–228.

Parsley, M. J., P. J. Anders, A. I. Miller, L. G. Beckman, and G. T. McCabe Jr. 2002. Recovery of White Sturgeon Populations through Natural Production: Understanding the Influence of Abiotic and Biotic Factors on Spawning and Subsequent Recruitment. Pages 55–66 in W. Van Winkle, P. J. Anders, D. H. Secor, and D. A. Dixon (eds.). *Biology, Management, and Protection of North American Sturgeon*. Symposium 28. Bethesda, MD: American Fisheries Society.

Perry, R. W. 2010. *Survival and Migratory Dynamics of Juvenile Chinook Salmon (*Oncorhynchus tshawytscha*) in the Sacramento-San Joaquin River Delta*. PhD dissertation. University of Washington, Seattle.

Perry, R. W., J. R. Skalski, P. L. Brandes, P. T. Sandstrom, A. P. Klimley, A. Ammann, and B. MacFarlane. 2010. Estimating Survival and Migration Route Probabilities of Juvenile Chinook Salmon in the Sacramento–San Joaquin River Delta. *North American Journal of Fisheries Management* 30:142–156.

Perry, R. W., P. L. Brandes, J. R. Burau, A. P. Klimley, B. MacFarlane, C. Michel, and J. R. Skalski. In press. Sensitivity of survival to migration routes used by juvenile Chinook salmon to negotiate the Sacramento-San Joaquin River Delta. Environmental Biology of Fishes.

Poytress, W. R., J. J. Gruber, D. A. Trachtenbarg, and J. P. Van Eenennaam. 2009. *2008 Upper Sacramento River Green Sturgeon Spawning Habitat and Larval Migration Surveys*. Annual Report of U.S. Fish and Wildlife Service to U.S. Bureau of Reclamation, Red Bluff, CA.

Quinn, T. P. 2005. *The Behavior and Ecology of Pacific Salmon and Trout*. Seattle: University of Washington Press.

Raymond, H. L. 1968. Migration Rates of Yearling Chinook Salmon in Relation to Flows and Impoundments in the Columbia and Snake Rivers. *Transactions of the American Fisheries Society* 97:356–359.

Reed, D. J. 2002. Understanding Tidal Marsh Sedimentation in the Sacramento–San Joaquin Delta, California. *Journal of Coastal Research* Special Issue (36):605–611.

Reiser, D. W., and T. C. Bjorn. 1979. *Habitat Requirements of Anadromous Salmonids*. General Technical Report PNW–96. Portland, OR: U.S. Forest Service, Pacific Northwest Forest and Range Experiment Station.

Resource Management Associates, Inc. 2003. *Draft Upper Sacramento River Water Quality Modeling with HEC-5Q: Model Calibration and Validation*. December.

Resource Management Associates, Inc. (RMA). 2010. Numerical Modeling in Support of Bay Delta Conservation Plan Technical Study #4—Evaluation of Tidal Marsh Restoration Effects (Preliminary Results, March 2010—For Internal Review Only).

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

Resource Management Associates, Inc. (RMA). 2010a. Spatial Animation of Observed Turbidity Time Series for the Sacramento–San Joaquin Delta.

Resource Management Associates, Inc. (RMA). 2010b. Turbidity and Adult Delta Smelt Forecasting with RMA 2-D Models: December 2009–May 2010.

San Joaquin River Group Authority. 2008. *2007 Annual Technical Report on Implementation and Monitoring of the San Joaquin River Agreement and the Vernalis Adaptive Management Plan*. January. Prepared by San Joaquin River Group Authority, Davis, CA. Prepared for California Water Resource Control Board in compliance with D-1641. Sacramento, CA. Available: <http://www.sjrg.org/technicalreport/>.

San Joaquin River Group Authority. 2010. *2009 Annual Technical Report on Implementation and Monitoring of the San Joaquin River Agreement and the Vernalis Adaptive Management Plan*. January. Prepared by San Joaquin River Group Authority, Davis, CA. Prepared for California Water Resource Control Board in compliance with D-1641. Sacramento, CA. Available: <http://www.sjrg.org/technicalreport/>.

Sandhu, N., D. Wilson, R. Finch, and F. Chung. 1999. *Modeling Flow-Salinity Relationships in the Sacramento-San Joaquin Delta Using Artificial Neural Networks*. Technical Information Record OSP-99-1. Sacramento: California Department of Water Resources.

Schaffter, R. G. 1997. White Sturgeon Spawning Migrations and Location of Spawning Habitat in the Sacramento River, California. *California Fish and Game* 83(1):1–20.

Schoellhamer, D., S. Wright, J. Z. Drexler, M. Stacey, and S. C. Model. 2007. White paper for the California Bay/Delta Science Program. Sacramento: The Resources Agency of the State of California.

Schreck, C. B., J. C. Snelling, R. E. Ewing, C. S. Bradford, L. E. Davis, and C. H. Slater. 1994. *Migratory Characteristics of Juvenile Spring Chinook Salmon in the Willamette River*. Completion Report. Bonneville Power Administration.

Seneviratne, S., and S. Wu. 2007. Chapter 3, Enhanced Development of Flow–Salinity Relationships in the Delta Using Artificial Neural Networks: Incorporating Tidal Influence. In *Methodology for Flow and Salinity Estimates in the Sacramento-San Joaquin Delta and Suisun Marsh*. 28th Annual Progress Report to the State Water Resources Control Board in Accordance with Water Right Decisions 1485 and 1641. California Department of Water Resources, Bay-Delta Office.

Simenstad, C., J. Toft, H. Higgins, J. Cordell, M. Orr, P. Williams, L. Grimaldo, Z. Hymanson, and D. Reed. 2000. *Sacramento/San Joaquin Delta Breached Levee Wetland Study (BREACH)*. Preliminary report. Seattle: Wetland Ecosystem Team, University of Washington School of Fisheries.

Singer, M. B., R. Aalto, and L. A. James. 2008. Status of the Lower Sacramento Valley Flood Control System within the Context of its Natural Geomorphic Setting. *Natural Hazards Review* 9:104–115.

Snider, B., and R, G. Titus. 2000a. *Timing, composition and abundance of juvenile anadromous salmonid emigration in the Sacramento River near Knights Landing, October 1996–September 1997*. California Department of Fish and Game, Stream Evaluation Program Technical Report No. 00-4. July.

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

Snider, B., and R, G. Titus. 2000b. *Timing, composition and abundance of juvenile anadromous salmonid emigration in the Sacramento River near Knights Landing, October 1997–September 1998*. California Department of Fish and Game, Stream Evaluation Program Technical Report No. 00-5. July.

Snider, B., and R, G. Titus. 2000c. *Timing, composition and abundance of juvenile anadromous salmonid emigration in the Sacramento River near Knights Landing, October 1998–September 1999*. California Department of Fish and Game, Stream Evaluation Program technical Report No. 00-6. December.

Snider, B., and R. G. Titus. 1998. Evaluation of juvenile anadromous salmonid emigration in the Sacramento River near Knights Landing, November 1995–July 1996. California Department of Fish and Game, Stream Evaluation Program. August.

Snider, B., R. Titus, and K. Vyberberg. 2001. *Evaluation of Effects of Flow Fluctuations on the Anadromous Fish Populations in the Lower American River*. Sacramento: California Department of Fish and Game Stream Evaluation Program.

Sommer, T. R., M. L. Nobriga, W. C. Harrell, W. Batham, and W. J. Kimmerer. 2001. Floodplain Rearing of Juvenile Chinook Salmon: Evidence of Enhanced Growth and Survival. *Canadian Journal of Fisheries and Aquatic Sciences* 58(2):325–333.

Sommer, T. R., M. L. Nobriga, W. C. Harrell, W. Bathan, and W. J. Kimmerer. 2001. Floodplain rearing of juvenile Chinook salmon: evidence of enhanced growth and survival. *Canadian Journal of Fisheries and Aquatic Sciences* 58:325–333.

Sommer, T. R., M. L. Nobriga, W. C. Harrell, W. Bathan, and W. J. Kimmerer. 2001. Floodplain rearing of juvenile Chinook salmon: evidence of enhanced growth and survival. *Canadian Journal of Fisheries and Aquatic Sciences* 58:325–333.

Sommer, T. R., W. C. Harrell, A. Mueller-Solger, B. Tom and W. J. Kimmerer. 2004. Effects of Flow Variation on Channel and Floodplain Biota and Habitats of the Sacramento River, California, USA. *Aquatic Conservation: Marine and Freshwater Ecosystems* 14:247–261.

Sommer, T. R., W. C. Harrell, and M. L. Nobriga. 2005. Habitat Use and Stranding Risk of Juvenile Chinook Salmon on a Seasonal Floodplain. *North American Journal of Fisheries Management* 25:1493–1504.

Sommer, T. R., W. C. Harrell, Z. Matica, and F. Feyrer. 2008. Habitat Associations and Behavior of Adult and Juvenile Splittail (Cyprinidae: *Pogonichthys macrolepidotus*) in a Managed Seasonal Floodplain Wetland. *San Francisco Estuary and Watershed Science* 6(2):article 3.

Sommer, T., C. Armor, R. Baxter, R. Breuer, L. Brown, M. Chotkowski, S. Culberson, F. Feyrer, M. Gingras, B. Herbold, W. Kimmerer, A. Mueller-Solger, M. Nobriga, and K. Souza. 2007. The Collapse of Pelagic Fishes in the Upper San Francisco Estuary. *Fisheries* 32(6):270–277.

Sommer, T., F. H. Mejia, M. L. Nobriga, F. Feyrer, and L. Grimaldo. 2011. The Spawning Migration of Delta Smelt in the Upper Estuary. *San Francisco Estuary and Watershed Science* (9)2.

Sommer, T., W. C. Harrell, and M. L. Nobriga. 2005. Habitat use and stranding risk of juvenile Chinook salmon on a seasonal floodplain. *North American Journal of Fisheries Management* 25:1493–1504.

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

Stevens, D. E., and L. W. Miller. 1970. Distribution of Sturgeon Larvae in the Sacramento-San Joaquin River System. *California Fish and Game* 56:80–86.

Stevens, D. E., and L. W. Miller. 1983. Effects of River Flow on Abundance of Young Chinook Salmon, American Shad, Longfin Smelt, and Delta Smelt in the Sacramento-San Joaquin River System. *North American Journal of Fisheries Management* 3:425–437.

Streif, B. 2007. Pacific Lamprey – *Lampetra tridentata*. Portland, OR: U.S. Fish and Wildlife Service. Available: <http://www.fws.gov/pacific/Fisheries/sphabcon/lamprey/pdf/111407%20PL%20Fact%20Sheet.pdf>.

SWAN team. 2009. SWAN Scientific and Technical Documentation 40.72. Delft University of Technology.

U.S. Bureau of Reclamation. 1994. Central Valley Project Improvement Act–Programmatic Environmental Impact Statement (CVPIA–PEIS), *Impact Assessment Methodology for Fish*. Draft Working Paper #3. December. Sacramento, CA.

U.S. Bureau of Reclamation. 2004. *Long-Term Central Valley Project and State Water Project Operations Criteria and Plan Biological Assessment*. June 30.

U.S. Bureau of Reclamation. 2008. *Biological Assessment on the Continued Long-Term Operations of the Central Valley Project and the State Water Project*. Available: <http://www.usbr.gov/mp/cvo/ocap_page.html>.

U.S. Department of the Interior. 2000. *Record of Decision for the Trinity River Mainstem Fishery Restoration Environmental Impact Statement/Environmental Impact Report*. Sacramento, CA.

U.S. Environmental Protection Agency. 2003. *EPA Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards*. (EPA 910-B-03-002.) Region 10, Office of Water. Seattle, WA.

U.S. Fish and Wildlife Service. 1995. Working paper: *Habitat Restoration Actions to Double Natural Production of Anadromous Fish in the Central Valley of California*. Volume 2. May 9. Prepared under the direction of the Anadromous Fish Restoration Program Core Group, Stockton, CA.

U.S. Fish and Wildlife Service. 2000. *Impacts of Riprapping to Ecosystem Functioning, Lower Sacramento River, California*. Prepared for the U.S. Army Corps of Engineers, U.S. Fish and Wildlife Service's Fish and Wildlife Coordination Act Report and Biological Opinion, and for proposed bank protection work. June. Available: <http://www.fws.gov/sacramento/hc/reports/sac_river_riprap.pdf>.

U.S. Fish and Wildlife Service. 2003. *Flow–Habitat Relationships for Spring-Run Chinook Salmon Spawning in Butte Creek*. Butte Creek 2-D Modeling Final Report. Sacramento Fish and Wildlife Office, Energy Planning and Instream Flow Branch.

U.S. Fish and Wildlife Service. 2005. Flow-Habitat Relationships for Fall-Run Chinook Salmon Spawning in the Sacramento River between Battle Creek and Deer Creek. Sacramento Fish and Wildlife Office, Energy Planning and Instream Flow Branch. Sacramento, CA.

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

U.S. Fish and Wildlife Service. 2006. Abundance and Survival of Juvenile Chinook Salmon in the Sacramento-San Joaquin Estuary. *2000 Annual Progress Report*. Stockton Fish and Wildlife Office. Stockton, CA.

U.S. Fish and Wildlife Service. 2008. *Biological Opinion on the Effects of the Proposed Coordinated Operations of the CVP and SWP to the Threatened Delta Smelt (*Hypomesus transpacificus*) and its Designated Critical Habitat*. Reference 81420-2008-F-1481-5.

Van Eenennaam, J. P., J. Linares-Casenave, X. Deng, and S. I. Doroshov. 2005. Effect of Incubation Temperature on Green Sturgeon Embryos, *Acipenser medirostris*. *Environmental Biology of Fishes* 72:145–154.

Vogel, D. 2008. *Biological Evaluations of the Fish Screens at the Glenn–Colusa Irrigation District's Sacramento River Pump Station: 2002–2007*. Red Bluff, CA: Natural Resource Scientists, Inc.

Vogel, D. A. and K. R. Marine. 1991. *Guide to Upper Sacramento River Chinook Salmon Life History*. July. Prepared for the U.S. Bureau of Reclamation, Central Valley Project by CH2M Hill.

Wagner, W., M. Stacey, L. Brown, and M. Dettinger. 2011. Statistical Models of Temperature in the Sacramento–San Joaquin Delta under Climate Change Scenarios and Ecological Implications. *Estuaries and Coasts* 34(3):544–556. doi:10. 1007/s12237-010-9369-z.

Wang, Y. L., R. K. Buddington, and S. I. Doroshov. 1987. Influence of Temperature on Yolk Utilization by the White Sturgeon, *Acipenser transmontanus*. *Journal of Fish Biology* 30:263–271.

Wilbur, R. and A. Munévar. 2001. Chapter 7, Integration of CALSIM and Artificial Neural Networks Models for Sacramento-San Joaquin Delta Flow-Salinity Relationships. *Methodology for Flow and Salinity Estimates in the Sacramento-San Joaquin Delta and Suisun Marsh*. 22nd Annual Progress Report to the State Water Resources Control Board. Sacramento, CA.

Williams, J. G. 2001. Chinook Salmon in the Lower American River, California's Largest Urban Stream. Pages 1–37 in R. Brown (ed.). Contributions to the Biology of Anadromous Salmonids of the Central Valley, California. *Fish Bulletin* 179:2. Sacramento: California Department of Fish and Game.

Williams, J. G. 2006. Central Valley Salmon: a Perspective on Chinook and Steelhead in the Central Valley of California. *San Francisco Estuary and Watershed Science* 4(3):article 2.

Williams, J. G., and G. M. Mathews. 1995. A Review of Flow and Survival Relationships for Spring and Summer Chinook Salmon, *Oncorhynchus tshawytscha*, from the Snake River Basin. *U.S. National Marine Fisheries Service Fishery Bulletin* 93:732–740.

Wright, S. A., and D. H. Schoellhamer. 2004. Trends in the Sediment Yield of the Sacramento River, California, 1957–2001. *San Francisco Estuary and Watershed Science* 2(2):article 2. Available: <http://escholarship.org/uc/item/891144f4>.

Wright, S. A., and D. H. Schoellhamer. 2005. Estimating Sediment Budgets at the Interface between Rivers and Estuaries with Application to the Sacramento-San Joaquin River Delta. *Water Resources Research* 41, W09428. doi:10.1029/2004WR003753.

Yarrow, M., V. H. Marín, M. Finlayson, A. Tironi, L. E. Delgado, and F. Fischer. 2009. The Ecology of *Egeria densa* Planchon (Liliopsida: Alismatales): A Wetland Ecosystem Engineer? *Revista Chilena de Historia Natural* 82(2):299–313.

Admin Draft

Note to Reader: This is a revised working draft prepared by the BDCP consultants. This document is currently undergoing review by the Department of Water Resources with input from the Department of Fish and Game, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Bureau of Reclamation and does not necessarily reflect the position of the state or federal agencies. It is expected to go through several more revisions prior to being released for formal public review and comment in 2012. All members of the public will have an opportunity to provide comments on the public draft of a revised version of this document during the formal public review and comment period. Responses will be prepared only on comments submitted in the formal public review and comment period.

Young, P. S., and J. J. Cech Jr. 1996. Environmental Tolerances and Requirements of Splittail. *Transactions of the American Fisheries Society* 125:664–678.

Ysebaert, T., M. Fettweis, P. Meire, and M. Sas. 2005. Benthic Variability in Intertidal Soft Sediments in the Mesohaline Part of the Schelde Estuary. *Hydrobiologia* 540:197–216.

C.7.1 Personal Communications

Hannon, John. Fisheries Biologist. U.S. Bureau of Reclamation. August 11, 2010—email to Rick Wilder about use of SRWQM and Reclamation Egg Mortality Model.

Kirkland, M. Senior Engineer. California Department of Water Resources Division of Environmental Services. September 15, 2011—email response to Sophia Unger regarding potential effects of diverting Sacramento River flow at the Fremont Weir on Sutter Bypass inundation.

Kurth, Ryon. Staff Environmental Scientist. California Department of Water Resources. July 6, 2010—email to Rick Wilder about spawning location of Pacific and river lamprey in the Feather River.

Miller, B. J. Consulting Engineer. October 5, 2011—emails to Marianne Guerin, Associate, Research Management Associates, with Excel data analysis estimating entrainment.

Munévar, Armin. Engineer. CH2M Hill. April 2009—technical memorandum to BDCP Integration Team regarding an evaluation of operations of the Fremont Weir to increase the frequency and duration of inundation of the Yolo Bypass.

Redler, Yvette. Bay Delta Branch Chief. National Marine Fisheries Service, Protected Resources Division, Sacramento, CA. February 6, 2012—email to William Mitchell, Fisheries Biologist, ICF International, Sacramento, CA.

Seesholtz, A. Staff Environmental Scientist. California Department of Water Resources. January 10, 2012—email response to Rick Wilder regarding green sturgeon eggs sampled at the Thermalito Afterbay Outlet pool in June 2011.

Sommer, Ted. Senior Environmental Scientist. California Department of Water Resources. June 28 and 29, 2010—telephone communications with Sophie Unger about splittail spawning timing and conditions.

Admin Draft