RECLAMATION

Appendix F
Fish

North-of-the-Delta Offstream Storage Investigation

July 2017

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F.1 Introduction

Two primary planning objectives of the North-of-the-Delta Offstream Storage (NODOS)/Sites Reservoir Project would provide benefits to fish:

- Increase anadromous fish survival in the Sacramento River and the health and survivability of other aquatic species.
- Improve Delta Environmental Water Quality.

This appendix evaluates the relative effectiveness of Sites Reservoir Alternatives A, B, C, and D to meet aquatic habitat enhancement goals in the Sacramento River system and Delta. These goals include increased reliability and discharge from reservoir coldwater pools to provide instream flows and water temperatures to benefit Chinook Salmon (*Oncorhynchus tshawytscha*), steelhead (*Oncorhynchus mykiss*), Green Sturgeon (*Acipenser medirostris*), Delta Smelt (*hypomesus transpacificus*), and other fish species. The capacity for increased flows, especially during drier years and summer months, also helps to maintain Delta X2[1] west of Collinsville (81 kilometers [km]), and improves estuarine habitat values for Delta Smelt and emigrating salmonids.

F.2 Survival of Anadromous Fish and Other Aquatic Species

Sites Reservoir alternatives A, B, C, and D could potentially be beneficial for anadromous fish and other aquatic species in the Sacramento, Trinity, Feather, and American River watersheds.

For this assessment, Chinook Salmon were used as an indicator species to model and qualitatively analyze potential NODOS/Sites Reservoir Project-related impacts, and in evaluating performance of aquatic habitat goals. Chinook Salmon are anadromous fish that spawn in freshwater streams and grow to adulthood in the ocean. Four runs of Chinook Salmon pass through the Delta, and spawn in the Sacramento River and its tributaries. The four runs are recognized and named for the timing of their entry into the Sacramento River system: (1) fall-run, (2) late fall-run, (3) winter-run, and (4) spring-run (Hallock and Fry 1967; Healey 1991). Table F-1 summarizes the legal status of the four runs, categorized as evolutionarily significant units (ESUs) under the Federal Endangered Species Act (ESA) and the California Endangered Species Act (CESA).

[1] X2 is a Delta management tool, defined as the distance in kilometers from the Golden Gate Bridge to the location where the tidally averaged near-bottom salinity in the Delta measures 2 parts per thousand.

Table F-1. Legal Status of Chinook Salmon (*Oncorhynchus tshawytscha*) Runs in the Sacramento Valley

Chinook Salmon *(Oncorhynchus tshawytscha)* run	Federal Legal Status [a]	State Legal Status [a]
Central Valley fall-run ESU	SC	SSC
Central Valley late fall-run ESU	SC	SSC
Sacramento River winter-run ESU	E	E
Central Valley spring-run ESU	T	T

[a] Legal status is as follows:
E = Endangered under ESA and CESA
ESU = evolutionarily significant unit
SC = Considered a Species of Concern by National Oceanic and Atmospheric Administration Fisheries
SSC = Considered a California Species of Special Concern by the California Department of Fish and Wildlife
T = Threatened under the ESA and CESA
CESA = California Endangered Species Act
ESA = Endangered Species Act (Federal)

The life history and habitat requirements of Chinook Salmon have been well-documented (e.g., Healey 1991; Moyle 2002; Myers et al. 1998; Reiser and Bjorn 1979). The freshwater period of a salmon's life is divided into four general life stages:

1. Adult upstream migration (immigration)
2. Spawning and incubation
3. Egg development and emergence of fry
4. Juvenile/smolt out-migration (emigration) to the Delta

Table F-2 summarizes how the timing and duration of these life stages differ among the four runs in the Sacramento River.

At least one life stage of Chinook Salmon is present in the Sacramento River system throughout the year. High water temperatures can limit salmon growth and survival during the summer months, especially during drier years or periods of low flows. The relative number and distribution of the various life stages change throughout the year depending on the temporal and spatial distribution of the runs. The four runs of Chinook Salmon rear in the Delta for variable periods of time, but some fish may migrate through the Delta and may be present for only a short time.

Sacramento River Winter-run Chinook Salmon

Sacramento River winter-run Chinook Salmon were listed as threatened under the Federal ESA on August 4, 1989 (54 Federal Register [FR] 32085), and reclassified as endangered by the National Marine Fisheries Service (NMFS) on January 4, 1994 (59 FR 440). The ESU of the Sacramento River winter-run Chinook Salmon includes naturally spawned populations of Winter-run Chinook Salmon in the Sacramento River and its tributaries in California (59 FR 440), as well as two artificial propagation programs: Winter-run Chinook Salmon from the Livingston Stone National Fish Hatchery (NFH); and Winter-run Chinook Salmon in a captive broodstock program, maintained at Livingston Stone NFH and the University of California Bodega Marine Laboratory.

Table F-2. Timing of Migration and Life Stage Development by Chinook Salmon Run in the Sacramento Valley

Chinook Salmon Run	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Upstream migration past Red Bluff Diversion Dam												
Fall-run	Peak	Active Light								Light		Active Peak
Late fall-run	Active		Peak	Active								
Winter-run			Light	Active	Active	Peak	Active		Light			
Spring-run					Active			Peak	Active			
Spawning and incubation												
Fall-run	Active Peak	Active	Light									
Late fall-run			Light	Active	Peak Active		Light					
Winter-run	Active						Active	Peak		Active		
Spring-run	Active										Active	Peak
Egg development and emergence												
Fall-run	Light	Active		Peak		Light						
Late fall-run				Active								
Winter-run							Active					
Spring-run	Active						Peak				Active	
Out-migration to Delta												
Fall-run				Light			Peak	Active	Light			
Late fall-run												
Winter-run				Active								
Spring-run		Peak			Active							

Light activity
Active
Peak Activity

Historically, winter-run Chinook Salmon spawned in the upper reaches of Sacramento River tributaries, including the McCloud, Pit, and Little Sacramento Rivers. Shasta and Keswick Dams now block access to the historic spawning areas. Winter-run Chinook Salmon, however, were able to take advantage of cool summer water releases downstream of Keswick Dam. In the 1940s and 1950s, the population showed signs of recovery. However, beginning in 1970, the population experienced a dramatic decline, to a low of approximately 200 spawners by the early 1990s (Good et al. 2005).

Adult winter-run Chinook Salmon pass under the Golden Gate Bridge from November through May, and pass into the Sacramento River from mid-December through early July. Winter-run Chinook Salmon spawn in the upper main stem Sacramento River from mid-April to mid-August. Fry and smolts emigrate downstream from mid-July through mid-March through the Sacramento River (Figure F-1), reaching San Francisco Bay from September through June.

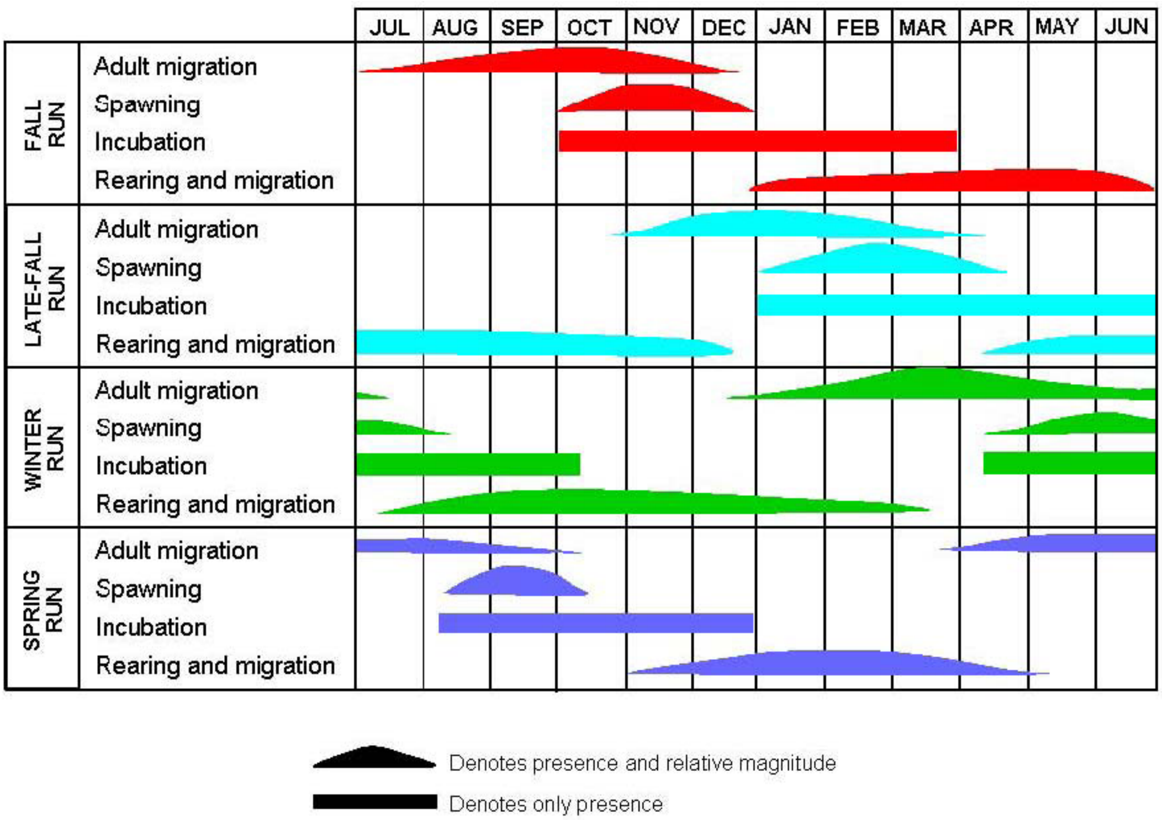

Figure F-1. Life History and Timing of Chinook Salmon Stocks in the Sacramento River

Sacramento River winter-run Chinook Salmon are likely to occur throughout the Delta and San Francisco Bay during periods of migration (NMFS 2001). A 1997 study conducted by the NMFS Tiburon Laboratory found that residency time of juvenile Chinook Salmon in the San Francisco Bay estuary was about 40 days, with little growth occurring during that time.

The critical habitat for the Sacramento River winter-run Chinook Salmon was designated by NMFS on June 16, 1993 (58 FR 33212). The designated critical habitat pursuant to the Federal ESA includes the Sacramento River from Keswick Dam, Shasta County (River Mile 302) to Chipps Island (River Mile 0) at the westward margin of the Sacramento-San Joaquin Delta; and waters from Chipps Island westward to Carquinez Bridge, including Honker Bay, Grizzly Bay, Suisun Bay, and Carquinez Strait; all waters of San Pablo Bay westward of the Carquinez Bridge, and all waters of San Francisco Bay from San Pablo Bay to the Golden Gate Bridge (58 FR 33212). Designated critical habitat for Chinook Salmon consists of four Primary Constituent Elements (PCEs) that are essential to the conservation of the species: (1) freshwater spawning sites with suitable substrate and water quality conditions; (2) freshwater rearing sites with forage, cover, and suitable water quality; (3) freshwater migration corridors free of obstructions and with suitable cover and water quality; and (4) estuarine areas free of obstructions with suitable cover, forage, and water quality (70 FR 52488 and 58 FR 33212).

Central Valley Spring-run Chinook Salmon

The Central Valley spring-run Chinook Salmon was listed as threatened pursuant to the Federal ESA on September 16, 1999 (64 FR 50394), which issued its final decision on June 28, 2005—to retain the status of Central Valley spring-run Chinook Salmon as threatened (70 FR 37160).

Spring-run Chinook Salmon generally occur in the Delta during migration to and from spawning and rearing habitat in the Sacramento River and its tributaries. Spring-run Chinook Salmon enter the Delta as sexually immature adults typically from February through July; peak migration is during April and May (Taylor and Wise 2008). The adults mature in cool, deep pools in rivers upstream of the valley floor during the summer, and spawn in suitable habitat adjacent to these areas from August through October, peaking in mid-September (Moyle 2002; Taylor and Wise 2008). Juvenile spring-run Chinook Salmon can rear for several months to over a year before undergoing smoltification process (i.e., hormone-driven developmental process to increase salinity tolerance and trigger schooling and downstream migration) prior to emigrating to estuarine environment. Most juvenile spring-run Chinook Salmon emigrate as smolts, although some portion of an annual year-class may emigrate as fry to rear in freshwater basins. Emigration timing varies among the tributaries of origin, and can occur during the period extending from November through June (69 FR 19975; Taylor and Wise 2008). Figure F-1 summarizes the relative seasonality of various life stages of spring-run Chinook Salmon in the Sacramento River and Delta.

The designated critical habitat for the Central Valley spring-run Chinook Salmon ESU is in the following counties: Tehama, Butte, Glenn, Shasta, Yolo, Sacramento, Solano, Colusa, Yuba, Sutter, Trinity, Alameda, San Joaquin, and Contra Costa. The approximate quantity of habitat areas designated as critical habitat includes 1,158 miles of stream habitat in the Sacramento River Basin, and 254 square miles of estuary habitat in the San Francisco-San Pablo-Suisun Bay complex (70 FR 52488). The PCEs that are essential for conservation of Central Valley spring-run Chinook Salmon are similar to the Sacramento River winter-run Chinook Salmon PCEs described above.

Central Valley Fall-run and Late Fall-run Chinook Salmon

The Central Valley fall-run and late fall-run Chinook Salmon ESUs were classified as Species of Concern on April 15, 2004 (69 FR 19975). These ESUs include naturally spawned populations of fall-run and late fall-run Chinook Salmon in the Sacramento River and San Joaquin River Basins, and their tributaries east of Carquinez Strait, California (64 FR 50394).

Central Valley Fall-run Chinook Salmon

Central Valley fall-run Chinook Salmon contain the largest population size of the four runs of Chinook Salmon in California. The fall-run Chinook Salmon supports commercial and recreational fisheries along the Pacific Coast and in the Sacramento River and Delta. Fall-run Chinook Salmon are already sexually maturing as they enter the freshwater environment, and are typically ready to spawn within days once they reach their spawning areas. Adult Chinook Salmon annually migrate upstream through the Delta from August through December. The spawning peak occurs upstream of the Delta from October through March, depending on the spawning location (Taylor and Wise 2008).

More than 90 percent of the entire run has entered rivers by the end of November, and migration and spawning can continue into December. Fall-run Chinook Salmon migrate downstream through the Delta between February and June (Taylor and Wise 2008). The Delta is considered to be the major rearing area for juvenile Fall-run Chinook Salmon. Figure F-1 summarizes the seasonality of the various life stages of fall-run Chinook Salmon in the Sacramento River and Delta.

Central Valley Late Fall-run Chinook Salmon

Late fall-run Chinook Salmon occur in the Delta during migration to and from spawning and rearing habitat in the Sacramento River and its tributaries. Adult migration of late fall-run Chinook Salmon through the Delta generally begins in October, peaks in December, and ends in April (Moyle 2002) during a period of typically high, fluctuating flows. Spawning occurs upstream of the Delta from January to March, although it may extend into April in dry years. Late fall-run Chinook Salmon juveniles emigrate from their spawning and rearing areas to the Delta from October through March (Taylor and Wise 2008). Figure F-1 summarizes the seasonality of the various life stages of late fall-run Chinook Salmon in the Sacramento River and Delta.

The majority of emigrating juveniles are smolt-sized by the time they reach the lower Sacramento River and Delta, typically from November through January. Occurrence of juvenile late fall-run Chinook Salmon in the lower river appears to coincide with the first storms. However, the later the first storm occurs, the fewer juvenile late fall-run Chinook Salmon could successfully migrate to the Delta (Snider and Titus 2000a, 2000b). A small portion of emigrating juveniles could use the Delta as rearing habitat for a short period of time.

Central Valley Steelhead

The Central Valley (CV) steelhead (*Oncorhynchus mykiss*) distinct population segment (DPS) was listed as threatened pursuant to the Federal ESA on March 19, 1998 (63 FR 13347). CV steelhead consist of populations in the Sacramento and San Joaquin River (inclusive of and downstream of the Merced River) Basins in California’s Central Valley (70 FR 52488). Crude estimates made in the early 1990s, which included both hatchery and wild fish, indicated that there were about 10,000 adult fish. From 1992 to present, an average of 1,282 adult fish returned to the upper Sacramento River (CalTrout 2016).

Steelhead is the name commonly applied to the anadromous form of the biological species of O. mykiss, and rainbow trout is the name applied to the landlocked and freshwater resident form of the species. Steelhead can reach up to 55 pounds in weight and 45 inches in length, although average size is much smaller (NMFS 2014). Adults are usually dark in color on the dorsal side, then shading to silvery white on the underside, with a speckled body and a red stripe running along their lateral sides.

Unlike Chinook Salmon, steelhead do not necessarily die after spawning. With suitable conditions, adult steelhead are able to emigrate back out to estuarine waters and come back to freshwaters to spawn again. Steelhead typically rear in freshwater, usually from 1 to 3 years—a longer period than other salmonids. There is great variation in the amount of time that steelhead spend in freshwater during their lives. Throughout their range, steelhead remain at sea for one to four growing seasons before returning to freshwater to spawn (Burgner et al. 1992). Because juvenile steelhead remain in the creeks year-round, adequate flows, suitable water temperatures, and an abundant food supply are necessary throughout the year to sustain steelhead populations. The most critical period is in the summer and early fall, when these conditions become limiting. Steelhead also require cool, clean, well-oxygenated water, and appropriate gravel for spawning. Spawning habitat condition is strongly affected by water flow and quality, especially temperature, dissolved oxygen, shade, and silt load; all of which can greatly affect the survival of eggs and larvae.

The spawning season for CV steelhead extends from late December through April of the following year, although they often move up coastal streams in the fall and then hold in deep pools until the spawning period (Moyle 2002). Steelhead likely enter estuaries in early winter in preparation for the spawning migration. For some populations, sandbars at the mouths of natal rivers block entry until sufficient rain has fallen to create a passable channel. When migrating, steelhead prefer main channels as opposed to side channels, and require deep holding pools with cover, such as underwater ledges and caverns. Coarse gravel beds in riffle areas are used for egg laying and yolk sac fry habitat once eggs have hatched.

Designated critical habitat for Central Valley steelhead includes most of the Sacramento River from Tehama County down to the San Joaquin River in San Joaquin County (70 FR 52488). The designation includes natal spawning and rearing waters, migration corridors, and estuarine areas that serve as rearing areas. The lateral extent of this critical habitat is defined by the ordinary high-water line.

North American Green Sturgeon

The Southern DPS of the North American Green Sturgeon (*Acipenser medirostris*; hereafter referred to as Green Sturgeon) was listed as threatened on April 7, 2006 (71 FR 17757).

The Green Sturgeon is a long-lived, slow-growing, and late-maturing anadromous native fish that occur in low numbers in the San Francisco Bay–Sacramento River and San Joaquin River Delta system (Moyle 2002). Adult males range from 4.5 to 6.5 feet, and adult females range from 5 to 7 feet in length (NMFS 2016). They can weigh up to 350 pounds, with 5 rows of 23 to 30 scutes (i.e., modified scales) along the side of the body; and 1 to 2 scutes behind the dorsal fins. The coloring on the dorsal side varies from olive-green to gray or golden-brown (NMFS 2003).

In the Sacramento River system, Green Sturgeon migration and spawning has been well-documented by direct observation; angler catch; and eggs, larvae, and young-of-year detection from fish surveys (Kohlhorst 1976). Anglers have reported catching six Green Sturgeon on the San Joaquin River since the implementation of Sturgeon Report Card by the California Department of Fish and Wildlife in 2007 (Jackson and Van Eenennaam 2013). To date, however, spawning activities of Green Sturgeon on the San Joaquin River have not been confirmed.

Adults begin their upstream migration in March, and enter the Sacramento River until the end of September (Taylor and Wise 2008). Spawning occurs upstream of the Delta from February through July, with peak activity believed to occur from April through June (Moyle et al. 1995; Taylor and Wise 2008). Green Sturgeon spawning occurs predominately in the Upper Sacramento River. Juvenile Green Sturgeon spend 1 to 3 years in freshwater prior to emigrating to the ocean (NMFS 2005).

Critical habitat has been designated for Green Sturgeon (74 FR 52300). Designated critical habitat for the Southern DPS Green Sturgeon consists of PCEs that are essential to the conservation of the species. Because the Green Sturgeon occupies different systems during different life stages, the PCEs have been identified for three systems: (1) freshwater riverine systems, (2) estuarine areas, and (3) nearshore coastal marine waters. Specific PCEs include food resources for all life stages; substrate in riverine system suitable for egg deposition and embryo development; water flow and water quality for growth and survival; and migratory corridor necessary for safe and timely passage in riverine and estuarine habitats, with proper depth of 16.4 feet for holding pools and sediment quality for viability of all life stages (74 FR 52300).

In California, specific areas designated as critical habitat include Coastal U.S. marine waters within a depth of 60 fathoms at Monterey Bay; the Sacramento, lower Feather, and lower Yuba Rivers; the Sacramento-San Joaquin Delta; and Suisun, San Pablo, San Francisco and Humboldt Bays.

This designated critical habitat for Green Sturgeon encompasses approximately 897 square miles of estuarine habitat, 11,421 square miles of marine habitat, 487 square miles of habitat in the Sacramento-San Joaquin Delta, and 135 square miles of habitat in the Yolo and Sutter Bypasses (Sacramento River, California).

Other Native Fish Species

In addition to the species discussed above, Table F-3 presents other important fish species in the Sacramento River, Delta, and Suisun Bay that could potentially benefit from ecosystem improvement operations during NODOS/Sites Reservoir Project operations.

Table F-3. Other Important Fish Species Inhabiting the Sacramento River

Common Name	Scientific Name	Status or Importance
Hardhead	*Mylopharodon conocephalus*	State species of concern
Sacramento Splittail	*Pogonichthys macrolepidotus*	State species of concern
White Sturgeon	*Acipenser transmontanus*	Important to recreation
American Shad	*Alosa Sapidissima*	Important to recreation

Benefits to Anadromous Fish and Other Aquatic Species in the Sacramento River

Operations to Improve the Survivability of Anadromous Fish: As a component of the primary planning objectives, the NODOS/Sites Reservoir Project staff identified a series of ecosystem improvement operations that would benefit anadromous fish:

- Improve the reliability of coldwater pool storage in Shasta Lake to increase the United States Department of the Interior, Bureau of Reclamation's (Reclamation) operational flexibility to provide suitable water temperatures in the Sacramento River. This operationally translates into the increase of Shasta Lake May storage levels, and increased coldwater pool in storage, with particular emphasis on Below Normal, Dry, and Critical water-year types.
- Provide releases from Shasta Dam of appropriate water temperatures, and subsequently from Keswick Dam, to maintain mean daily water temperatures year-round at levels suitable for anadromous salmonid species and life stages in the Sacramento River between Keswick Dam and Red Bluff, with particular emphasis on the months of highest potential water temperature–related impacts (July through November) during Below Normal, Dry, and Critical water–year types.
- Increase the availability of coldwater pool storage in Folsom Lake by increasing May storage and coldwater pool storage to allow Reclamation additional operational flexibility to provide suitable water temperatures in the lower American River (LAR). This operation uses additional coldwater pool storage by providing releases from Folsom Dam (and subsequently from Nimbus Dam) to maintain mean daily water temperatures at levels suitable for juvenile steelhead over-summer rearing and fall-run Chinook Salmon spawning in the LAR from May to November during all water-year types.
- Stabilize LAR flows to minimize dewatering of fall-run Chinook Salmon redds (October through March) and steelhead redds (January through May), and reduce isolation events (flow increases to greater than or equal to 4,000 cubic feet per second [cfs]), with subsequent reduction to less than 4,000 cfs) of juvenile anadromous salmonids; particularly October through June. Reduce the reliance on Folsom Lake as a "real-time, first response facility" to meet Delta objectives and demands, particularly January through August, to reduce flow fluctuation and water temperature–related impacts to LAR fall-run Chinook Salmon and steelhead.
- Provide summer through fall (May through December) supplemental Delta outflow to maintain X2 position west of Collinsville; and increase estuarine habitat, reduce entrainment, and improve food availability for anadromous fishes and other estuarine-

dependent species (Delta Smelt, longfin smelt, Sacramento splittail, starry flounder, and California bay shrimp).

- Improve the reliability of coldwater pool storage in Lake Oroville to improve water temperature suitability for juvenile steelhead and spring-run Chinook Salmon over-summer rearing and fall-run Chinook Salmon spawning in the lower Feather River May through November during all water-year types. Provide releases from Oroville Dam to maintain mean daily water temperatures at levels suitable for juvenile steelhead and spring-run Chinook Salmon over-summer rearing, and fall-run Chinook Salmon spawning in the lower Feather River. Stabilize flows in the lower Feather River to minimize redd dewatering, juvenile stranding, and isolation of anadromous salmonids.
- Stabilize flows in the Sacramento River between Keswick Dam and Red Bluff to minimize dewatering of fall-run Chinook Salmon redds (for the spawning and embryo incubation life stage periods October through March), particularly during fall.

Each alternative would be operated to meet these objectives; this strategy tries to balance operations to provide water supply, anadromous fish, Delta water quality, and hydropower generation benefits. The reservoir and the system operations were modeled through a wide range of hydrologic and operational conditions. Anadromous fish operations were determined through a collection of flow/storage thresholds and forecast-based decisions.

Physical Effects of Sites Reservoir Alternatives: Table F-4 summarizes the physical effects of the alternatives that would affect Chinook Salmon and other species (e.g., steelhead trout, white sturgeon) in these watersheds.

Modeling of Sites Reservoir Alternatives: The predicted effect of Alternatives A, B, C, and D are based on comparisons to the No Action Alternative. Effects of the alternatives were evaluated using two different models that analyze the relationships of flow and water temperature on Chinook Salmon in the Sacramento River: the Interactive Object-oriented Simulation (IOS) and Delta Passage Model (DPM) models, and the Salmonid Population Model (SALMOD). The assumptions and parameters of these models are discussed in Attachment 1.

Table F-4. Potential Anadromous Fish, Delta Environmental Quality, and Other Environmental Benefits

Item	Alternative A		Alternative B		Alternative C		Alternative D	
	Average	Dry and Critical Years	Average	Dry and Critical Years	Average	Dry and Critical Years	Average	Dry and Critical Years
Increase in Storage Associated with Coldwater Pool Improvement								
Trinity End of May (TAF)	32	39	36	45	40	46	10	0
Trinity End of Sept (TAF)	43	64	42	53	51	73	3	7
Shasta End of May (TAF)	50	142	70	159	64	175	38	110
Shasta End of Sept (TAF)	101	139	106	180	108	175	132	198
Folsom End of May (TAF)	4	13	0	2	3	10	0	1
Folsom End of Sept (TAF)	22	19	22	32	24	25	28	30
Oroville End of May (TAF)	40	74	36	72	36	78	52	97
Oroville End of Sept (TAF)	13	33	9	34	7	32	32	63
Winter-run Chinook								
Egg to Fry Survival for Winter-run Chinook (Increase) – IOS Model	2.8%	13.4%	3.1%	12.3%	3.8%	17.5%	3.8%	TBD
Returning Winter-Run Chinook Female Spawners (Increase) – IOS Model	8.1%	8.3%	8.1%	8.3%	8.3%	6.5%	11.2%	TBD
Sacramento River Chinook Salmon – All Runs (SALMOD)								
Average Increase (number of juvenile fish per year) – fall-run, late fall-run, winter-run, spring-run	936,000		683,000		756,000		986,000	
American River Flows								
Stabilize flows in the Lower American River to minimize dewatering of Fall-run Chinook Salmon redds (i.e., October through March) and steelhead redds (i.e., January through May), and reduce isolation events (specifically, flow increases to 4,000 cfs with subsequent reductions to less than 4,000 cfs) of juvenile anadromous salmonids; particularly from October through June.								

Item	Alternative A		Alternative B		Alternative C		Alternative D	
	Average	Dry and Critical Years	Average	Dry and Critical Years	Average	Dry and Critical Years	Average	Dry and Critical Years
Anadromous Fish and Other Aquatic Species – Sacramento River Flows Below Keswick								
Monthly Flow (% Increase in CFS Dec-Feb)	7.0%	17.1%	6.8%	17.2%	6.4%	15.9%	7.6%	TBD
Anadromous Fish and Other Aquatic Species – Sacramento River Reductions in Diversions at Specific Locations								
GCID Hamilton City Intake (TAF/season)	-65%	-75%	-19%	-21%	-67%	-80%	-35%	-42%
TCCA Red Bluff and GCID Hamilton City (TAF/Season)	-27%	-29%	-8.4%	-12%	-29%	-25.5%	-13%	-16%

cfs = cubic feet per second
GCID = Glenn-Colusa Irrigation District
IOS = Interactive Object-oriented Simulation
SALMOD = Salmonid Population Model
TAF = thousand acre-feet
TBD = to be determined
TCCA = Tehama-Colusa Canal Authority

Modeling Results: Under Alternatives A, B, C, and D, the most substantial expected change shown in the IOS/DPM model is for increased egg-fry and fry-smolt survival of winter-run Chinook Salmon during critical years. Egg-fry survival is predicted to increase more than 25 percent under Alternatives A, C, and D; and more than 20 percent under Alternative B in critical years. Increased fry-smolt survival is predicted to be the greatest under Alternative D, with a 34 percent increase during critical years. Alternative D also has a simulated 11 percent increase in returning female spawners over the entire simulation period.

SALMOD model results (Figure F-2) indicate a slight positive (2 to 4 percent) change for annual production for all four stocks under any alternative in the full simulation period. More notable increases are observed under Dry and Critical conditions, where fall-run and late fall-run production is expected to increase by up to 10 percent. Alternative D shows the largest increase in production during Dry and Critical years for fall-run, late fall-run, and winter-run Chinook Salmon (3 to 14 percent). Winter-run stocks show consistently minor increase (1 to 4 percent) under any alternative or water-year (Figure F-2).

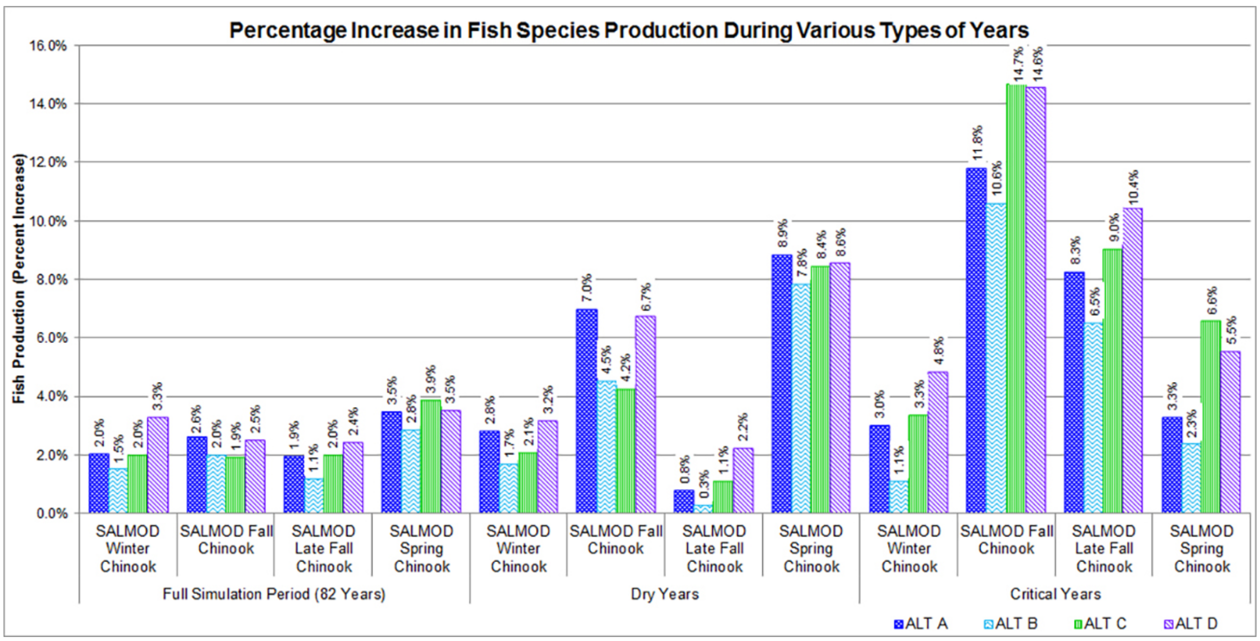

Figure F-2. SALMOD Estimates of Percent Change in Annual Chinook Salmon Production by Stock, Water Year, and Sites Reservoir Alternatives

The models generally show a decrease in predicted temperature- and flow-related mortality under any water-year or alternative. There is a slight decrease in annual mortality due to flow for winter-run Chinook; no change for late fall-run Chinook under the full simulation and Dry water-years; and a slight positive change in Critical years. Fall-run and spring-run Chinook are expected to have no or minor negative changes during any water-year.

The effects of flow and temperature were pooled together for a total combined effect. The effect of temperature was more pronounced in the actual total number of juvenile mortality numbers, and therefore, weighted the combined total to a greater extent to which the temperature trends/changes were mirrored in the combined total results. Exceptions were for fall-run and late fall-run Chinook. The full simulation period for fall-run and late fall-run Chinook shows no change to slight positive change. The same pattern was evident for late fall-run Chinook for the Dry and Critical water-years, but was not seen for fall-run Chinook.

Conclusions from Modeling Results

Each alternative is expected to meet the primary NODOS/Sites Reservoir Project planning objective to increase the survival of, and improve instream habitat for, Chinook Salmon and other aquatic species in the Sacramento River and tributaries. The expected benefits to Chinook survival appear to be greatest during Critical water-years when populations are more likely to suffer stress and mortality related to low flows and higher temperatures from late spring through early fall, especially during drier water-years.

All alternatives would create potential for modifications to the operation of Shasta, Oroville, and Folsom Reservoirs. These modifications would result in changes in flows that would affect water temperatures and instream habitats. Water temperature is a key factor for managing Chinook populations because temperature has a strong influence on the timing of migration, mortality rates, and predator behavior. The alternatives also support restoration actions on the Sacramento River, including:

- An improved temperature regime below Shasta Lake
- Reduced diversions from the Sacramento River
- Stabilization of flows for anadromous fish

Temperature can be an important influence on the timing of smolt runs. A threshold water temperature or a pattern of variation for a prolonged period may initiate the downstream migration. Evidence suggests there is a strong positive correlation between daytime migratory activity and water temperature. Although many juveniles migrate at higher numbers at night, a temperature cue may be an initial prompt to begin seaward migration.

There are optimum temperatures for Chinook survival and growth in which mortality is minimized. As temperatures reach minimum and maximum threshold values, stress levels elevate and mortality rates increase and affect abundance. Temperature also influences predator feeding behavior. Metabolism increases with temperature; therefore, predators are capable of consuming more prey. Temperature has other physiological effects that may influence the amount of prey consumed, as well as the density of the predator itself.

Instream flow is highly influential in the rates at which young salmon migrate. Downstream migration rates and smolt survival in the Delta increase with flow (Groot and Margolis 1991), presumably due to less time to interact with obstacles and potential threats along the course of the migration when the juvenile Chinook are being carried downstream by high flows.

During project operations, water would be diverted from the Sacramento River during higher flows—generally winter months—stored in Sites Reservoir, and released during periods of higher consumptive demand. Water diversions into Sites Reservoir would then occur primarily during times of low ambient temperatures and higher flows, when water temperatures and flows are generally not a limiting factor on salmonid survival.

Increased instream flows would decrease temperature when flow and water temperature are more likely to adversely affect salmonid survival. Water temperatures are expected to be lower because the reduced demand for discharges from Shasta Lake, Folsom Lake, and Lake Oroville allow for increased storage of the coldwater pools in those reservoirs later into the summer and fall.

Flow benefits for salmonids from operating Sites Reservoir include increased discharges during existing lower flow periods in the spring, summer, and fall. Alternatives A and C, which include a new water diversion at Delevan, would provide an additional benefit to instream flow and aquatic habitat by allowing more water to remain in the main stem Sacramento River below diversions near Red Bluff and Hamilton City. Maintaining diversions below 2,000 cfs also generally improves the effectiveness of fish screens, and results in reduced mortality due to entrainment or impingement.

No single alternative evaluated provides consistently greater benefit under any water-year or for any Chinook stock. SALMOD indicates that temperature changes have a greater effect on mortality than did flow changes. The IOS/DPM model results indicate better survival for winter-run Chinook for egg-to-fry and fry-to-smolt life stages during critical years. The IOS model also predicts escapement (number of female spawners) of winter-run Chinook would be higher during the critical years.

F.3 Delta Environmental Water Quality Benefits

The Sites Reservoir alternatives would provide releases of water to the Sacramento River from the Delevan Pipeline that would increase inflow to the Delta. Delta fisheries are sensitive to a variety of water quality constituents. There is general consensus among fisheries agencies that there is larger and higher-quality habitat for Delta Smelt and other species when X2 is west of the confluence of the Sacramento and San Joaquin Rivers. Sites Reservoir would provide supplemental Delta outflow during summer and fall months (i.e., May through December) to improve X2 (if possible, west of Collinsville, 81 km). The abundance of several estuarine species, such as Delta Smelt, longfin smelt, Sacramento splittail, and starry flounder has been correlated with the location of X2. The physical effects of releases from the Delevan Pipeline that would improve Delta inflow are summarized in Table F-5. These releases from Sites Reservoir are distinct from releases for export water supply, and directly contribute to increases in Delta outflow.

Habitat quality in the Delta is degraded when the salinity in the Delta increases. The highest salinities occur during the fall and early winter, when Delta outflow is at its lowest. Water quality degradation is most pronounced in Dry and Critical water-years.

Table F-5. Potential Delta Environmental Water Quality Improvements

	Alternative A		**Alternative B**		**Alternative C**		**Alternative D**	
	Average	**Dry and Critical (TAF)**	**Average**	**Dry and Critical (TAF)**	**Average**	**Dry and Critical (TAF)**	**Average**	**Dry and Critical (TAF)**
Total Releases for Ecosystem Improvement and Water Quality (TAF per year)	212	208	216	217	242	255	175	162
Water Quality – Delta Environmental								
July through August Improvement in X2 (km)	-1.2	-0.9	-1.2	-1.1	-1.3	-1.3	-1.0	-0.7
September through November Improvement in X2 (km)	-0.5	-0.6	-0.6	-0.9	-0.8	-1.1	-0.3	-0.4

km = kilometer(s)
TAF = thousand acre-feet
X2 = A Delta management tool, defined as the distance in kilometers from the Golden Gate Bridge to the location where the tidally averaged near-bottom salinity in the Delta measures 2 parts per thousand

Figure F-3 shows the change in the average X2 positions during September through November in Dry and Critical water-years for each of the action alternatives. Sites Reservoir would be operated to provide releases targeted to improve Delta water quality in a manner that results in the greatest improvement in water quality during the fall in Dry and Critical years.

Delta Smelt

Following a (dramatic population decline in the 1980s, Delta Smelt were listed as threatened under the Federal ESA and the CESA in 1993 (58 FR 12854; Sweetnam and Stevens 1993).

Delta Smelt are small (typically <80 millimeters [mm] fork length [FL]), slender-bodied fish that are endemic to the San Francisco Estuary. This euryhaline species primarily inhabits the open, surface waters of the Delta and Suisun Bay (USFWS 1995). Delta Smelt have an unusual life history pattern relative to other fishes because they have a tiny geographic range compared with other smelt; most live only 1 year, have relatively low fecundity, and have pelagic larvae. Their short life span and low reproductive output makes them especially sensitive to inter-annual perturbation.

Adult Delta Smelt migrate upstream in the fall to spawn in the upper Delta. Spawning takes place between February and July, peaking in early-April through May. Delta Smelt spawn in sloughs and shallow edge-water habitat in channels in the upper Delta and in the Sacramento River above Rio Vista (Moyle 2002). Spawning has also been recorded in Montezuma Slough and Suisun Slough in Suisun Bay, as well as in the Napa River Estuary. Spawning takes place primarily at night during a full or new moon, presumably at low tide (Moyle 2002). Females lay 1,200 to 2,600 eggs, which are broadcast over the substrate in a single spawning event. The eggs are demersal and adhesive, using a stalk to attach to hard substrates Moyle 2002).

Eggs hatch within 9 to 13 days, and feeding begins 4 to 5 days later (Moyle 2002). A yolk sac keeps the newly hatched larvae semi-buoyant, allowing them to remain just off the bottom until their swim bladder and fins are fully developed. Within a few weeks, the swim bladder and fins develop and the smelt are able to move up into the water column, and are then washed downstream into the mixing zone or the area immediately above it. They remain in the general vicinity of the mixing zone, migrating vertically in the water column in response to photoperiod (diel migration) along with their zooplankton prey (Moyle 2002).

Delta Smelt grow rapidly, with juveniles reaching 40 to 50 mm FL by early August (Moyle 2002). Once they reach approximately 30 mm in length in the juvenile stage (25 to 50 mm), a greater variety of food is available to them and they are able to grow quickly. Over the next several months, Delta Smelt grow to reach lengths of 55 to 70 mm (standard length [SL]), at which point growth slows. This is presumably because the majority of available energy is used for gonad production. The majority of Delta Smelt die after spawning; however, a small number of adults continue to grow, reaching lengths of 90 to 120 mm SL. These second-year adults then die after spawning the following year.

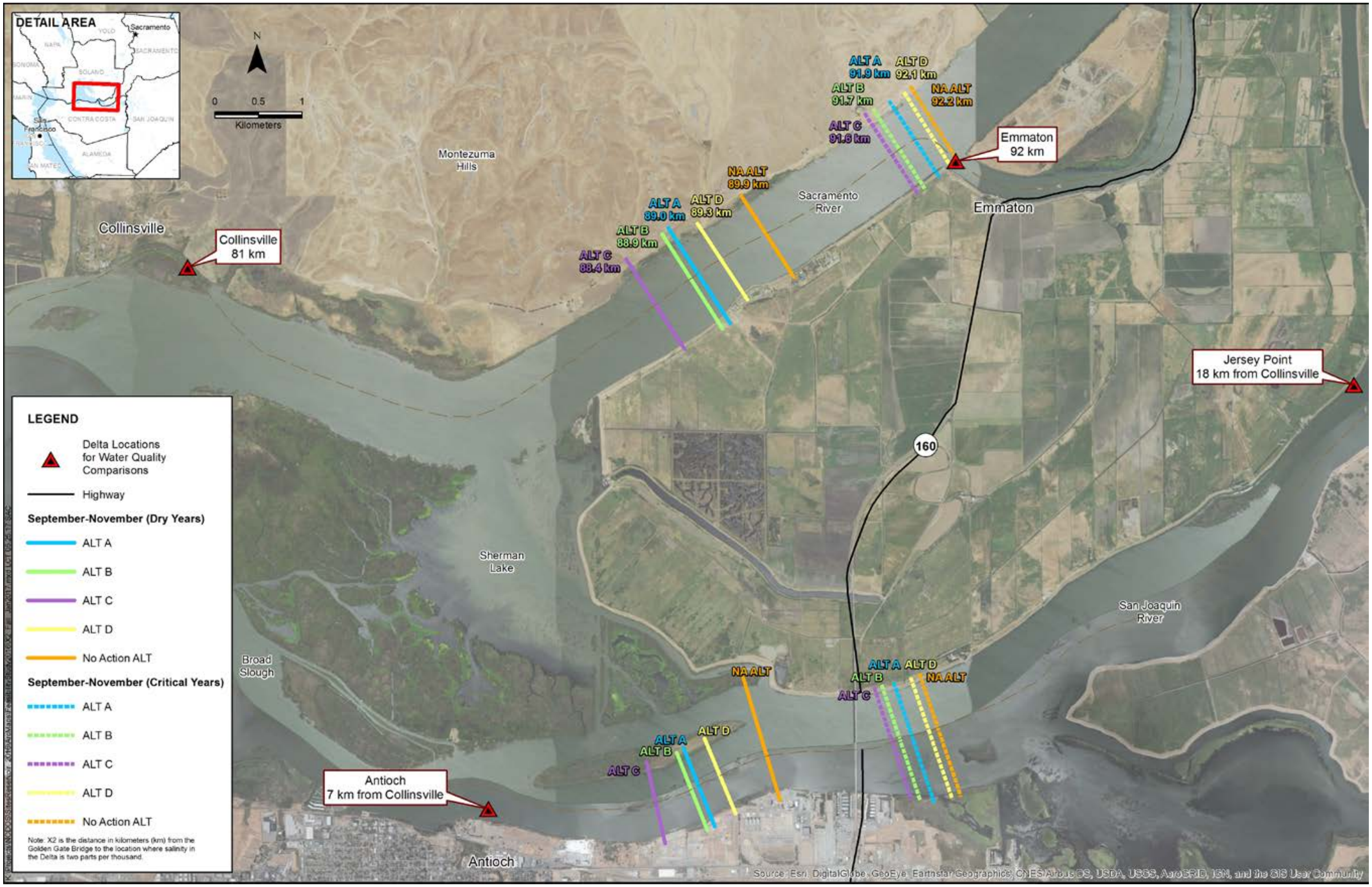

Figure F-3. Position of X2 During September – November in Dry and Critical Years

Critical habitat was designated for Delta Smelt on January 18, 1995 (59 Code of Federal Regulations 65256). Designated critical habitat for this species includes areas of all water and submerged lands below ordinary high water, and the entire water column bounded by and contained in Suisun Bay (including the contiguous Grizzly and Honker Bays); the length of Goodyear, Suisun, Cutoff, First Mallard (Spring Branch), and Montezuma Sloughs; and the existing contiguous waters contained within the Delta, as defined in Section 12220 of the California Water Code.

Delta Smelt require a water source with an electrical conductivity measurement (EC_w) of less than 12,000 EC_w to reproduce, and there is strong opinion that the survival of Delta Smelt increases as X2 moves west of Collinsville and downstream toward San Francisco Bay. State Water Resources Control Board Decision 1641 (D-1641) requires X2 implementation from February to June to improve habitat protection for fish in the Delta. The intent of the X2 requirement is to maintain adequate transport flows to move Delta Smelt away from the influence of the Central Valley Project/State Water Project water diversions and into low-salinity rearing habitat in Suisun Bay and the lower Sacramento River.

Other Native Fish Species

In addition to the species discussed above, Table F-6 presents other important fish species in the Delta and Suisun Bay that could potentially benefit from ecosystem improvement operations during NODOS/Sites Reservoir Project operations.

Table F-6. Other Important Fish Species Inhabiting the Delta

Common Name	Scientific Name	Status or Importance
Longfin Smelt	*Spirinchus thaleichthys*	Candidate species – Federal Threatened – State
Hardhead	*Mylopharodon conocephalus*	State species of concern
Sacramento Splittail	*Pogonichthys macrolepidotus*	State species of concern
White Sturgeon	*Acipenser transmontanus*	Important to recreation
American Shad	*Alosa Sapidissima*	Important to recreation

F.4 Potential for Future Restoration Benefits from Yolo Bypass Flows

Water supply for ecosystem improvement benefits would be adaptively managed consistent with the Water Storage Investment Program. Ongoing development of the restoration program in the Yolo Bypass is expected to provide an even greater opportunity for Sites Reservoir to benefit both salmonids and Delta Smelt. Sites Reservoir alternatives could also be used to deliver water to the Delta via the Yolo Bypass. Water could be released from the Holthouse Dam spillway to Funks Creek to deliver water to the Colusa Basin Drain, and then to the Yolo Bypass through the Knights Landing Ridge Cut. Water is needed to support the Yolo Bypass Salmonid Habitat Restoration and Fish Passage Project. Releases could also be provided via a wetland and tidal slough corridor through the Yolo Bypass and into the Delta to create a phytoplankton bloom, the critical base of the food web for Delta Smelt. This approach was tested with encouraging results in the fall of 2011 and 2012 with drainage flows from the Yolo Bypass. These flows produced an unusually large plankton bloom in the Rio Vista area of the lower Sacramento River.

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Acronyms and Abbreviations

CESA	California Endangered Species Act
cfs	cubic feet per second
CV	Central Valley
DPM	Delta Passage Model
DPS	distinct population segment
ECw	electrical conductivity measurement
ESA	Endangered Species Act (Federal)
ESU	evolutionarily significant unit
FL	fork length
FR	Federal Register
IOS	Interactive Object-oriented Simulation
km	kilometer
LAR	lower American River
mm	millimeter(s)
NFH	National Fish Hatchery
NMFS	National Marine Fisheries Service
NODOS	north-of-the-Delta offstream storage
PCE	Primary Constituent Element
Reclamation	United States Department of the Interior, Bureau of Reclamation
SALMOD	Salmonid Population Model
SL	standard length
X2	A Delta management tool, defined as the distance in kilometers from the Golden Gate Bridge to the location where the tidally averaged near-bottom salinity in the Delta measures 2 parts per thousand

Attachment I
Model Assumptions and Methods

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Attachment I Model Assumptions and Methods

Winter-run Chinook Life Cycle Model (WRCLCM) IOS/DPM: The IOS model is a life-cycle model providing a quantitative framework to evaluate the accumulated effects of flow, temperature, diversions, and habitat conditions on multiple life stages (eggs, alevins, fry, parr, smolts, subadults and adults) of winter-run Chinook Salmon that spawn in the upper reaches the Sacramento River, migrates through the Delta to the Pacific Ocean, and returns to the Upper Sacramento River to spawn. This model simulates individual daily cohorts of winter-run Chinook Salmon through their life cycle. The IOS models individual life stages using functional relationships, whose form and parameters values are informed by the best available information. Functional relationships for each life stage are linked together to form a complete life cycle model that estimates the daily number of eggs for each brood year, and progresses them through life stage transitions until spawning at age 3 or 4 (years), where the process begins again for the next generation. The smolt Delta migration portion of the life cycle is identical to that described for winter-run Chinook in the DPM.

IOS uses a descriptive and quantitative framework to evaluate the influence of different Central Valley water operations, and estimate the long-term response of Sacramento River winter-run Chinook populations to river discharge, temperature, and habitat quality at a reach scale.

Survival and abundance estimates generated by IOS are not intended to predict future outcomes or to predict actual survival. Rather, IOS provides an estimate of relative of survival and abundance which is useful for making comparisons between proposed operation alternatives. While IOS has been calibrated to the best available information, in most cases it is not possible to validate IOS results against actual fish abundance or survivals values because such data does not exist. Where suitable data is available (e.g. spawning escapement abundance) observed values are the result of past habitat conditions, predator abundance and other factors which are not representative of future conditions expected with NODOS project proposed alternatives. Uncertainty is explicitly modeled in the IOS model by incorporating environmental stochasticity and estimation error where data is available. Generally, IOS results are reported as averages or as probability distributions by years, by months, and/or by water-year type, but not as comparisons between specific days, months, or years.

The IOS/DPM was used to determine how salmonid smolt survival to Chipps Island might be influenced by Sites Reservoir. Although the DPM is based on studies of winter-run Chinook surrogates (late fall-run Chinook), it was applied to spring-run and fall-run Chinook Salmon by adjusting emigration timing and by assuming that migrating Chinook Salmon would respond similarly to Delta conditions.

The IOS/DPM predicts relative reach-specific survival estimates for winter, spring, and fall-run juvenile Chinook Salmon passing through the Delta, based on a detailed accounting of migratory pathways and reach-specific mortality as smolts travel through a network of Delta channels. It simulates migration and mortality of juvenile Chinook Salmon entering the Delta from the Sacramento, Mokelumne, and San Joaquin Rivers through a simplified Delta channel network, and provides quantitative estimates of relative juvenile Chinook Salmon survival through the Delta to Chipps Island.

IOS/DPM Assumptions: The following assumptions were applied in the IOS/DPM evaluations:

- IOS: The IOS life cycle model for winter-run Chinook Salmon incorporates a daily time step.
- DPM: Salmon smolts arriving at Delta distributaries enter downstream reaches in approximate proportion to the flow diverted. Smolt movement in the DPM occurs daily and is a function of reach-specific length and migration speed informed by acoustic tagging studies.

The IOS/DPM outputs include the following:

- Egg to fry survival rates
- Fry to smolt survival rates
- Adult winter-run Chinook Salmon escapement (female spawners) rates
- Juvenile migration survival through the Sacramento River upstream of the Delta (e.g., annual passage, annual percent difference); and
- Juvenile migration survival through the Delta (annual percent difference).

Salmonid Population Model (SALMOD) Model: SALMOD is a component of the Instream Flow Incremental Methodology. SALMOD simulates population dynamics for salmonids in freshwater, but not ocean habitats. SALMOD emulates dynamics of freshwater life history of anadromous and resident salmonid populations using streamflow, water temperature, and habitat type. SALMOD is a spatially explicit model that characterizes habitat quality and carrying capacity using the hydraulic and thermal properties of individual mesohabitats, which are the spatial computational units in the model.

SALMOD was developed as a tool to understand relationships between habitat dynamics and smolt growth, movement, and survival. SALMOD can:

- Quantify the impacts of flow and temperature regimes of alternatives on annual production potential;
- Illustrate the differences among water-year types; and
- Identify optimal conditions in terms of habitat, flow, and temperature for attaining maximum growth and production.

SALMOD is organized around events occurring during a biological year, beginning with spawning, and typically concluding with fish that are physiologically “ready” (e.g., pre-smolts) swimming downstream toward the ocean. SALMOD operates on a weekly time step for one or more biological years, and each year’s cohort is independent of each other. Input variables—streamflow, water temperature, number and distribution of adult spawners—are represented by weekly average values.

SALMOD tracks a population of spatially distinct cohorts that originate as eggs and grow from one life stage to another as a function of local water temperature. The biological characteristics of fish within a cohort are assumed to be the same. Streamflow and habitat type determine available habitat area for a particular life stage for each time step and computational unit. Habitat area, quantified as weighted usable area, is computed from flow versus microhabitat area functions developed empirically, or by using a physical habitat simulation model. The maximum number of individuals that can reside in each computational unit is calculated for each time step, based on streamflow, habitat type, and available microhabitat. This model provides potential fish production values reflecting the suitability of riverine habitat for fall-, late fall-, winter-, and spring-run Chinook Salmon.

SALMOD Assumptions: SALMOD represents population dynamics during freshwater life stages of anadromous fish that return to the stream as an adult to spawn. Egg and fish mortality are directly proportional to spatially and temporally variable microhabitat and macrohabitat limitations, which themselves are functions of the timing and quantity of flow and meteorological variables such as air temperature. Model processes include spawning (egg deposition), egg and alevin development and growth, mortality, and movement (due to habitat limitation, freshets, and seasonal stimuli). Pre-smolts do not graduate to the smolt stage in the model. Instead, they exit the study area, and the population is reinitialized with survey estimates of spawning adults each biological year.

Comparison of IOS/DPM and SALMOD: There are strengths and weakness to IOS/DPM and SALMOD, but a combination of both models can help to evaluate the influence of different Sacramento River water operations, and estimate the long-term response of Sacramento River Chinook populations to changing temperature and flow conditions. The SALMOD and IOS/DPM estimate production and mortality, and can help quantify the impacts of flow and temperature. As a life-cycle model, IOS incorporates the whole life cycle of a salmonid stock, but only winter-run Chinook Salmon was modeled. The IOS/DPM estimates Delta smolt survival for winter-, spring-, and fall-run Chinook Salmon using a daily time step. SALMOD uses a weekly time step and is habitat–based, and looks only at the juvenile (freshwater) life history phase, but it provides output for all four Sacramento Chinook runs. Fish mortality is the loss of fish from a population, and is defined as the number of fish lost or the rate of loss. Determining mortality rates is critical for determining abundance of fish populations. IOS/DPM and SALMOD estimate mortality rates or quantities. IOS uses survival as the final output, but it uses mortality rates to calculate egg to fry and fry to smolt survival.

Climate change and ocean productivity were not considered in either IOS/DPM or SALMOD. Climate change could require the additional projects in the future to capture surface water runoff, or alter the flows or temperatures of released reservoir flows. Climate change could affect the ability of a Sites Reservoir alternative to meet the completeness criteria by:

- Increasing ambient temperatures and thereby affecting the coldwater storage of reservoirs by affecting the stored water temperatures and/or thermocline patterns
- Altering the timing or rate of Sierra Nevada snowmelt
- Altering weather patterns and the quantity of precipitation received

SALMOD considers the freshwater life history phases of Chinook Salmon, but does not consider the variety of factors (commercial and/or recreational fishing, variability in food supplies) that affect salmon in the ocean. Consequently, SALMOD may overestimate the number of returning spawners and the potential beneficial effects of the proposed alternative or its ability to meet the primary planning objective related to increased anadromous fish survival. Additional future projects may be required to meet anadromous fish survival objectives.

Similarly, IOS/DPM and SALMOD do not address longer-term dynamics in riparian habitats important for long-term survival of Chinook Salmon populations. Longer-term dynamics include stream bed mobilization events, riparian vegetation recruitment, and geomorphic events like scour, channel migration, and sediment deposition. Under general geomorphic models of the Sacramento River system, it is expected that 5-year flow events are typically required to initiate bed mobilization to prepare bed gravels for redds or flush silt from gravels. Generally, 10-year flow events are required to initiate bed and bank scour to redistribute gravels, and remove vegetation and deposit fresh sediment to create suitable substrate for cottonwood recruitment. Cottonwood recruitment is important for the maintenance of shaded riverine aquatic habitat to help maintain suitable water temperatures, contribute organic matter to the water column to support food web production, and to provide large woody debris for instream habitat structures.

Interpretation of SALMOD Output: SALMOD estimates annual production potential, or the number of out-migrants, and annual mortality. The model evaluates changes in the Chinook Salmon population between Keswick Dam and Red Bluff Diversion Dam. The production numbers obtained from SALMOD are best used as an index in comparing to a specified baseline condition rather than absolute values. Annual production potential at Red Bluff Diversion Dam and mortality for each run of Chinook Salmon in the Sacramento River were the outputs generated for Sites Reservoir. SALMOD results are useful in a comparative analysis, and indicate condition (e.g., compliance with a standard) and trend (e.g., generalized impacts).

The production numbers obtained from SALMOD are best used as an index in comparing to a specified baseline condition rather than absolute values. Absolute differences computed at a point in time between model results for an alternative and a baseline to evaluate impacts is an inappropriate use of model results (e.g., computing differences between the results from a baseline and an alternative for a particular day or month and year within the period of record of simulation).

SALMOD results may not allow for interpretation of processes that are not explicitly modeled or that need changes to the assumed parameters and data. Examples are alternatives that include reduced diversions or improvements to rearing habitats. Metrics such as annual production potential and annual mortality of juvenile salmonids help address management-oriented questions.